# Fish Biology

## For 4th Grade Zoology

## Second semester (406 Z)

**By**


**Dr./Salwa Mansour Mohamed**

**Zoology Department**
**Faculty of Science**
**south Valley University**


# 2022/2023

# Lecture 1

# 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.**

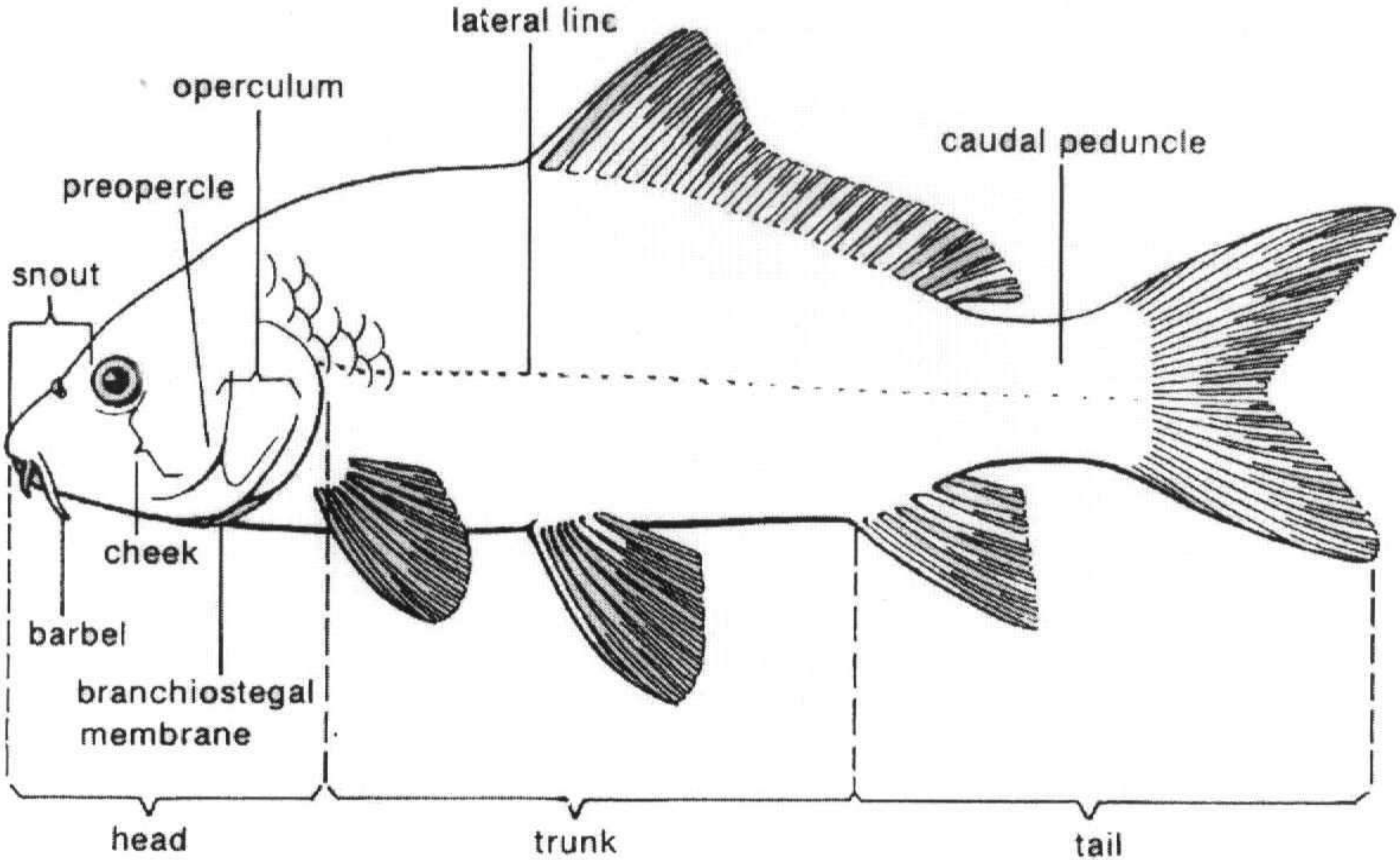
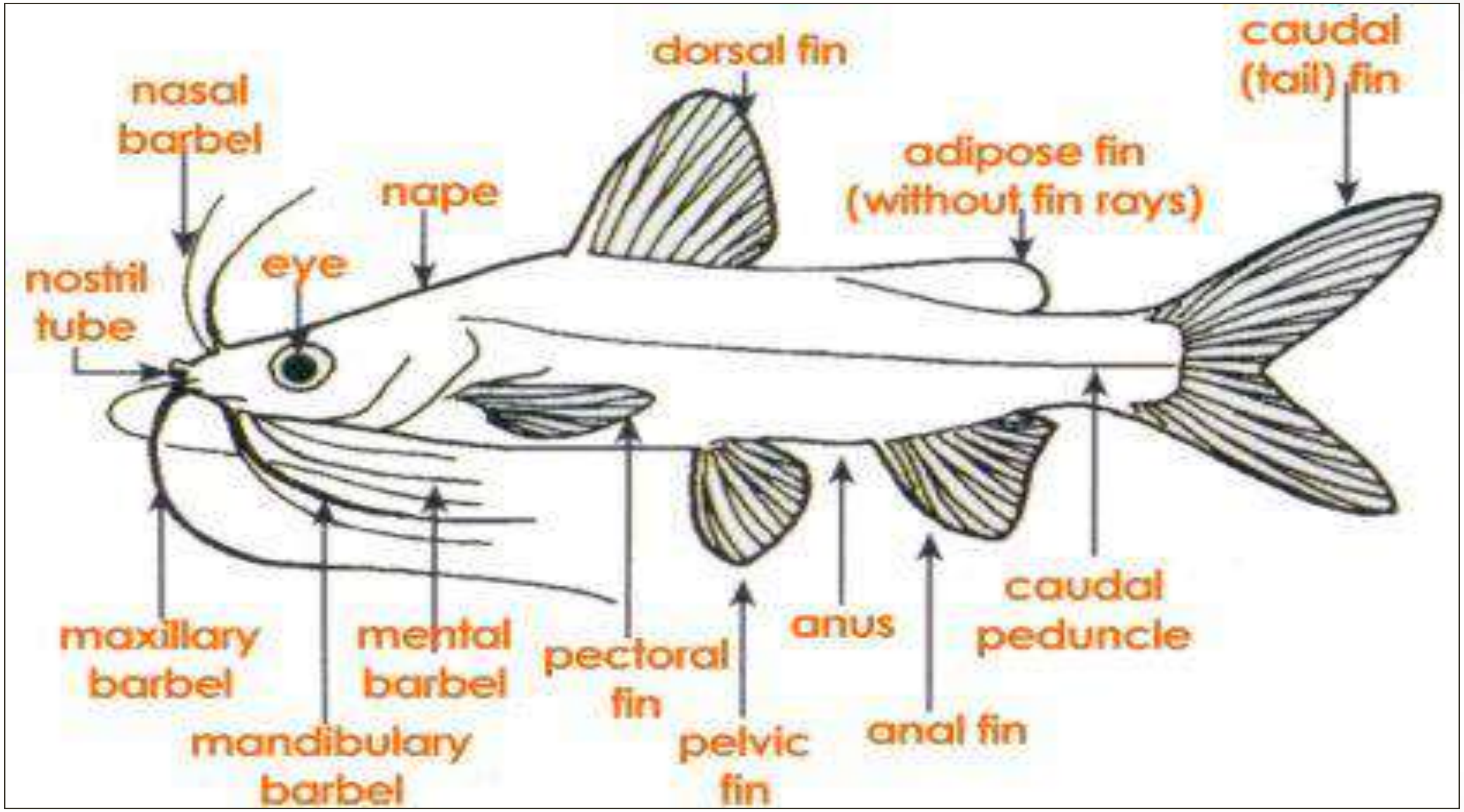



**FIGURE 2–1.** Diagram of bony fish, showing external features.



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

## 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 .**

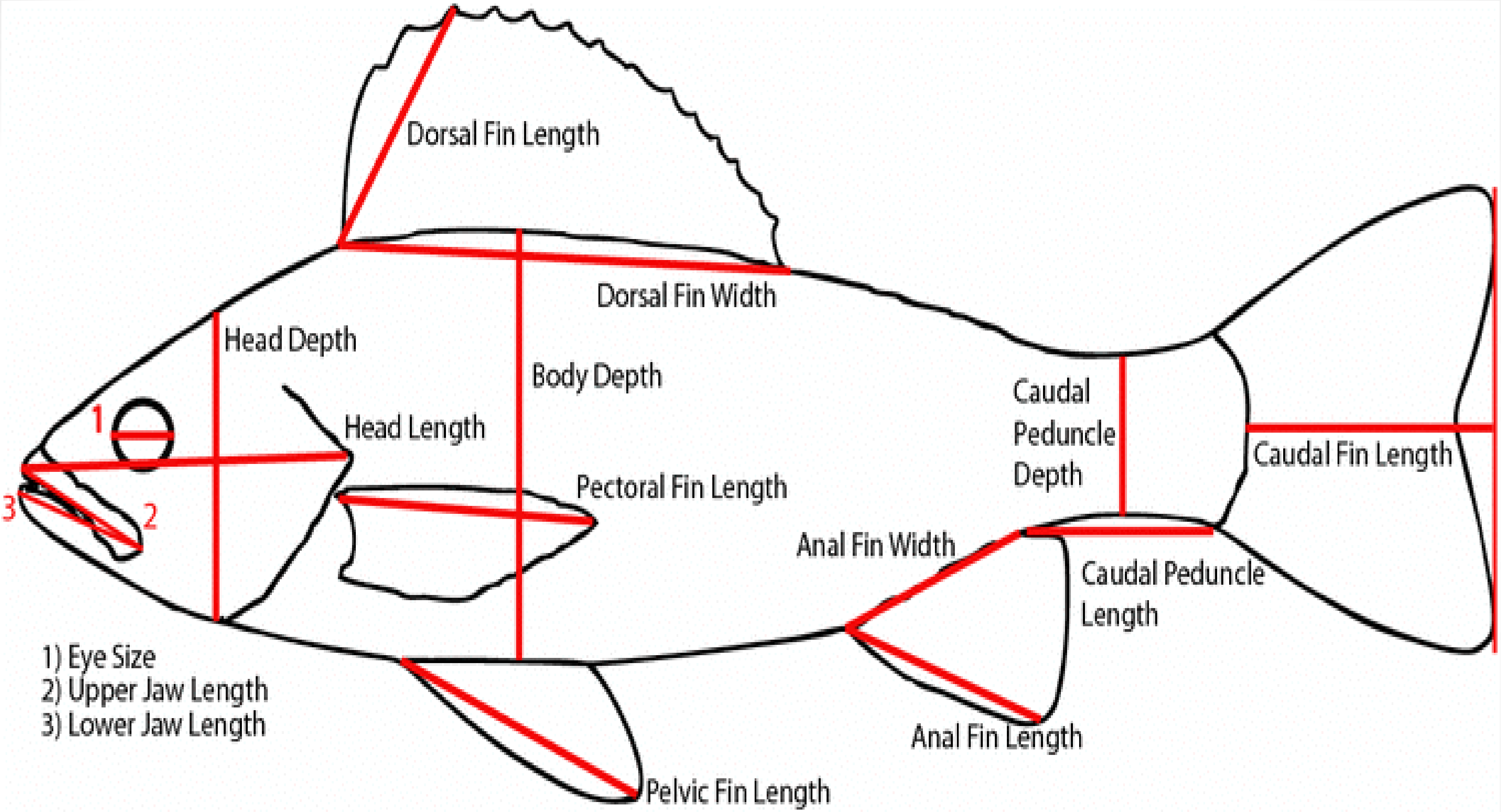
**4-Body depth:-[BD]**

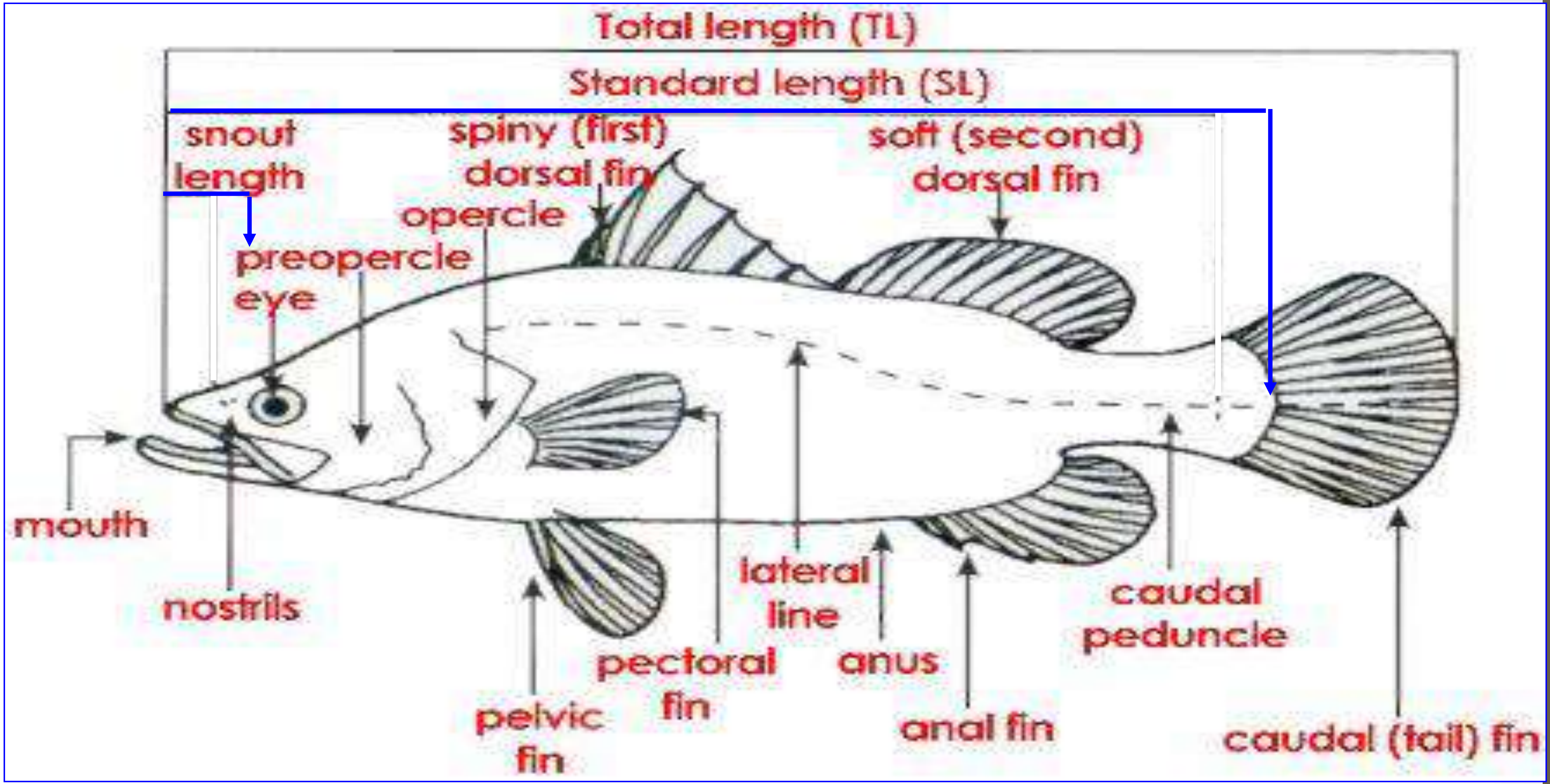
**It is taken from the deepest point.**

**5- Eye width: [EW]**

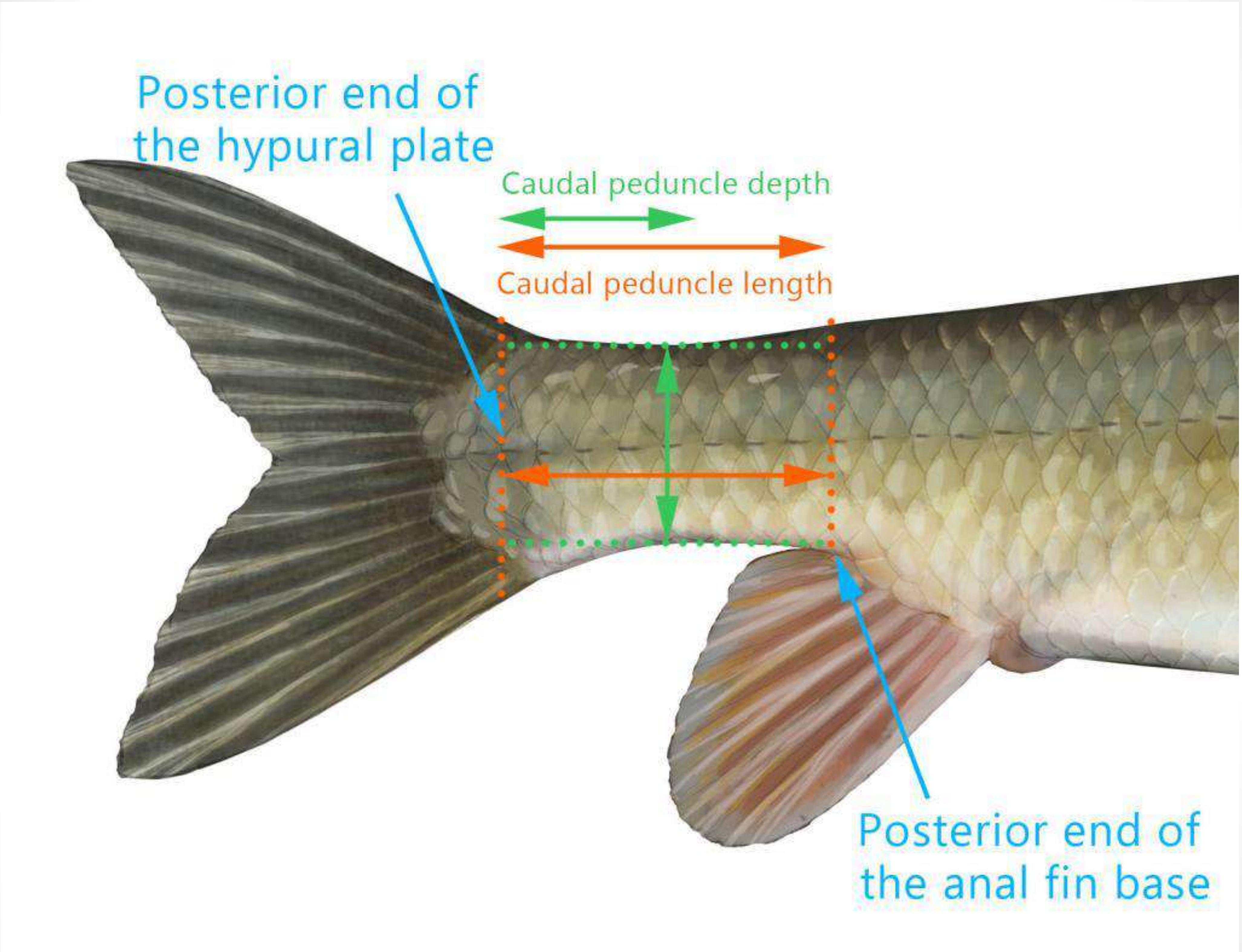
**6- Snout length:[SnL]**

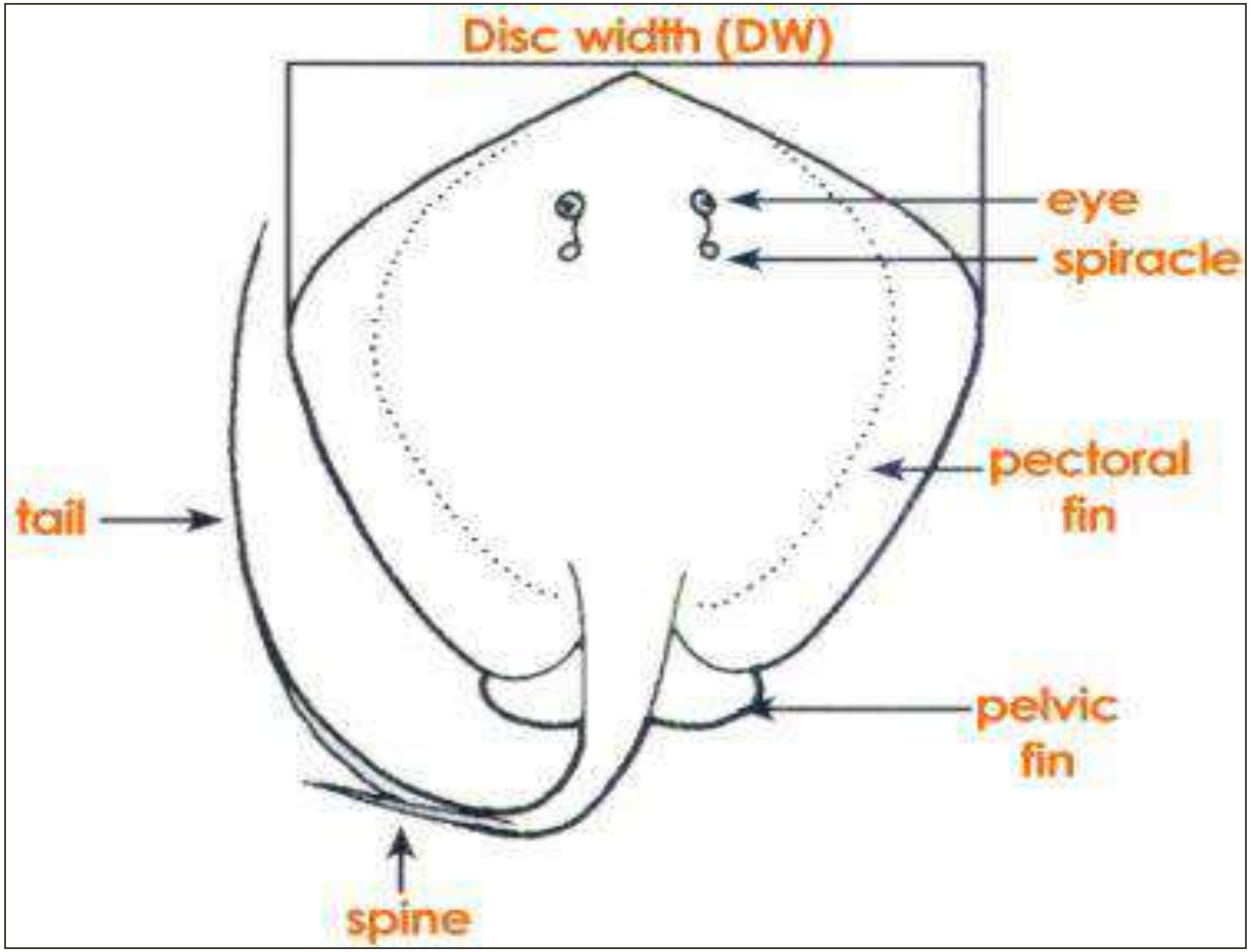
**7- Caudal peduncle length:[CPL]**


Dorsal Fin Length
Dorsal Fin Width
Head Depth
Body Depth
1
Head Length
3
2
Pectoral Fin Length
Caudal
Peduncle
Depth
Caudal Fin Length
Anal Fin Width
Caudal Peduncle
Length
1) Eye Size
2) Upper Jaw Length
3) Lower Jaw Length
Anal Fin Length
Pelvic Fin Length


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

A bony fish


Posterior end of
the hypural plate
Caudal peduncle depth
Caudal peduncle length
Posterior end of
the anal fin base

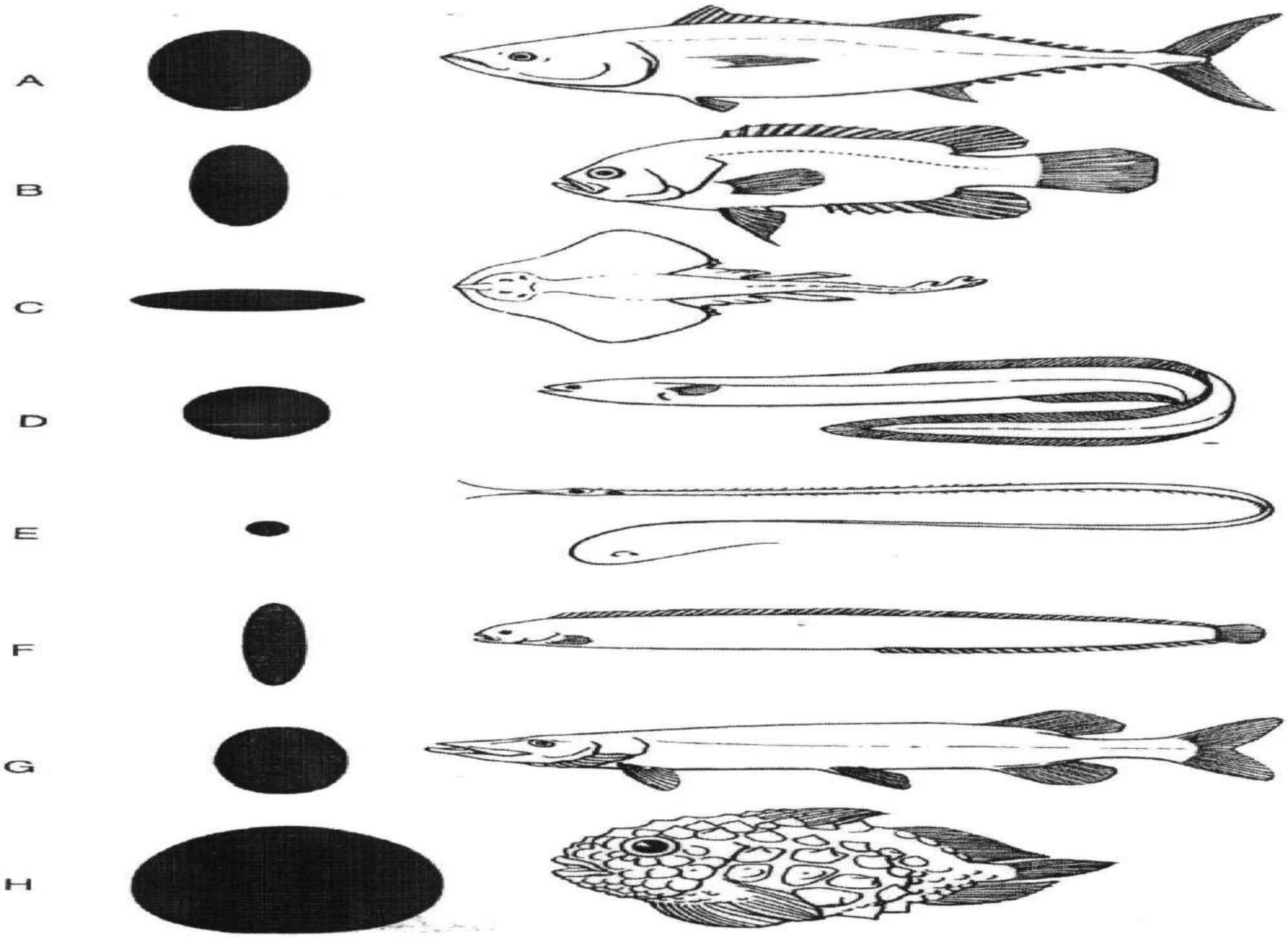

Disc width (DW)
eye
spiracle
pectoral fin
tail
pelvic fin
spine

A stingray

## 1- **Body shapes in fishes:**

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

## 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.)

**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** $\dfrac{\textbf{No. of scales above lateral line}}{\textbf{No. of scales below lateral line}}$

*Other examples of body shapes in fishes

فراشة البحر Sea moth

السمك البقرى Cowfish

Catfish bullhead

Seahorse

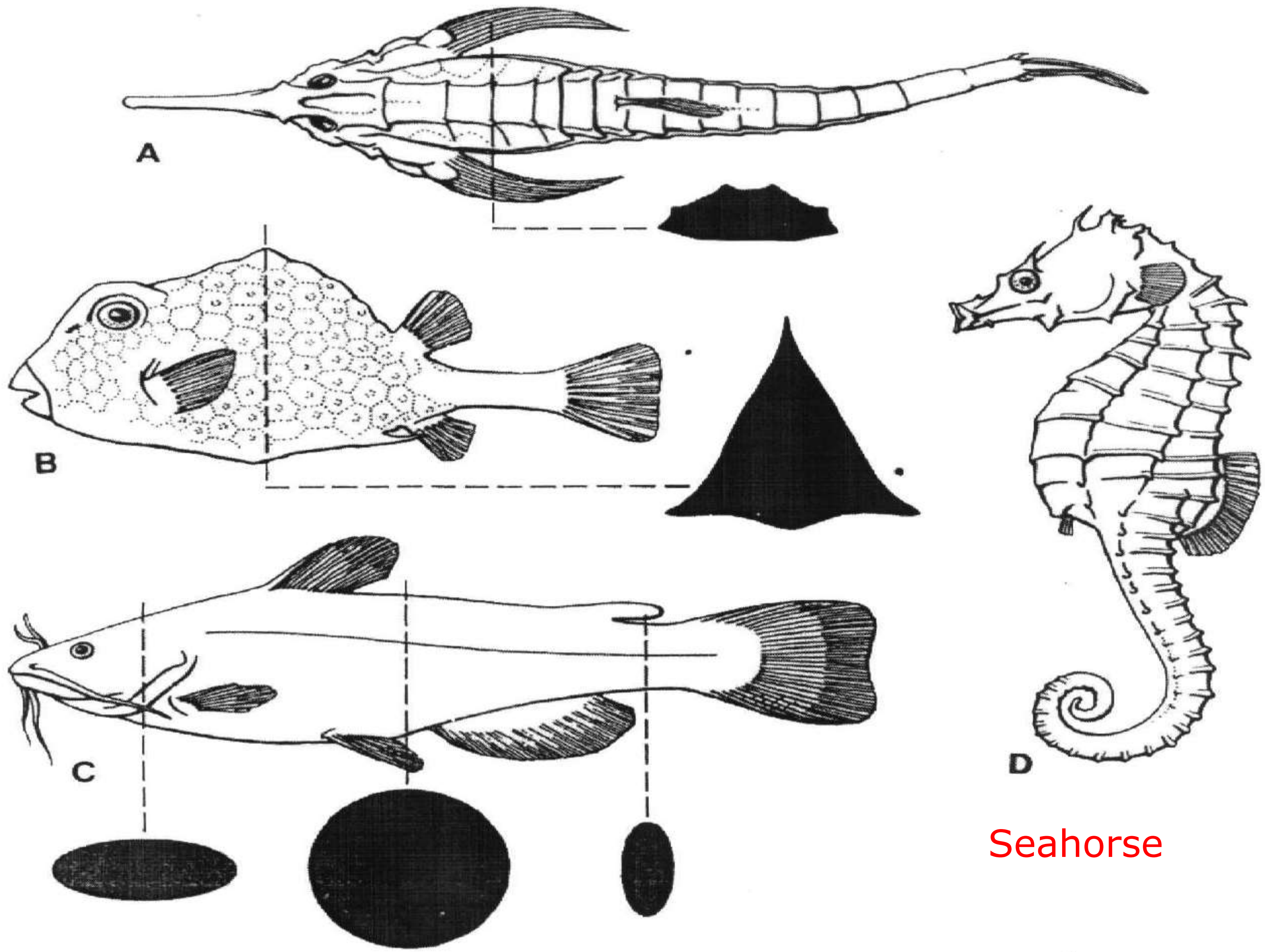
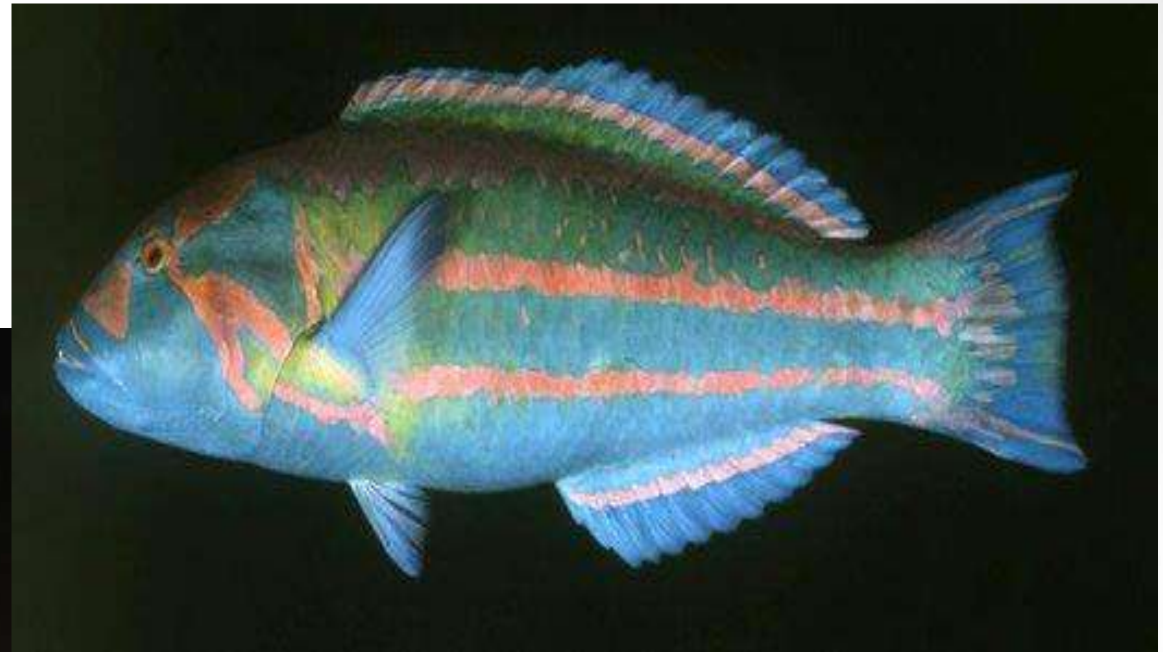



FIGURE 2–9. Examples of body shapes in fishes: *A*, Sea moth (Pegasidae); *B*, cowfish (Ostraciidae); *C*, *bullhead* (Ictaluridae); *D*, seahorse (Syngnathidae). (*B* and *C* based on Jordan and Evermann, 1900.)




#2109924

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

$$\text{Scale Formula} = \text{No. of scales along lateral line} \; \frac{\text{No. of scales above lateral line}}{\text{No. of scales below lateral line}}$$

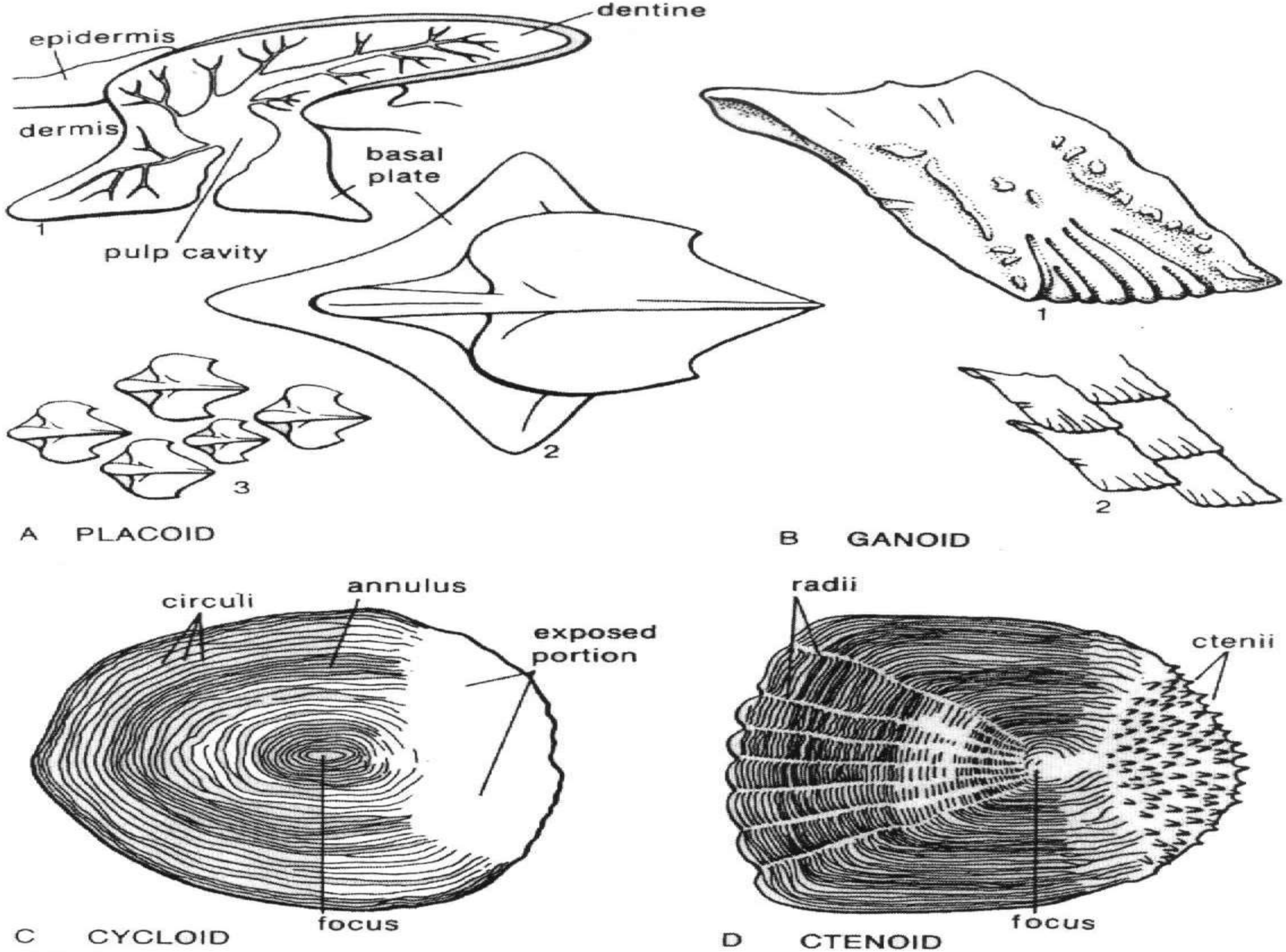
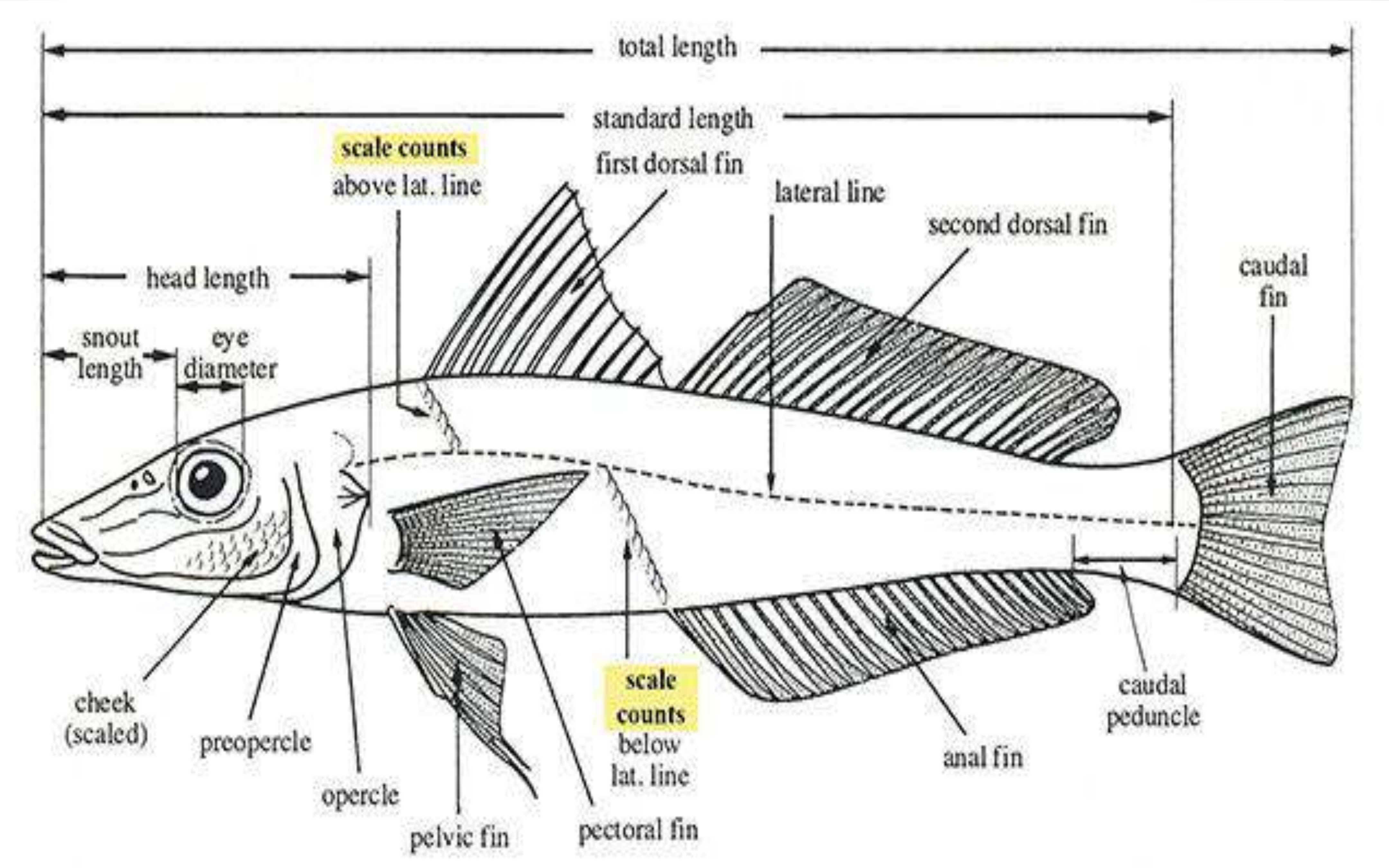


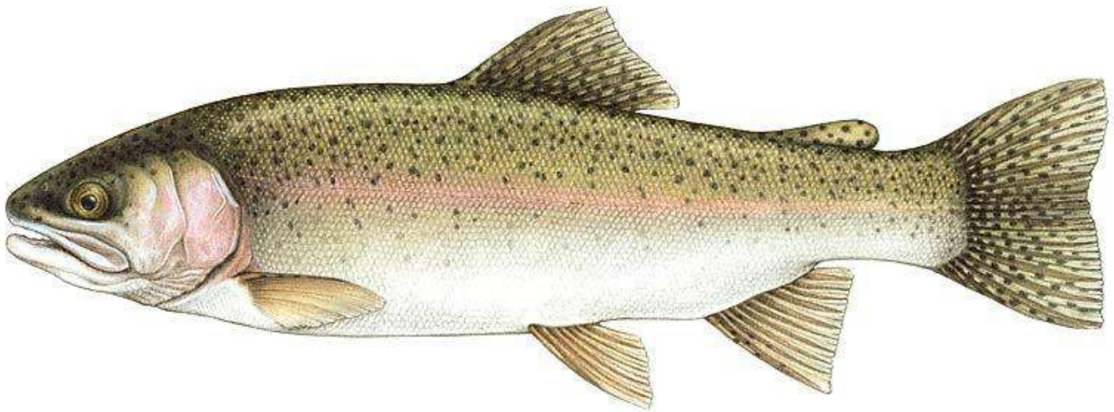

**FIGURE 2–20.** Examples of types of scales (anterior to left). *A*, Placoid— *1*, sagittal section, *2*, top view, *3*, disposition on skin; *B*, ganoid—*1*, single scale, *2*, disposition on fish; *C*, cycloid; *D*, ctenoid.


total length
standard length
scale counts
above lat. line
first dorsal fin
lateral line
second dorsal fin
head length
caudal
fin
snout
length
eye
diameter
cheek
(scaled)
preopercle
opercle
pelvic fin
pectoral fin
scale
counts
below
lat. line
anal fin
caudal
peduncle

# Positions of fish-mouth

**A.** Inferior (sturgeon)

**B**. Subterminal (dace)



**C**. Terminal (trout)


**D**. Superior (sandfish)

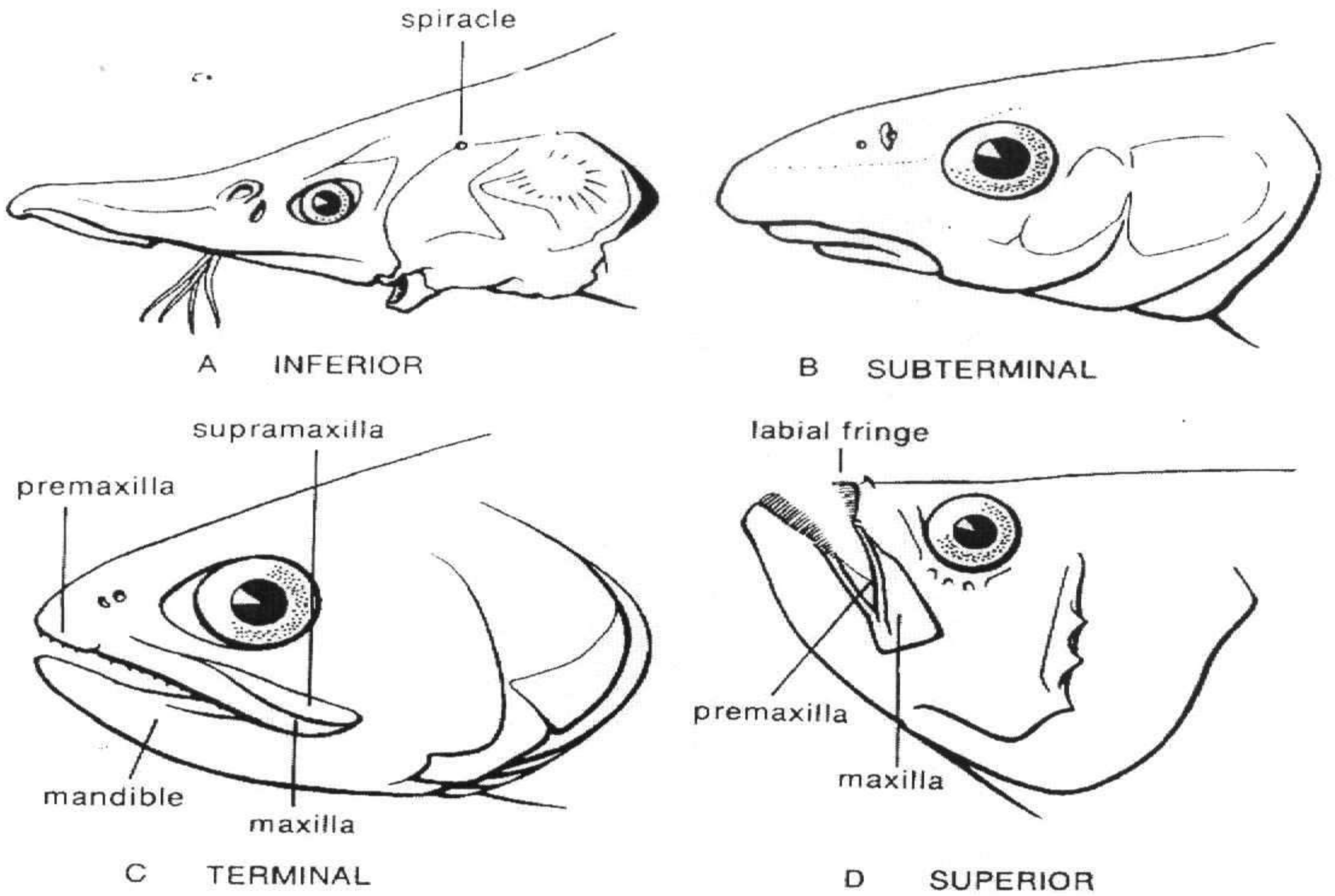
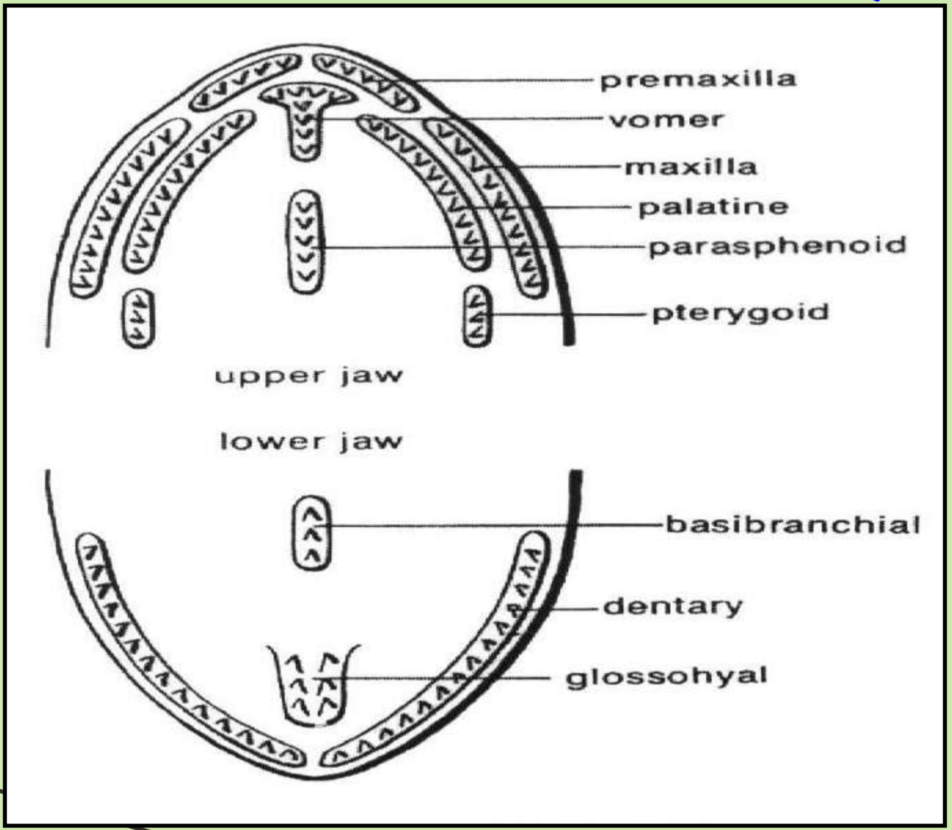



**FIGURE 2–2.** Examples of mouth positions in fishes. *A*, Inferior (sturgeon); *B*, subterminal (dace); *C*, terminal (trout); *D*, superior (sandfish). (*D*, based on Jordan and Evermann, 1900.)

**10- lips**

- small
- large
- fleshy

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




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

**12- teeth**

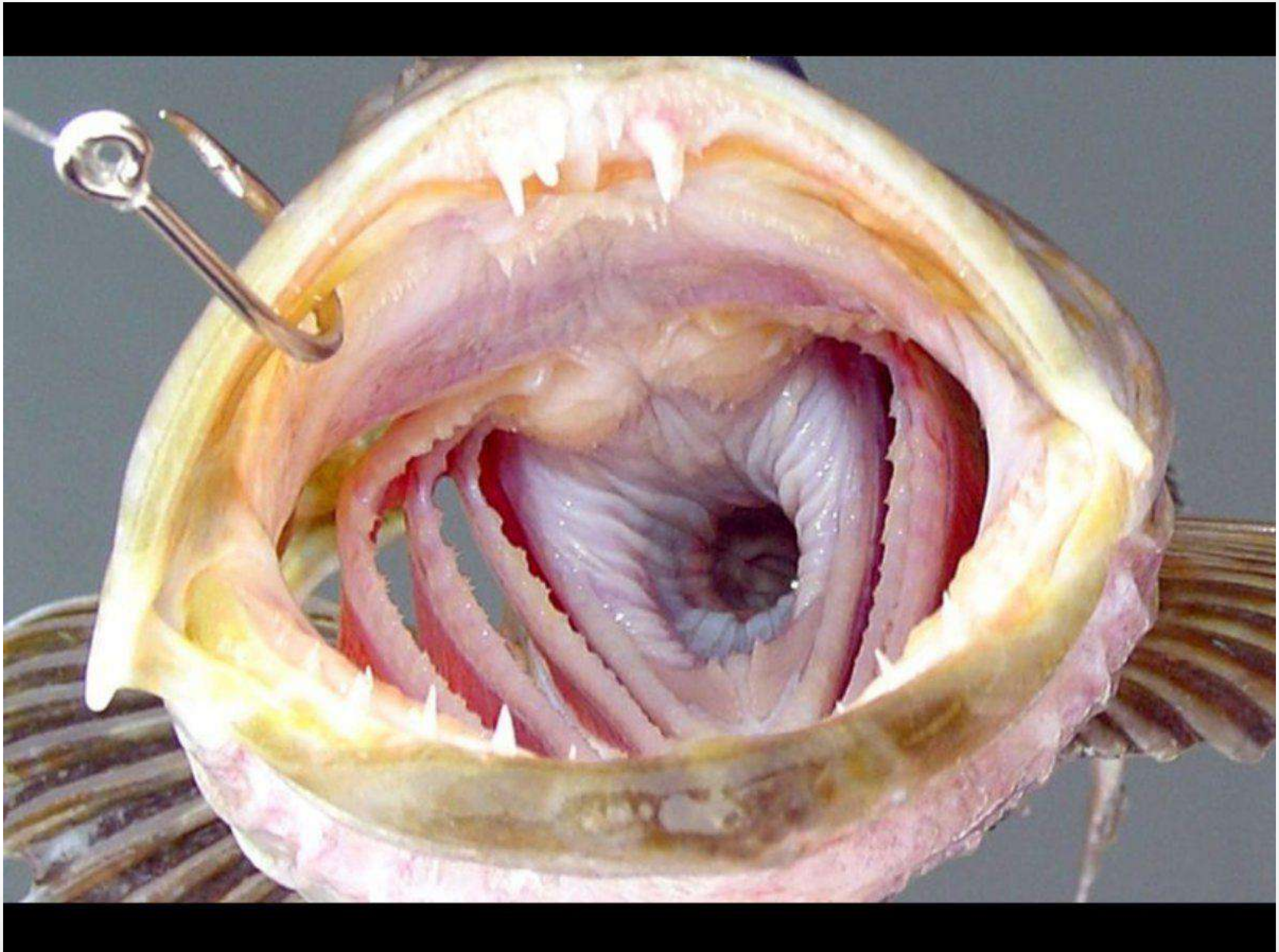
- pointed,
- rounded

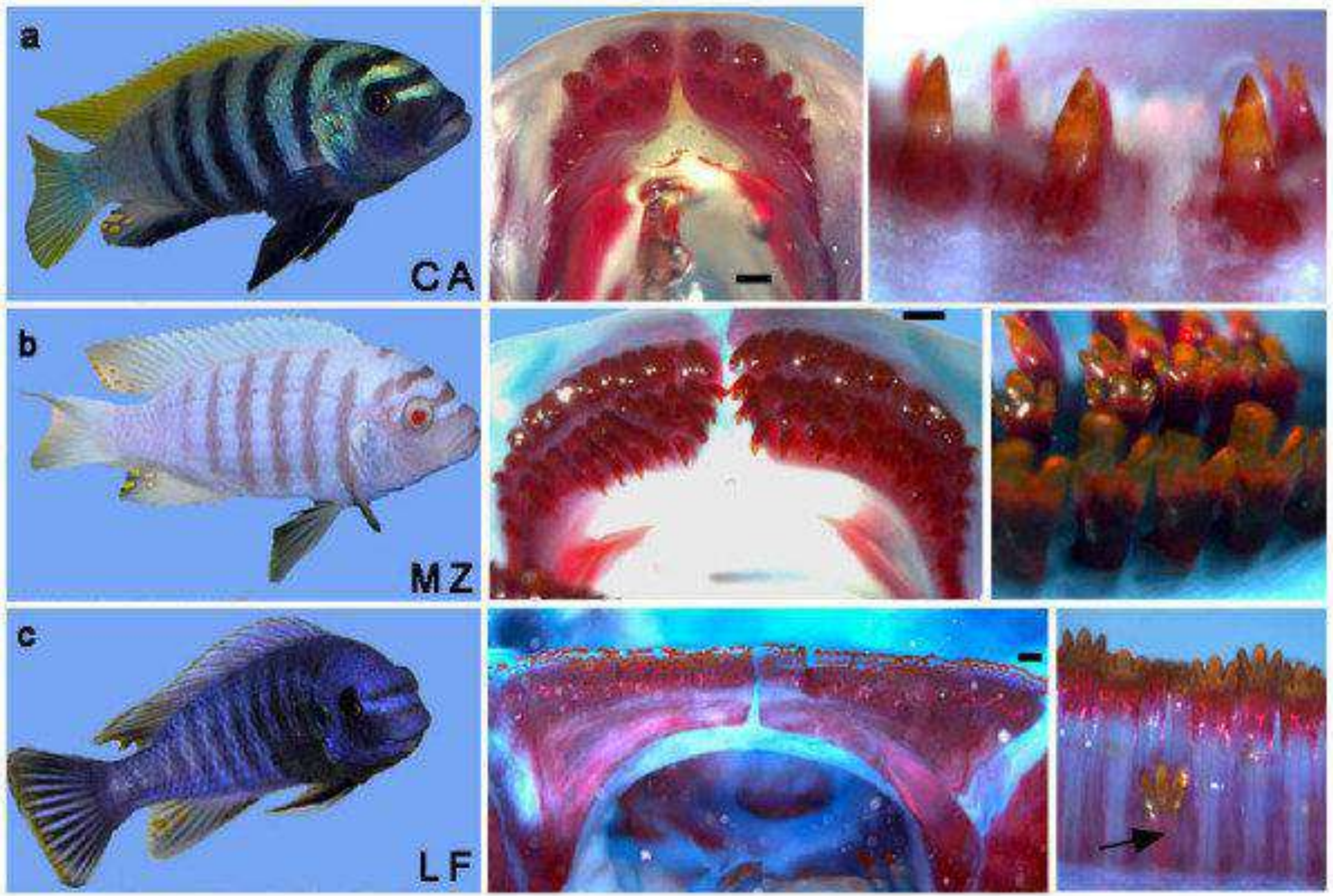
Shape: truncate, unicusped ,bicuspid, tricuspid, polycusped

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


Shutterstock

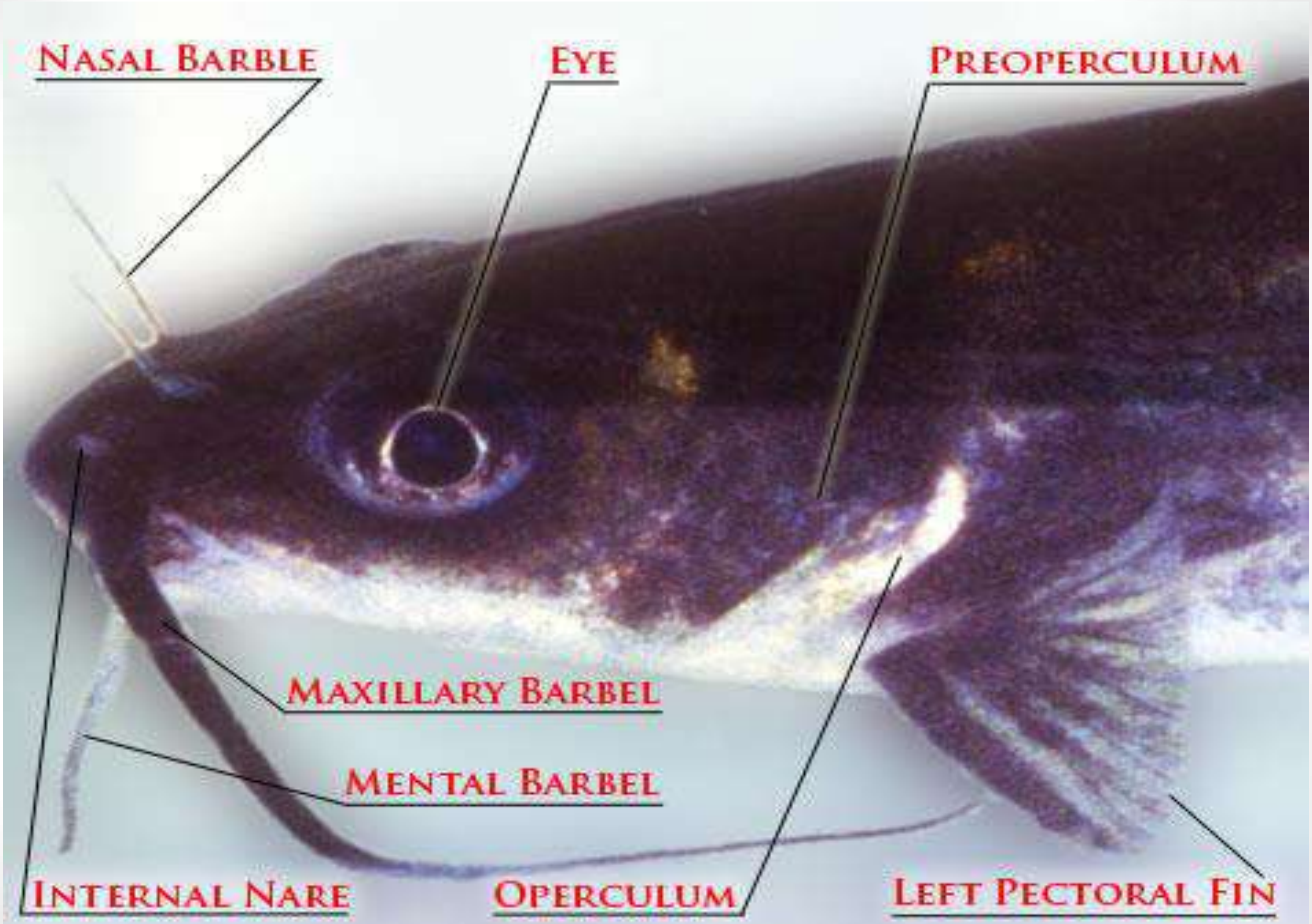

dreamstime





a
CA
b
MZ
c
LF

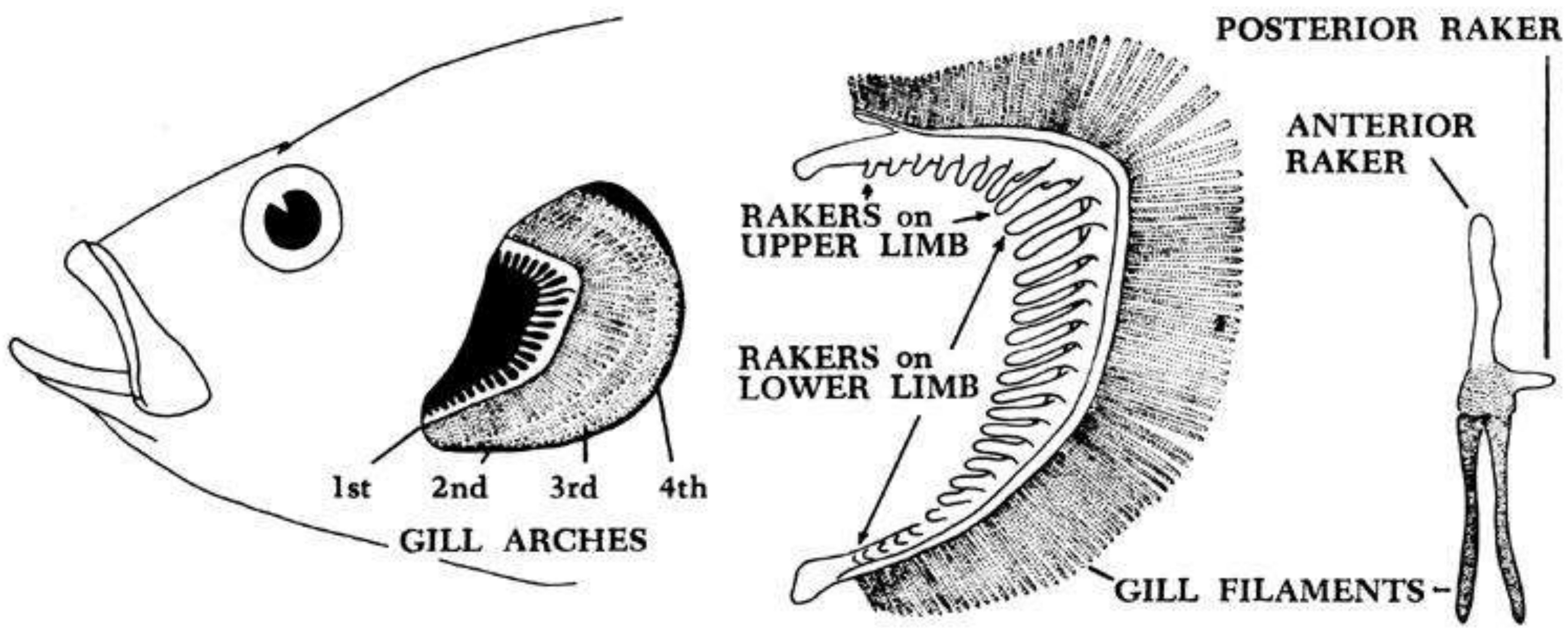
13- Barbel : present or absent.
Maxillary – Mental – Nasal ,………

A barbel is **a slender, whiskerlike sensory organ near the mouth**.
Fish that have barbels include the catfish, the carp, the goatfish, the hagfish, the sturgeon, the zebrafish, the black dragonfish and some species of shark such as the sawshark.


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)**

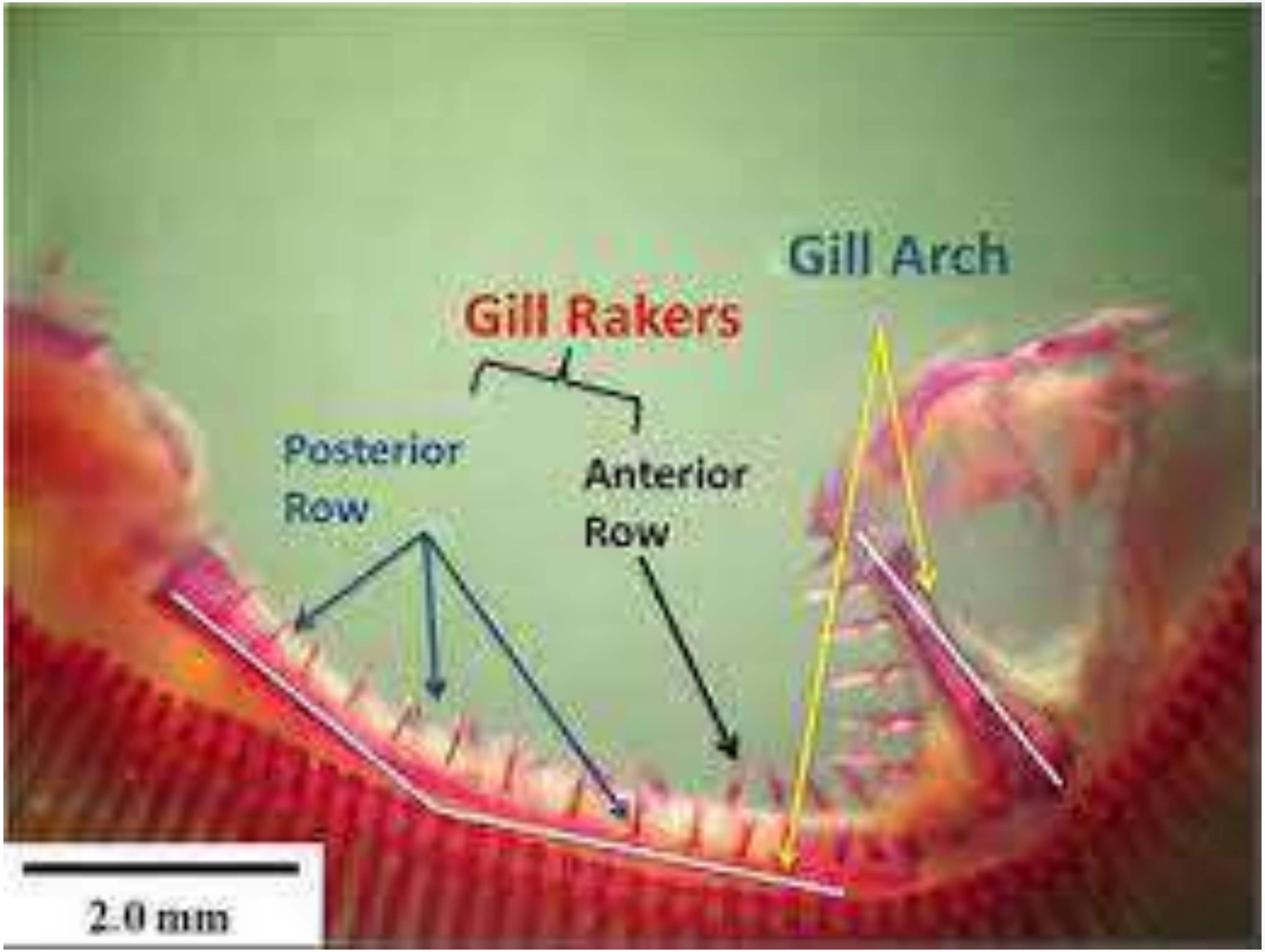


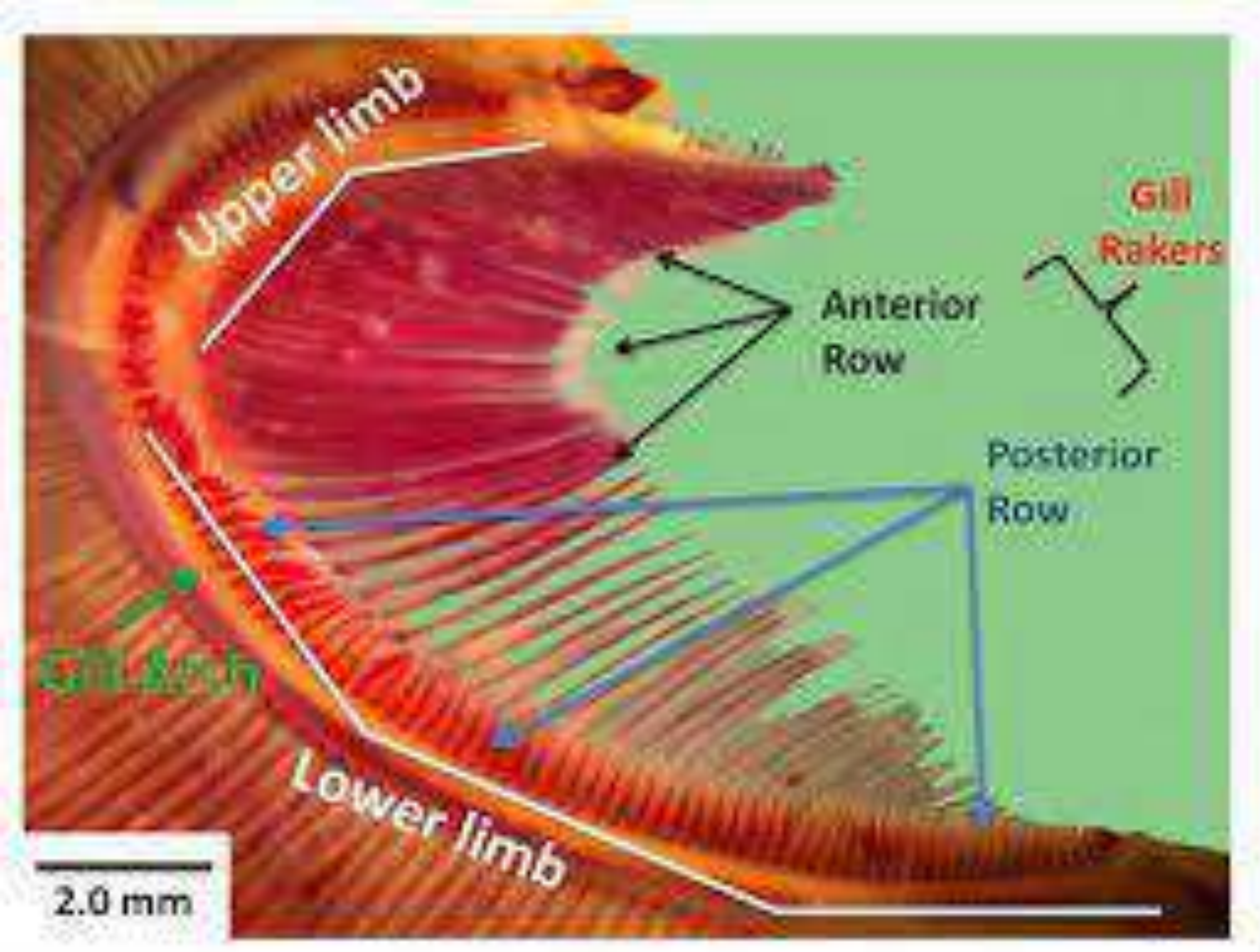

a) Position of Gill Arches inside Gill Cavity of a bony fish (Gill Cover or Operculum removed)

b) Side view of 1st Gill Arch (A raker in the angle between the upper and lower limbs is counted with the lower rakers)

c) Top view of cross-section of 1st Gill Arch

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


Gill Arch
Gill Rakers
Posterior
Row
Anterior
Row
2.0 mm


Upper limb
Gill
Rakers
Anterior
Row
Posterior
Row
Gill Arch
Lower limb
2.0 mm

# 17- Fins:

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

**Unpaired fins:**

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

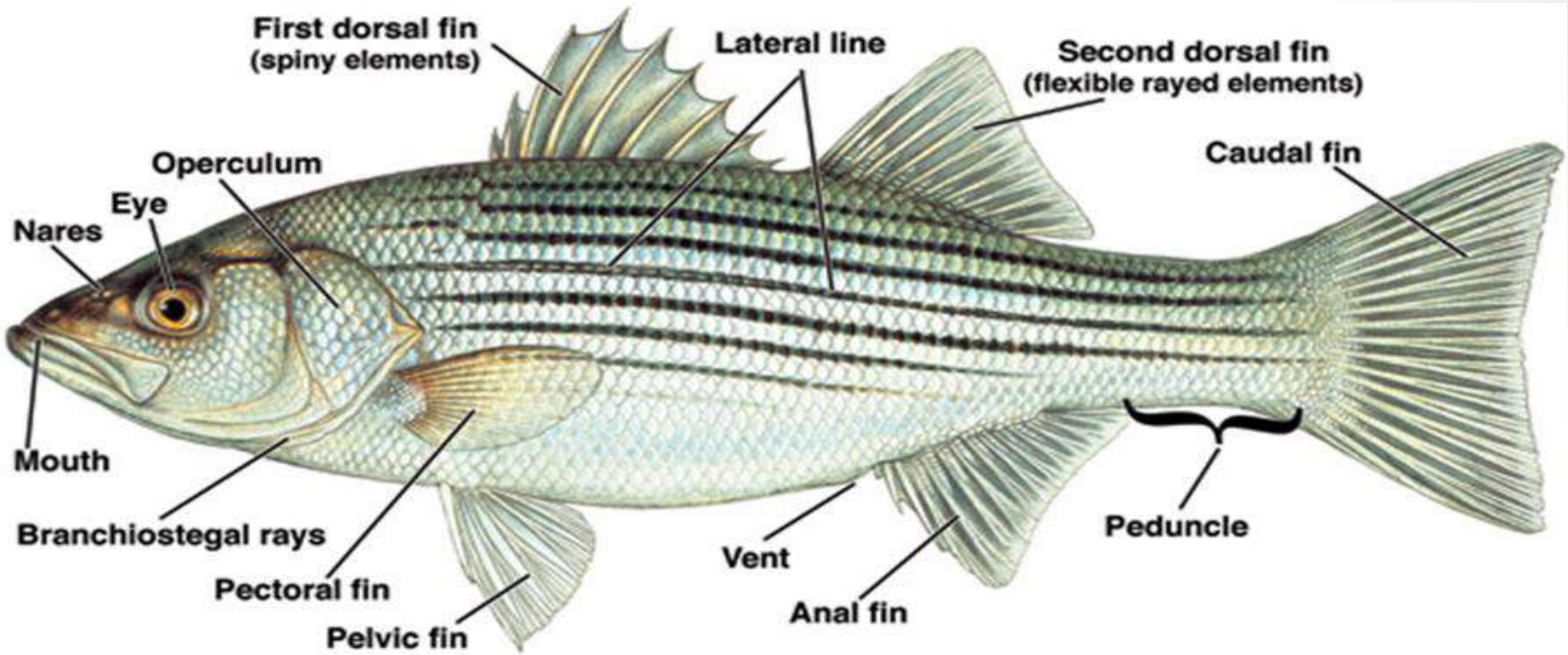
**Fin ray count: for the dorsal & anal fins)**

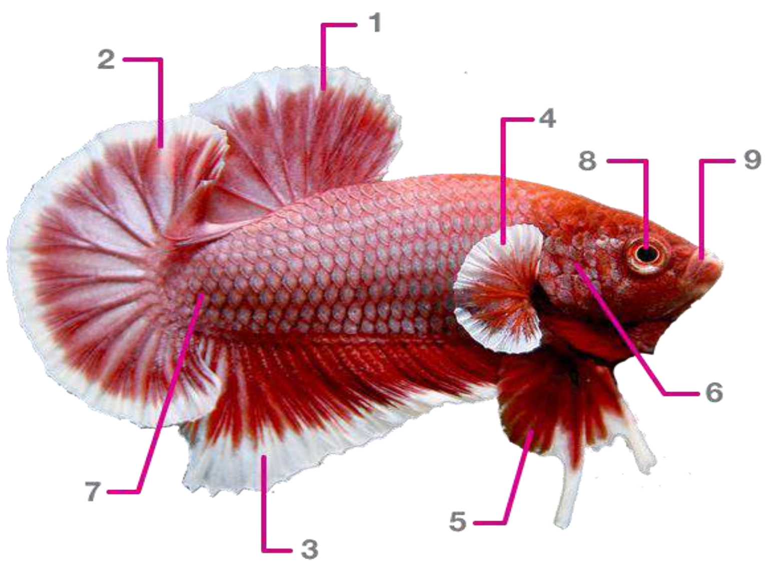
**Rays: may be spines or soft fin rayes.**

**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**




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

**Caudal fin types:** **as figure**

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

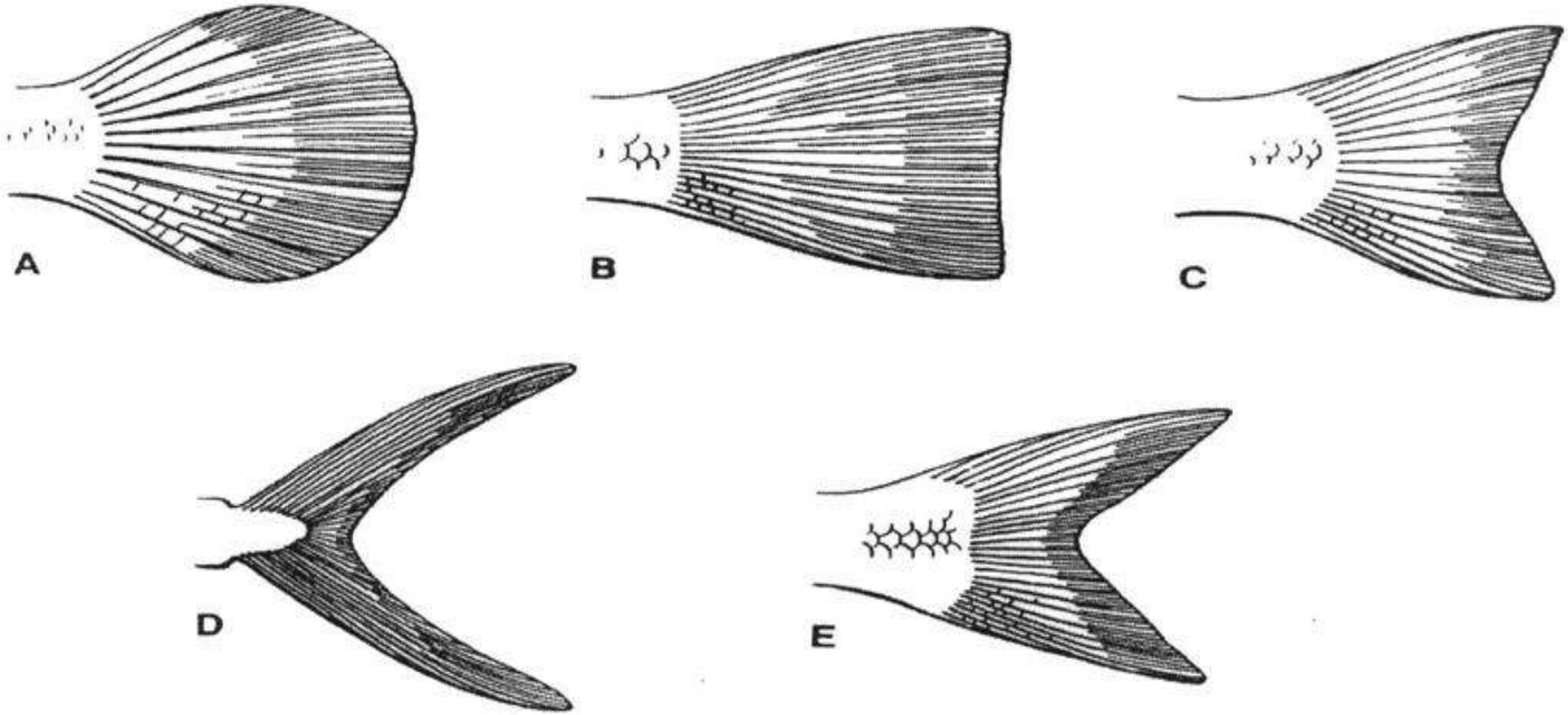
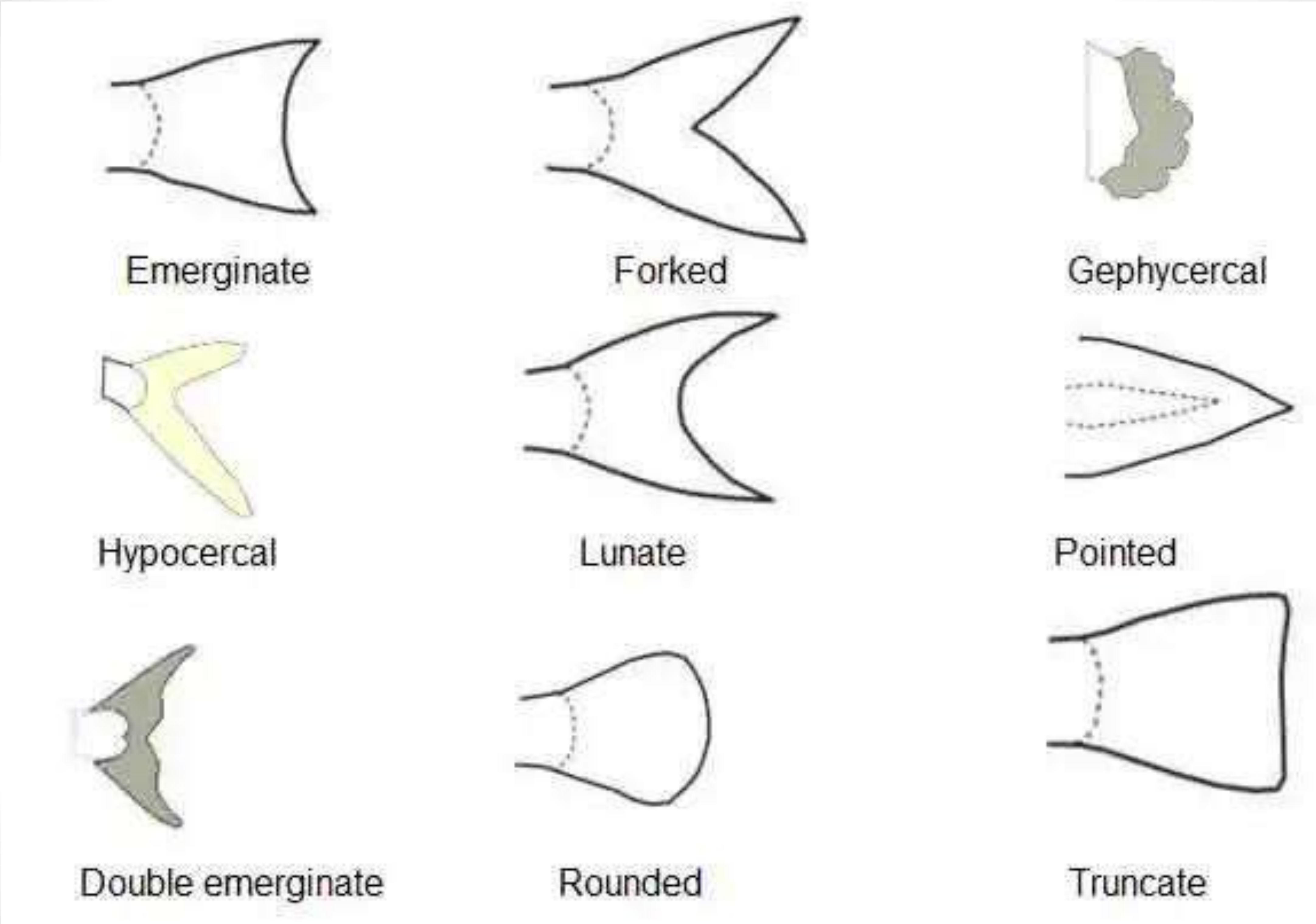
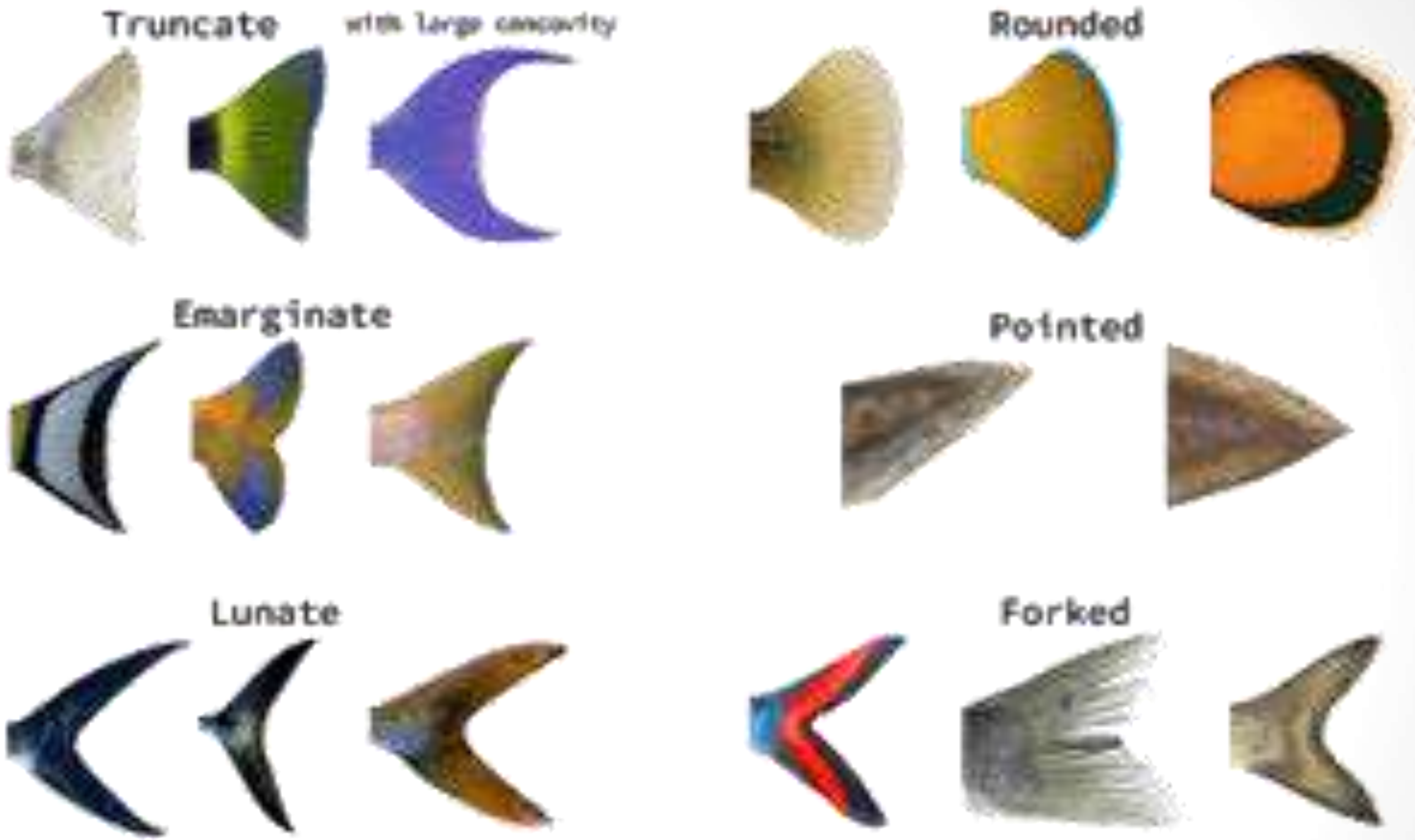
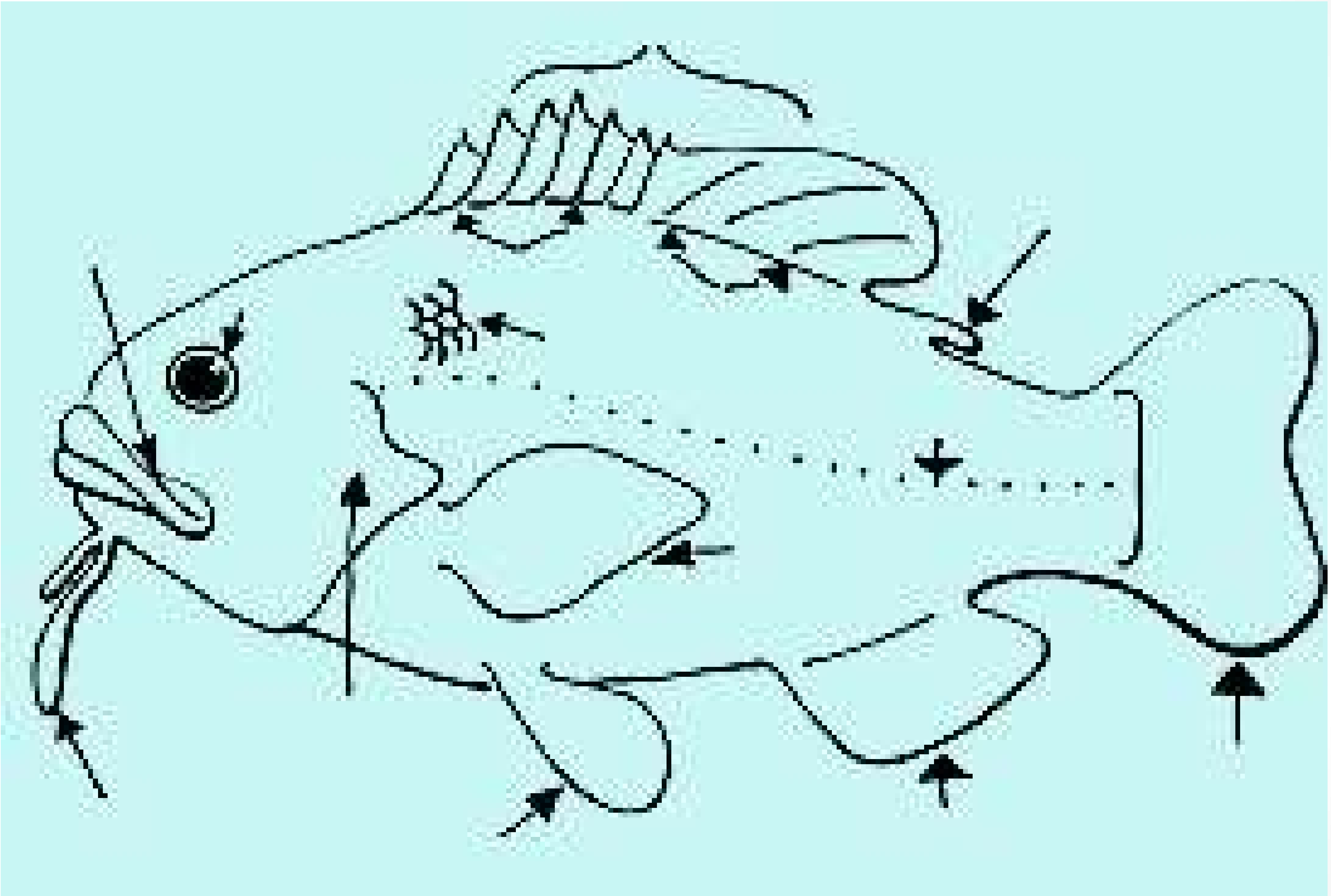



FIGURE 2–16. Representative shapes of caudal fins. *A*, Rounded; *B*, truncate; *C*, emarginate; *D*, lunate; *E*, forked.


Emerginate
Forked
Gephycercal
Hypocercal
Lunate
Pointed
Double emerginate
Rounded
Truncate



Truncate
with large concavity
Rounded
Emarginate
Pointed
Lunate
Forked

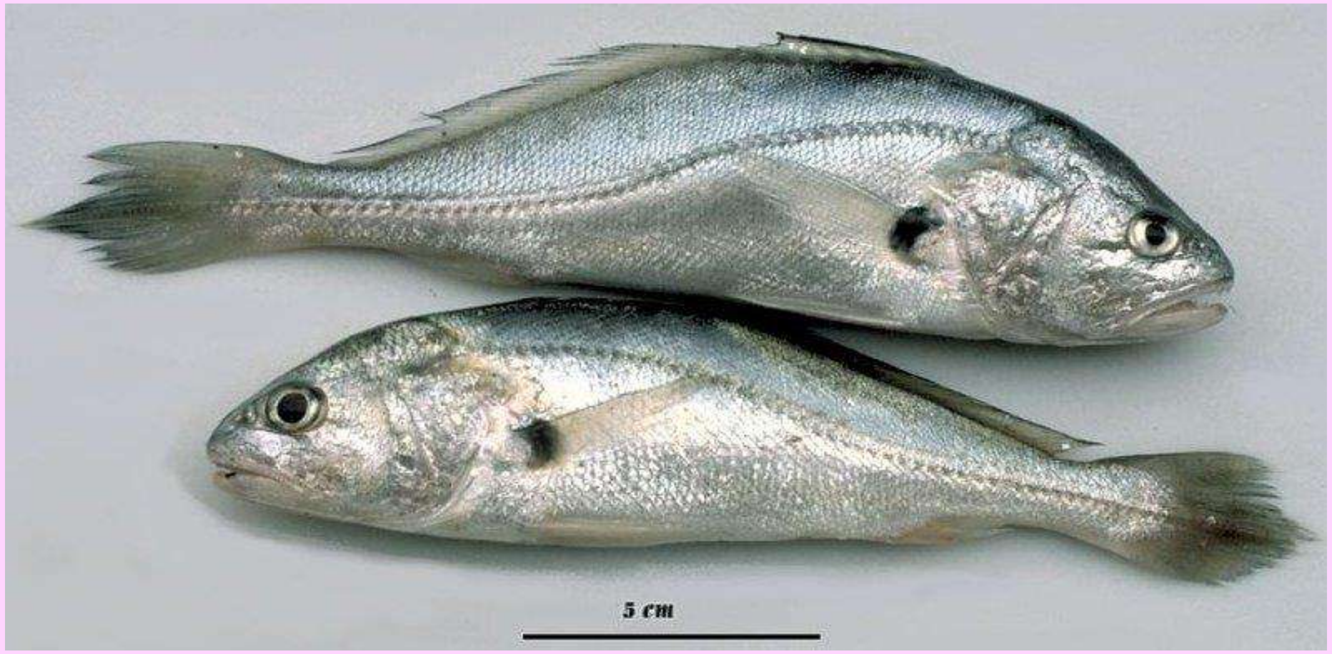


# Lectures 2

## External features

## ***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.**



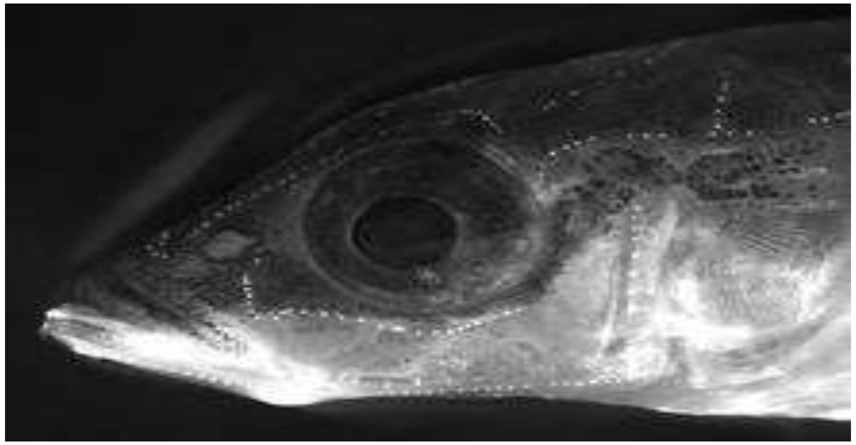
- **Lateral line system consists of jelly-filled canals just below the skin. It opens to the water outside by a series of tiny pores.**

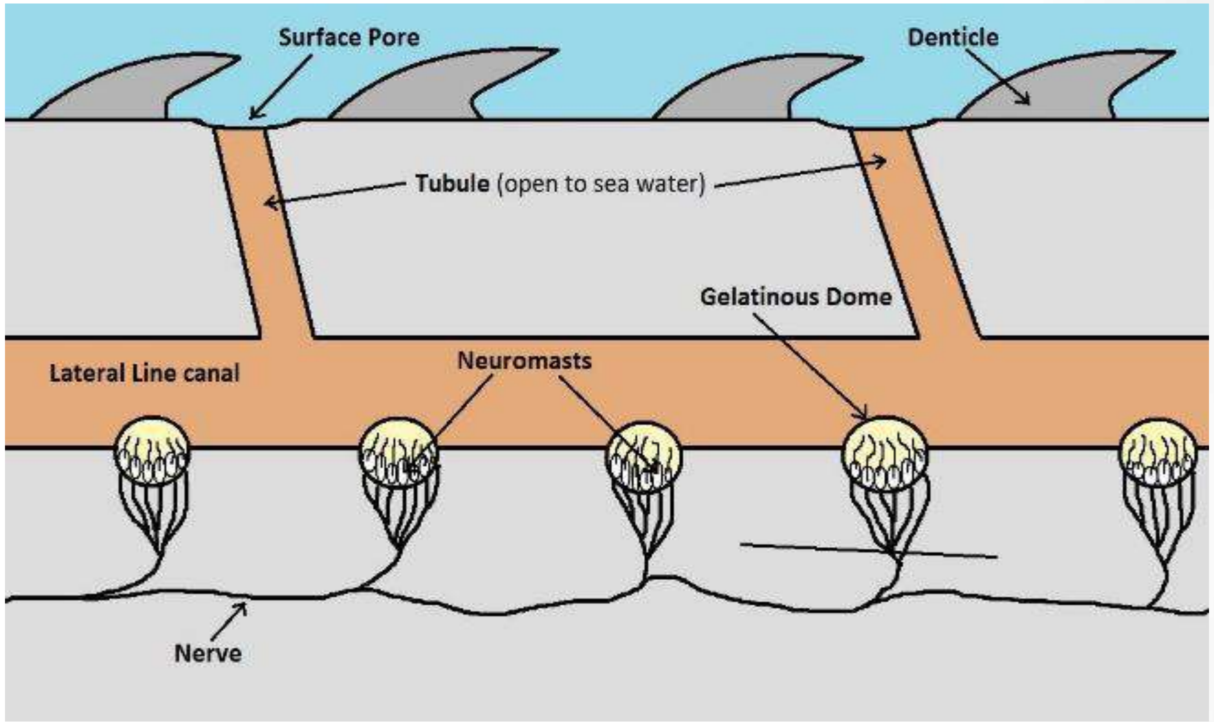
- **The functional unit of the lateral line is the neuromast (mechanoreceptors).**

- **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.**

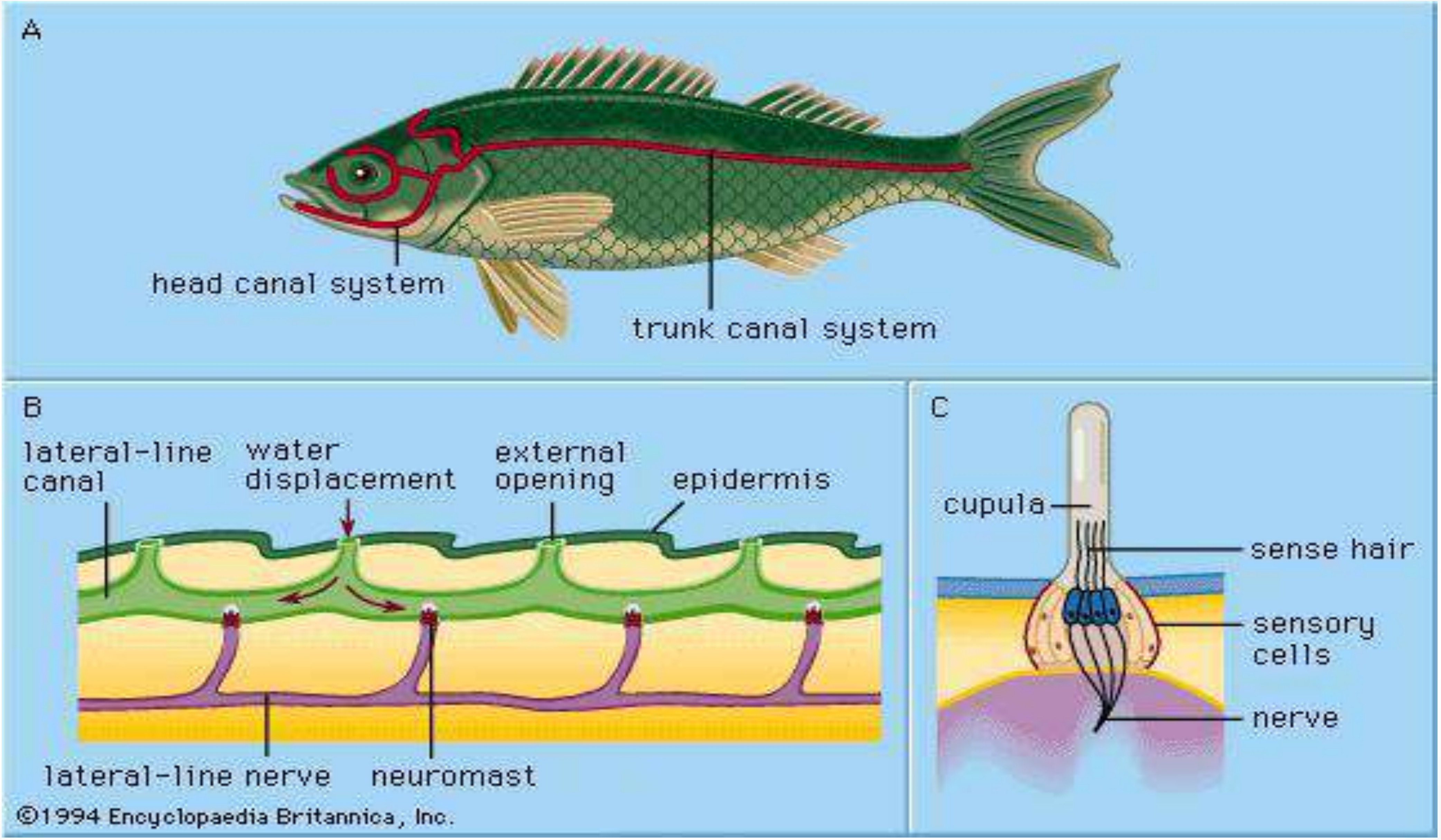
- **The rows of neuromasts appear on the surface of the skin & spread over the head, trunk and tail; however, for most fishes, they lie embedded in the floor of mucus-filled lateral line canals.**
- **The sensitivity of this system makes blind fish very difficult to be catched by hand.**

# The lateral line in fishes





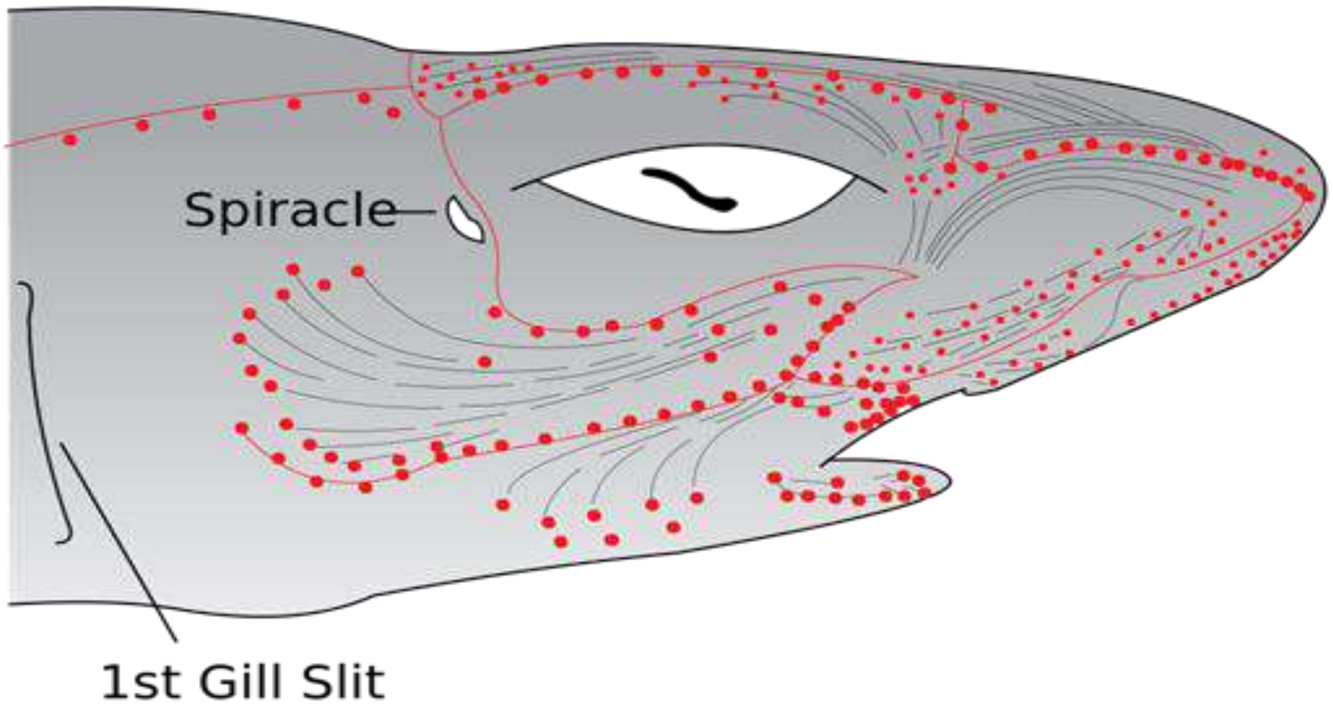
# The lateral line in fishes



# Ampullae of Lorenzini

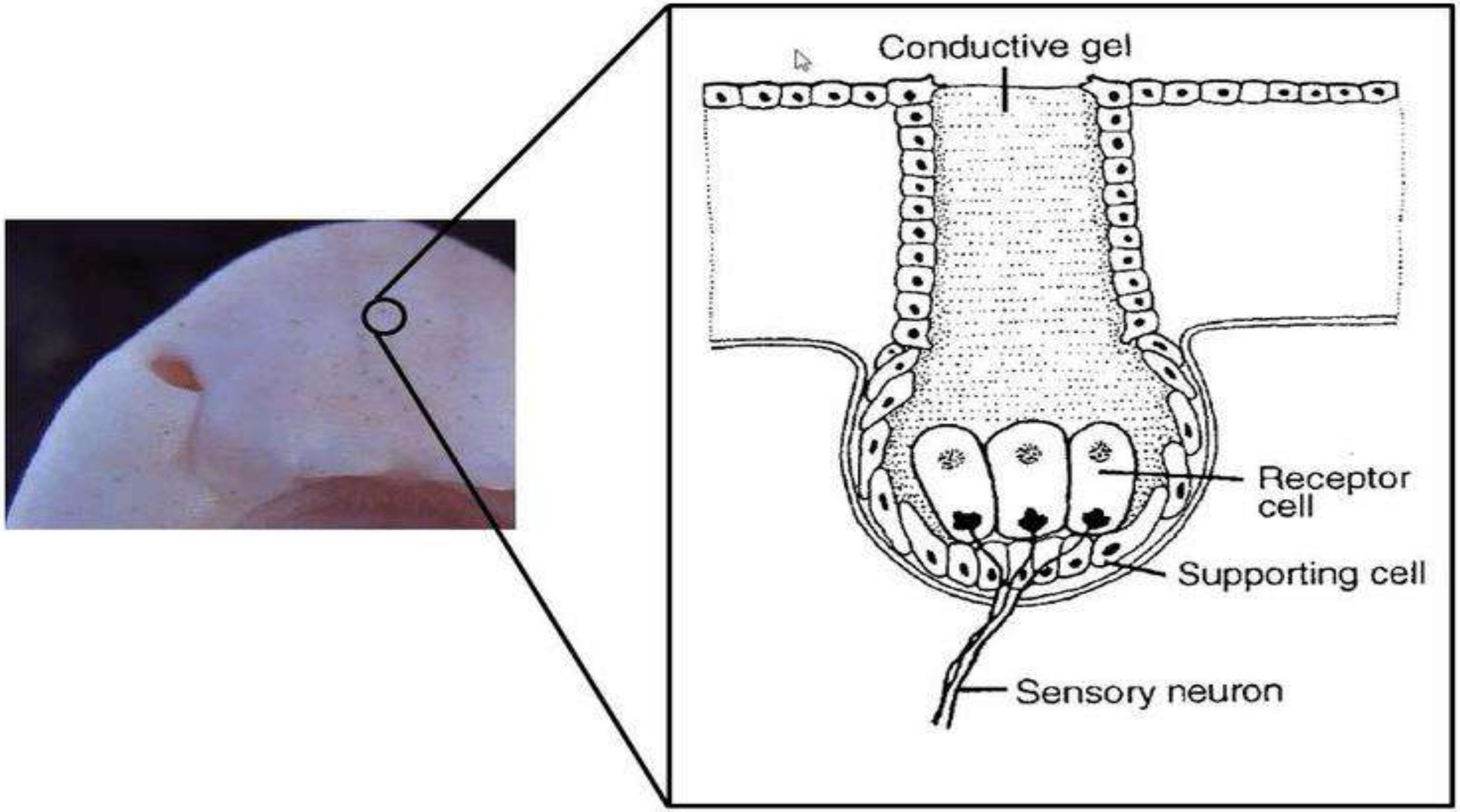
- The ampullae of Lorenzini are highly specialized sense organs called electroreceptors,
- They are mostly found in cartilaginous fish (sharks, rays, and chimaeras); and also, found in some other fishes.
- The ampullae of Lorenzini provide fish an additional sense capability of detecting electric and 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

# (Ampullae of Lorenzini)



## 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.

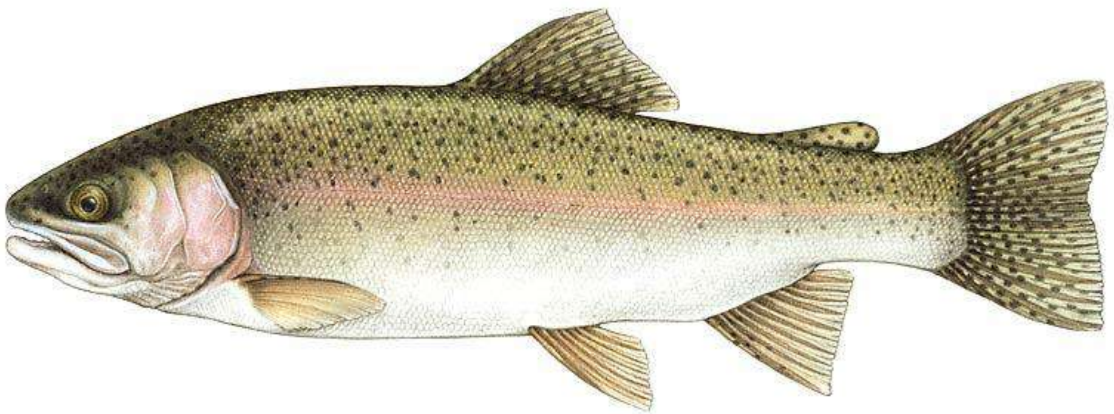
**Terminal Mouth**
Terminal mouths are located in the middle of the head, pointed straight forward, with both jaws being the same length. Most fishes have this mouth type than any other. Fish having a terminal mouth are generally mid water feeders, however they can feed at any location. These species 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)

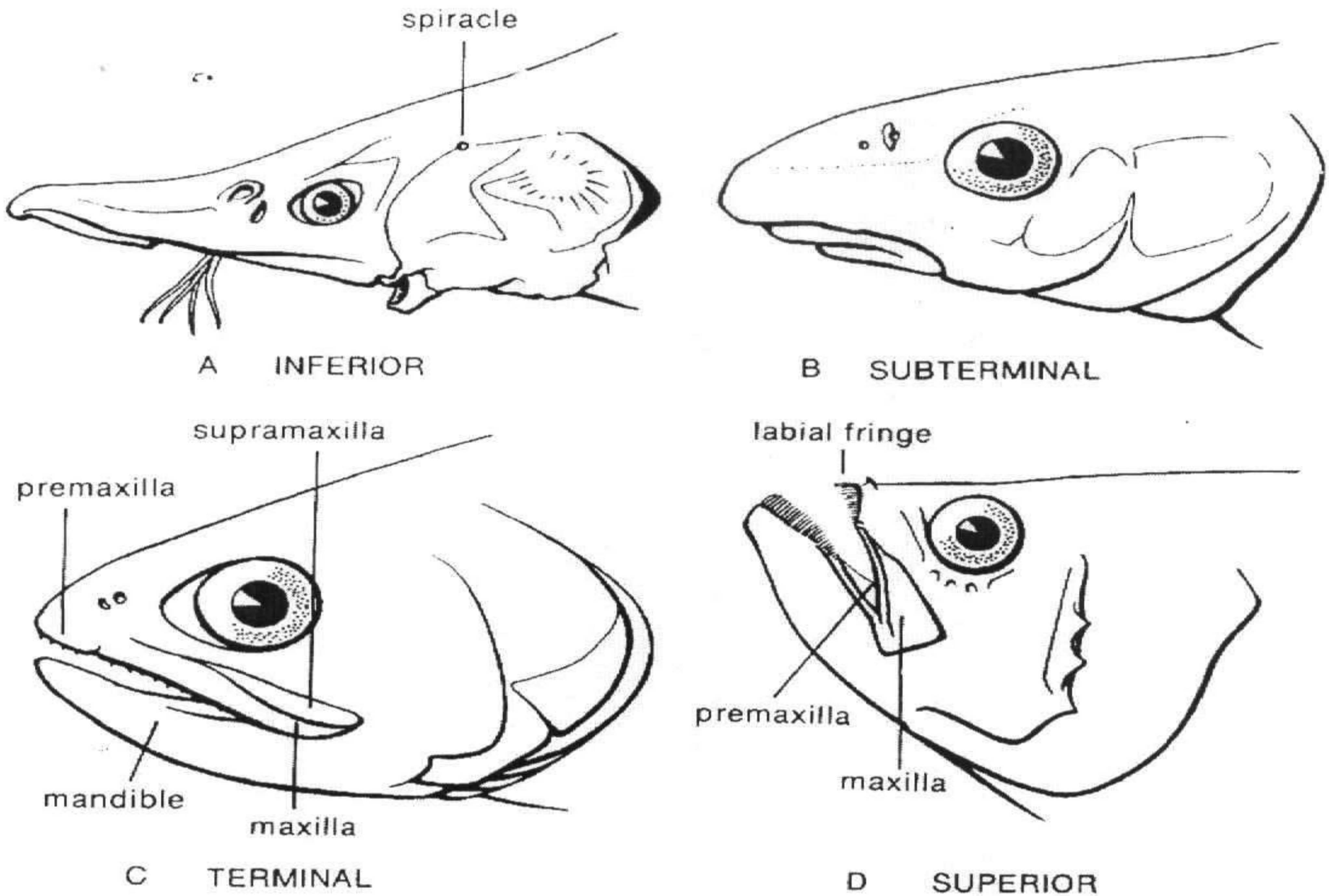



**FIGURE 2–2.** Examples of mouth positions in fishes. *A*, Inferior (sturgeon); *B*, subterminal (dace); *C*, terminal (trout); *D*, superior (sandfish). (*D*, based on Jordan and Evermann, 1900.)

# 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.

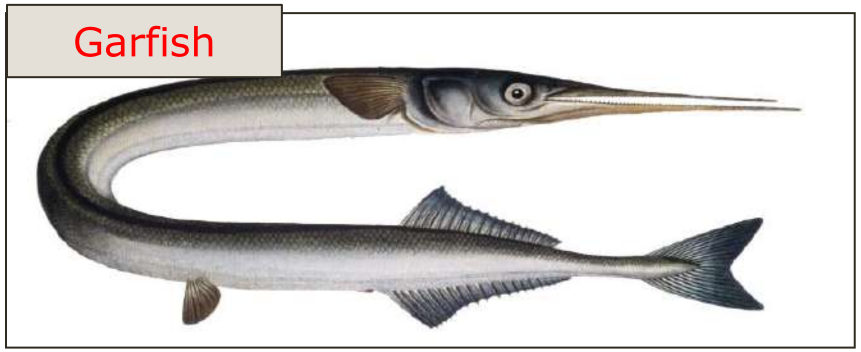
Protrusile Mouth

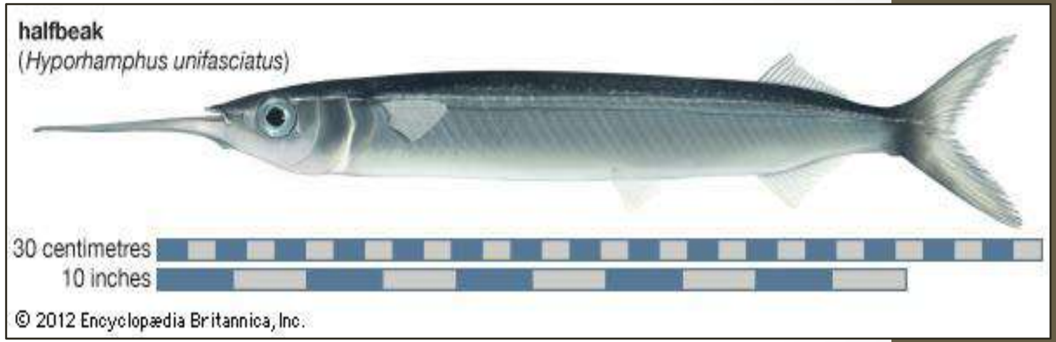
Sucker Mouth

## 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.

Garfish



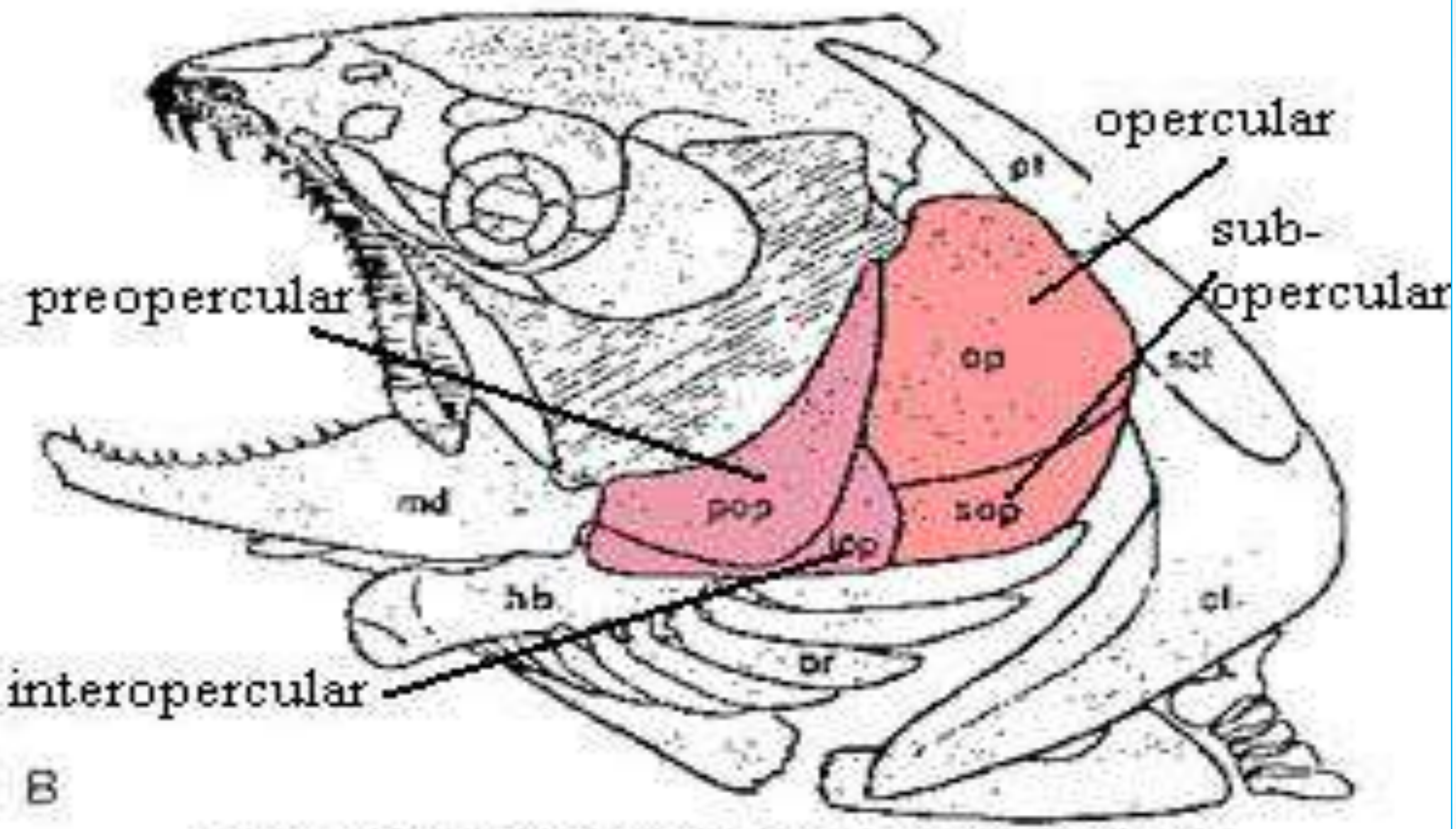



## Beak Mouth

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.

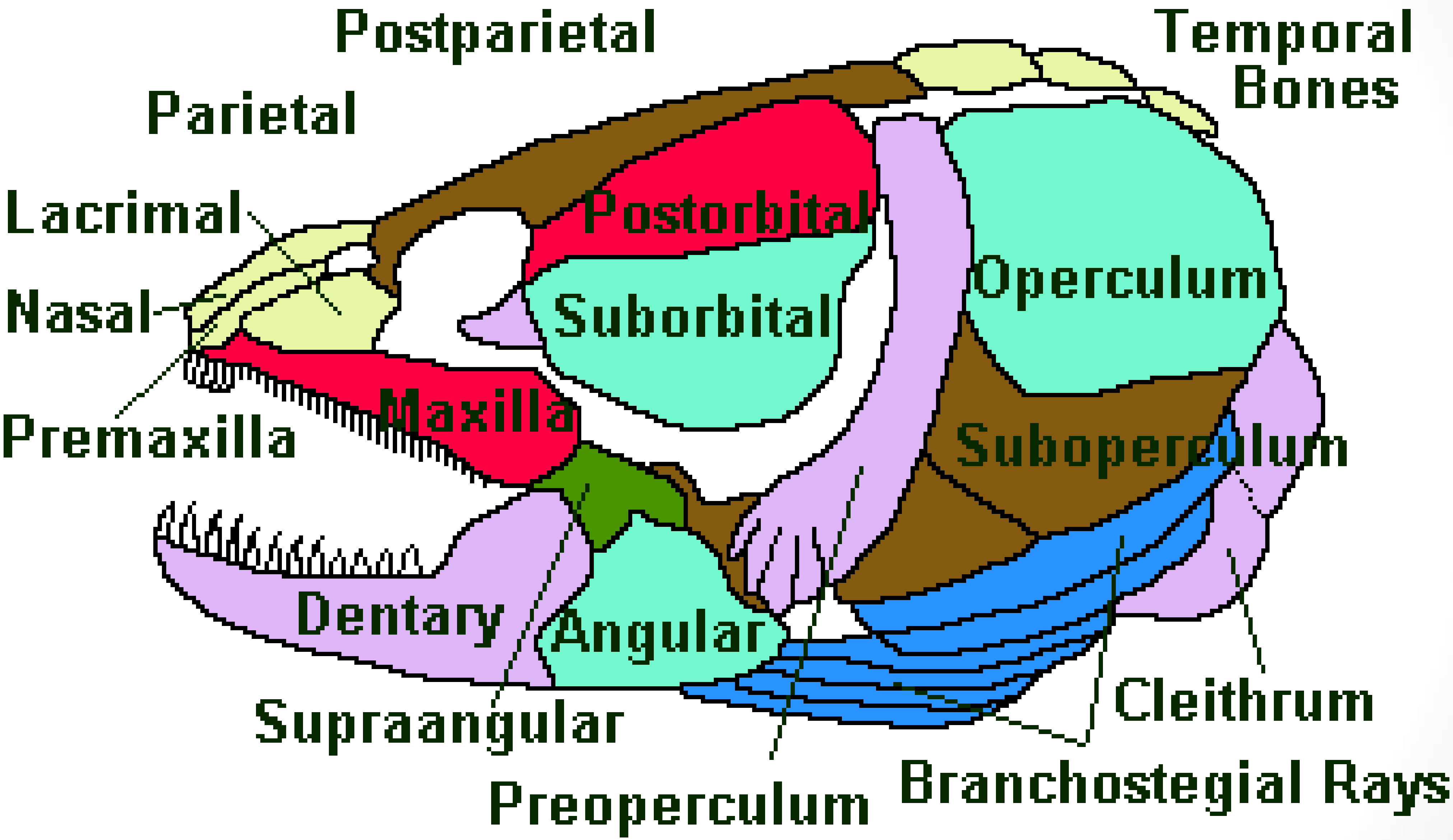

## ***The operculum:***

- 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**

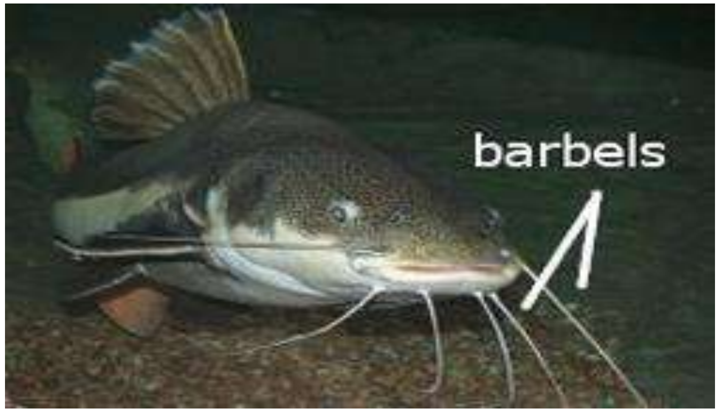
# A Primitive Bony Fish Skull



**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

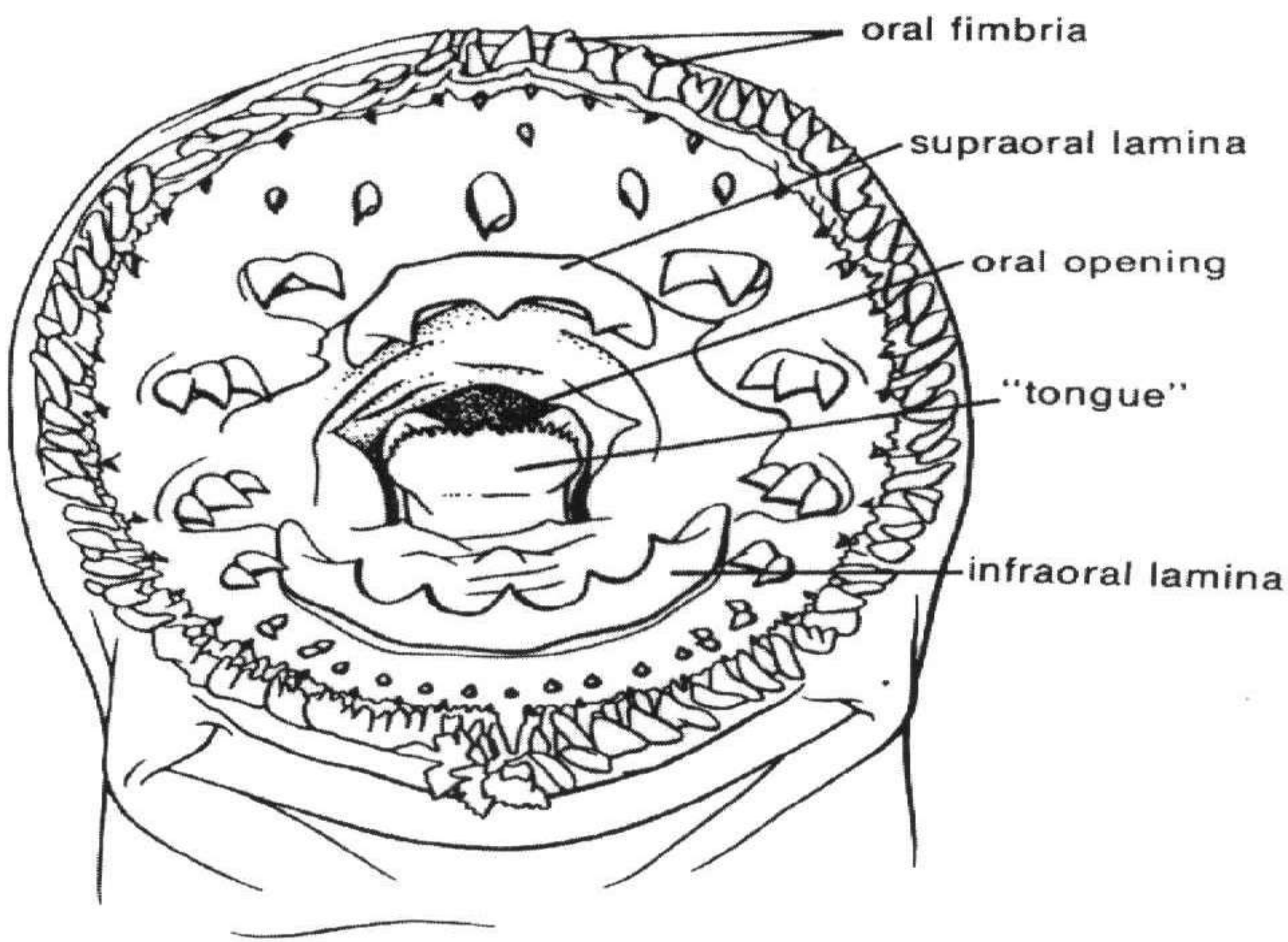



**FIGURE 2–4.** Oral disc of lamprey (*Lampetra minima*).

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

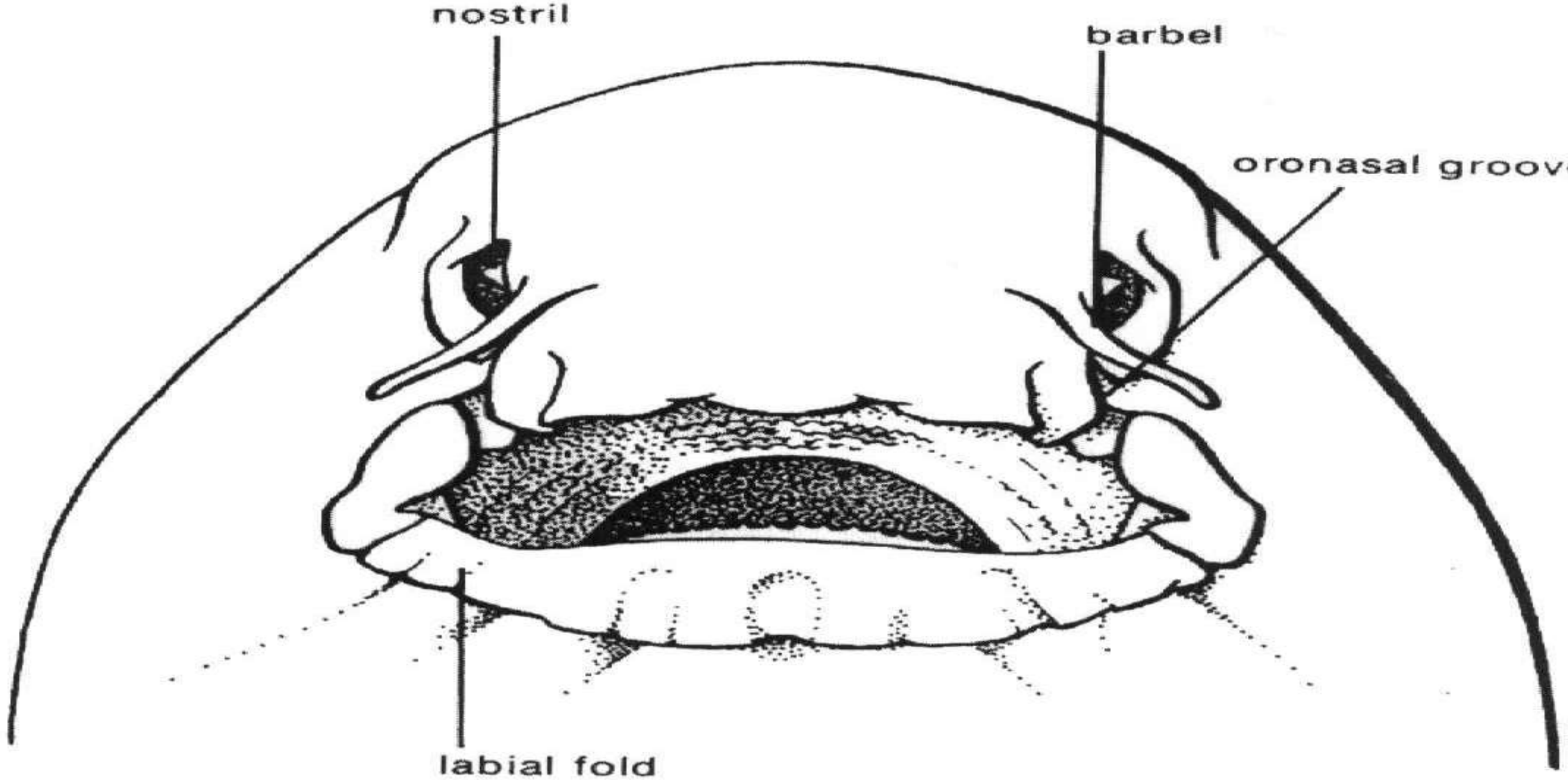
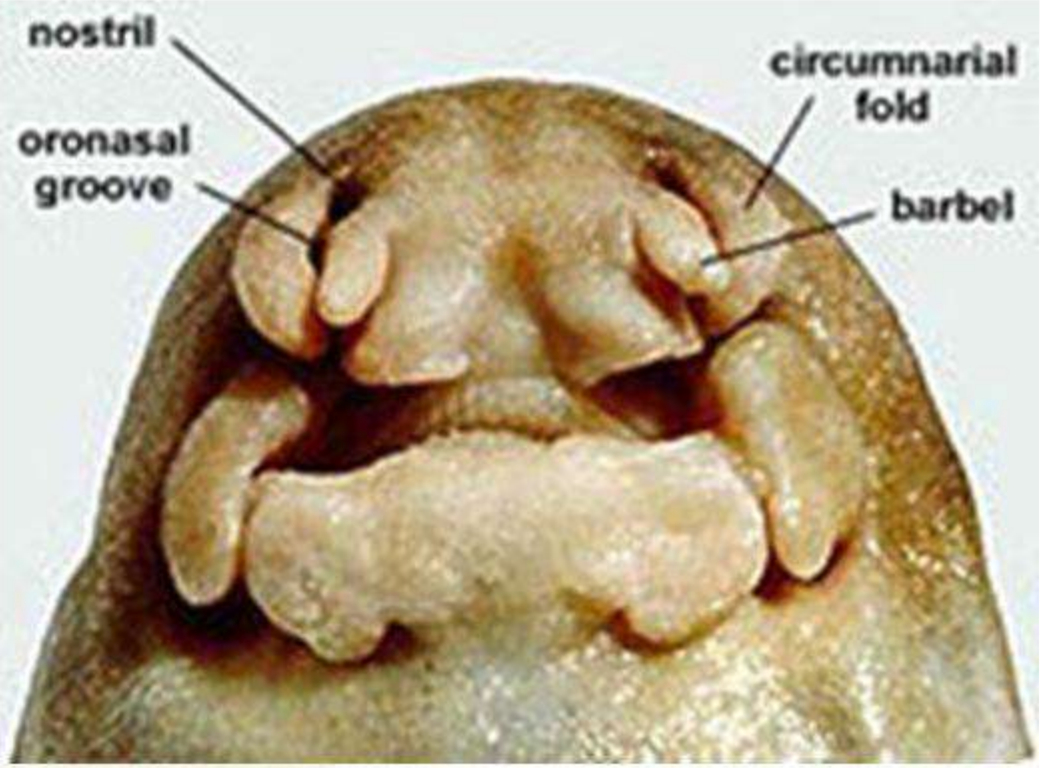
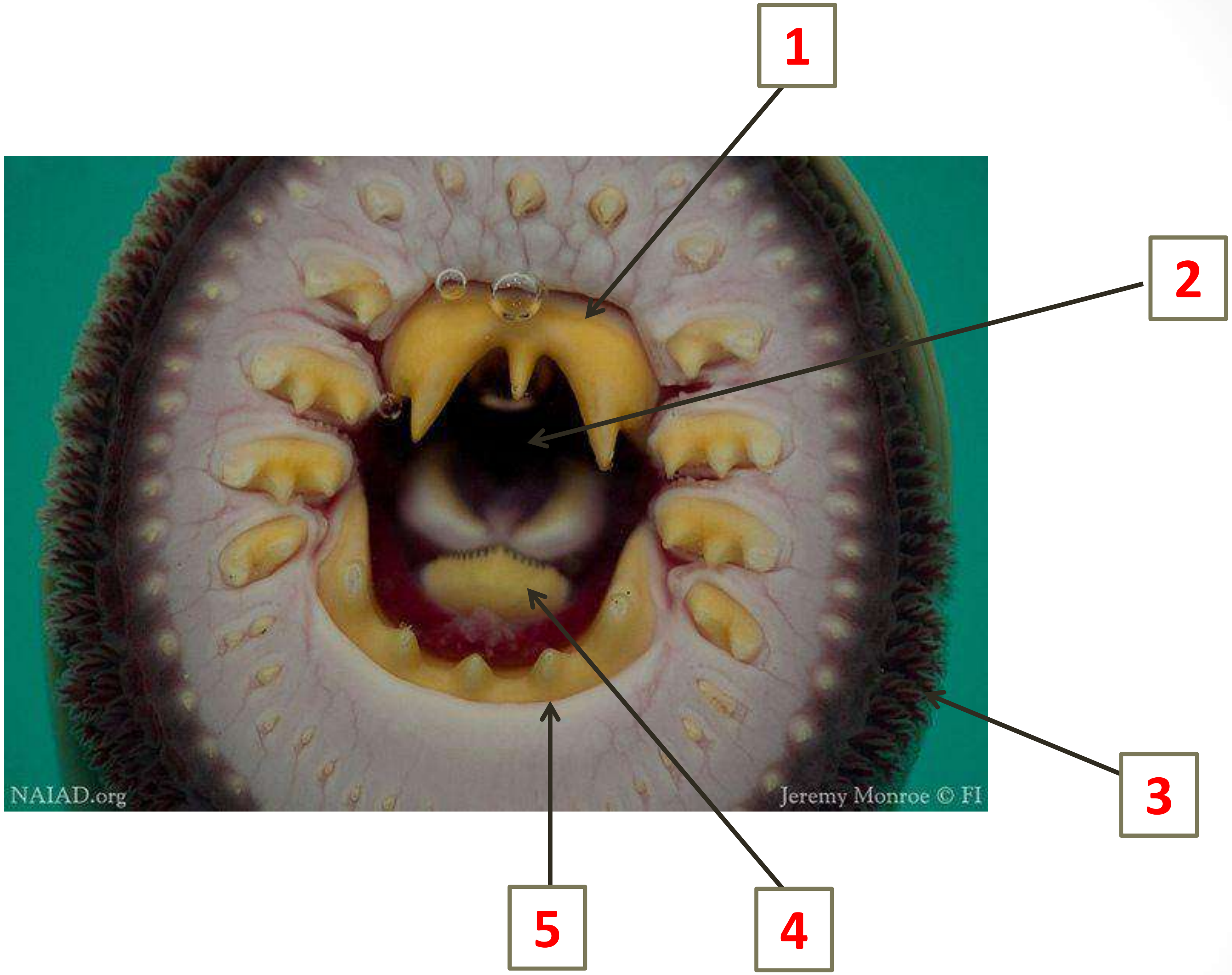



**FIGURE 2–3.** Ventral view of mouth and rostrum of shark (*Chiloscyllium indicum*) showing grooves and labial folds.

# Epaulette Shark

- Walks along sea bottom





1
2
3
4
5
NAIAD.org
Jeremy Monroe © FI

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

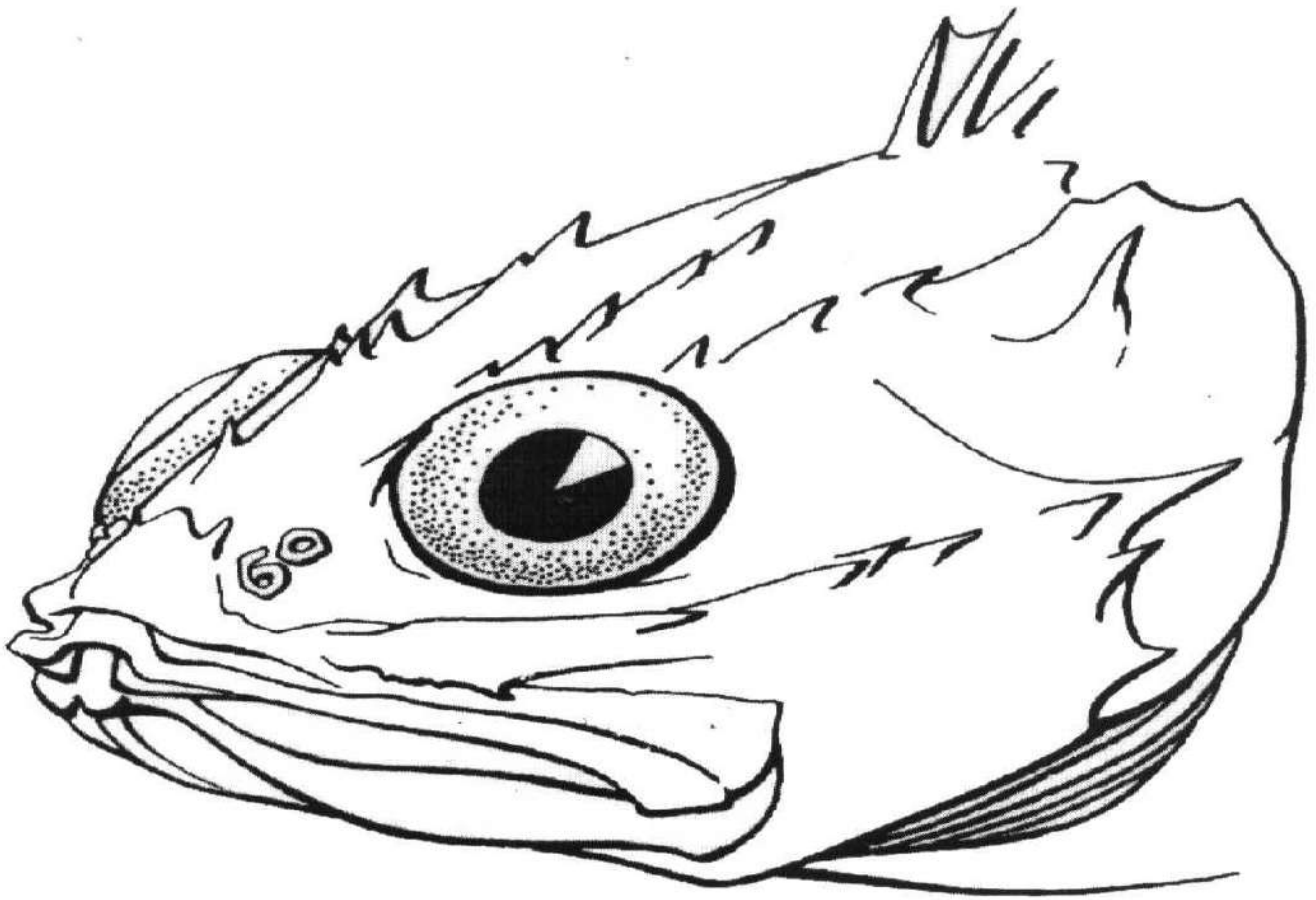


FIGURE 2–5. Diagram of head of rockfish (Scorpaenidae), showing spines.

# ***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.

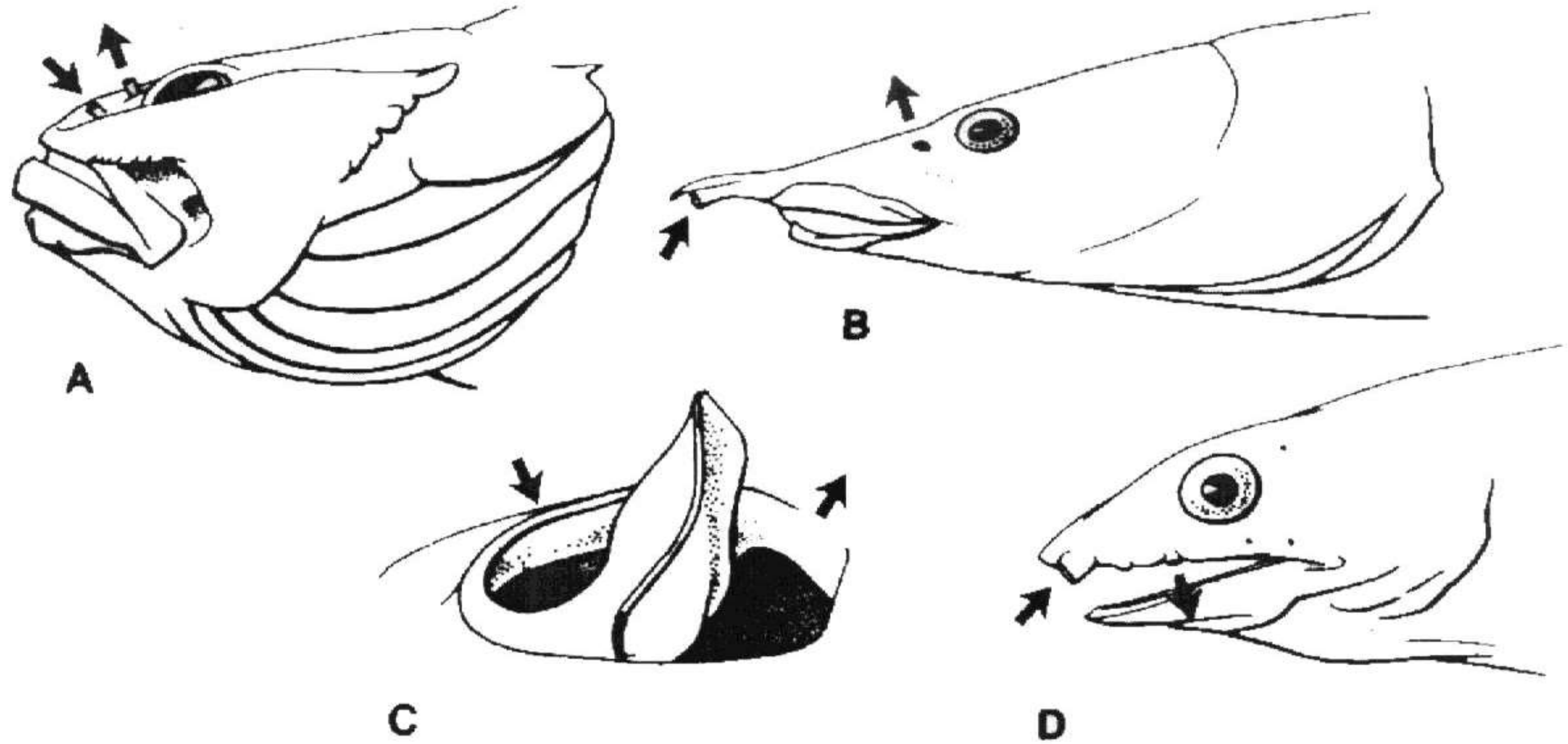
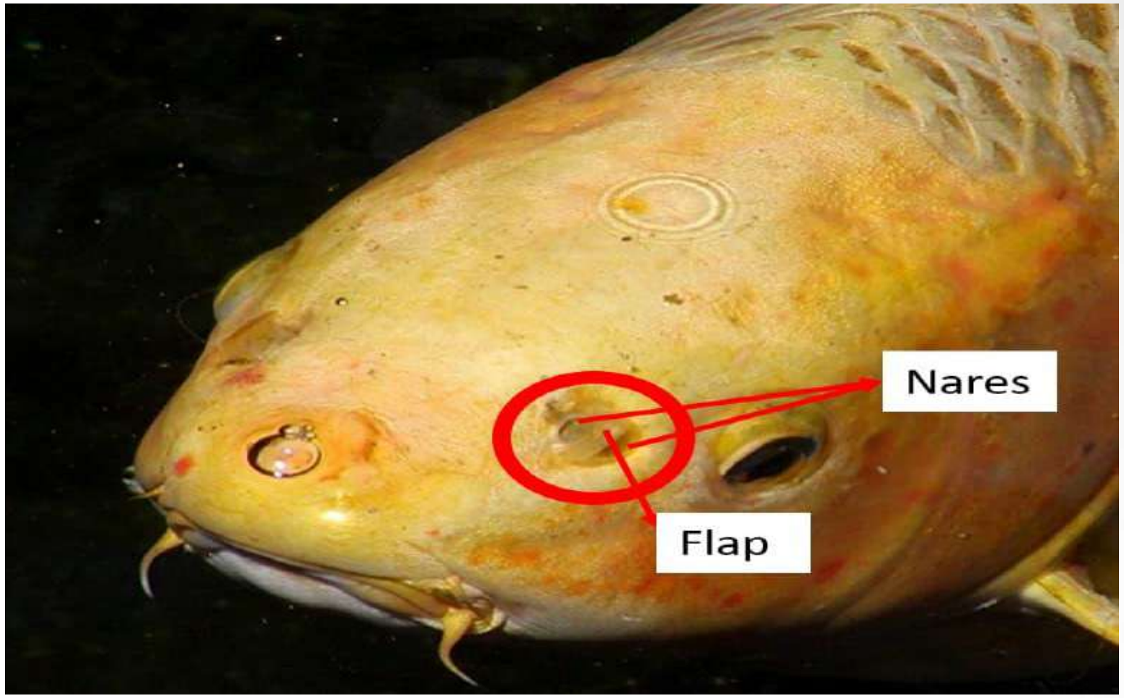
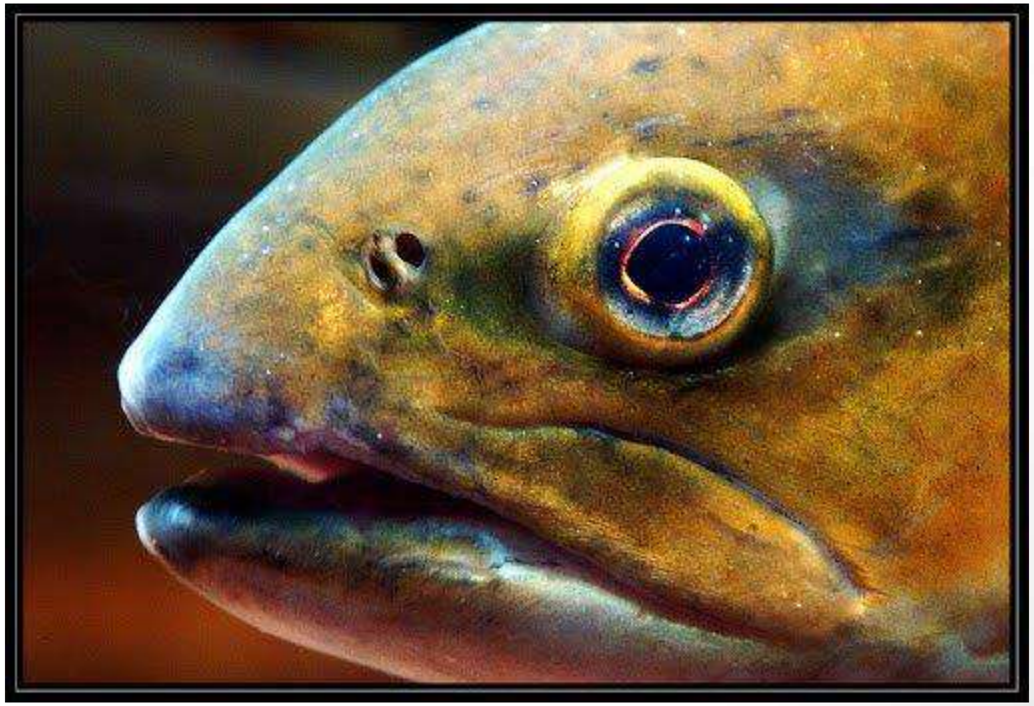



**FIGURE 2–7.** Nostril positions. *A*, Sculpin (Cottidae); *B*, spiny eel (Mastacembelidae); *C*, typical bony fish nostrils divided by flap of skin (Catostomidae); *D*, eel (*Myrophis*).


Nares
Flap



# *Fins of fishes

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

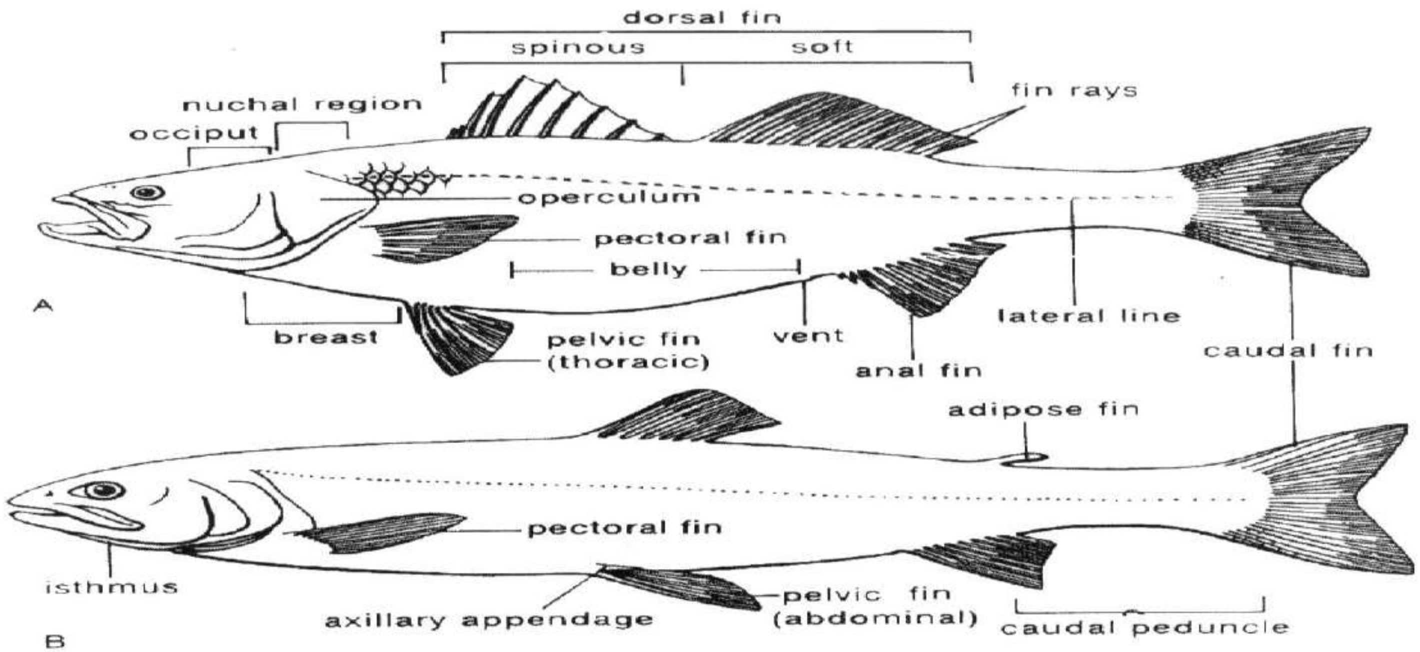



**FIGURE 2–10.** Body regions and fins. *A*, Spiny-rayed fish; *B*, soft-rayed fish.

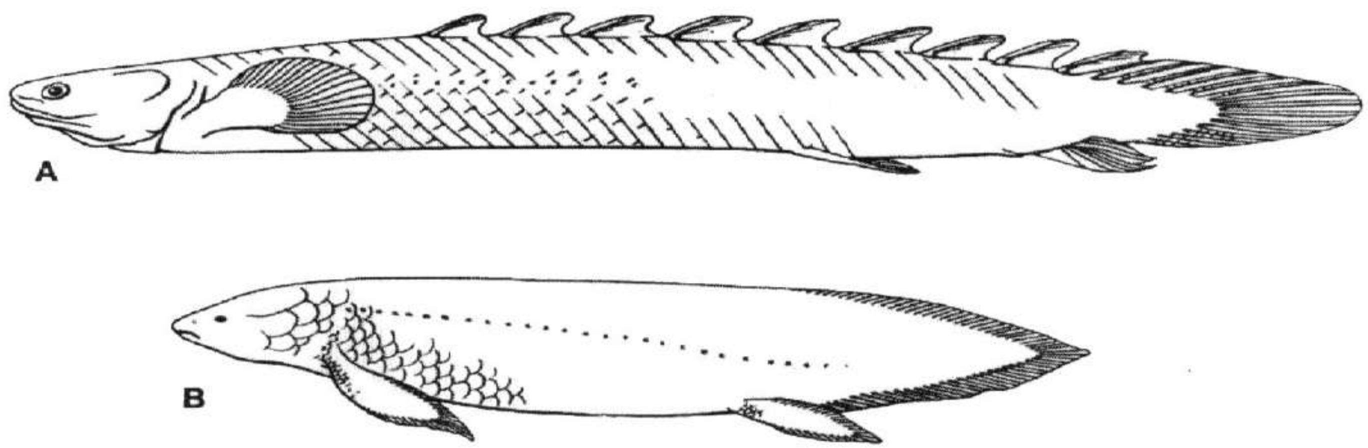



**FIGURE 2–11.** Examples of fishes with lobate paired fins. *A*, Bichir (*Polypterus*); *B*, Australian lungfish (*Neoceratodus*). (*B* based on Goodrich, in Lankester, 1909.)

1. Paired fins

# *Fishes with modified pectoral fins

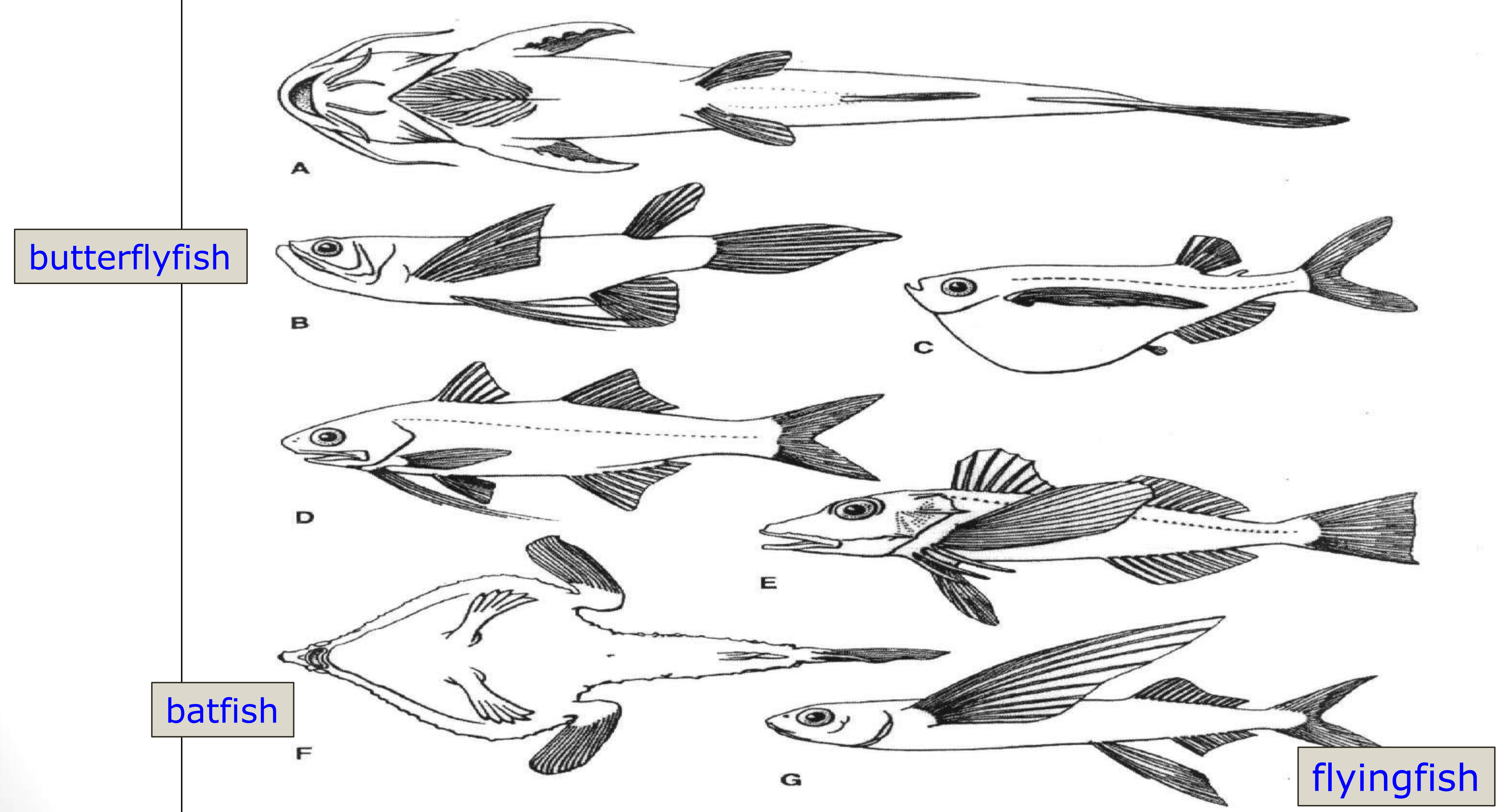



FIGURE 2–12. Examples of fishes with modified pectoral fins. *A*, Sisorid catfish (*Glyptothorax*); *B*, freshwater butterflyfish (*Pantodon*); *C*, hatchetfish (*Gastropelecus*); *D*, threadfin (Polynemidae); *E*, gurnard (Triglidae); *F*, batfish (Ogcocephalidae); *G*, flyingfish (Exocoetidae). (*B*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

## *Position of pelvic fins in fishes

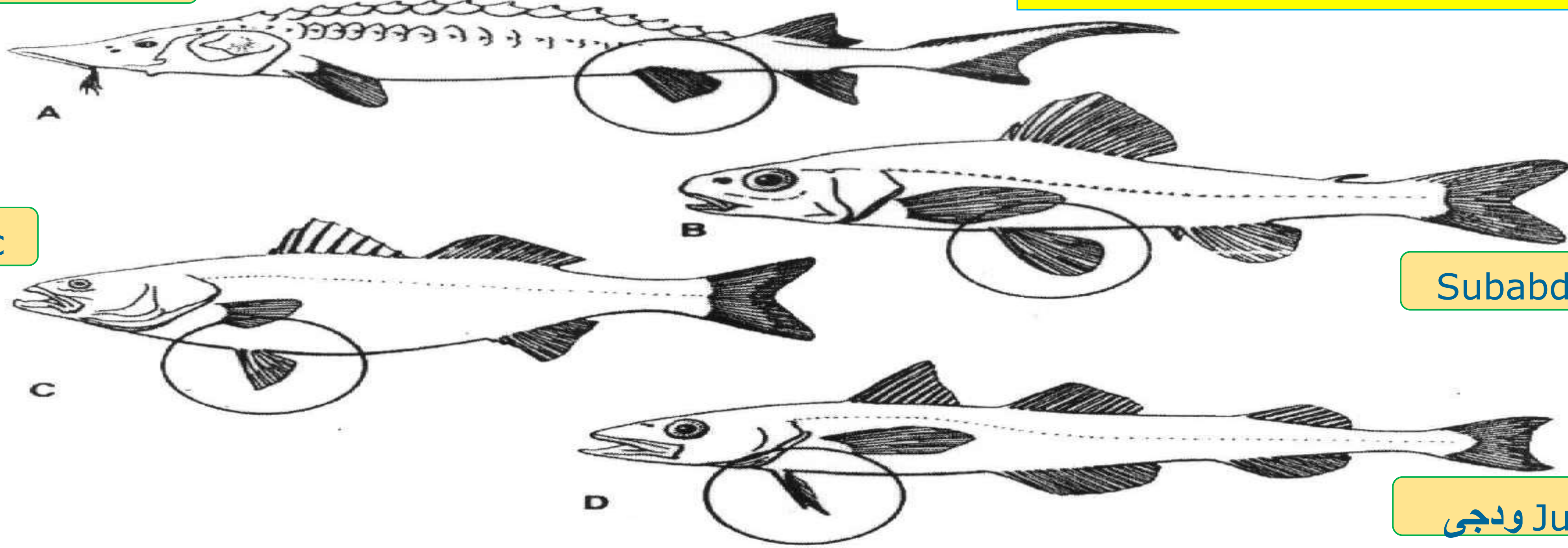



FIGURE 2–13. Examples of pelvic fin placement, pelvic fins circled. *A*, Abdominal (sturgeon, Acipenseridae); *B*, subabdominal (sand roller, Percopsidae); *C*, thoracic (bass, Percichthyidae); *D*, jugular (pollock, Gadidae). (Based on Jordan and Evermann, 1900.)

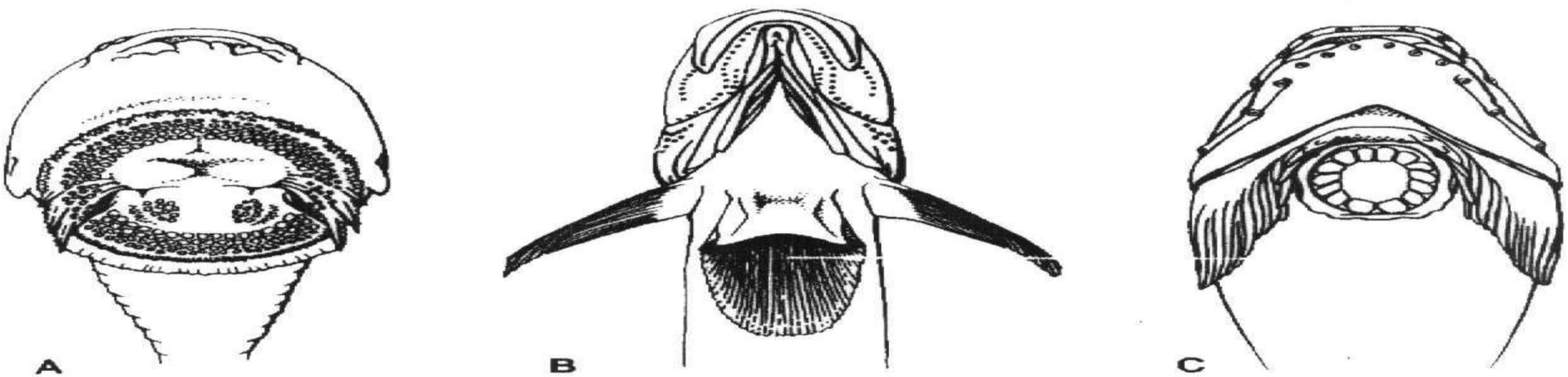



FIGURE 2–14. Pelvic fins modified as sucking devices. *A*, Clingfish (Gobiesocidae); *B*, goby (Gobiidae); *C*, Snailfish (Liparidae).

*Pelvic fins modified as sucking devices

## *median fins

**Dorsal fins modified into:**

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

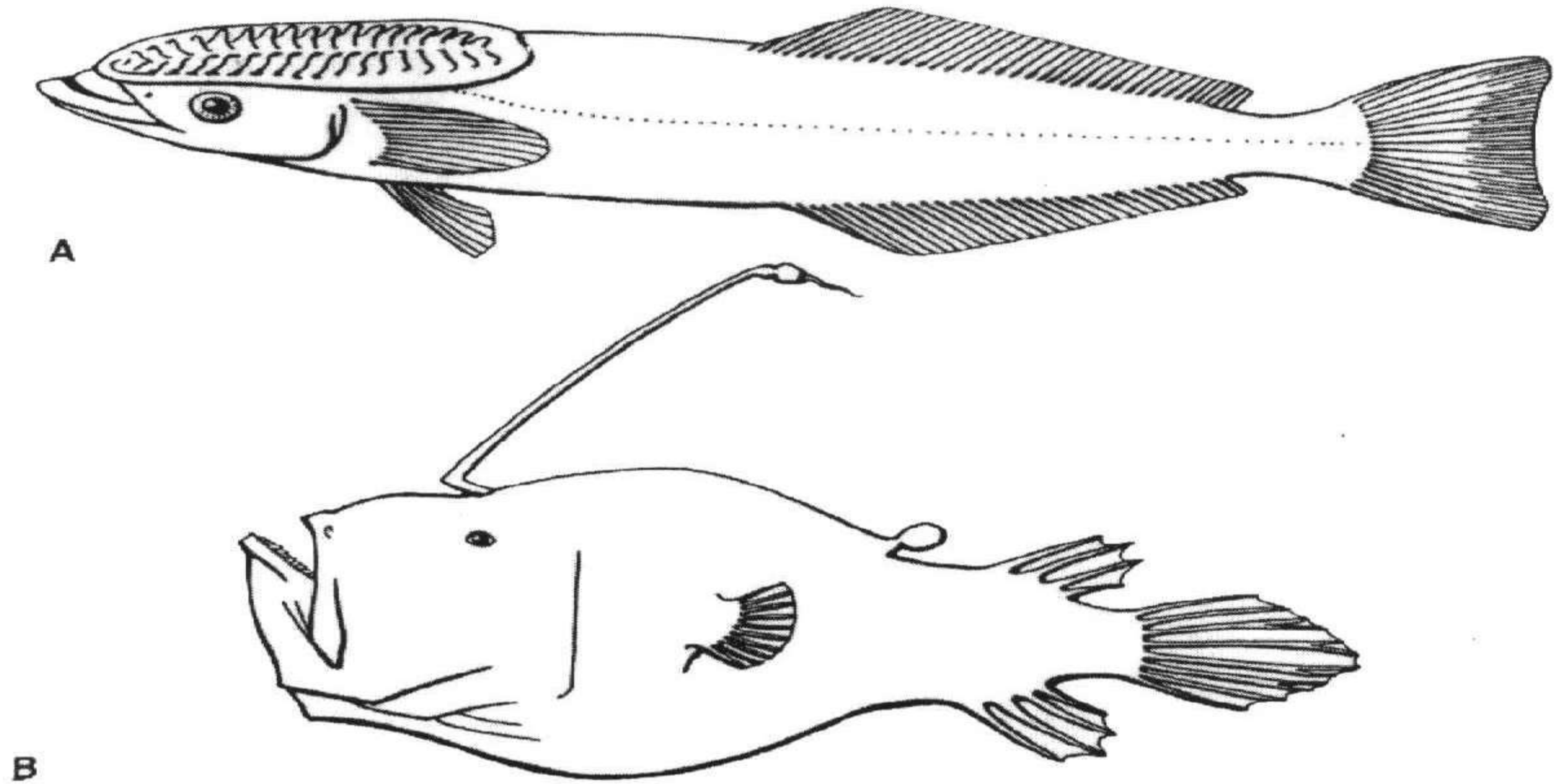
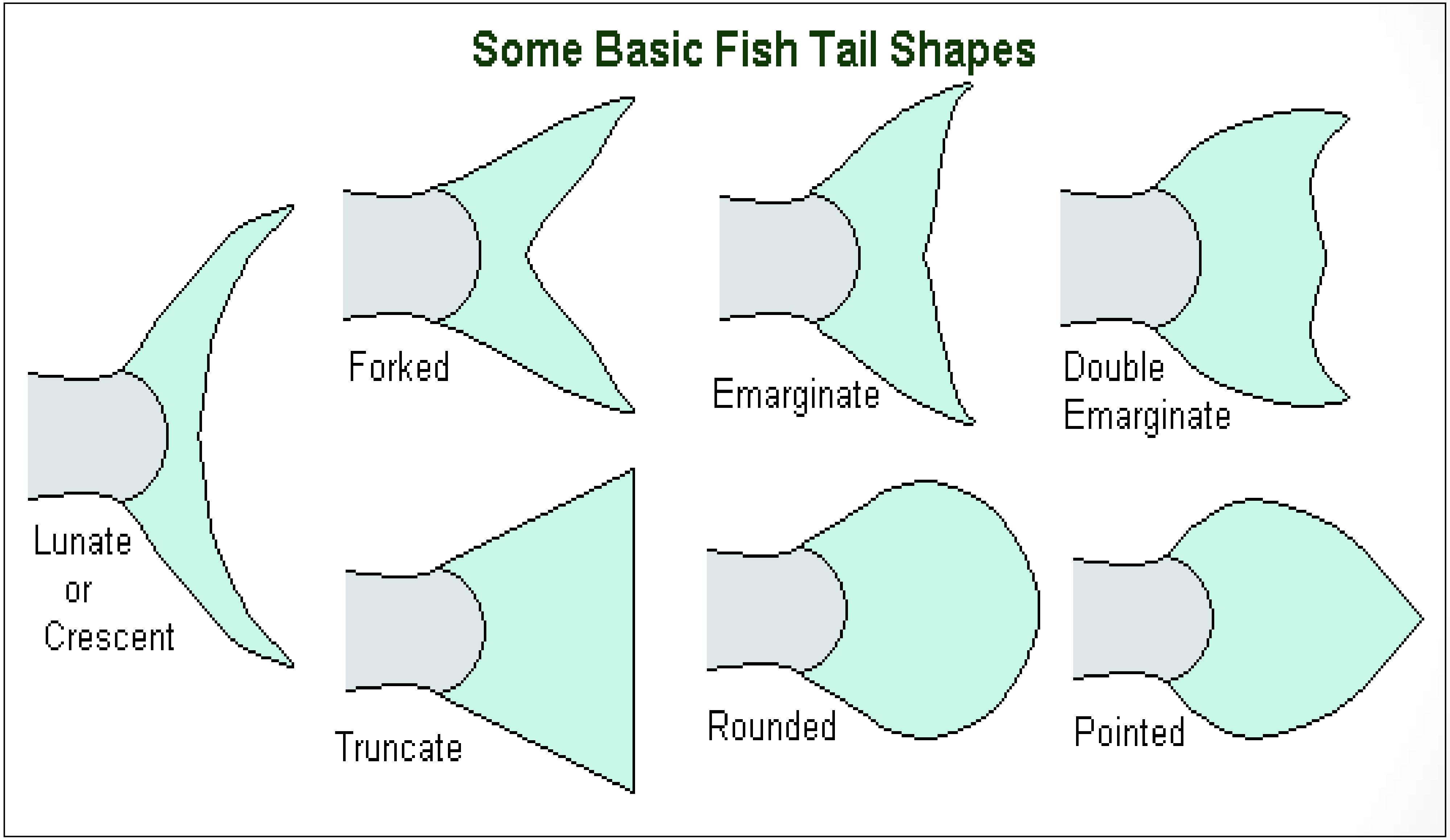



FIGURE 2–15. Modified dorsal fins. *A*, Sucking disc (remora, Echeneidae); *B*, fishing rod and lure (angler, Ceratiidae). (*B* based on Jordan and Evermann, 1900.)

*Representative shapes of caudal fins



# Types of caudal fins

a)- Heterocercal, b)- Abbreviate heterocercal

c)- Homocercal d)- Isocercal

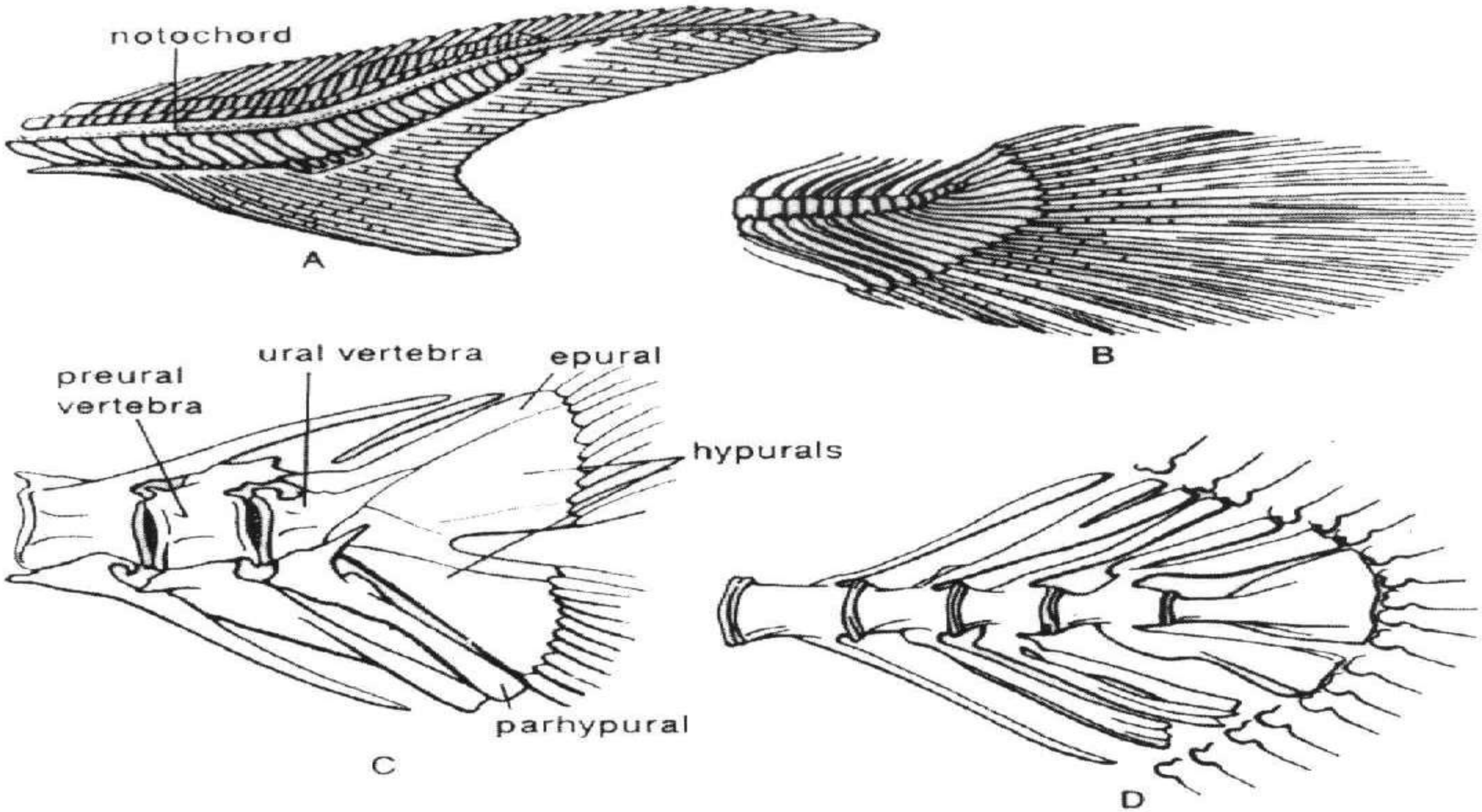



FIGURE 2–17. Types of caudal fins, showing structure. *A*, Heterocercal (sturgeon, Acipenseridae); *B*, abbreviate heterocercal (bowfin, Amiidae); *C*, homocercal (striped bass, Percichthyidae); *D*, isocercal (cod, Gadidae). (*A* based on Goodrich, 1930; *B* based on Jordan and Evermann, 1900.)

**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.

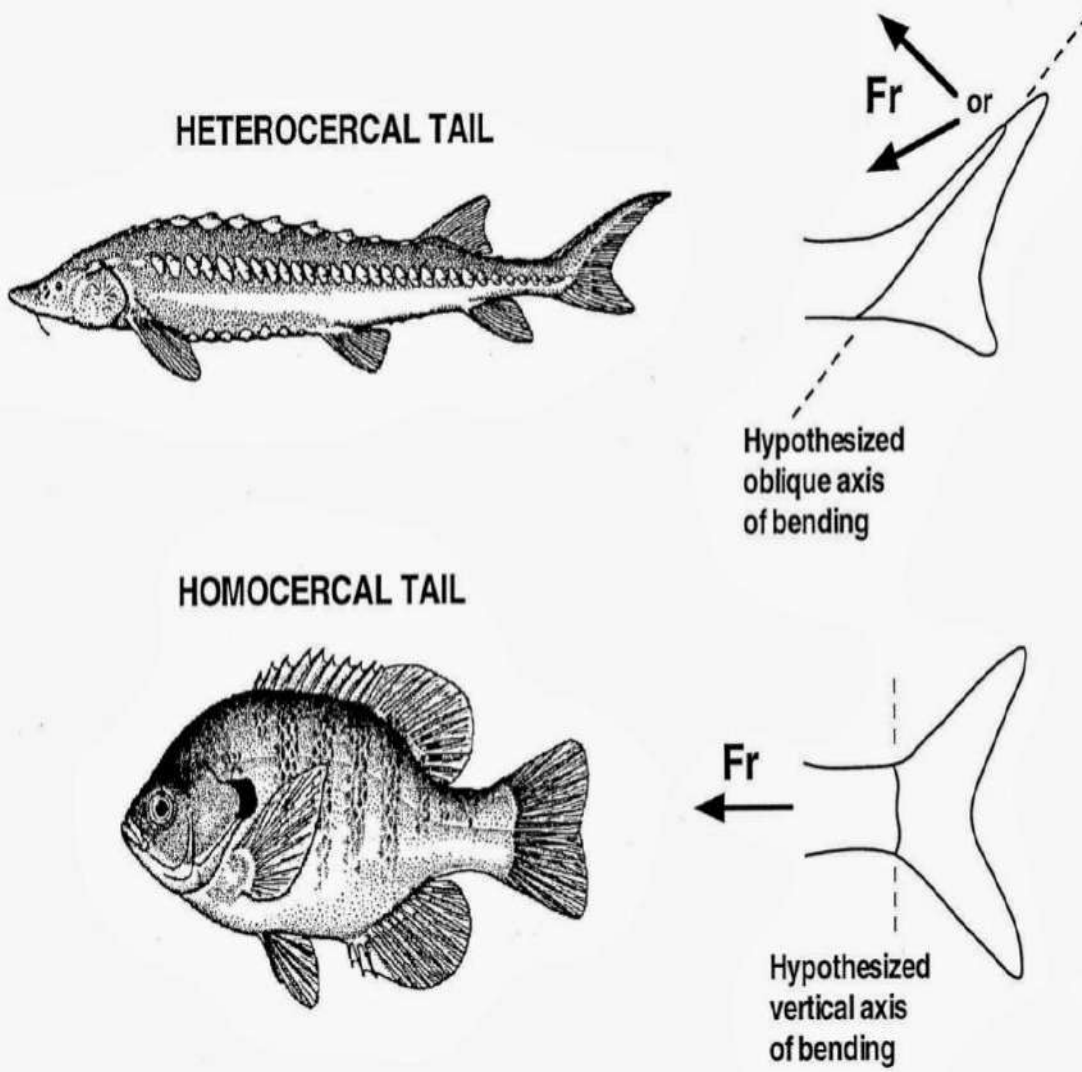
Such a type of tail is mainly found among the elasmobranchs (in the sharks (Chondrichthyes) and in the lower forms in general.

**Abbreviated heterocercal:** Vertebral column goes into upper lobe, but fin looks symmetrical.

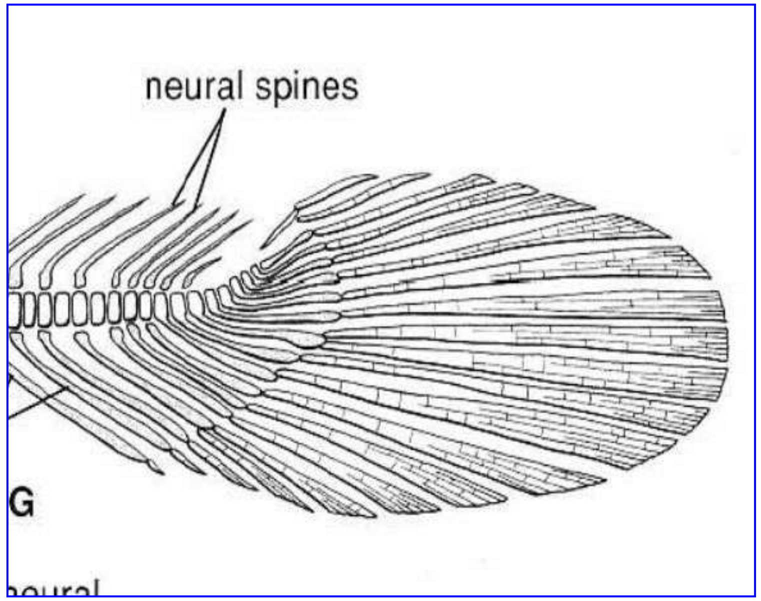
**Homocercal**: Describing the symmetric tail of a fish that has two lobes extending from the end of the vertebral column.

**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.



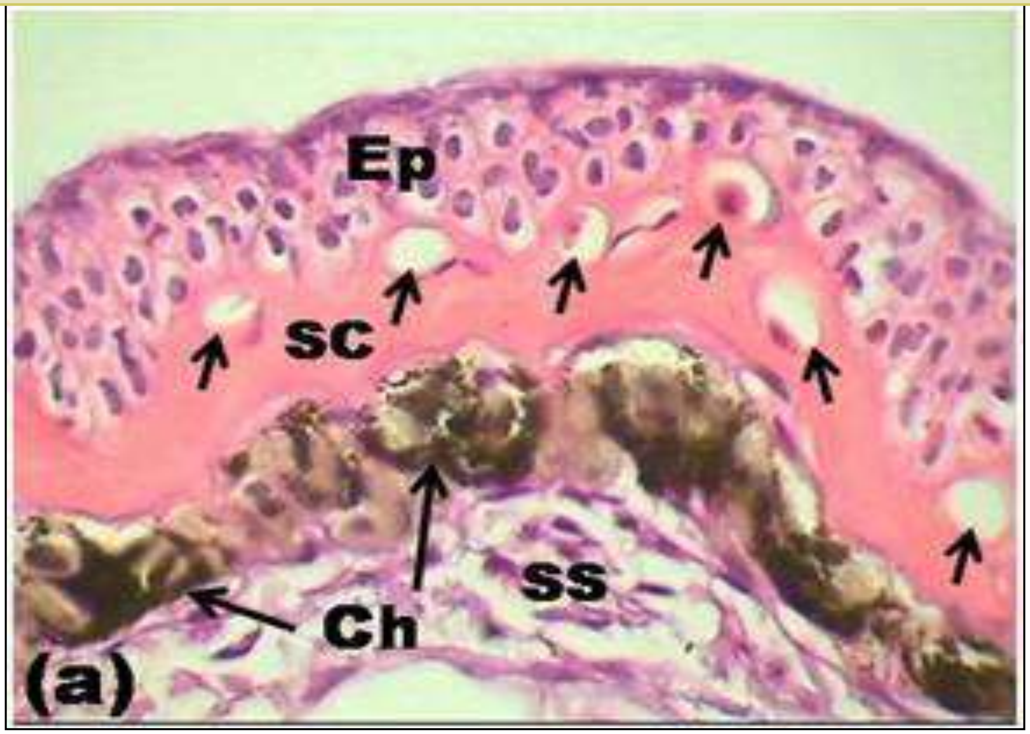

Isocercal

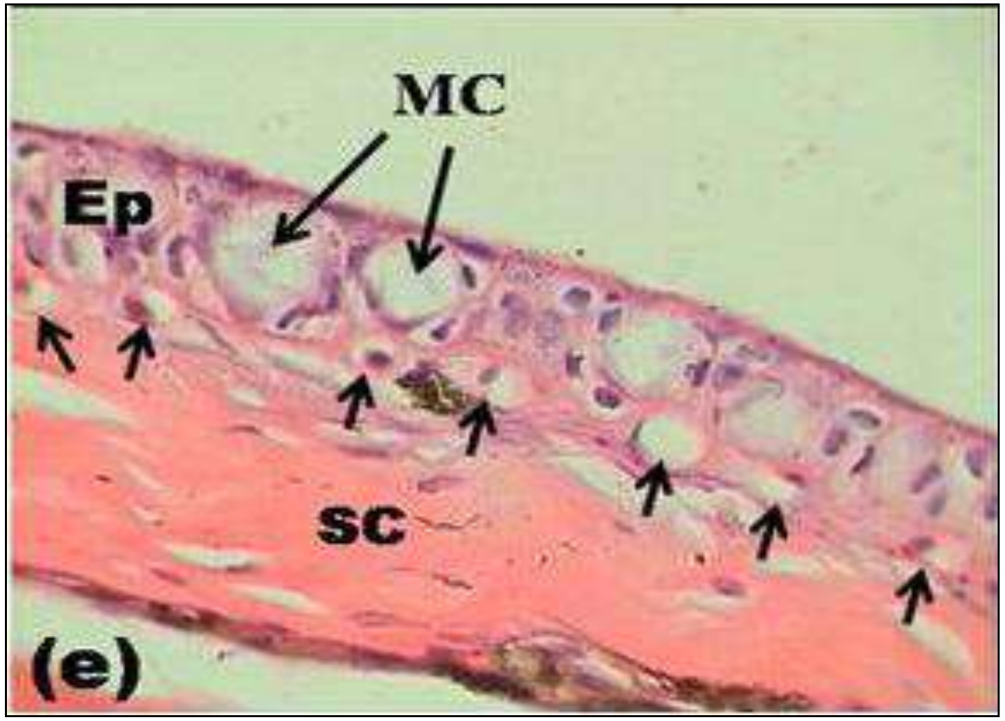



Abbreviated heterocercal

# *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

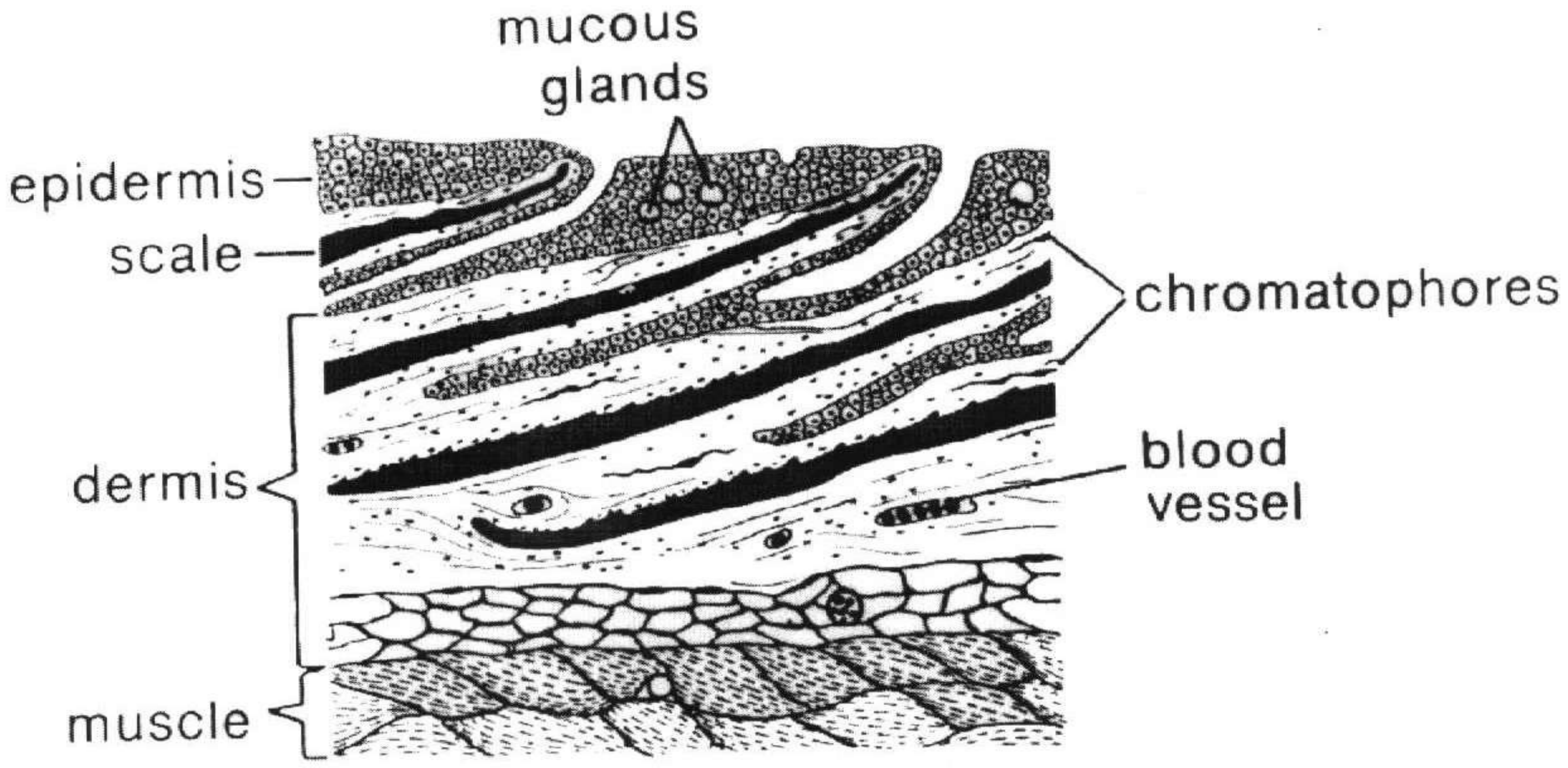



**FIGURE 2–18.** Section of fish skin. (Based on Wunder, 1936.)

# * 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.

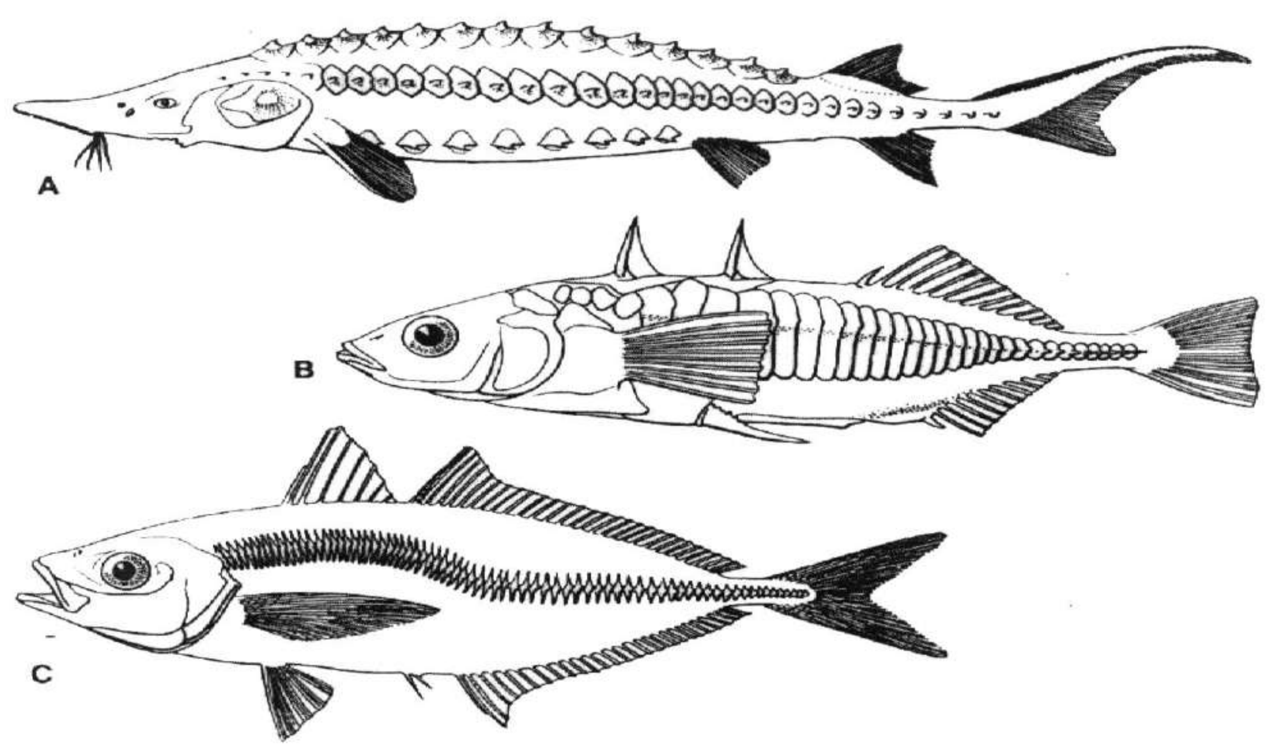



FIGURE 2–19. Examples of fishes with scutes. *A*, Sturgeon (Acipenseridae); *B*, stickleback (Gasterosteidae); *C*, jack (Carangidae). (*A* and *C* based on Jordan and Evermann, 1900.)

# Types of scales in fishes

1-Placoid

2-Ganoid

3-Cycloid

4-Ctenoid

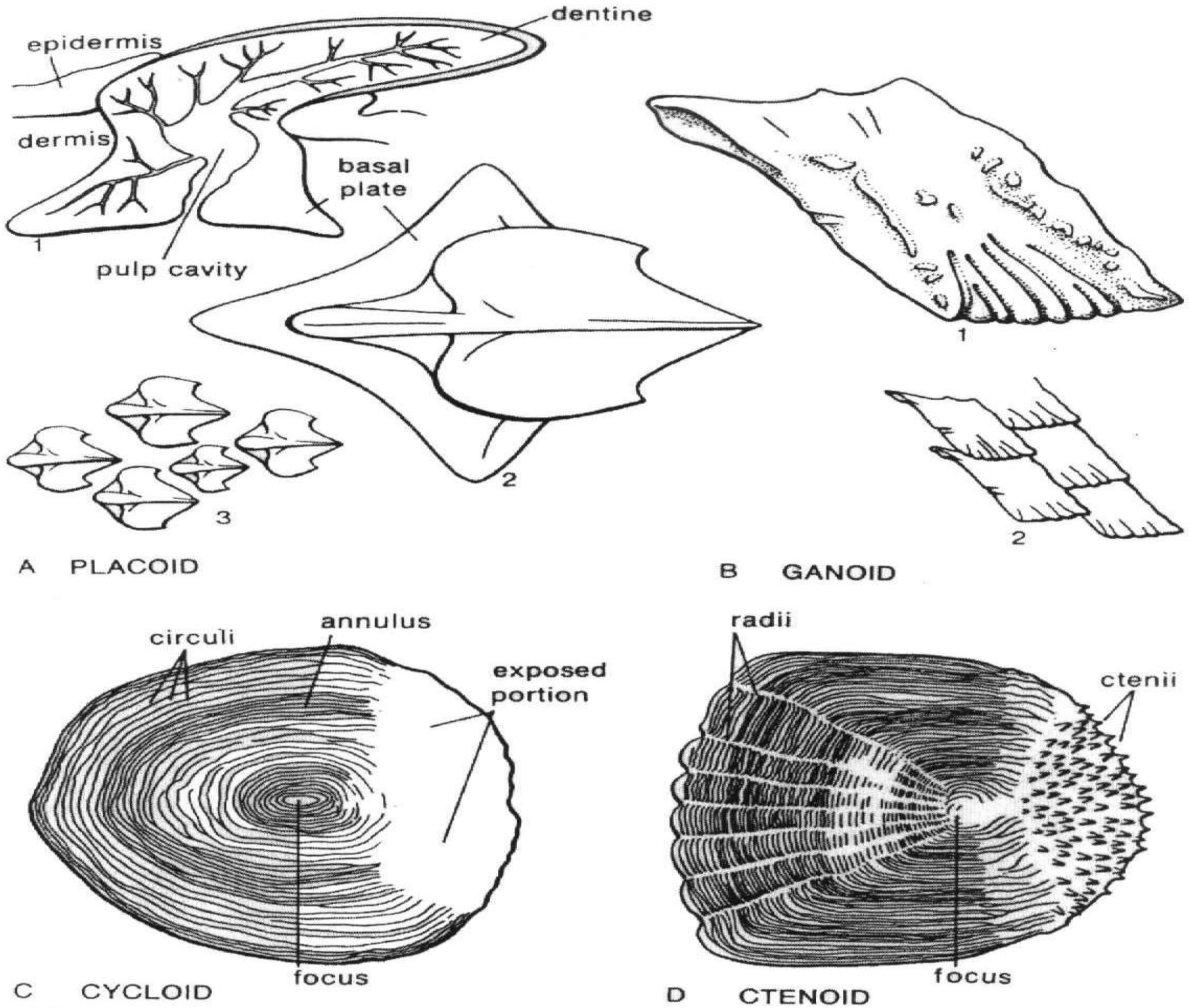



**FIGURE 2–20.** Examples of types of scales (anterior to left). *A*, Placoid— *1*, sagittal section, *2*, top view, *3*, disposition on skin; *B*, ganoid—*1*, single scale, *2*, disposition on fish; *C*, cycloid; *D*, ctenoid

# Lecture 3

# 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 البلطية.
- Mollusc-feeders as in case of *Tetradon* النفيخة .
- Worm feeders.
- Living animals feeders.

## (3)Omnivorous fishes

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

## (4)Scavengers (detritivorous or bottom feeders)

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

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

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

## (2)Sex

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

The females of the deep-water anglers الصياد 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 callarias* سمك القد:

*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* الشلبة:

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 البيس*

## *(6)*Light

it is a determining 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 البورى)

**(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)- In between (omnivorous) *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

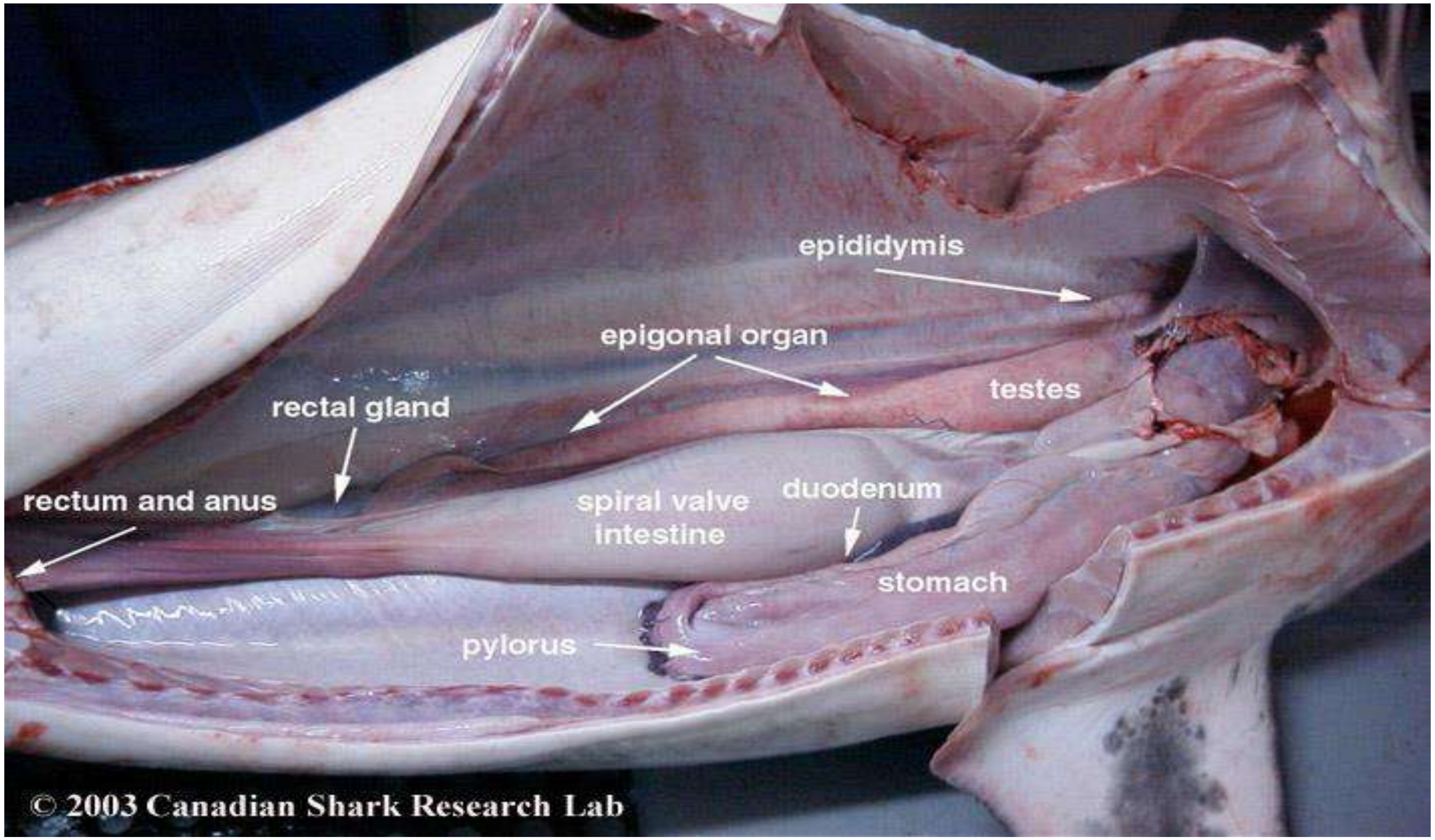
Foregut = Esophagus and Stomach

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

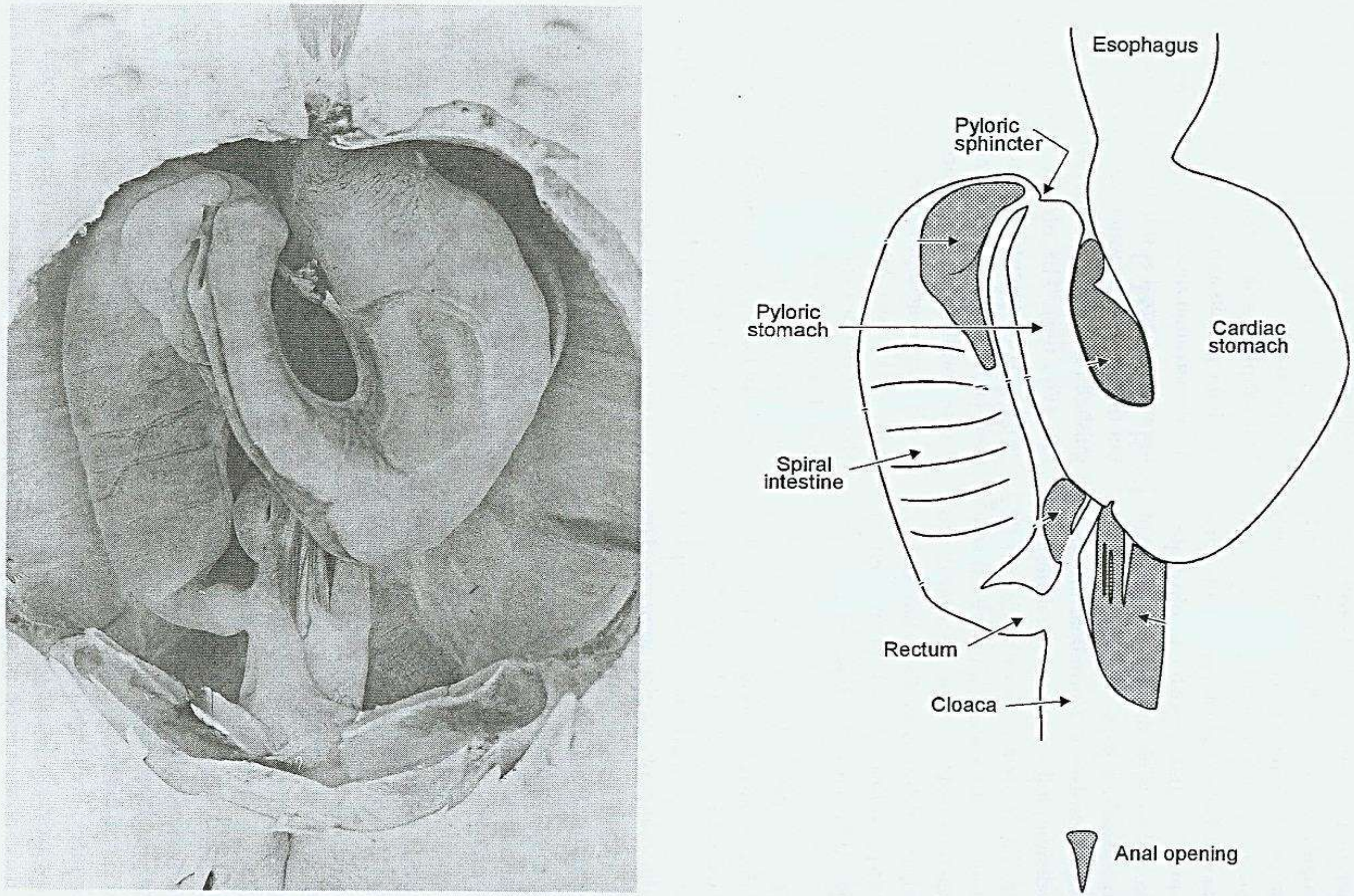



**FIGURE 6-1** Photograph and diagramatic representation of the gut of the skate *Raja clavata*. The body wall has been dissected away and the liver removed.

# Spiral Valves

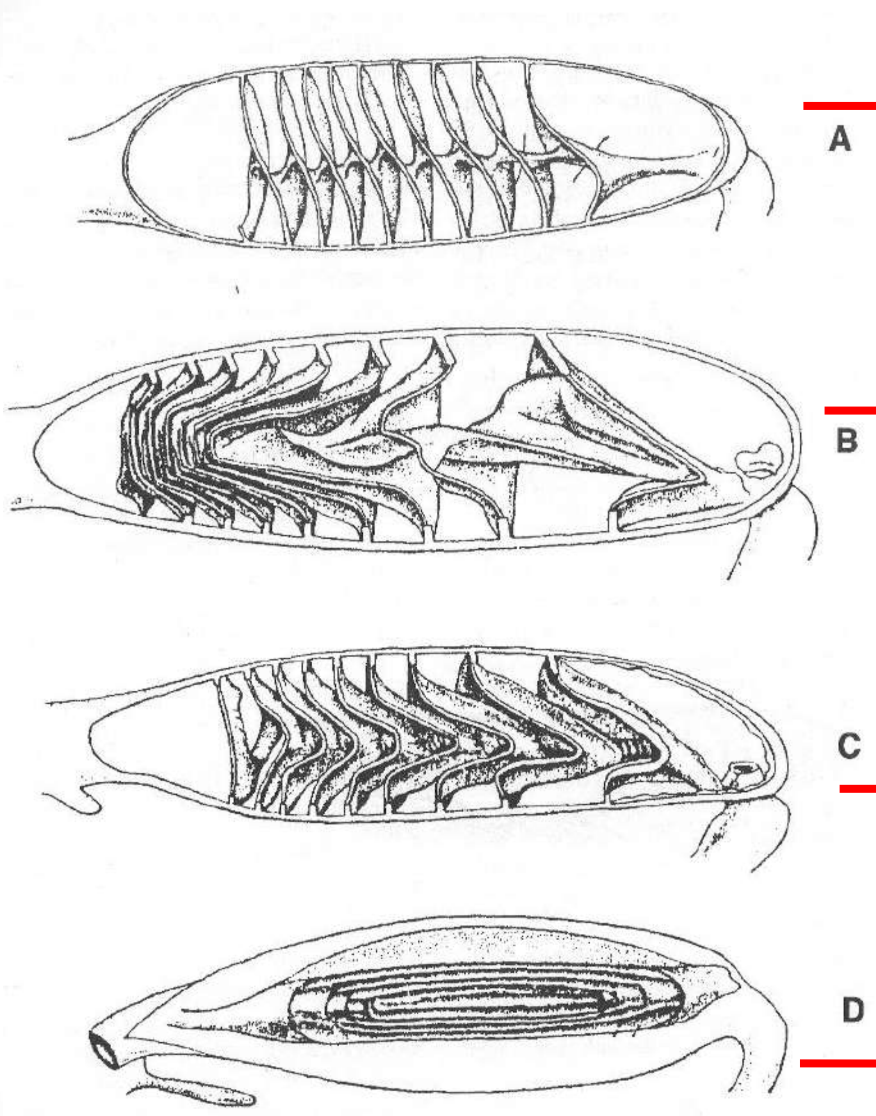



FIGURE 6-4 Examples of the arrangement of the spiral valve of the elasmobranch intestine. Columnar spiral (A), funnels pointing backward (B), funnels pointing forward (C) (all from *Raja* species), and cylindrical valve (scroll valve) from *Zygæna malleus* (D). (From Bertin 1958a, after Parker 1885.)

**Spiral winding around central column and attached to outer wall.**

**Series of interconnecting cones directed posteriorly.**

**Series of interconnecting cones directed anteriorly.**

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

# 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.)

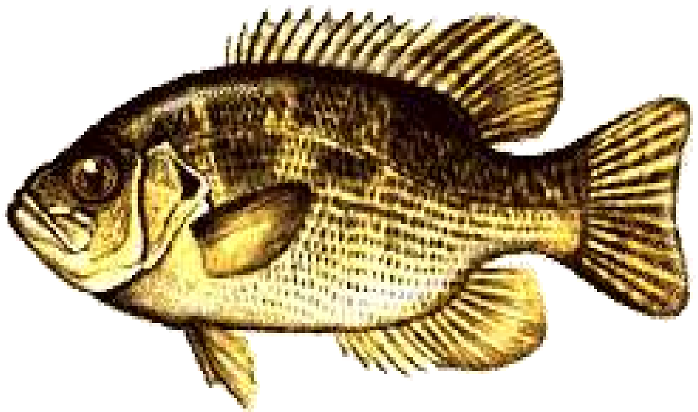
- Fish are sensitive to seasonal changes eg
  - Bluegill switch from invertebrates to algae at the end of the summer

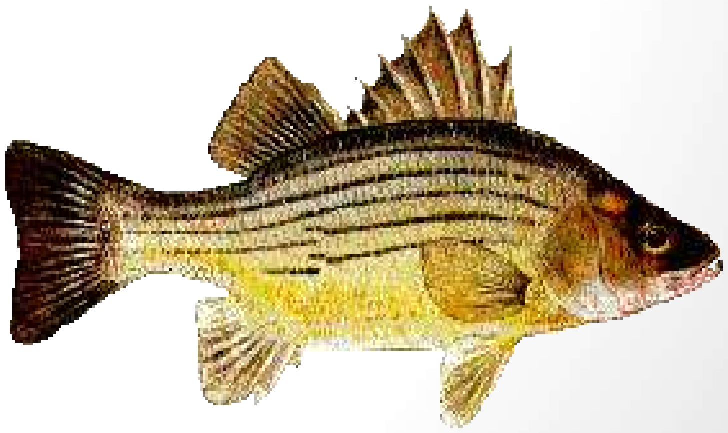
  – Amazon river fish switch from invertebrates to detritus in the rainy season.

- 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

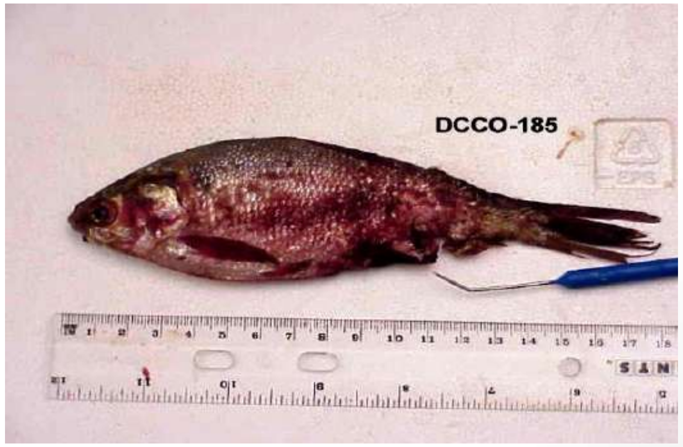
- Stomach contents may not accurately reflect
- diet. Why?

- 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**

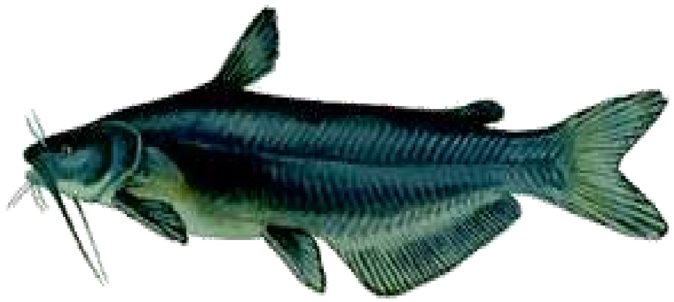



# 17.4 Removal, fixation and preservation

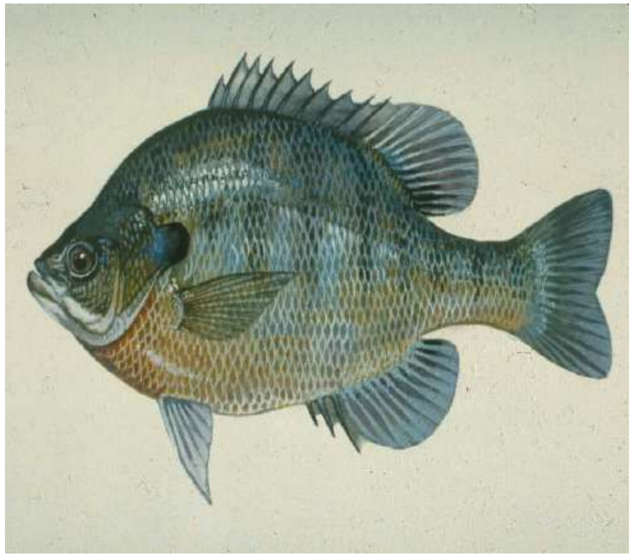
- Removal of gut contents

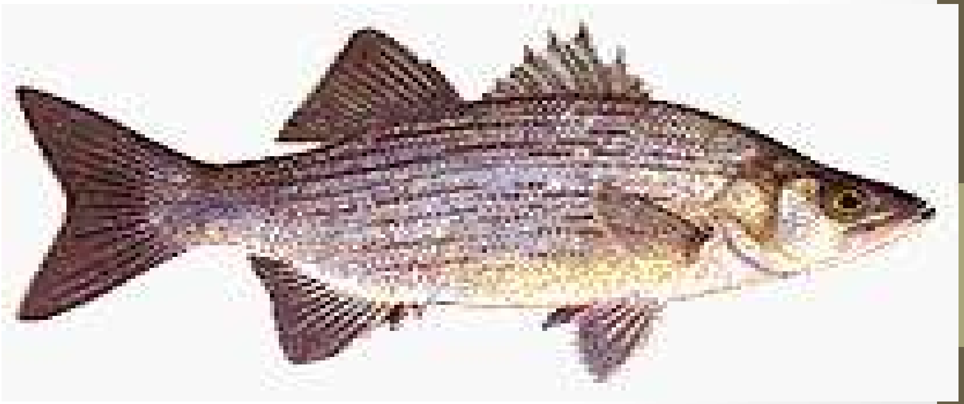
  - Flushing of stomach with one or more volumes of water
  - Insertion of acrylic tubing through digestive tract
  - Dissection

# 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

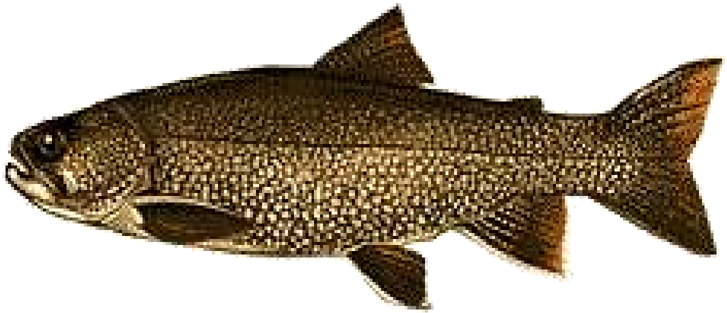
# If possible


- 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

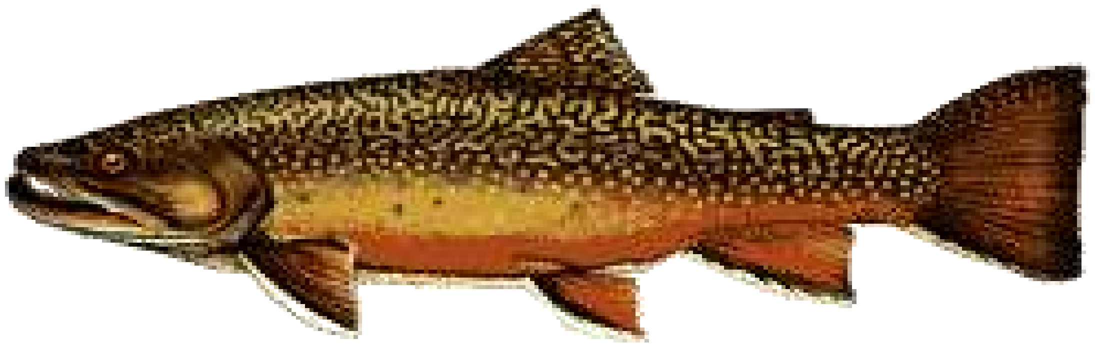
# 17.5 Identification - partly digested prey

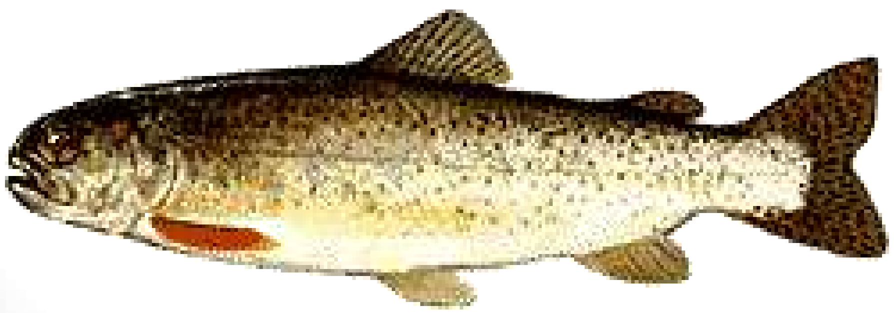
- Made difficult by digestion
- Find part of organism that is easily recognized
  - Exoskeleton in invertebrates
  - Otolith count for fish
  - Sculpturing along edges of leaves for macrophytes
  - Algae is found intact

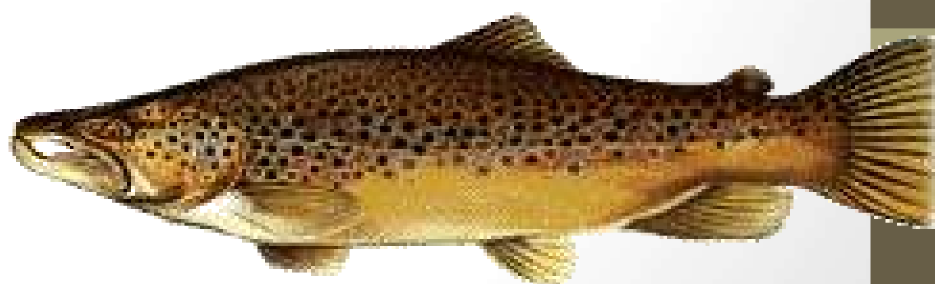
# Level of identification.



- Family
- Order
- Relative size

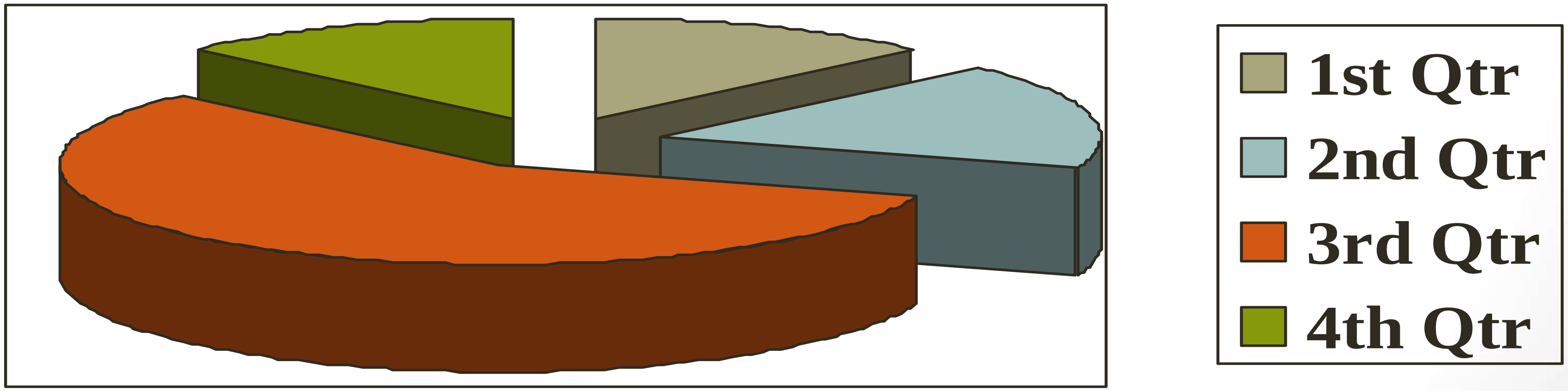






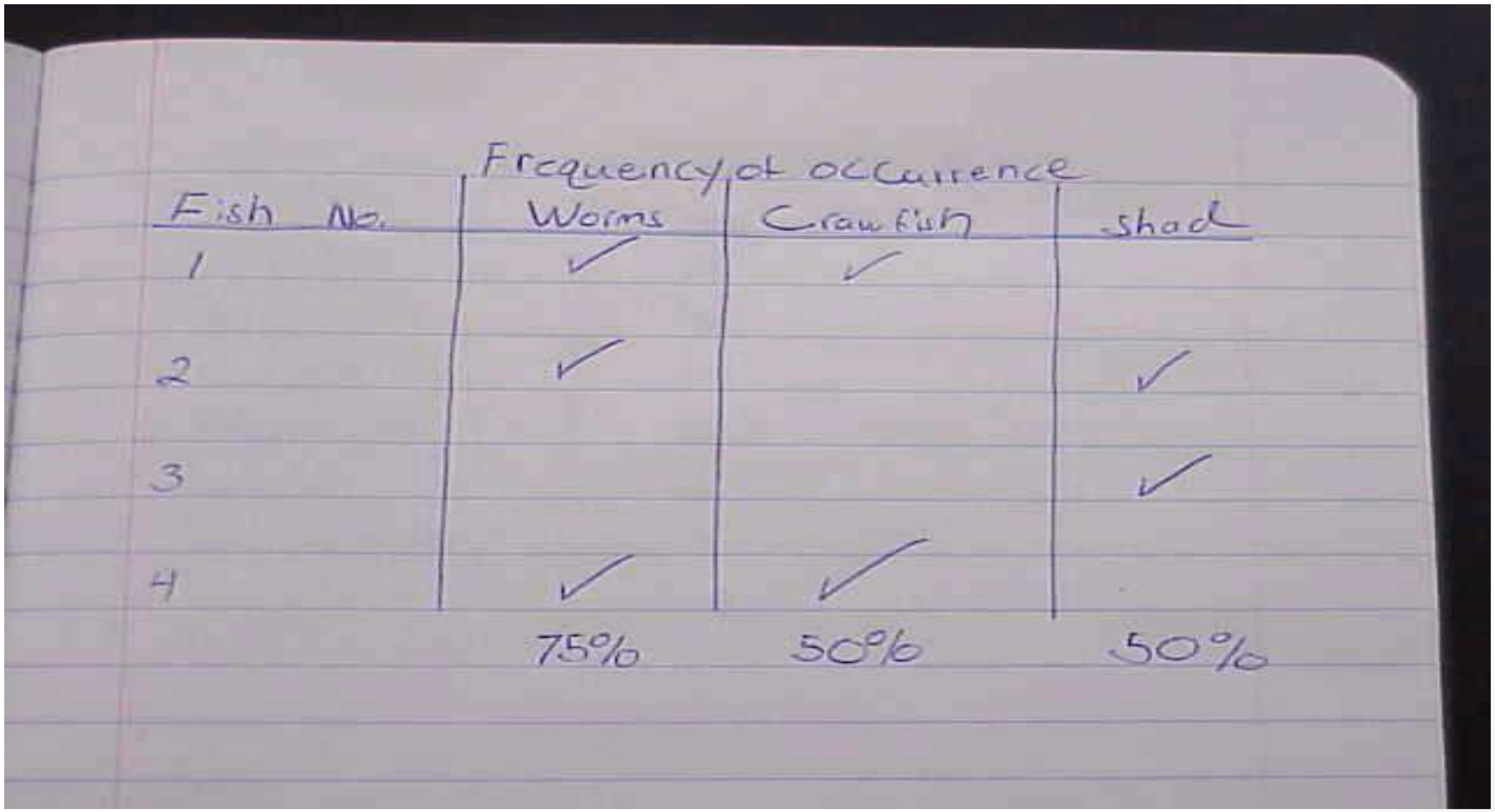
# 17.6 Quantitative description … 3 approaches

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



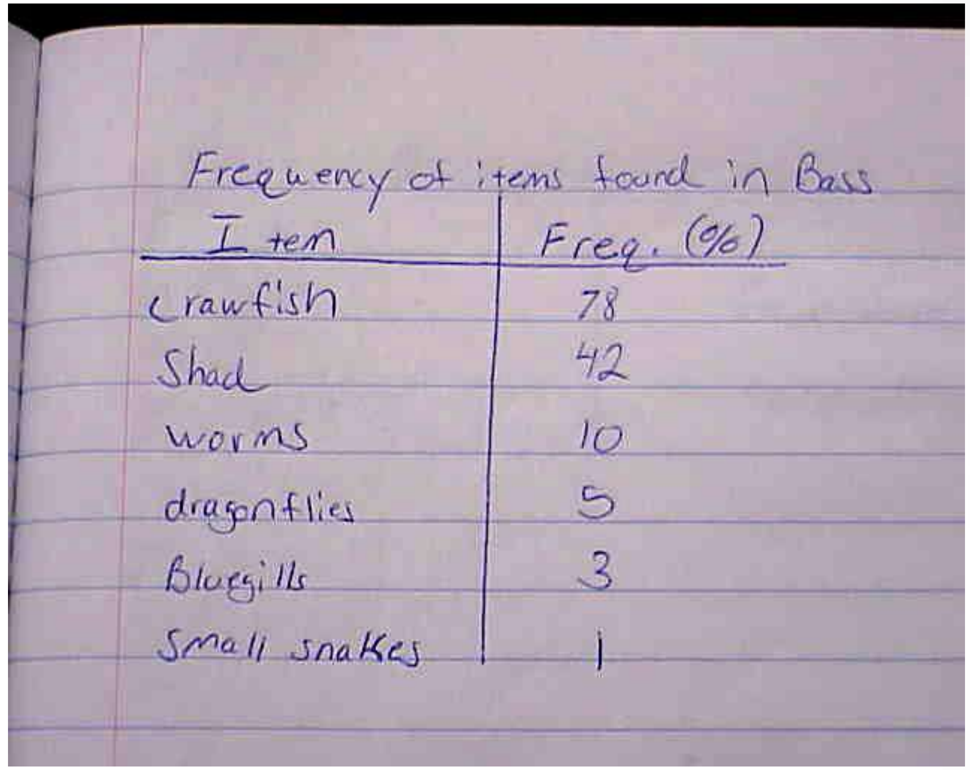
# Frequency of occurrence

- 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



Frequency of items found in Bass

| Item | Freq. (%) |
|---|---|
| crawfish | 78 |
| Shad | 42 |
| worms | 10 |
| dragonflies | 5 |
| Bluegills | 3 |
| Small snakes | 1 |

- 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

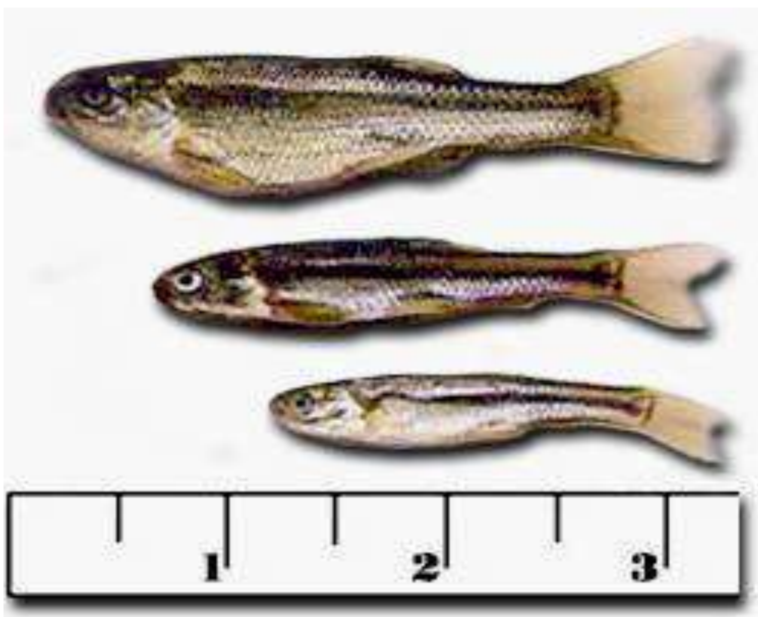
≠

# 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

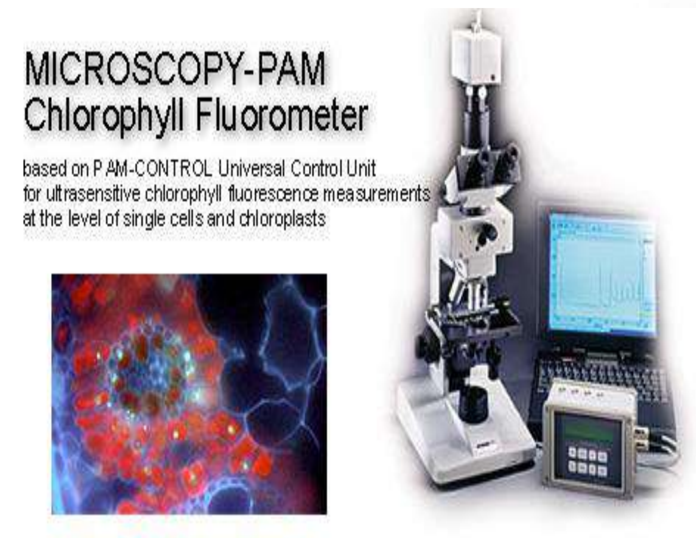



# Choose fragment found only once per prey

- 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 

# Lecture 4

## *Alimentary canal and associated structures

# Positions of bones that bearing teeth in bony fishes

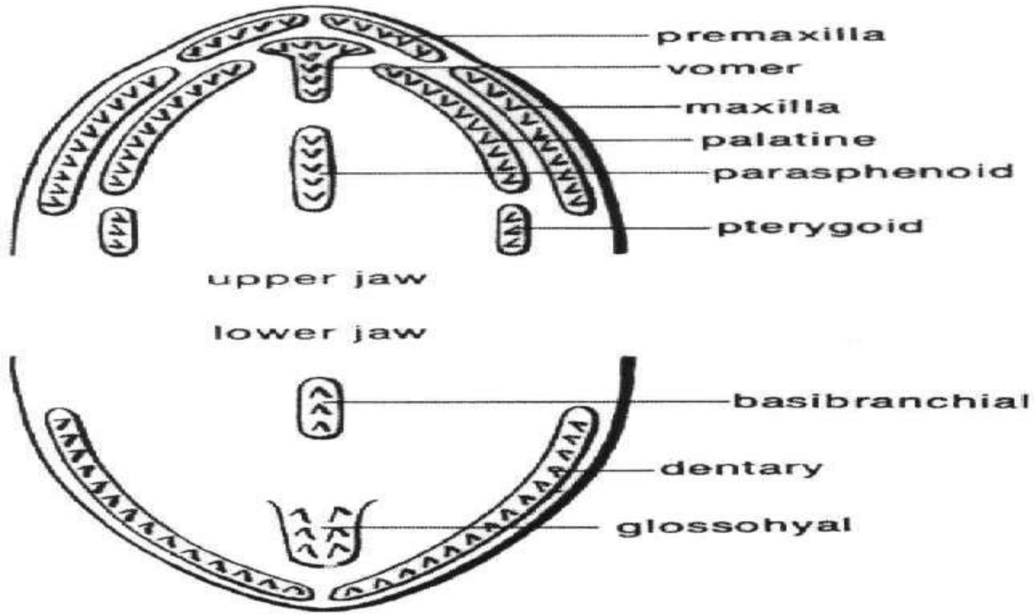



**FIGURE 2–22.** Diagram of positions of bones that can bear teeth in bony fishes.

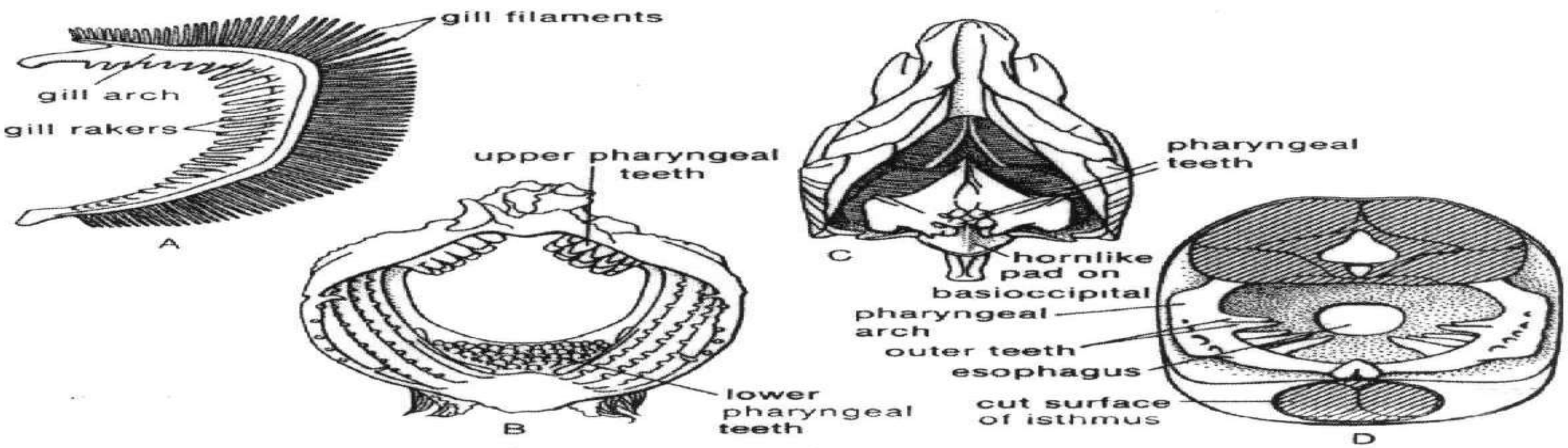



**FIGURE 2–23.** Examples of gill rakers and pharyngeal teeth. *A*, Diagram of gill arch with rakers and gills; *B*, anterior view of gill arches and pharyngeal teeth of surfperch (Embiotocidae); *C*, ventral view of the pharyngeal region of a carp (*Cyprinus*), with the pharyngeal arch displaced anteriorly 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.

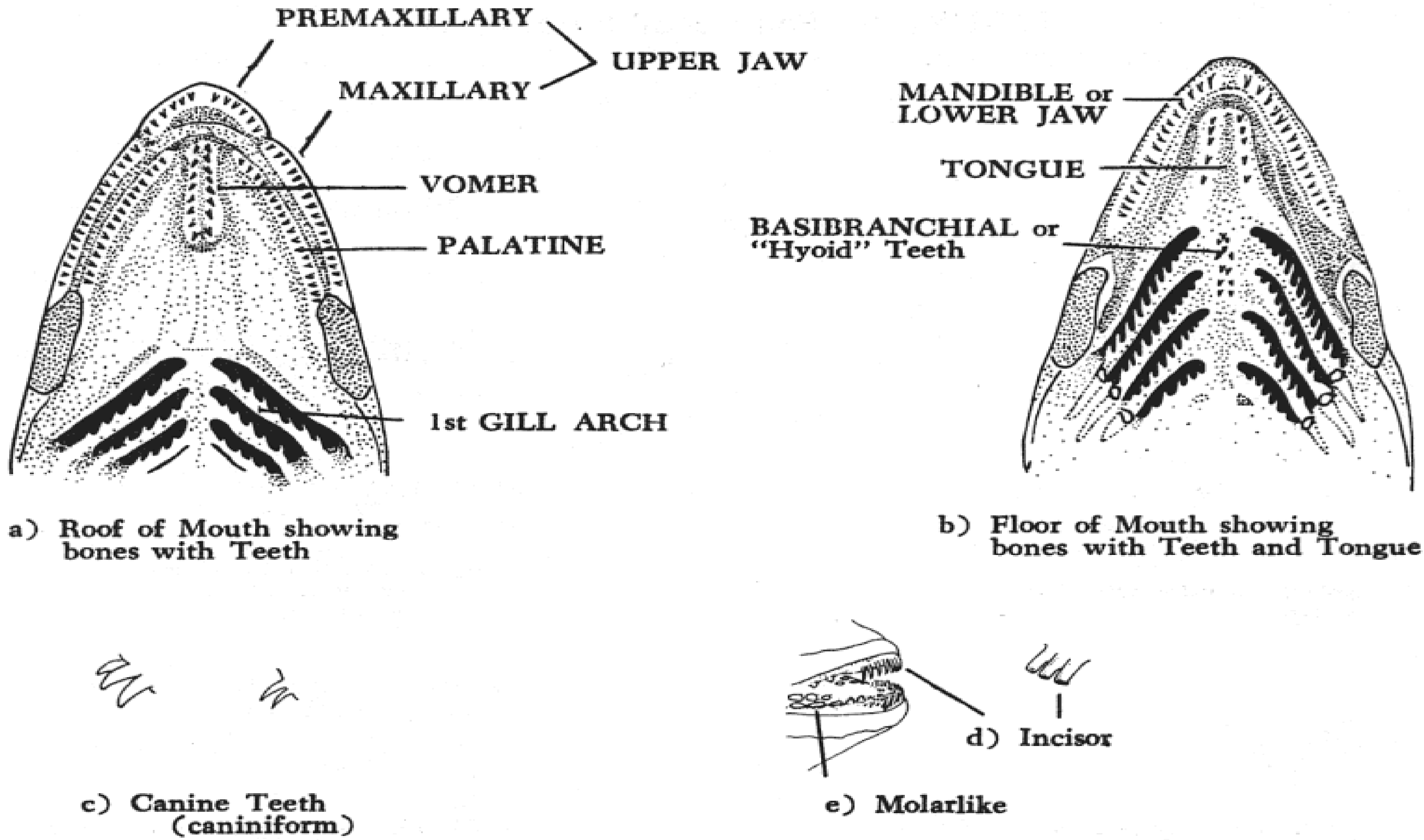
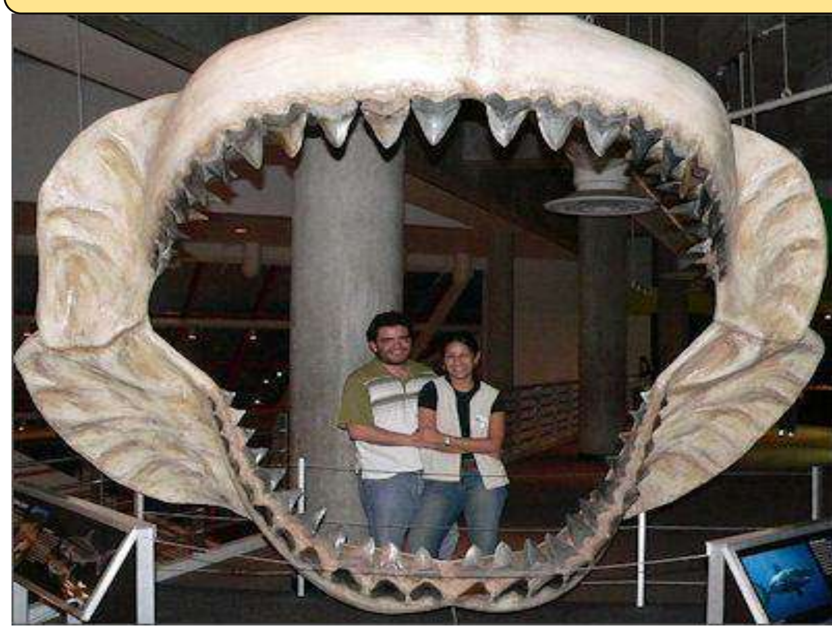


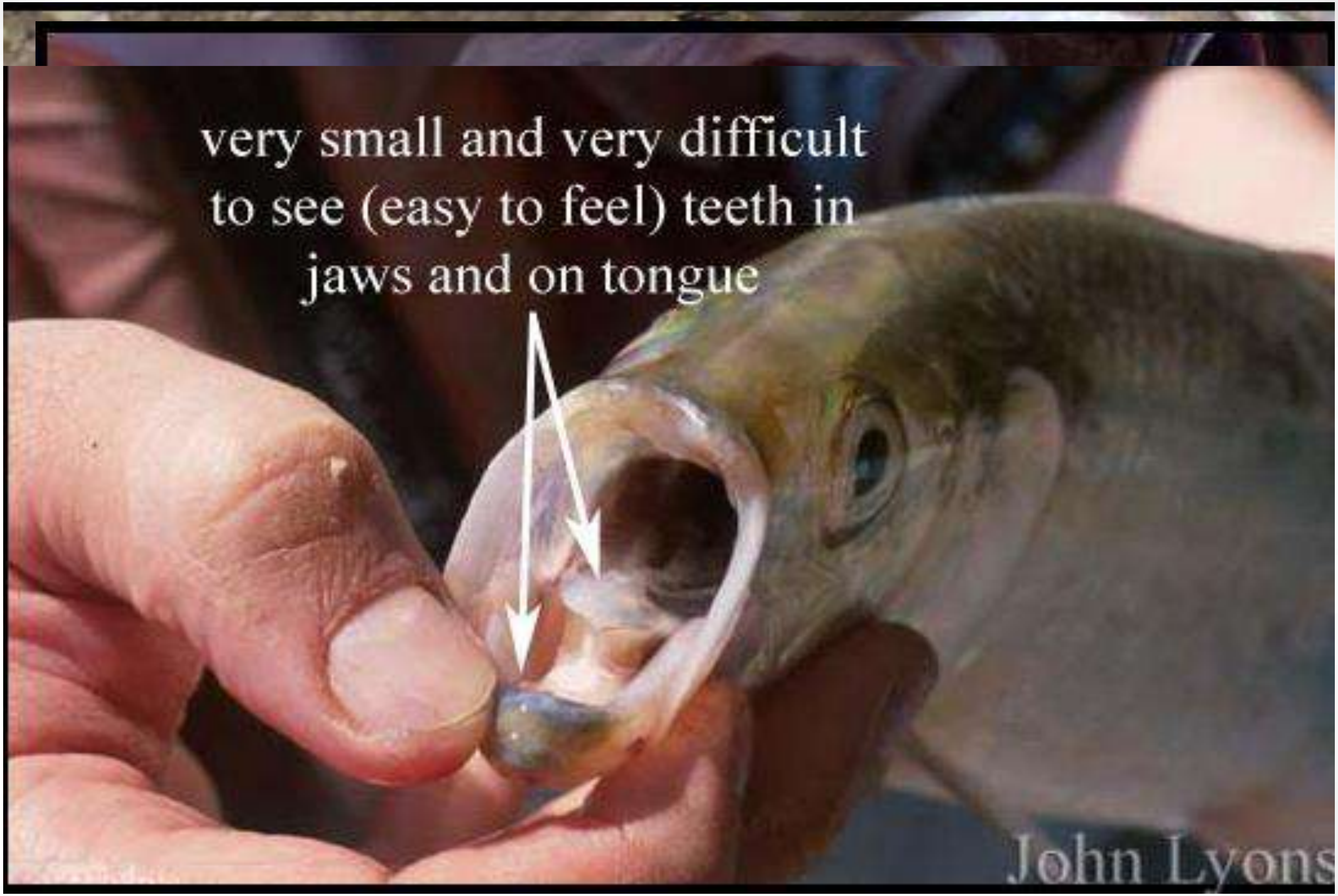

FIGURE 8. Bones and teeth inside mouth or bucal cavity.

**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


very small and very difficult to see (easy to feel) teeth in jaws and on tongue
John Lyons

# 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

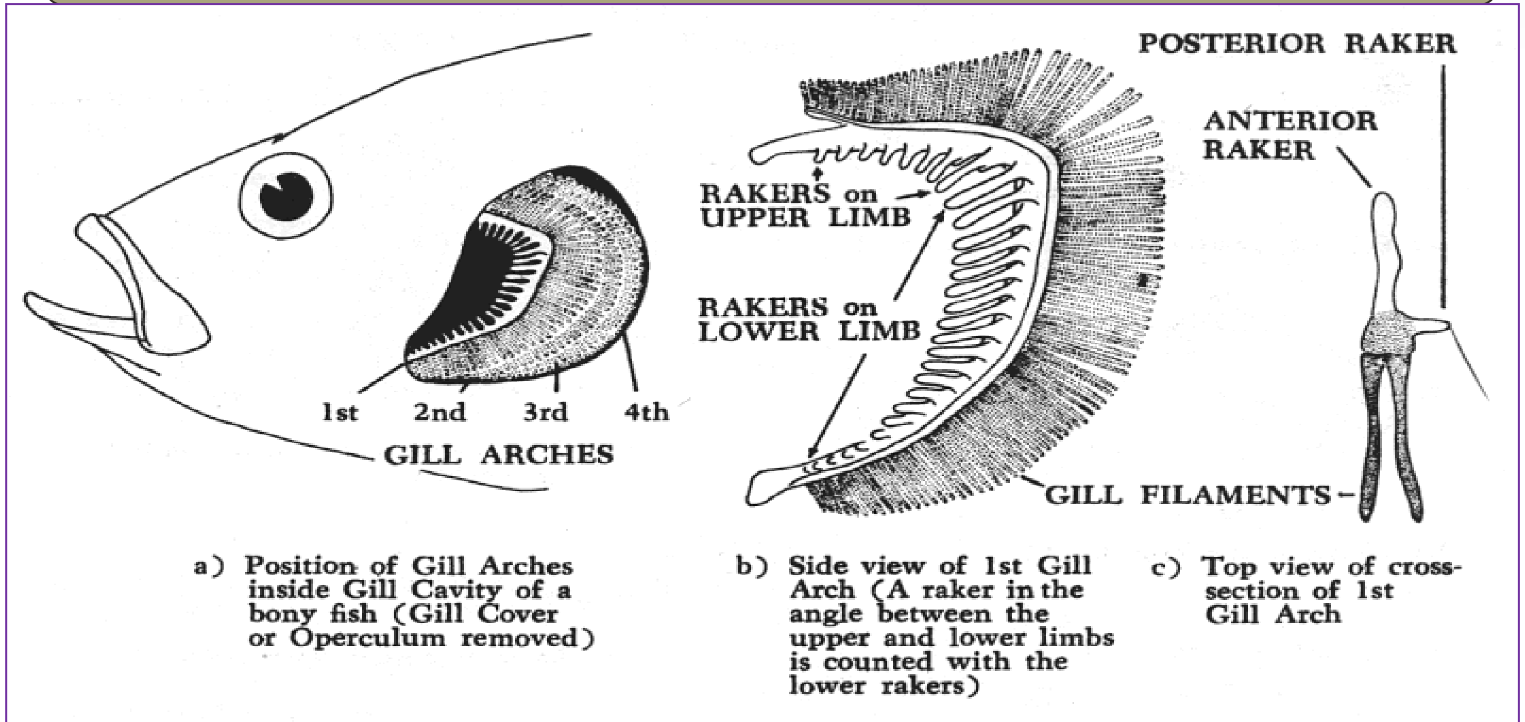
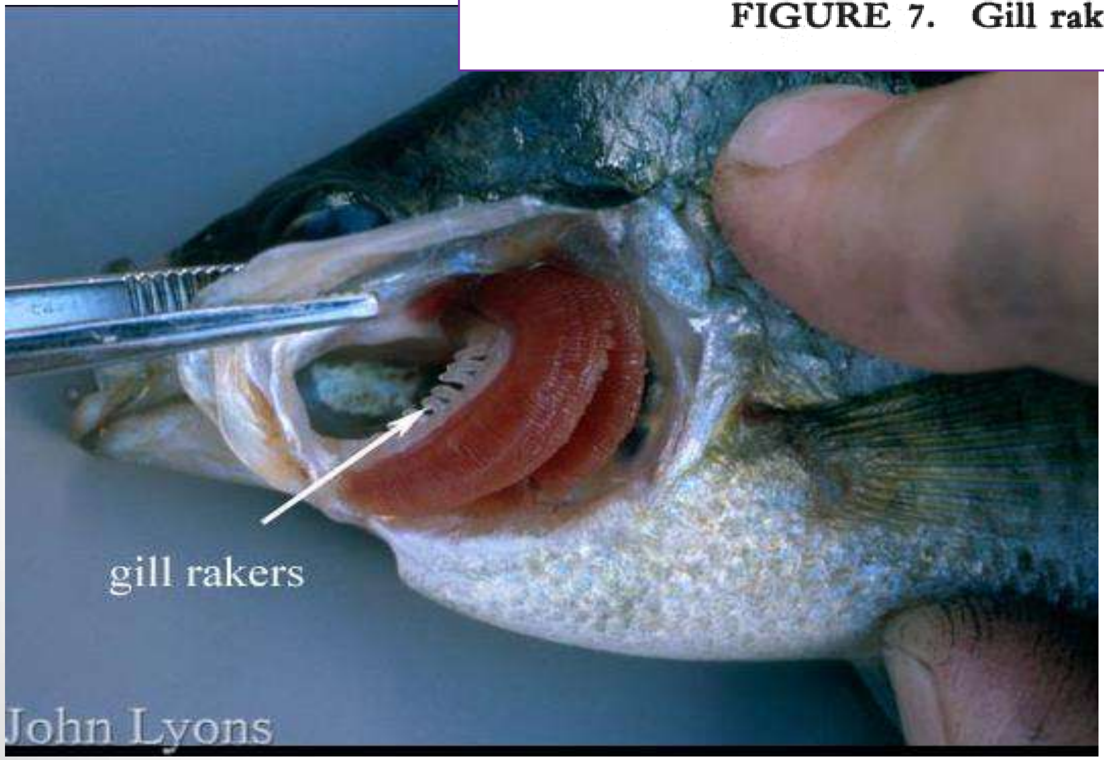
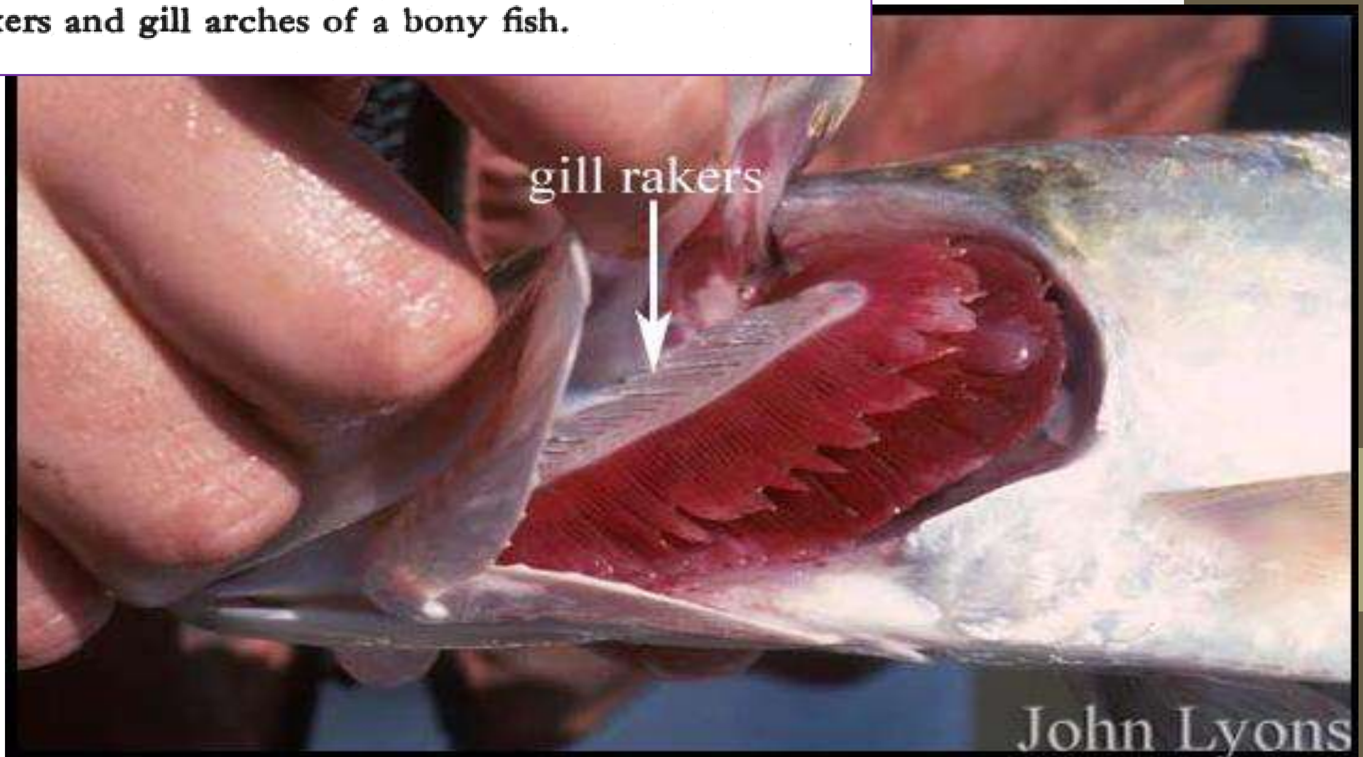



FIGURE 7. Gill rakers and gill arches of a bony fish.



# Esophagus, stomach, and intestine

- Esophagus, short with mucous cells or glands.

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

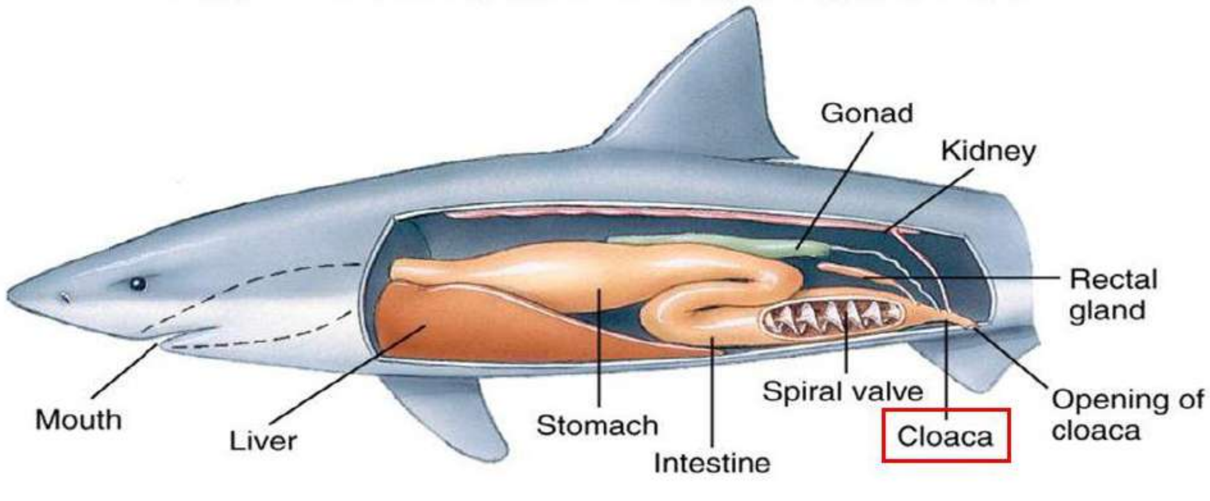
-Intestine differs in

Herbivorous carnivores omnivorous

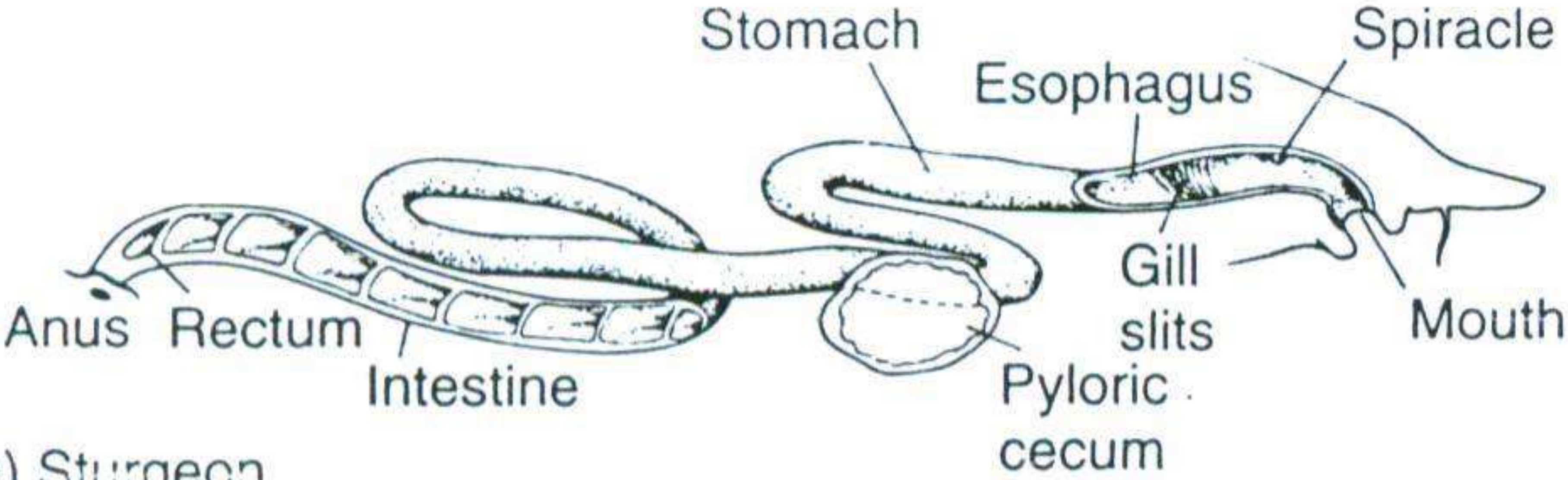
* A spiral valve present in intestine of cartilaginous fishes

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



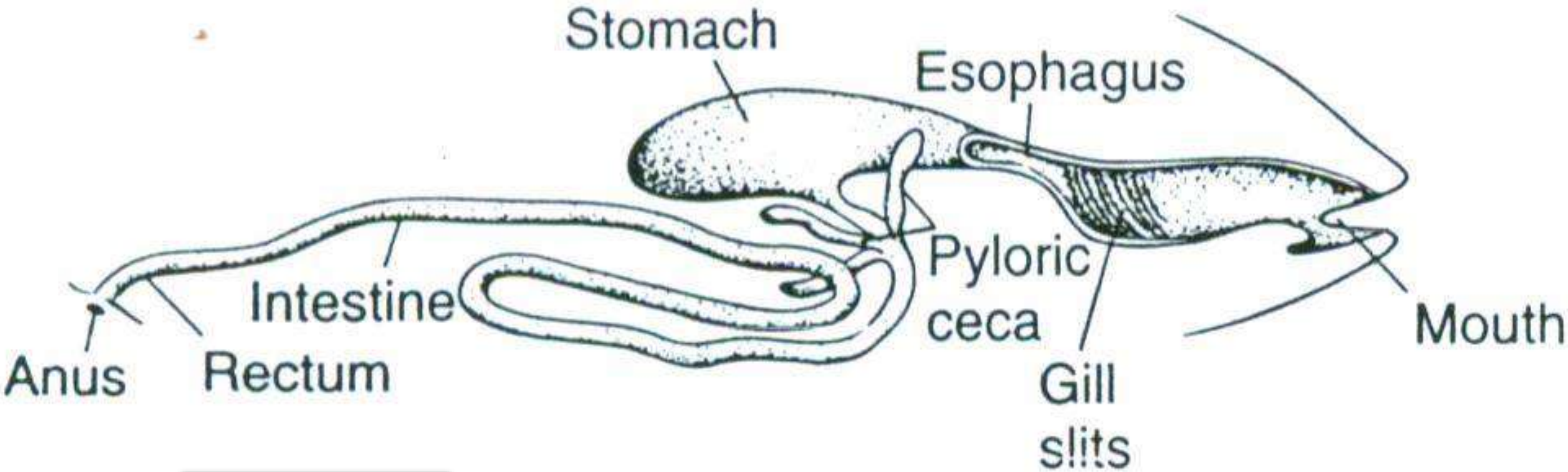



(a) **Cartilaginous fishes**




(e) Sturgeon

الحفش




(f) Perch

الفرخ

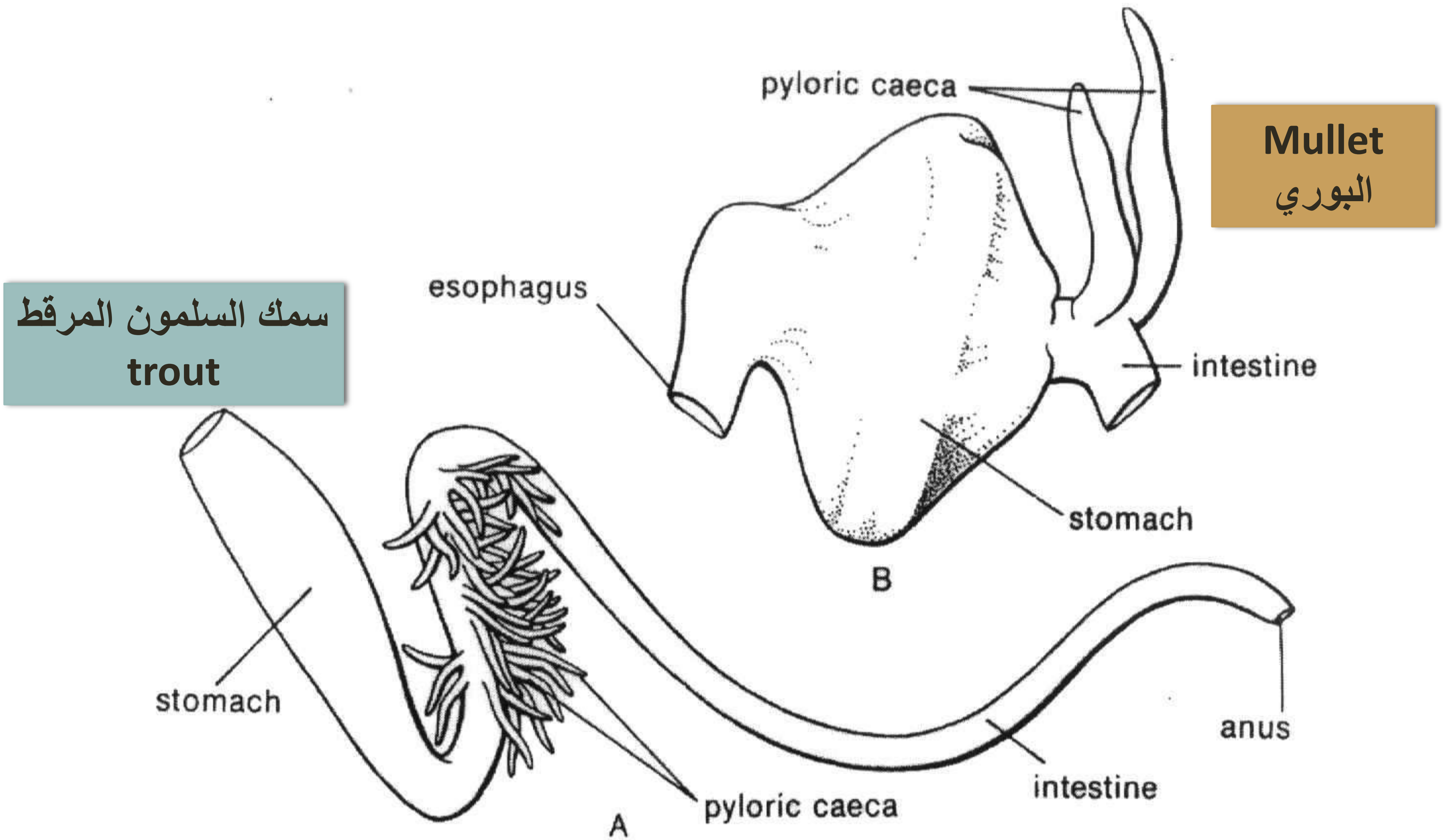



**FIGURE 2–24.** Examples of stomachs and pyloric caeca (anterior to left). *A*, Stomach, caeca, and intestine of trout (Salmonidae); *B*, stomach and pyloric caeca of mullet (Mugilidae).

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.

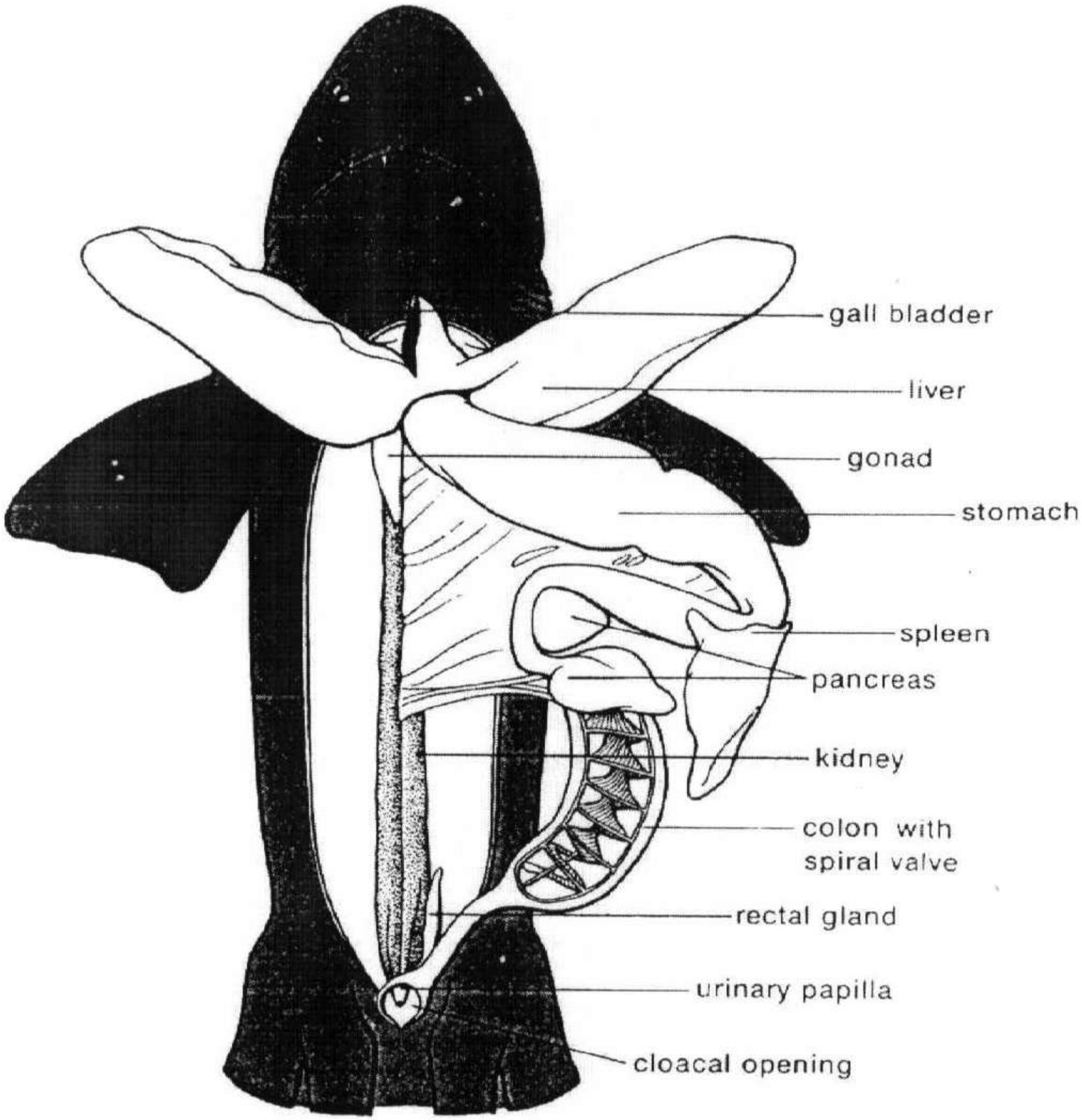



**FIGURE 2–27.** Diagram of viscera of shark (spiral valve opened to show internal structure). (Based on Daniels, 1934.)

# 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.

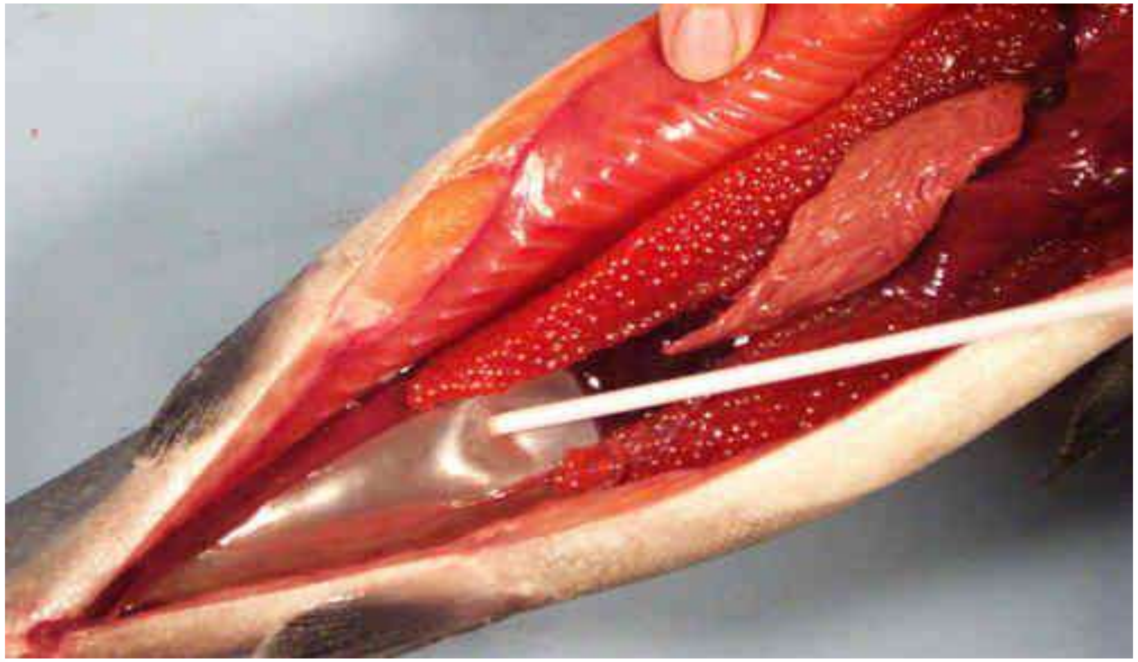
- The swim bladder is located in the body cavity and is derived from an outpocketing of the digestive tube.
- A)- It contains gas (usually oxygen) and functions as a **hydrostatic organ**, enabling the fish to maintain fish's depth without floating upward or sinking.
- It also serves as a **resonating 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.

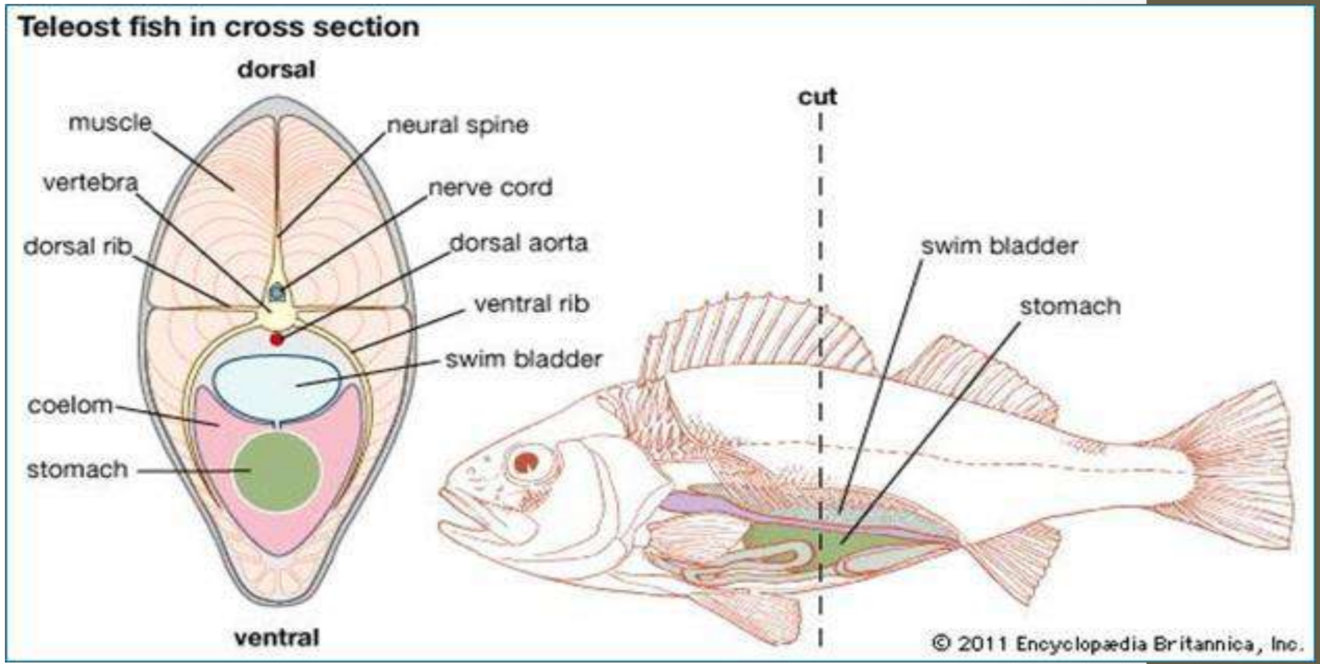
- According to calculations, the capacity of a gas bladder should be about **7%** of body volume for a freshwater fish and **5%** for a marine fish.
- In actual measurements, gas bladders of freshwater fishes are ranged from 7 to 11% of body volume, while those of marine fishes are ranged from 4 to 6% 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 **<u>lung</u>** **or** respiratory aid **instead of** a hydrostatic organ.

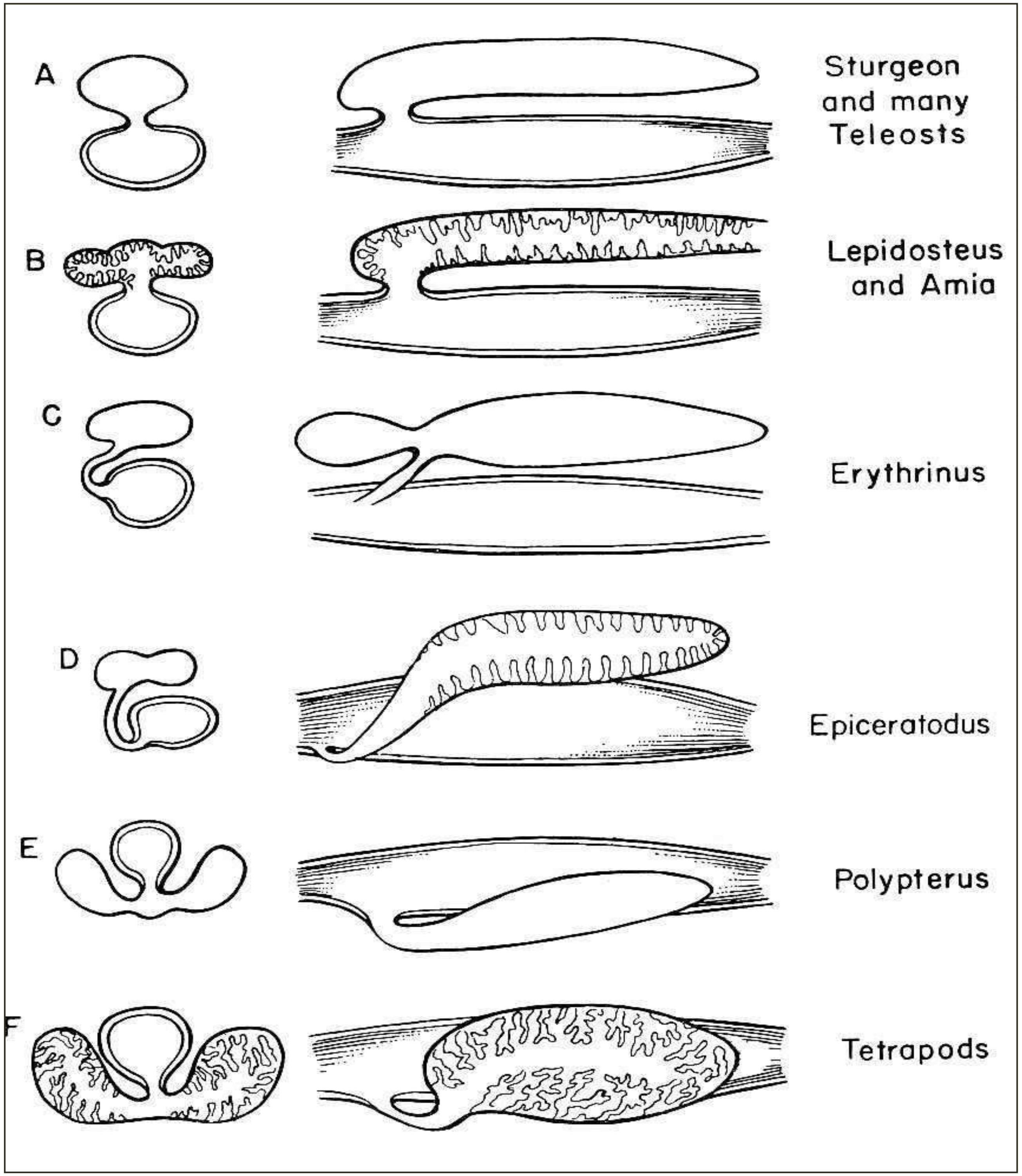
**D)-** The swim bladder **is missing** in **some** bottom-dwelling teleosts (deep-sea bony fish) **and in all** cartilaginous fish (sharks, skates, and rays).






A swim bladder

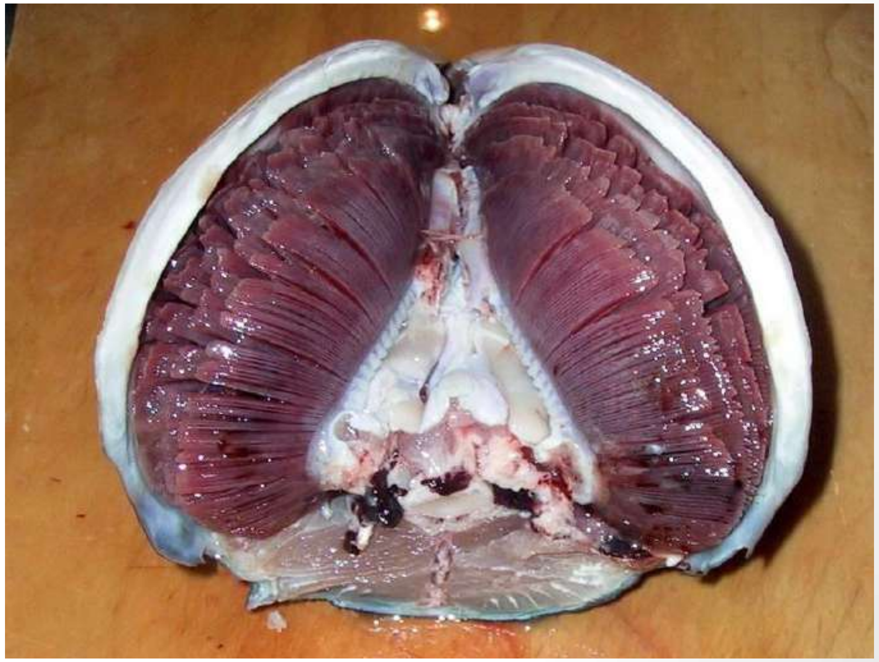
# Examples of gas bladder

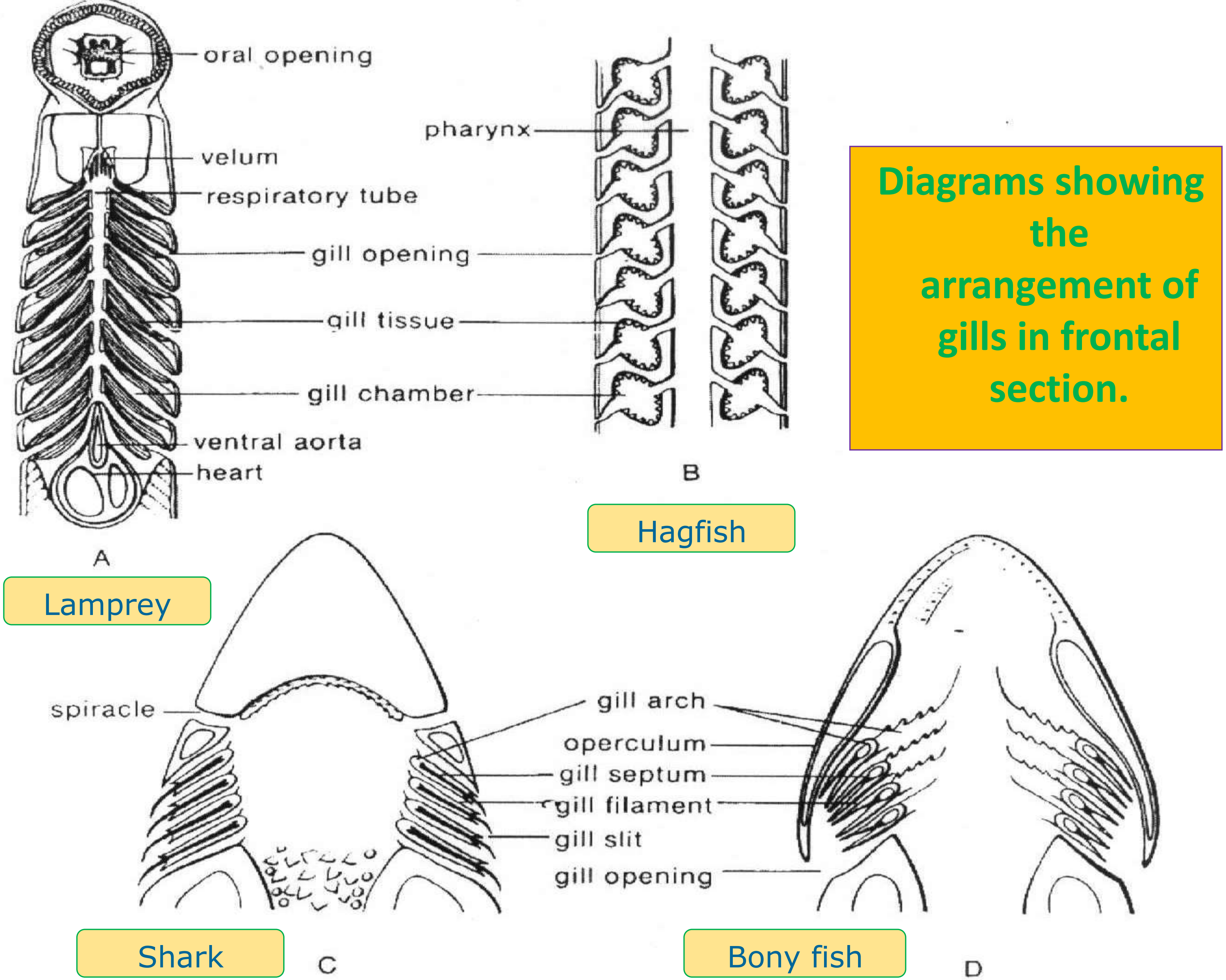


# Gills

*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.)

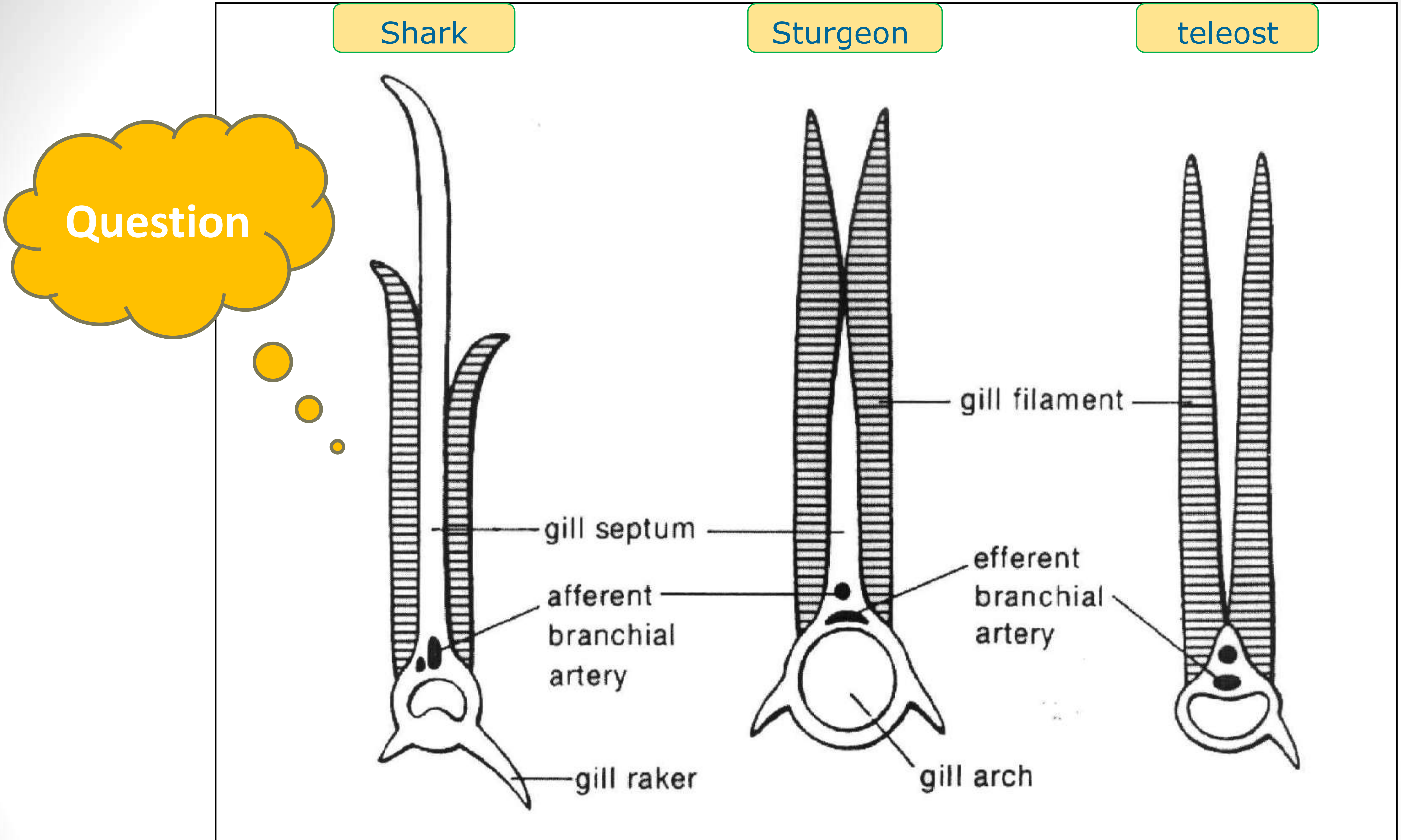



**FIGURE 2–30.** Relationship of branchial septum and gill tissue. *A*, Shark; *B*, sturgeon; *C*, teleost.

***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.**

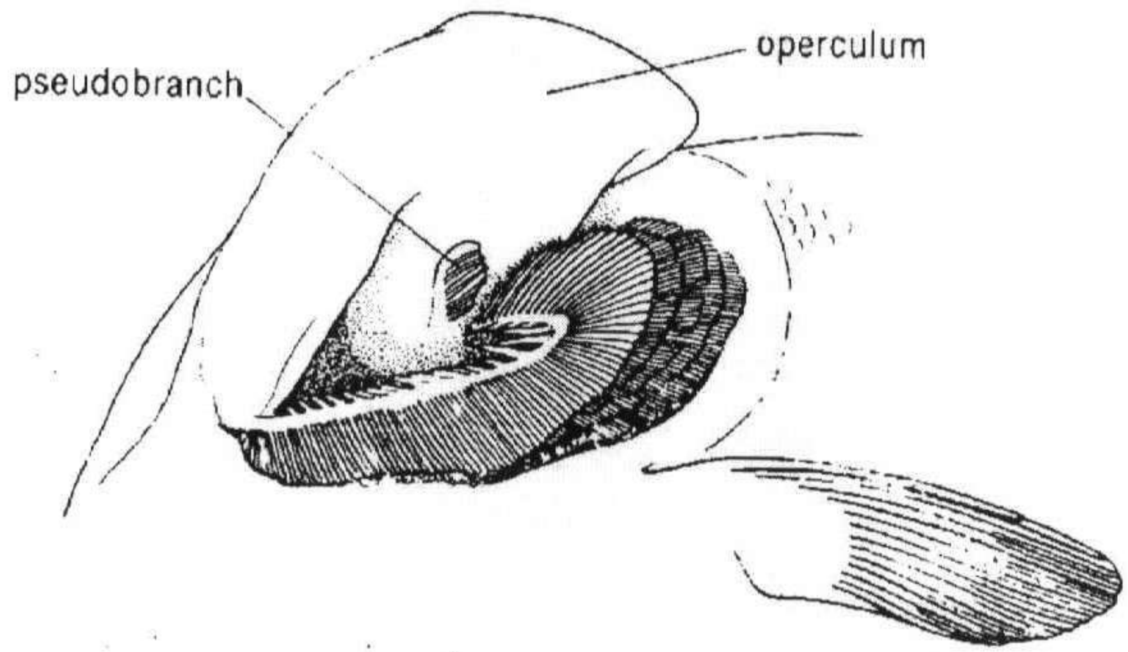



FIGURE 2-31. Position of pseudobranch in trout (Salmonidae).

**Sturgeon** سمك الحفش

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**<br>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.

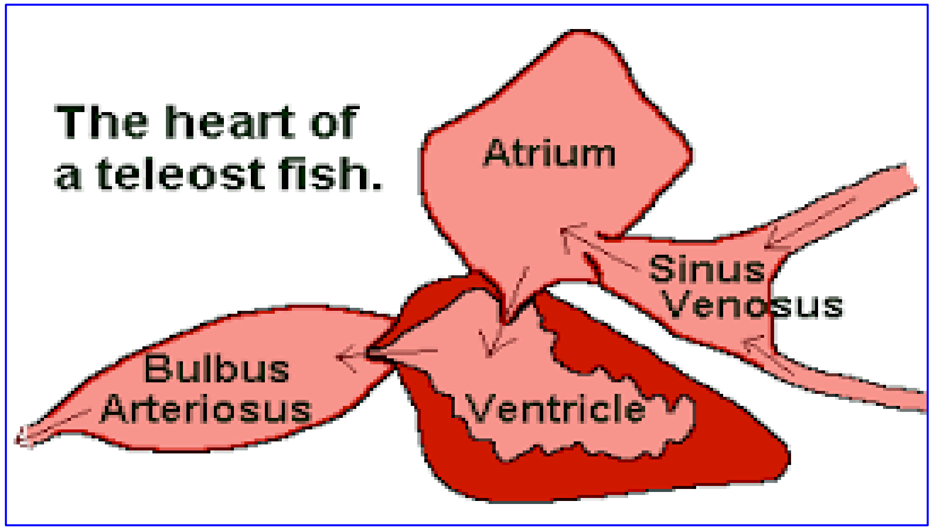
Some authors considered atrium and ventricles as the chambers of heart; while some considered sinus venosus and conus arteriosus also as the chambers of the heart.

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.

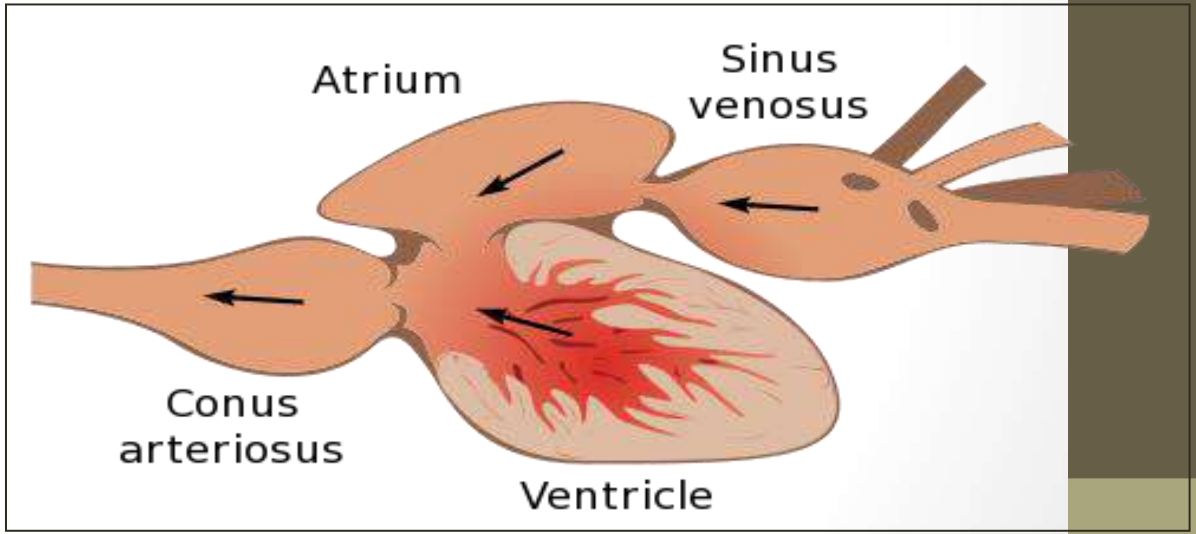
The distinction between the two is that: **the conus** arteriosus consists of cardiac musculature similar to the ventricle and is provided by a large number of valves arranged in successive rows; **while bulbus** arteriosus consists of only smooth muscle fibres and elastic tissues.

# Heart of bony fish:

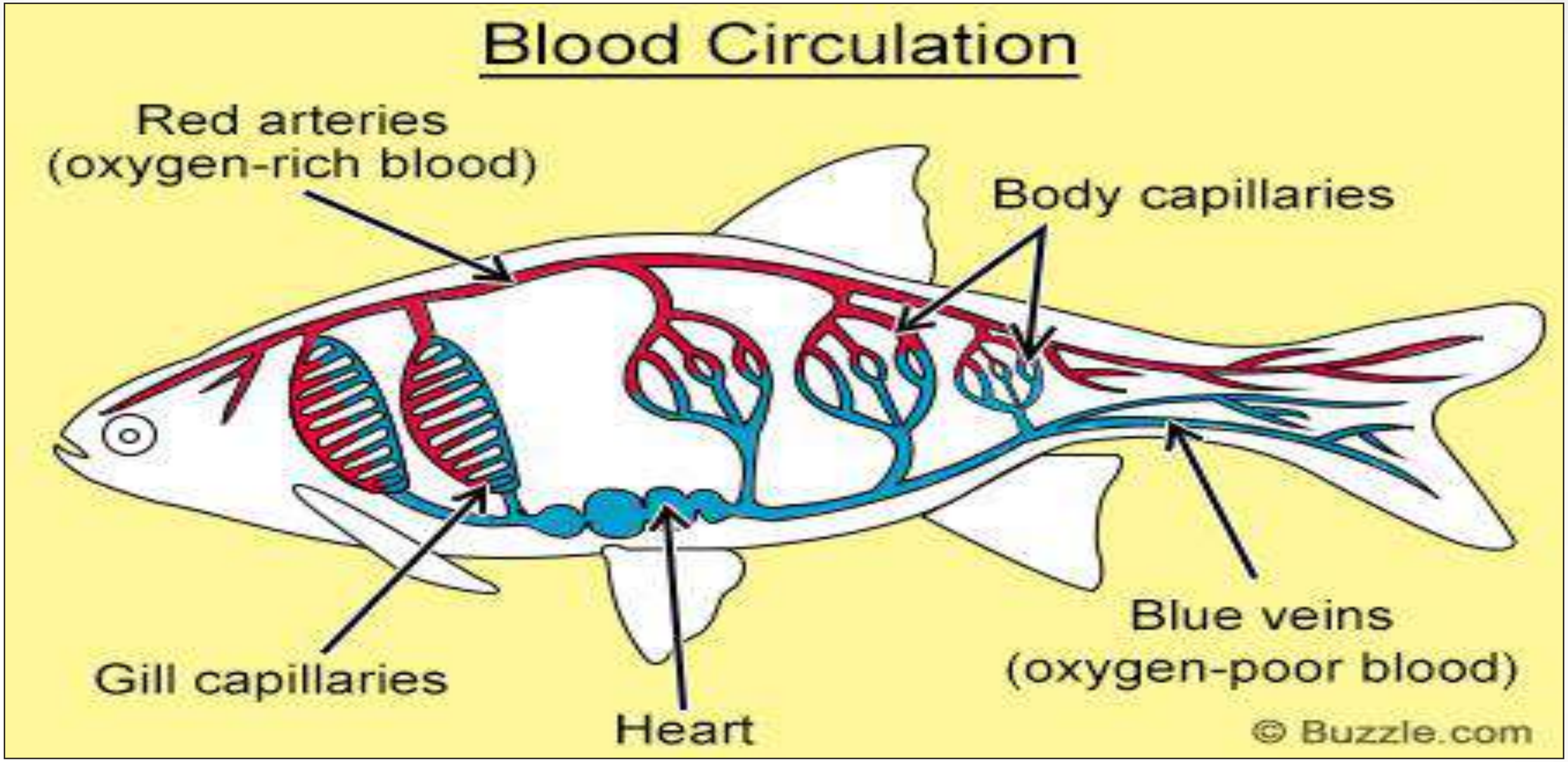
- A bony fish's **heart** has two chambers: an **atrium** and a **ventricle**.
- **The venous** side of the heart is preceded by an enlarged chamber called the **sinus venosus**.
- **The arterial** side of the heart is followed by a thickened muscular cavity called the **bulbus arteriosus**.

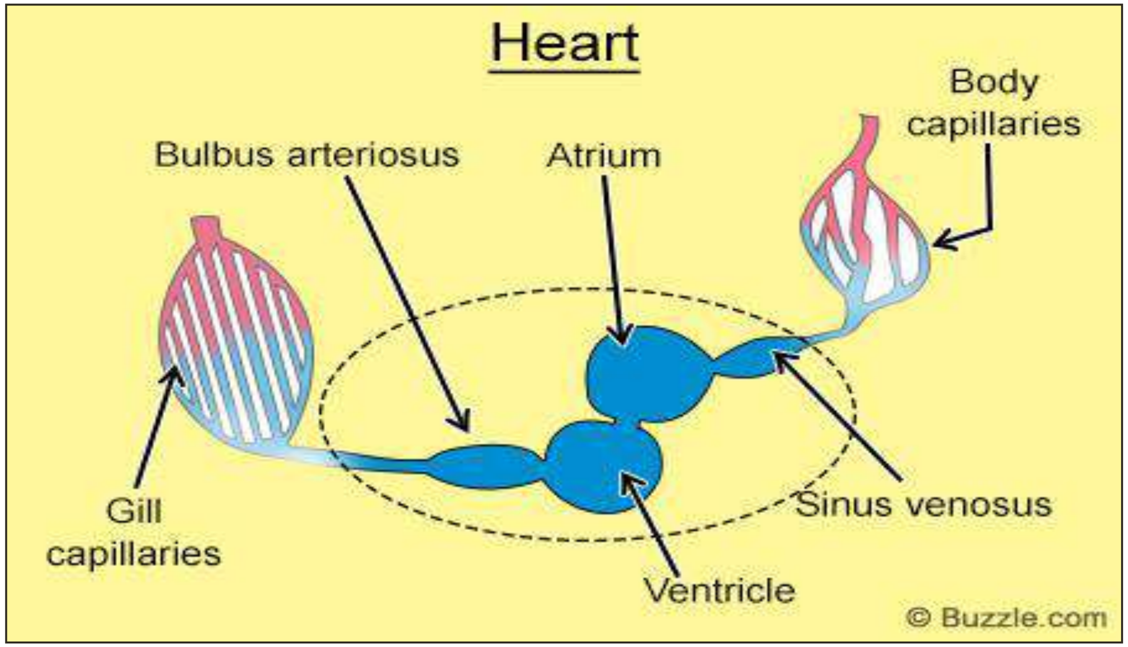


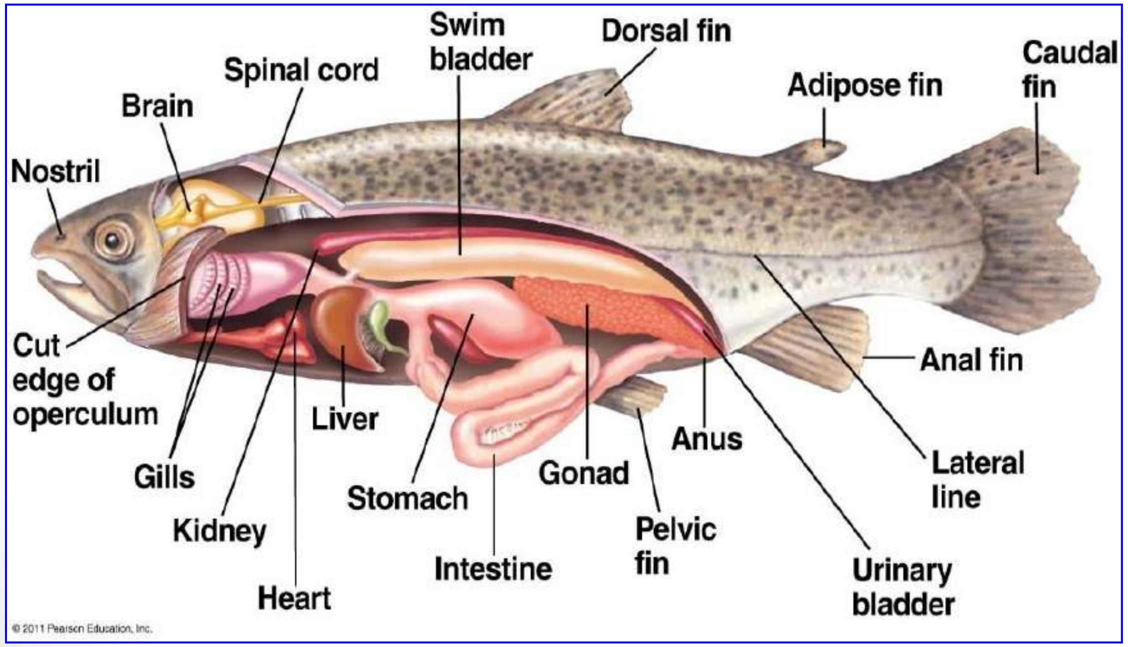

Heart of bony fish

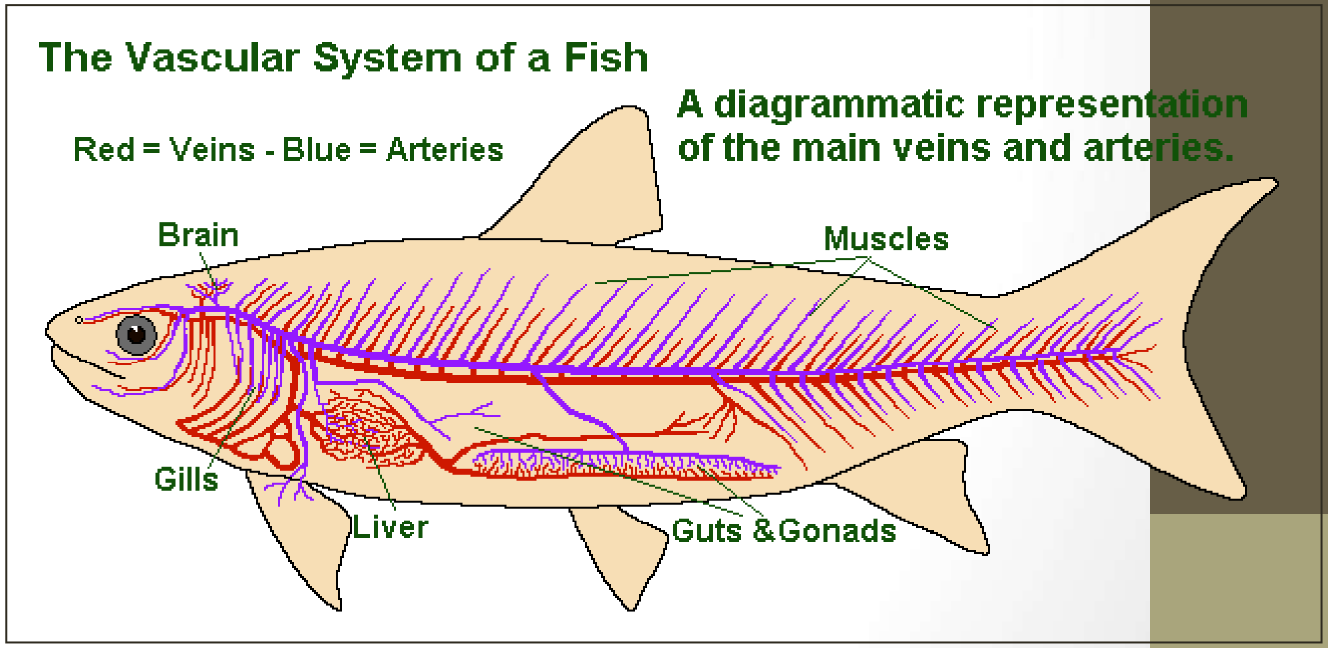



Heart of cartilaginous fish

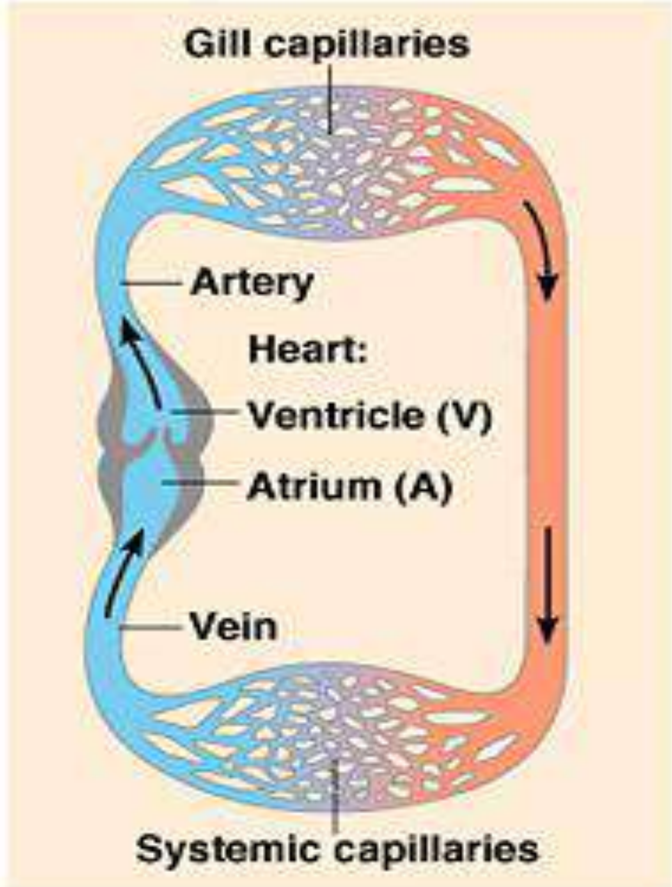

Blood Circulation
Red arteries
(oxygen-rich blood)
Body capillaries
Gill capillaries
Heart
Blue veins
(oxygen-poor blood)
© Buzzle.com


Heart
Bulbus arteriosus
Atrium
Body capillaries
Gill capillaries
Sinus venosus
Ventricle
© Buzzle.com


Swim bladder
Dorsal fin
Spinal cord
Brain
Adipose fin
Caudal fin
Nostril
Cut edge of operculum
Anal fin
Liver
Anus
Lateral line
Gills
Stomach
Gonad
Kidney
Pelvic fin
Intestine
Urinary bladder
Heart
© 2011 Pearson Education, Inc.

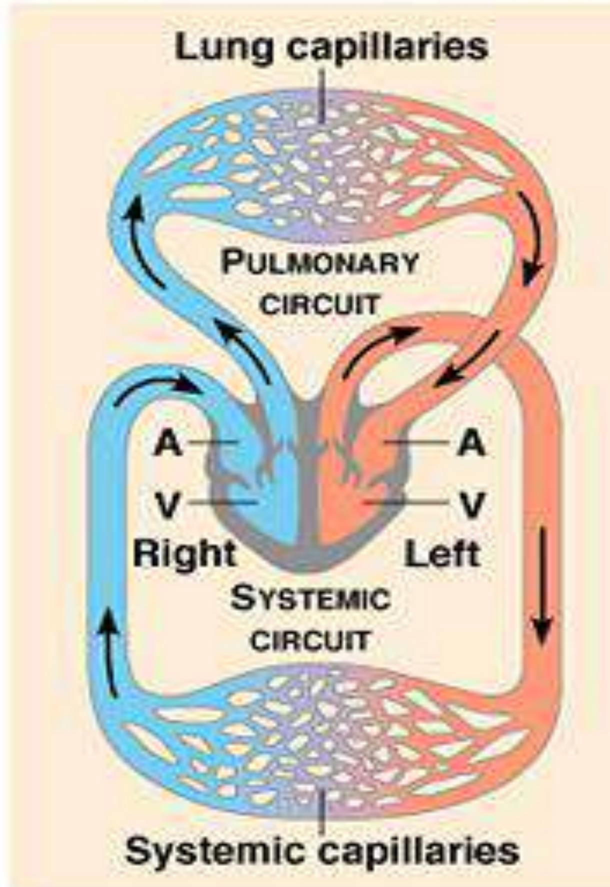

The Vascular System of a Fish
A diagrammatic representation of the main veins and arteries.
Red = Veins - Blue = Arteries
Brain
Muscles
Gills
Liver
Guts &Gonads

**Fishes have a Single-circuit closed circulatory system.**




(a) Fish



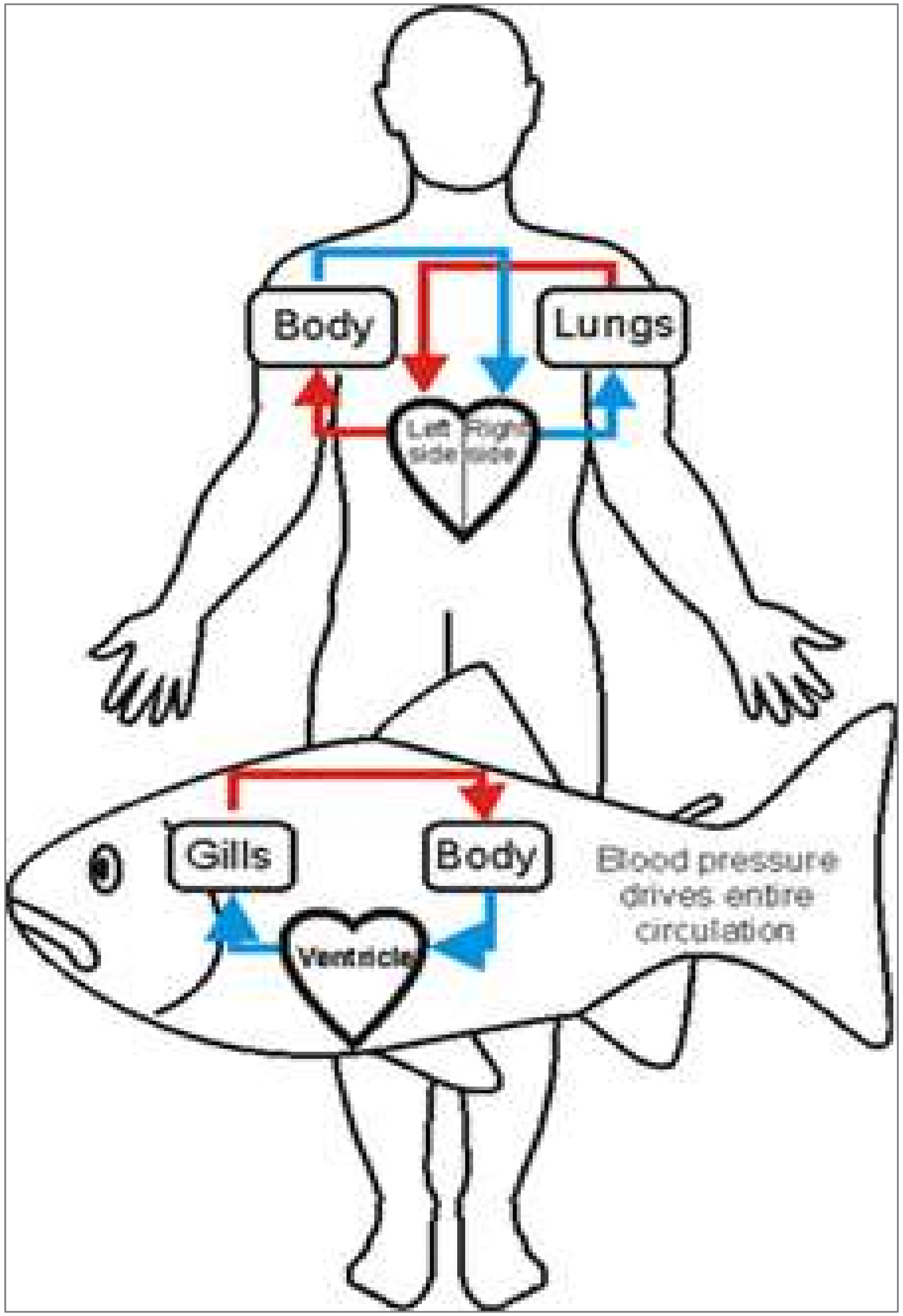



(c) Mammal

## 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

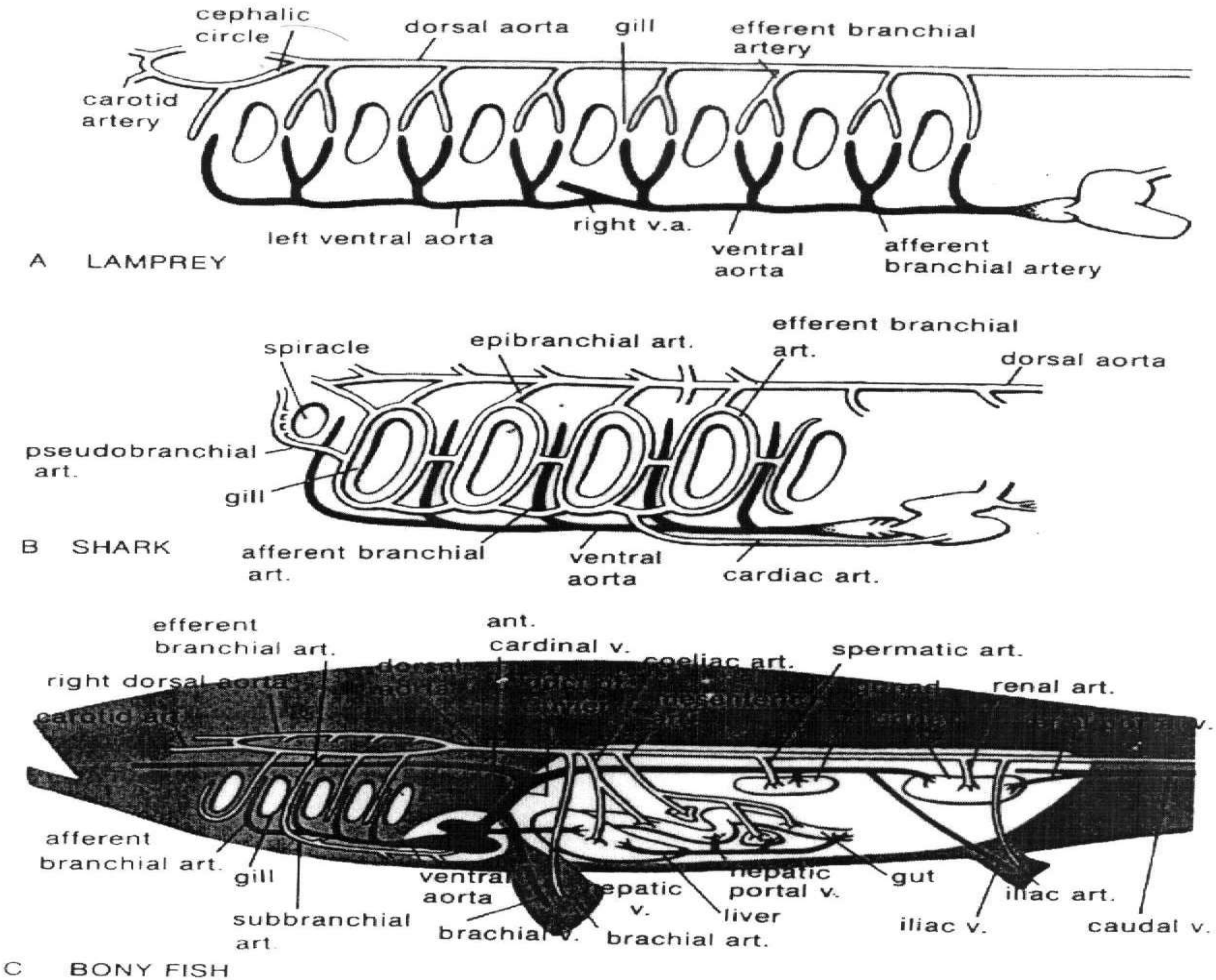


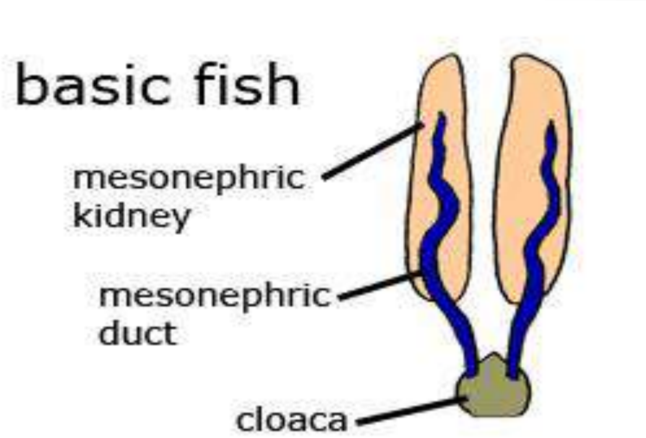

**FIGURE 2–33.** Diagrams of blood circulation. *A*, Lamprey, branchial arteries; *B*, shark, br arteries; *C*, bony fish, showing major blood vessels.

# Urinogenital system

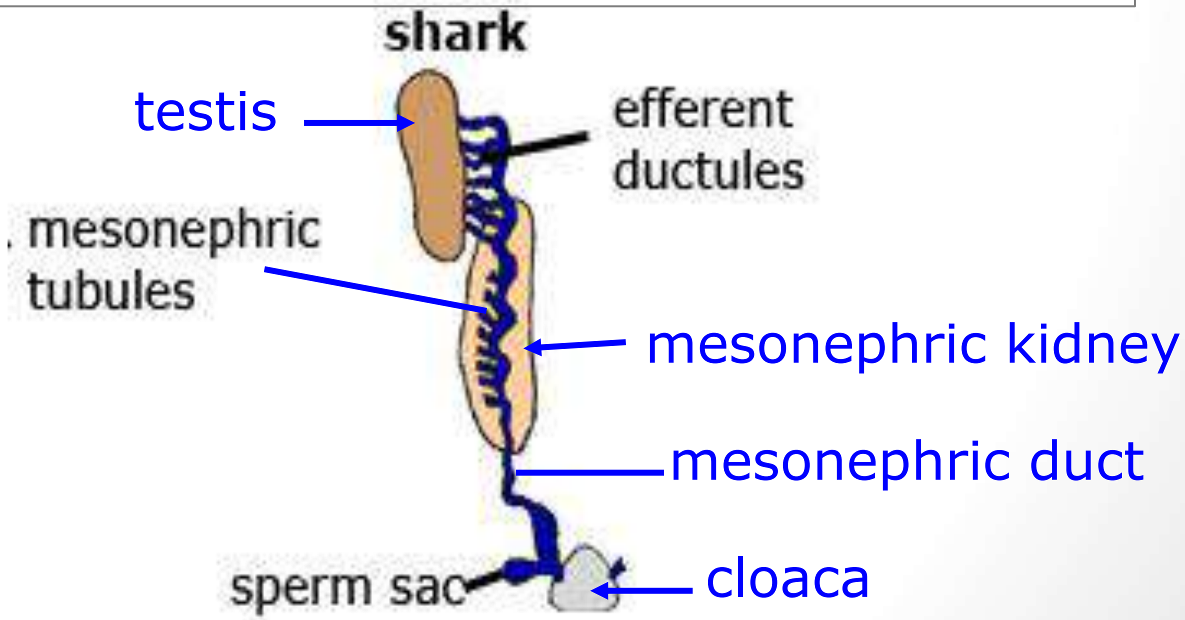
* kidney.

**Gonads

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

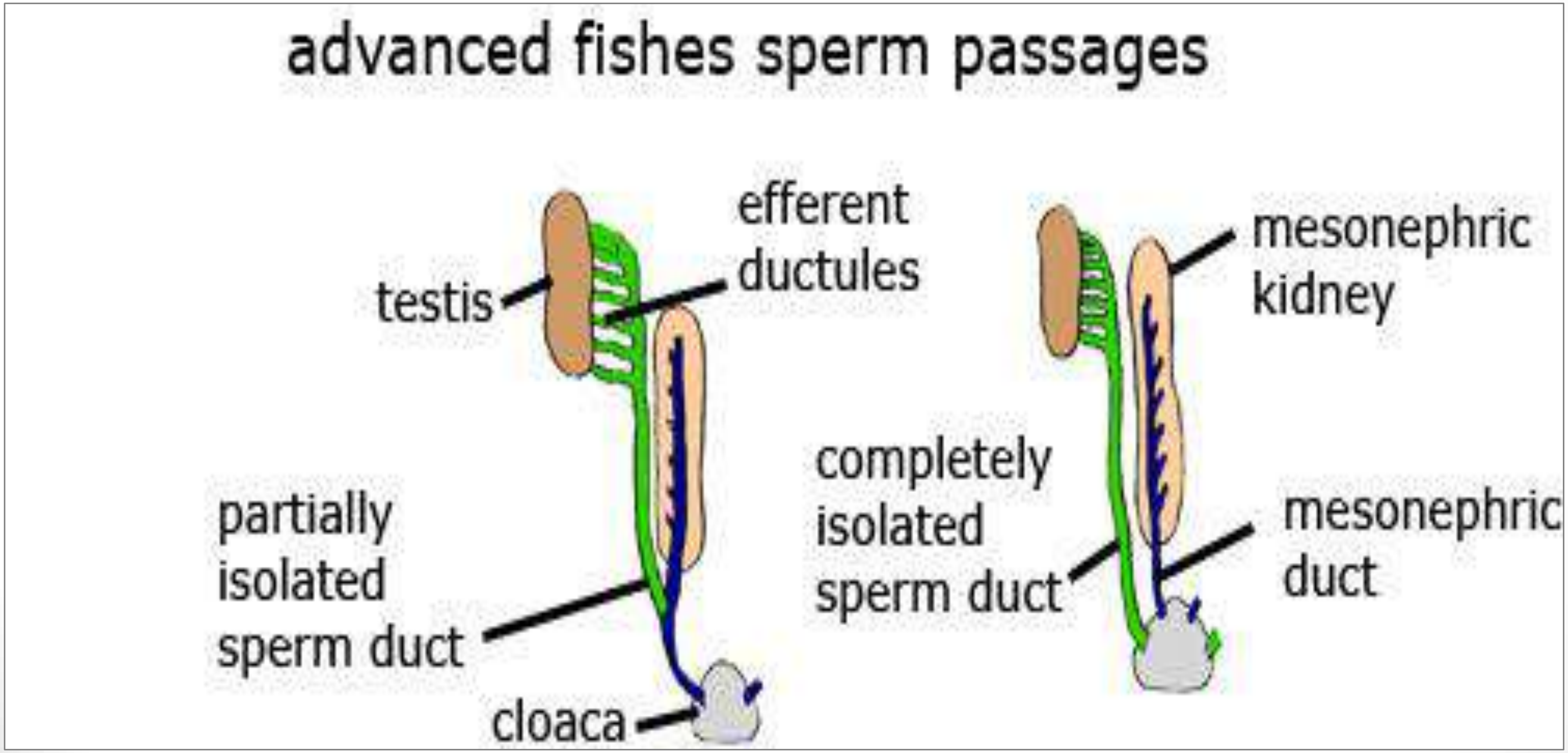



In sharks, and some other primitive bony fish, the testis is connected to the mesonephric duct by a series of small tubules (efferent ductules). In some instances these ducts are shared with the urinary system, in other species the efferent ductules from the testis are separated from the nephric tubules,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

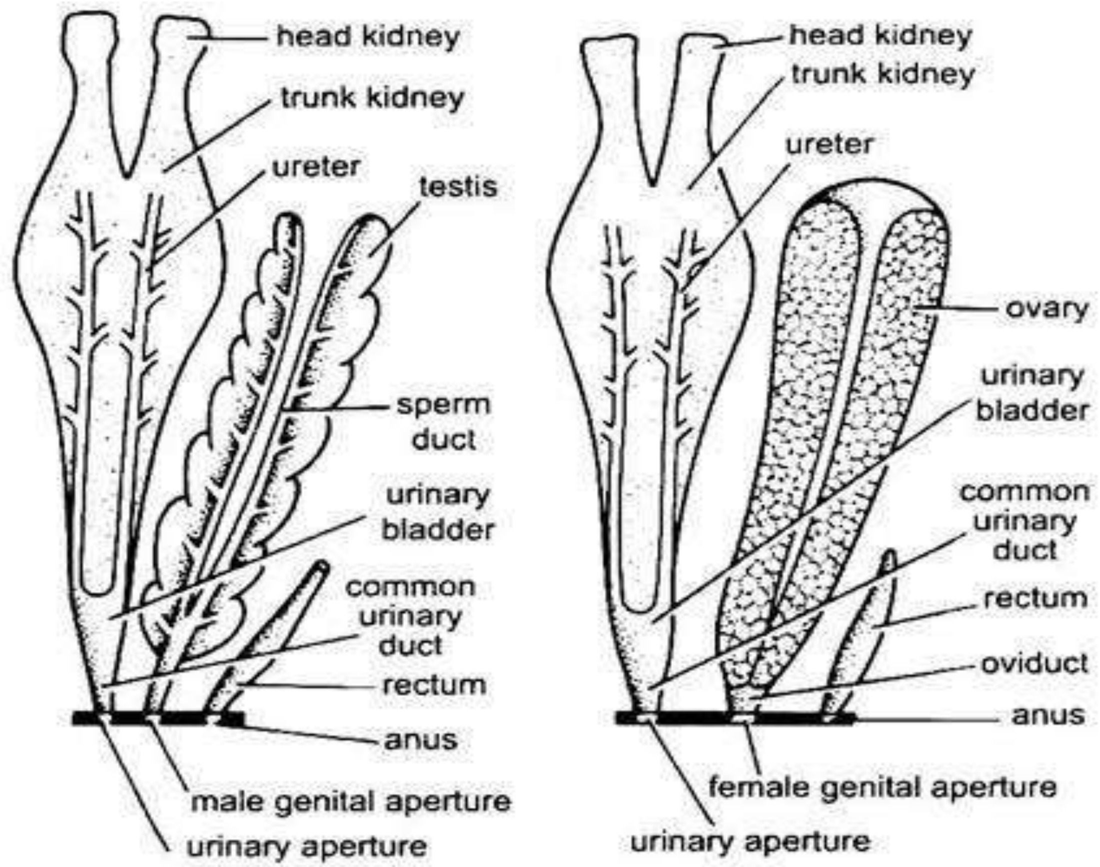
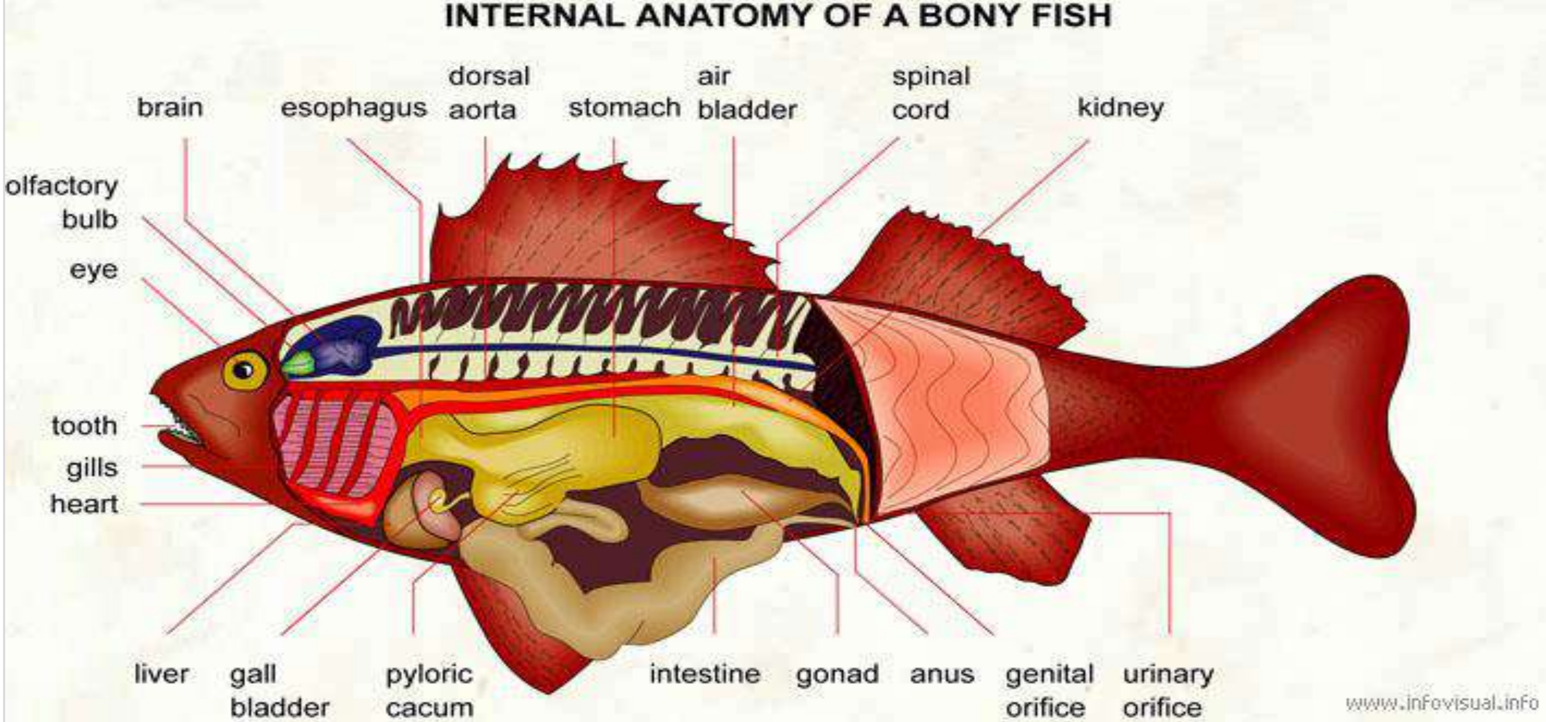
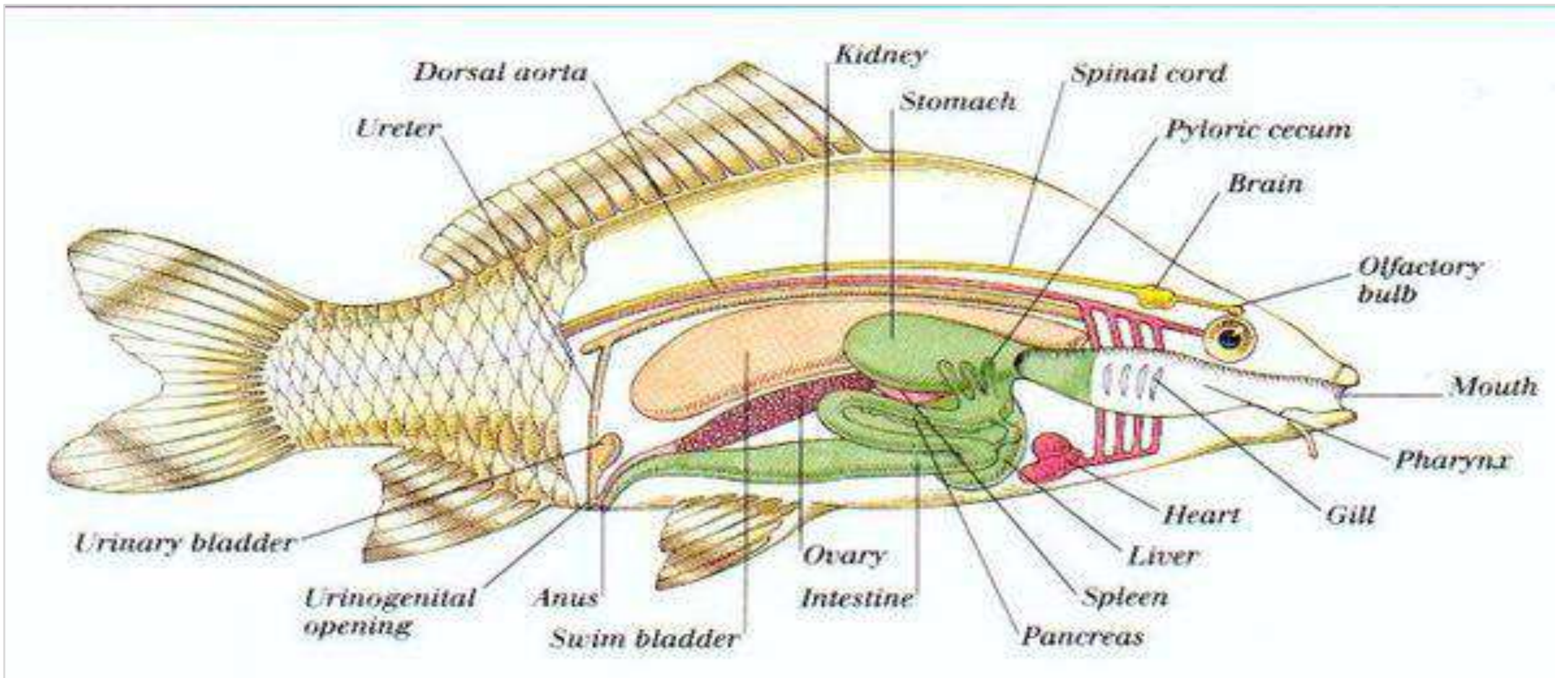



Fig. 15.14. *Labeo*. Urinogenital organs. A–Male; B–Female.


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
Intestine
Ovary
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.

# Fish kidneys

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

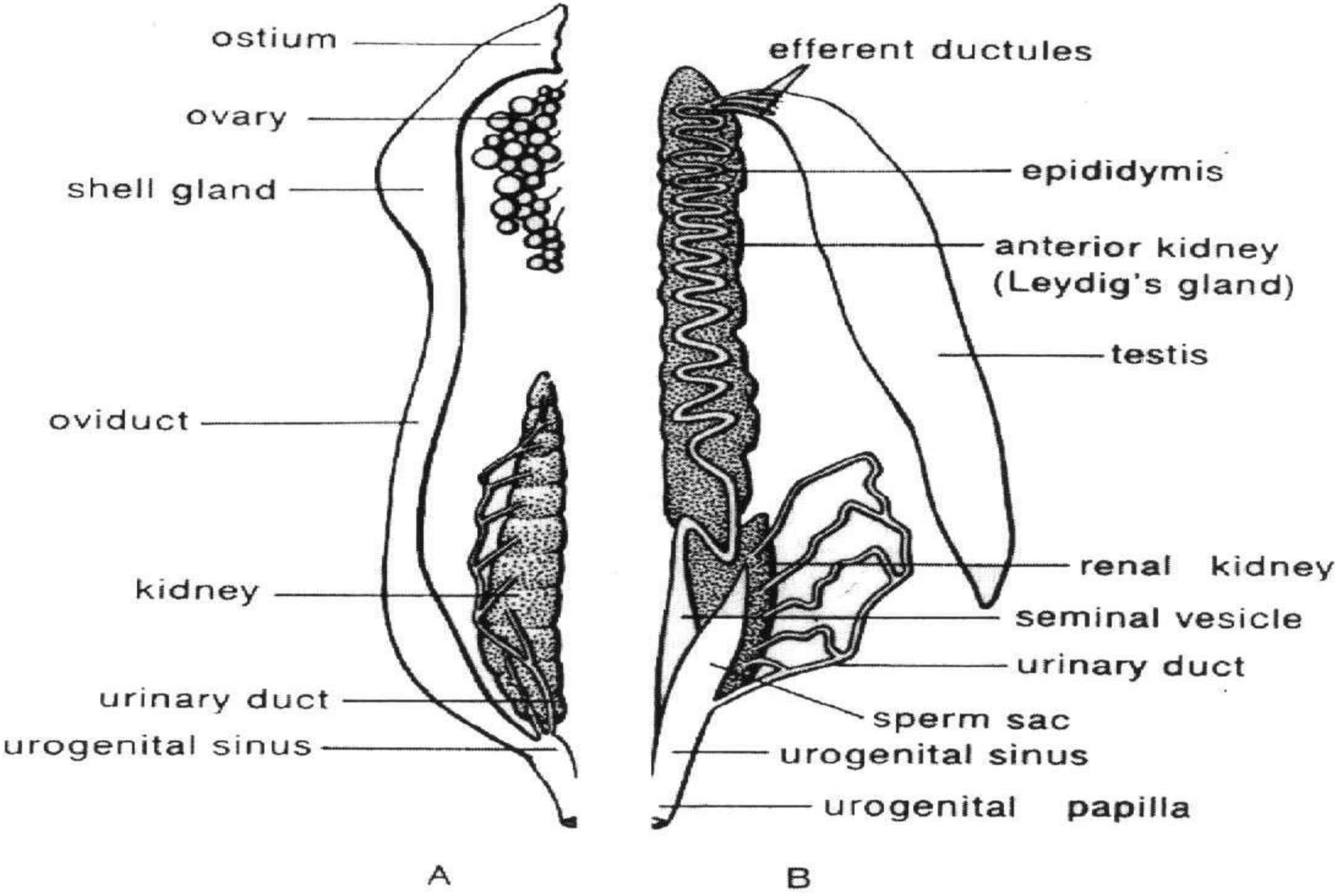



**FIGURE 2–35.** Diagram of urogenital organs of shark. *A*, Female; *B*, male. (Based on Goodrich, in Lankester, 1909.)

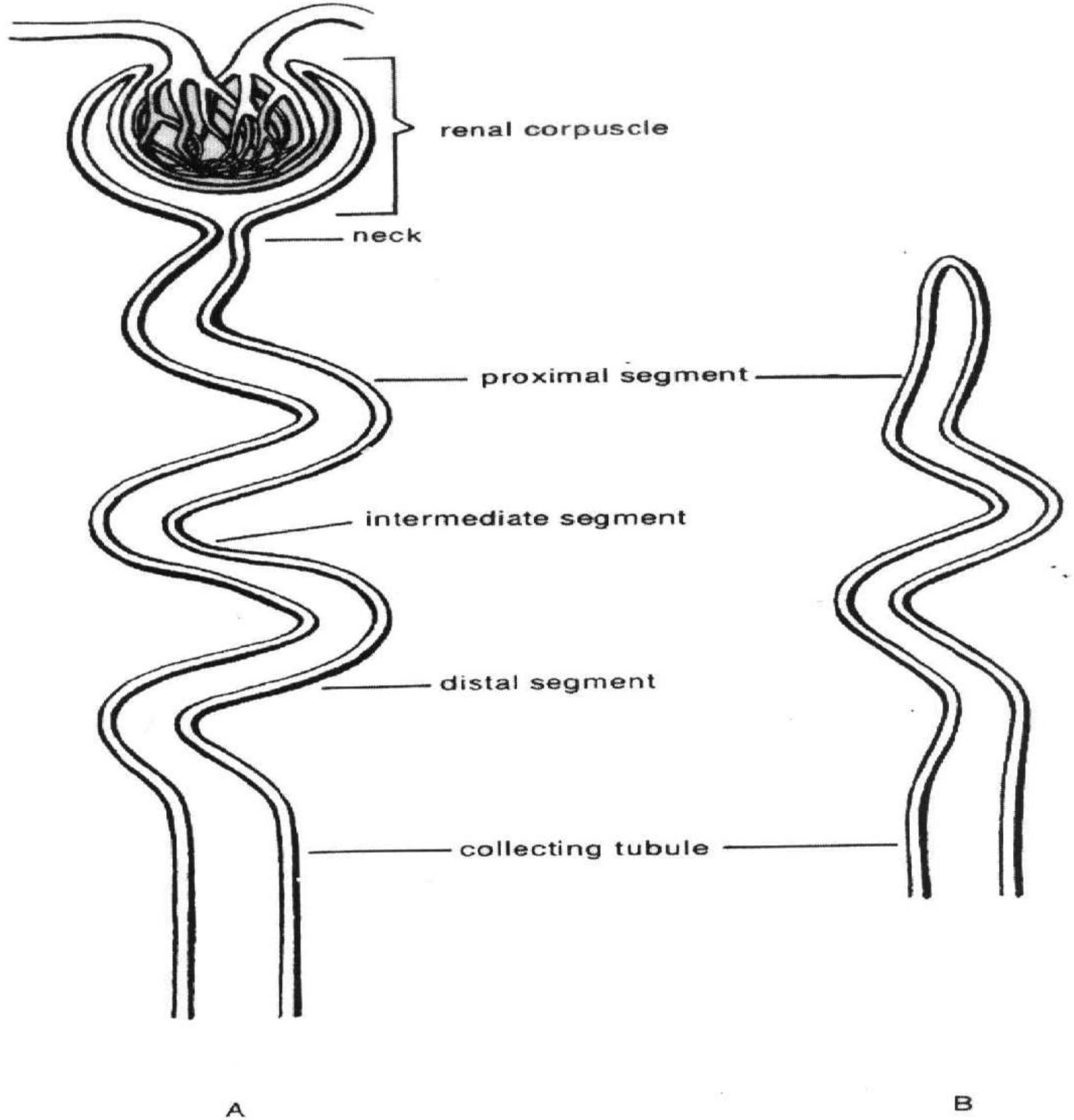
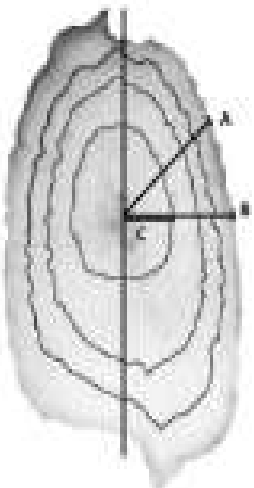


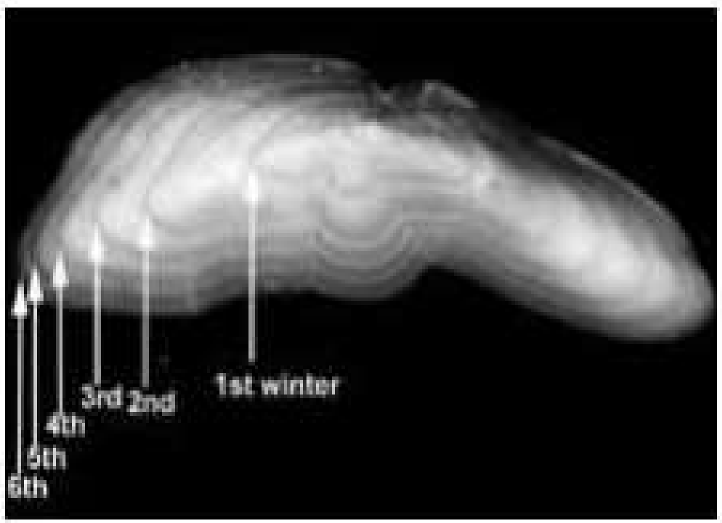

**FIGURE 2–36.** Schematic diagrams showing components of two types of nephrons found in bony fishes. *A,* Glomerular; *B,* aglomerular (in some marine fishes).

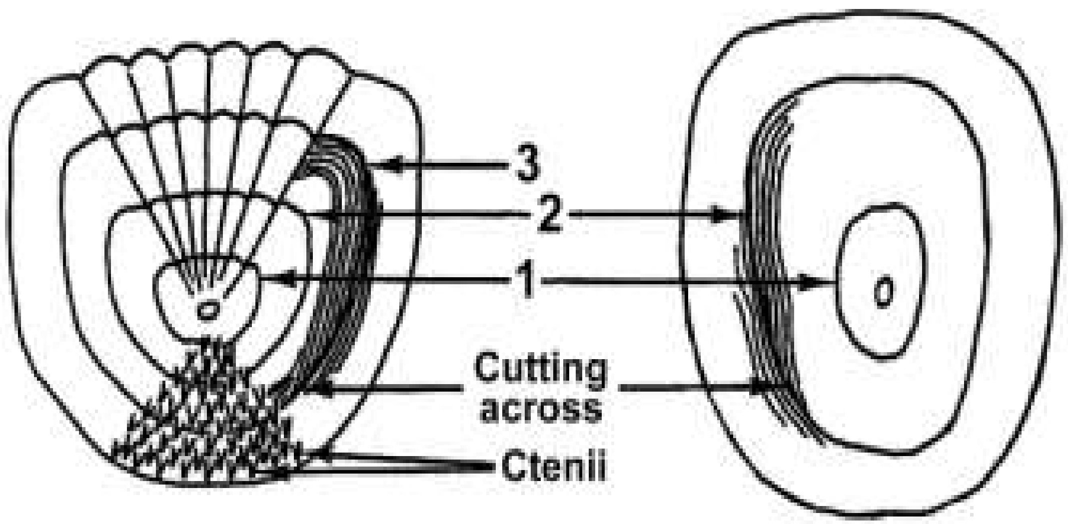
Lecture 5

# 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**.

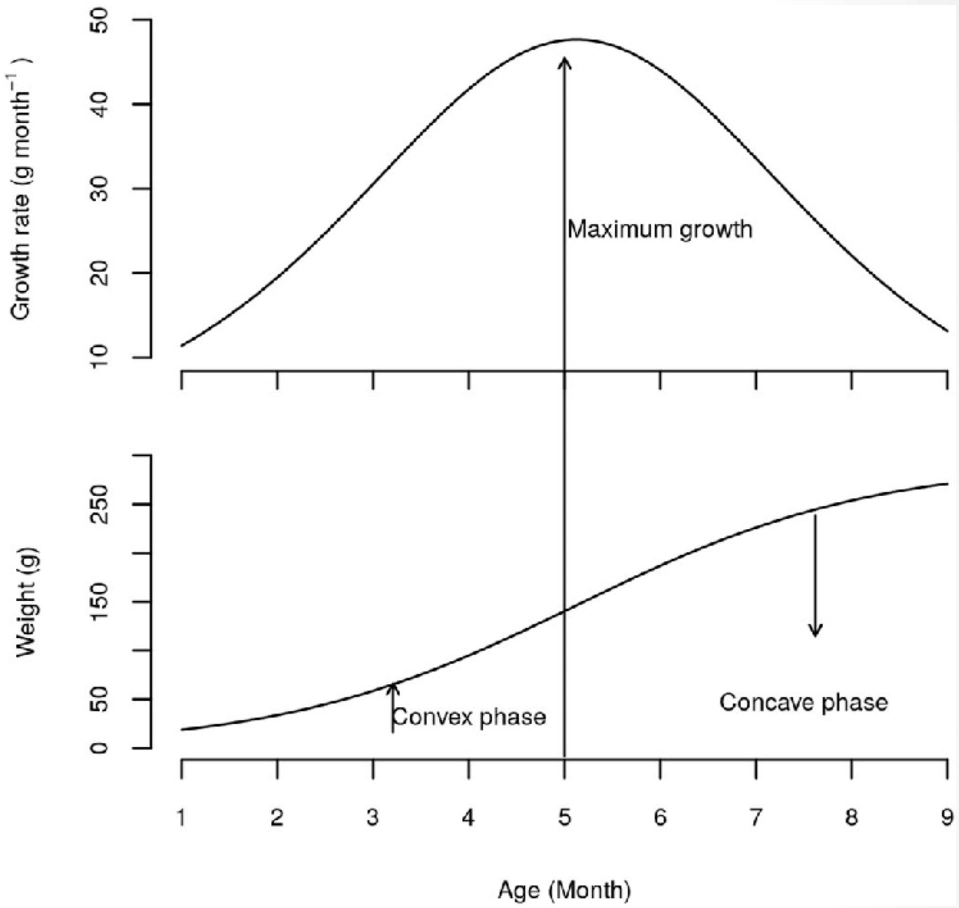
The growth **in length** indicates **long term change**, whereas growth **in weight** is more subject to **seasonal variation**.

## Knowledge of age and growth of fish has many applications:

1. We can calculate the time of sexual maturity of different species.
2. Further, we can know their spawning time.
3. Growth rate of fish also indicates the suitability of particular species for a particular type of the water-body.
4. Growth rate and age of fish also indicate the size of fish at different stages, e.g., fry, fingerling, and adult of different species.
5. The study of age and growth is helpful in catching fishes by using nets of desirable mesh size.

## Absolute growth:

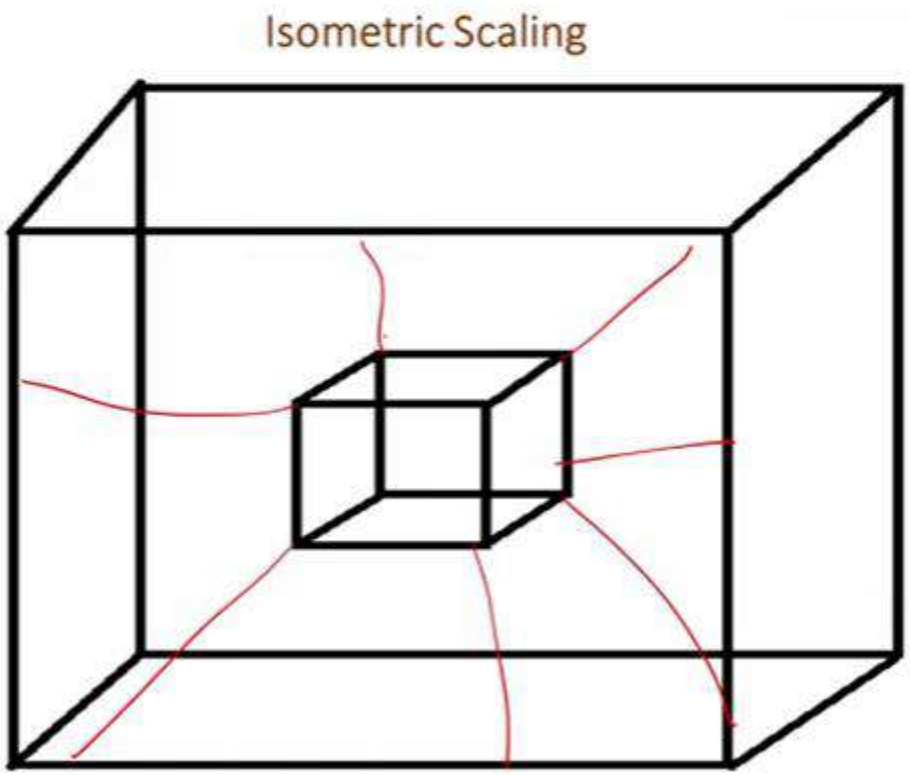
means the highest or perfect growth of fish from **embryonic** to **aging period**.



## 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 unbalanced growth. There may be various pattern of this type of growth. For example several fish grow more in length than width and weight.

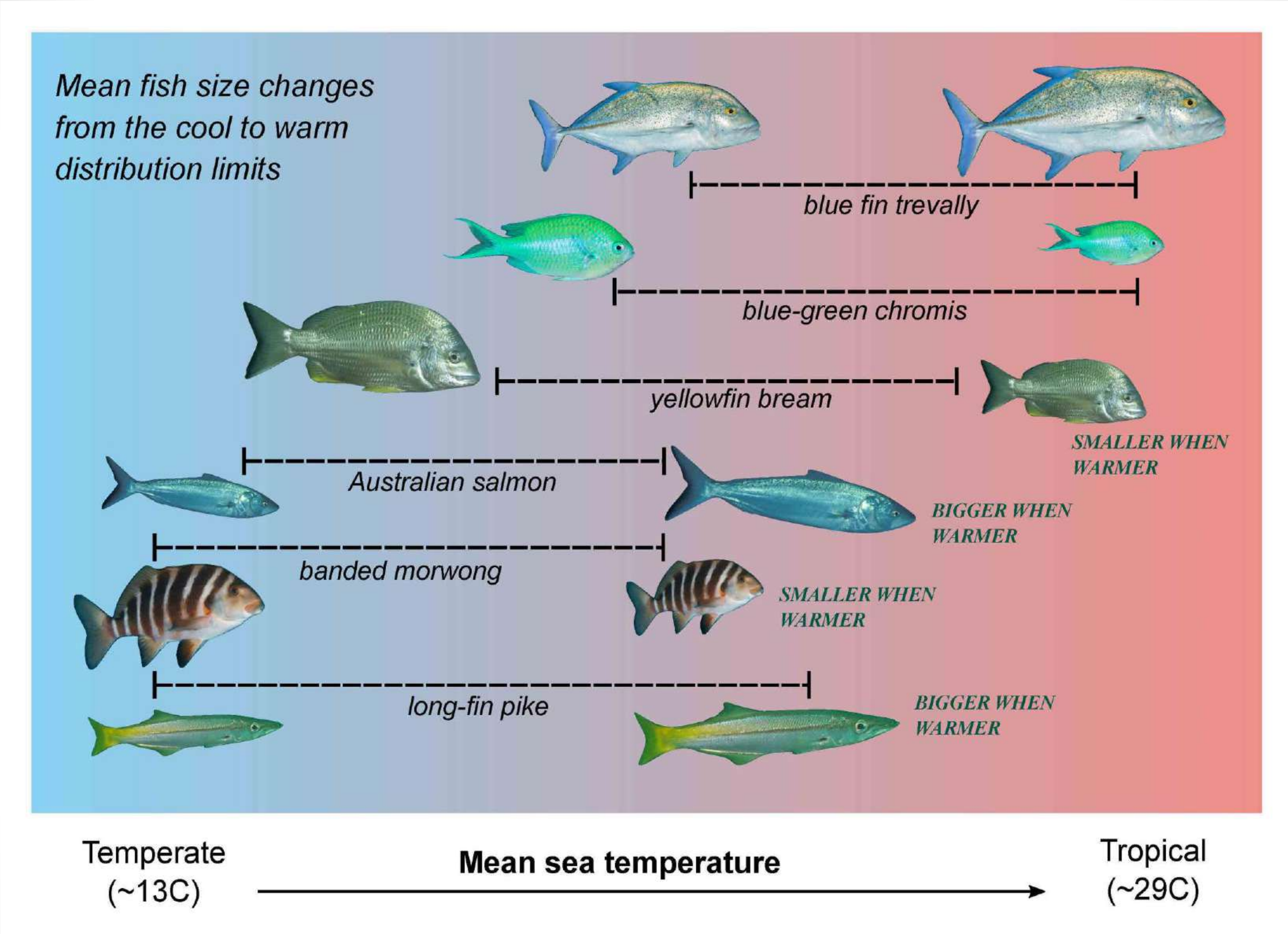
Table 2. Growth parameters of silver pompano

| Growth parameter | Formula |
|---|---|
| Absolute growth rate (g $day^{-1}$) | AGR = $(W_2 - W_1) / (t_2 - t_1)$ |
| Relative growth (%) | RG = $(W_2 - W_1) / W_1 \times 100$ |
| Relative growth rate | RGR = $(W_2 - W_1) / W_1 (t_2 - t_1)$ |
| Specific growth rate (% per day) | SGR= $(\ln W_2 - \ln W_1) / (t_2 - t_1) \times 100$ |
| Feed conversion ratio (FCR) | FCR = fi / ib |

$W_1$ = Initial wet weight of fish at stocking, $W_2$ = Final wet weight of fish, $t_1$ = Age at stocking, $t_2$ = Age at end of growout period, fi = Total feed intake, ib = Total fish biomass

# 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



Mean fish size changes from the cool to warm distribution limits
blue fin trevally
blue-green chromis
yellowfin bream
SMALLER WHEN WARMER
Australian salmon
BIGGER WHEN WARMER
banded morwong
SMALLER WHEN WARMER
long-fin pike
BIGGER WHEN WARMER
Temperate (~13C)
Mean sea temperature
Tropical (~29C)

# Condition factor or Ponderal Index

- The condition factor or Ponderal index, or coefficient of correlation expresses the condition of a fish, such as the degree of well being, fatness in numerical terms.
- The condition factor used to determined from length and weight of the fish.

## Ponderal index or condition factor

**K=IOOW/L3**

Where L is length in cms and

W is weight of fish in grams.

- 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.

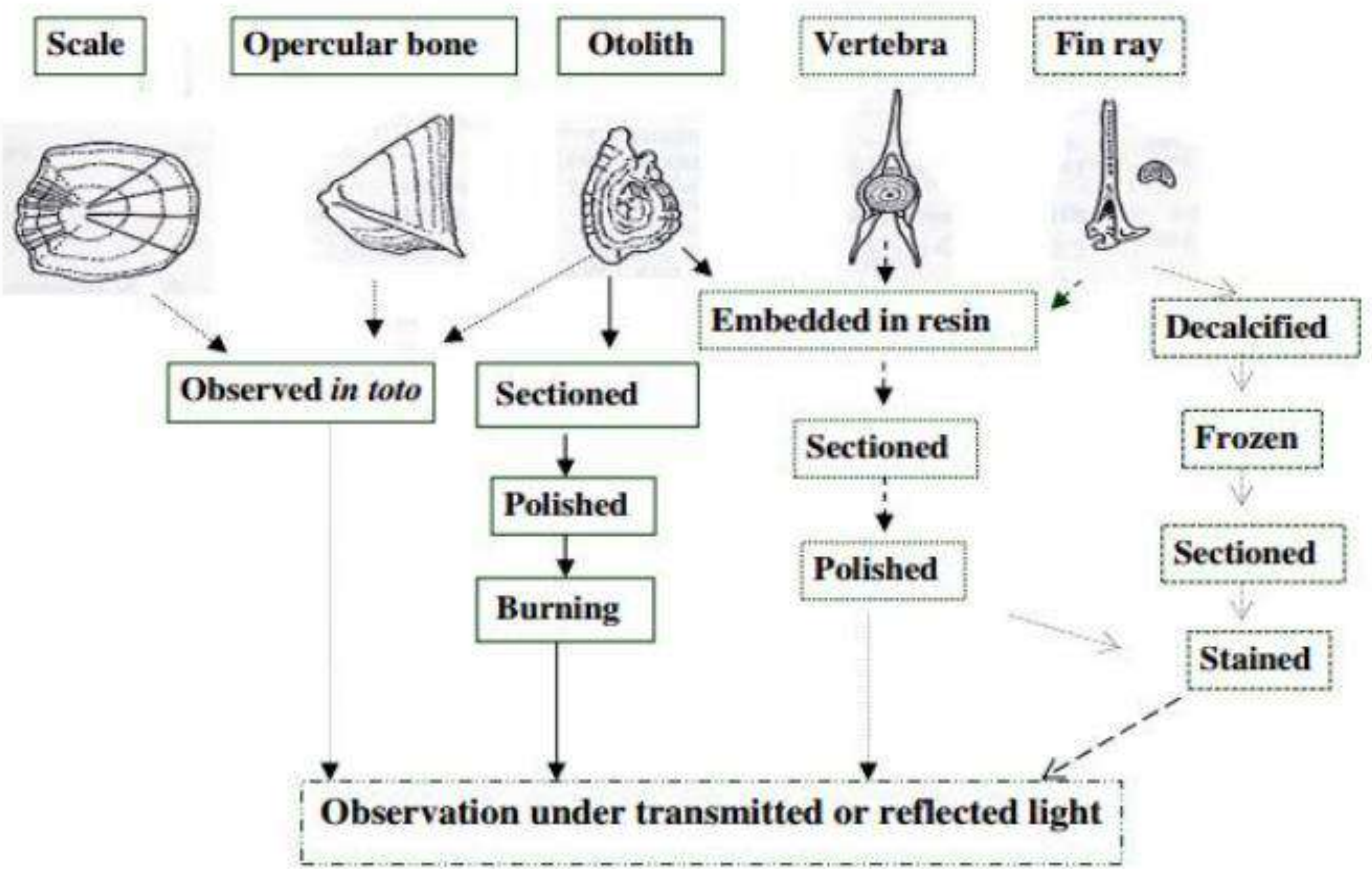
## Method for Determining Age

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

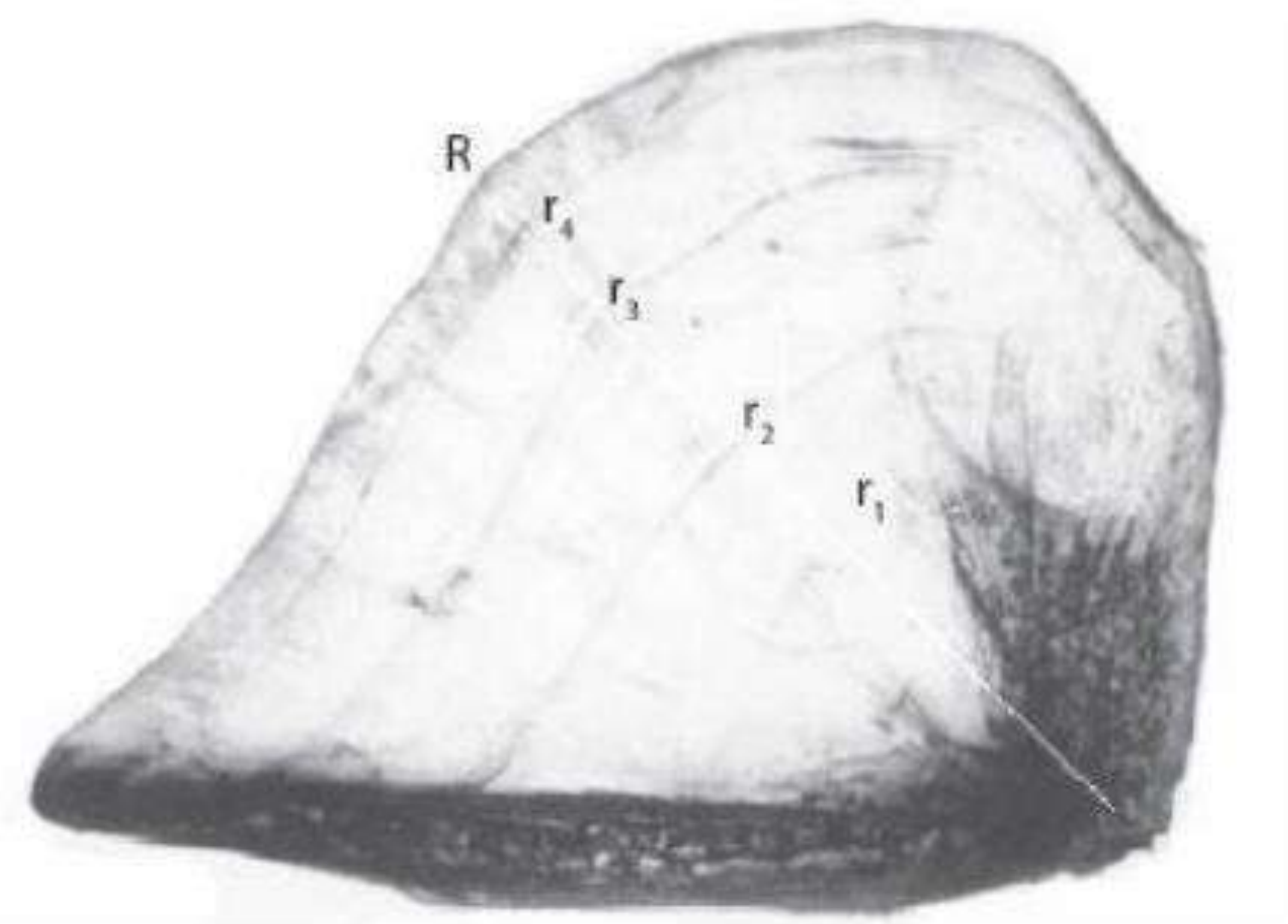


# By counting annuli on Bones

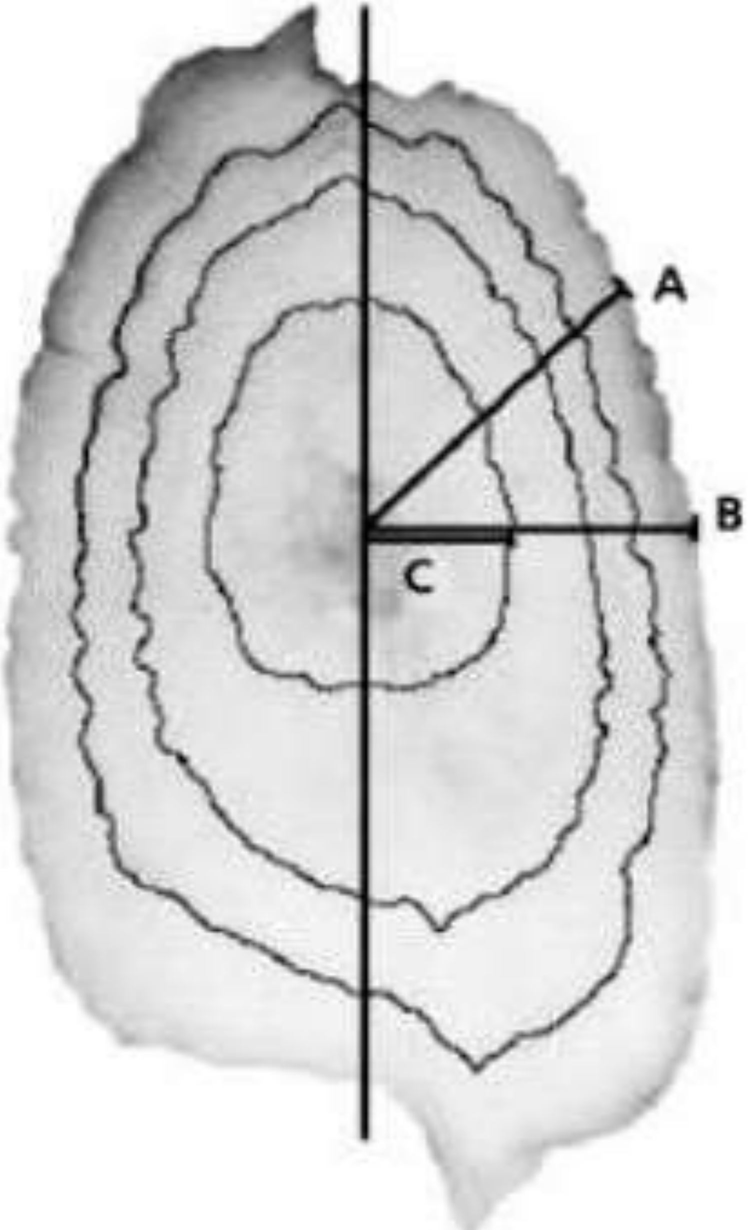
- The choice of calcified structures for aging varies among species, a structure used in one species may not be the same structure used in another.
- Not all bony structures lay down growth rings equally.

- 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

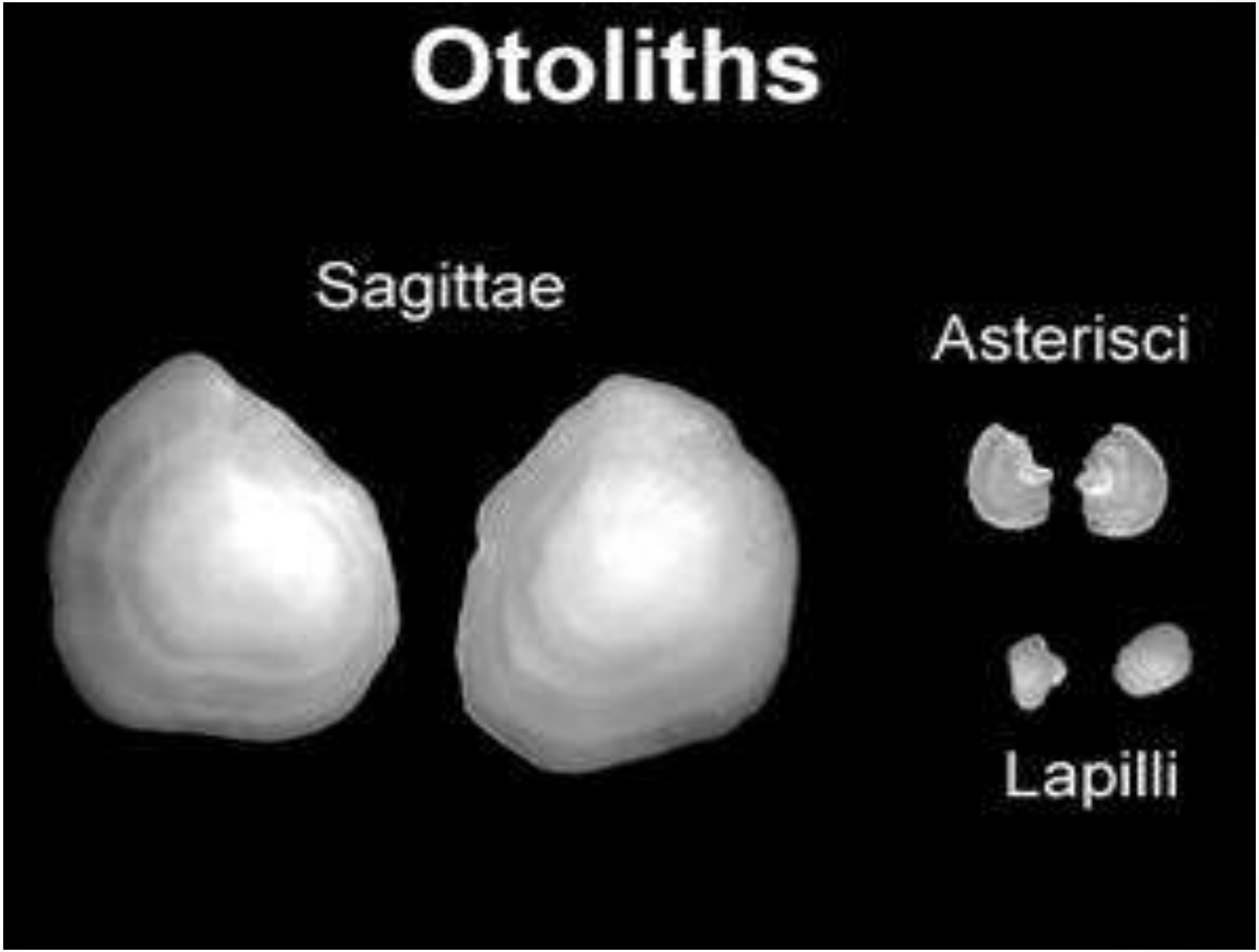


# Pectoral Spine

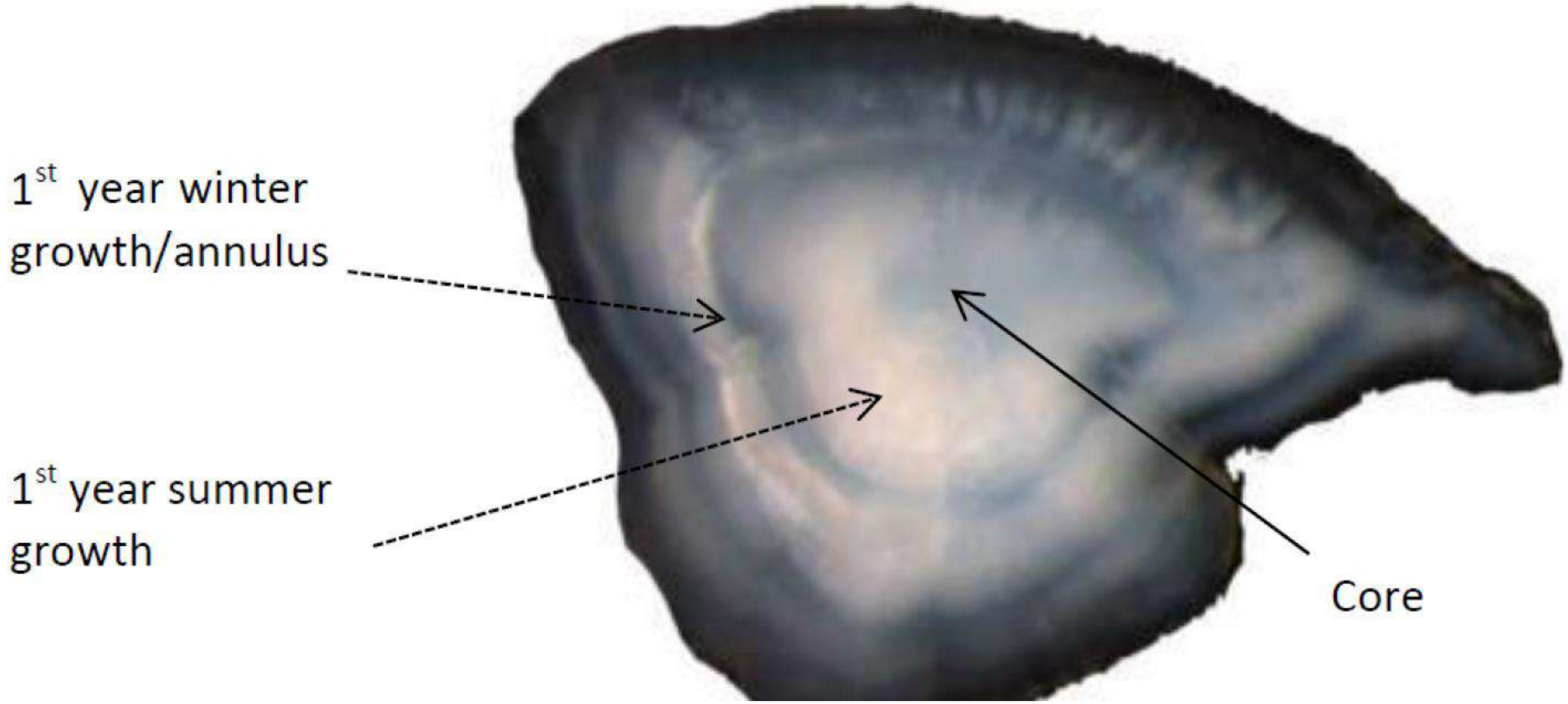


## By counting annuli on Otolith

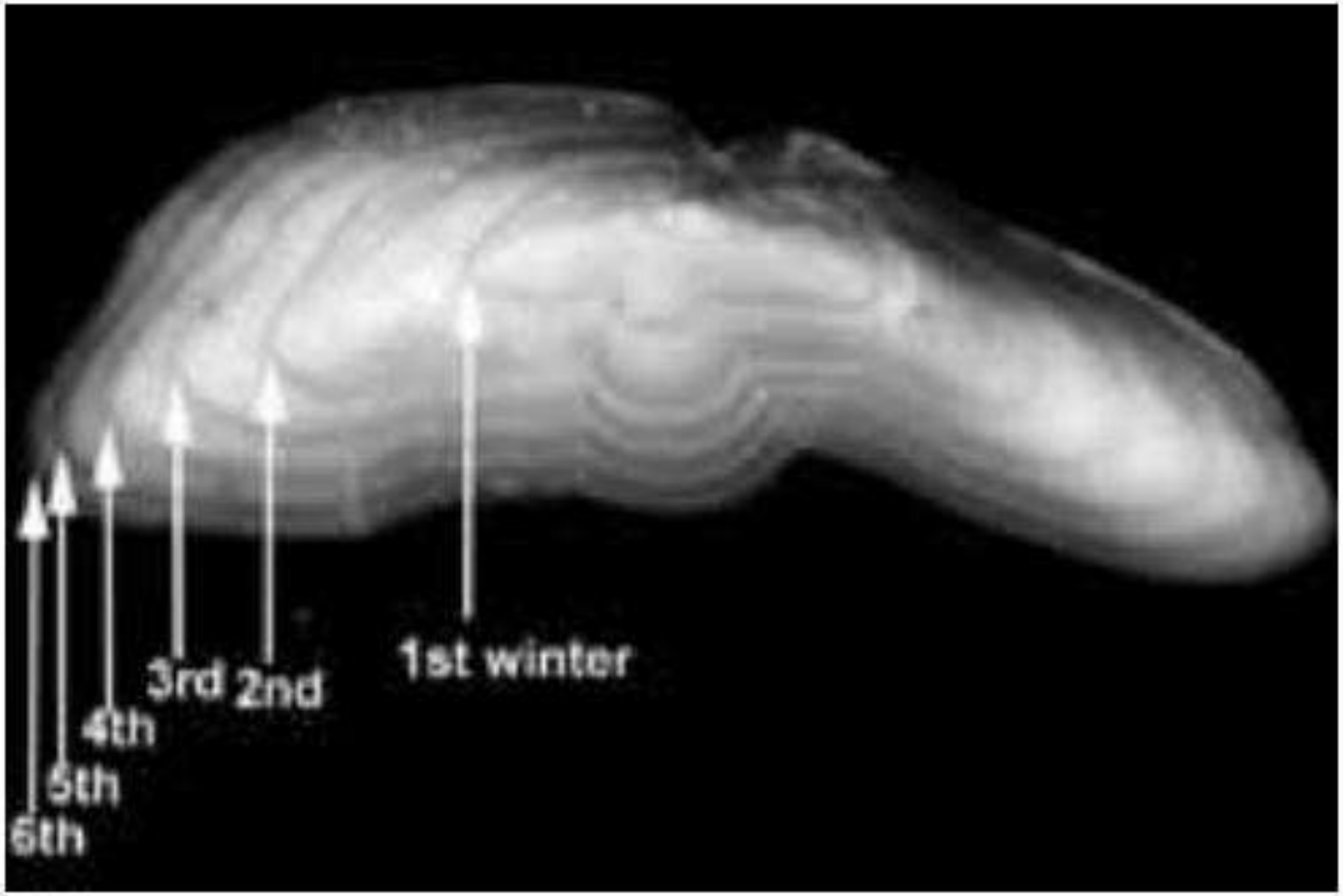
- Otoliths are the earbones of a teleost (bony) fish and are present in pairs; fish have three pairs, the lapilli, the sagittae and the astersci.
- These three pairs of otoliths in teleost fishes differ in form, function, size, shape, and ultrastructure.
- ' Otoliths are generally easier to read than scales and are more accurate, being internal and never reabsorbing like scales.


Otoliths
Sagittae
Asterisci
Lapilli

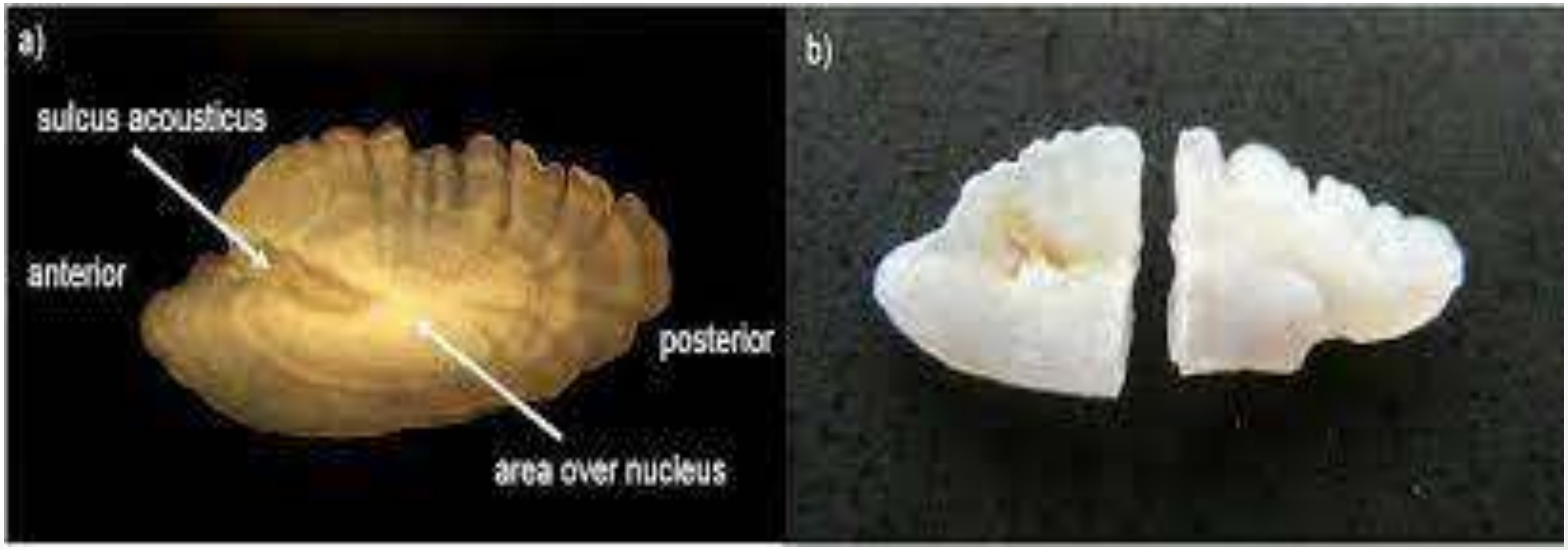
- Often the **sagittae** are analyzed for growth as they are the largest of the three otoliths and therefore easiest to remove.
- When preparing to analyze otoliths, generally if the otolith is <300 mm than it can be analyzed intact, when >300 mm otoliths contain too much three dimensional material and must be sectioned to analyze it more clearly.

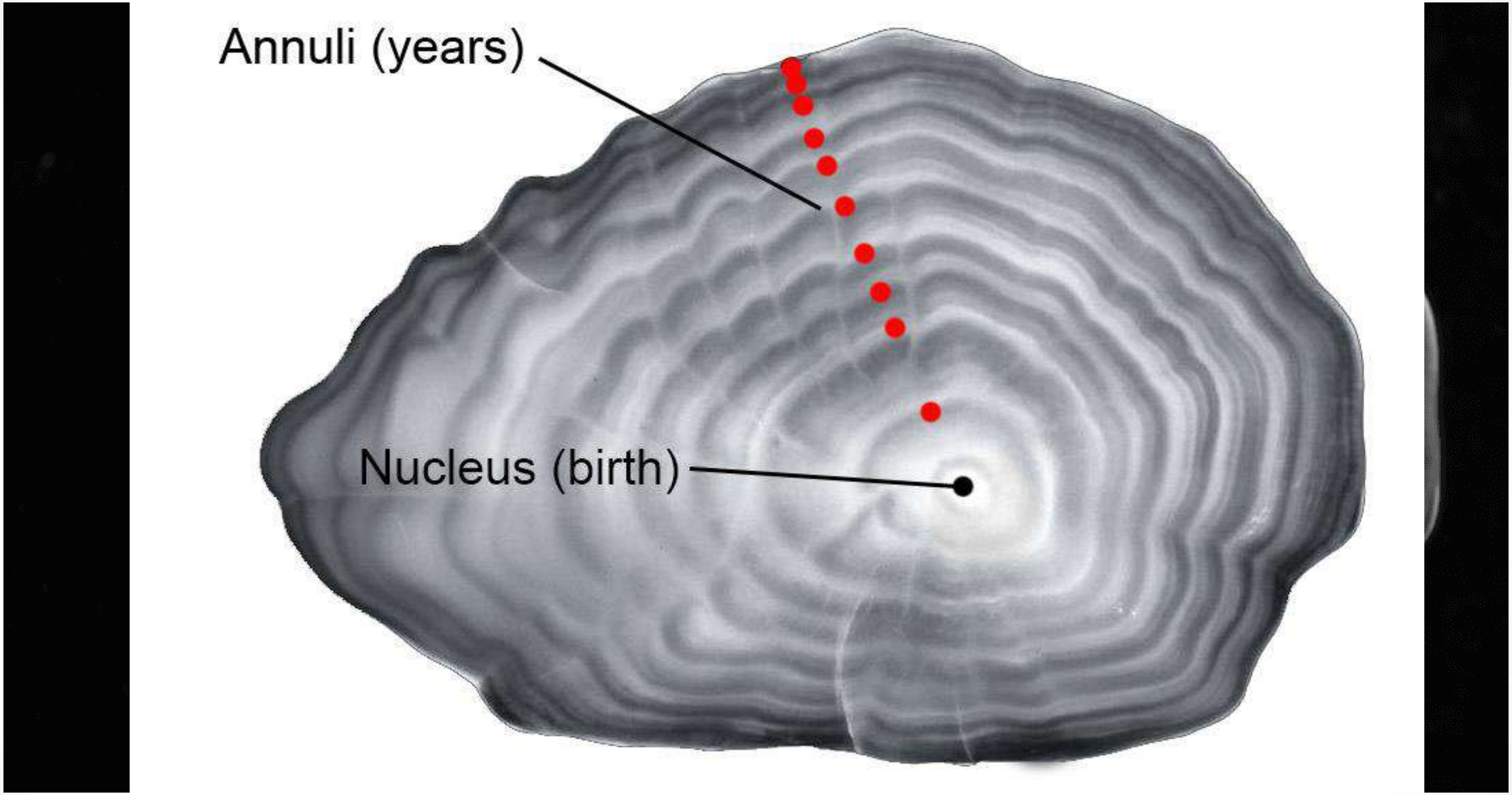

1st year winter growth/annulus
1st year summer growth
Core

# Otolith




Removing Otoliths from Fish
The Campana Lab
University of Iceland


a)
sulcus acousticus
anterior
posterior
area over nucleus
b)


Annuli (years)
Nucleus (birth)

## 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 1000 F.
- The annuli may be counted using a microscope, microfilm reader, or other such magnification device.

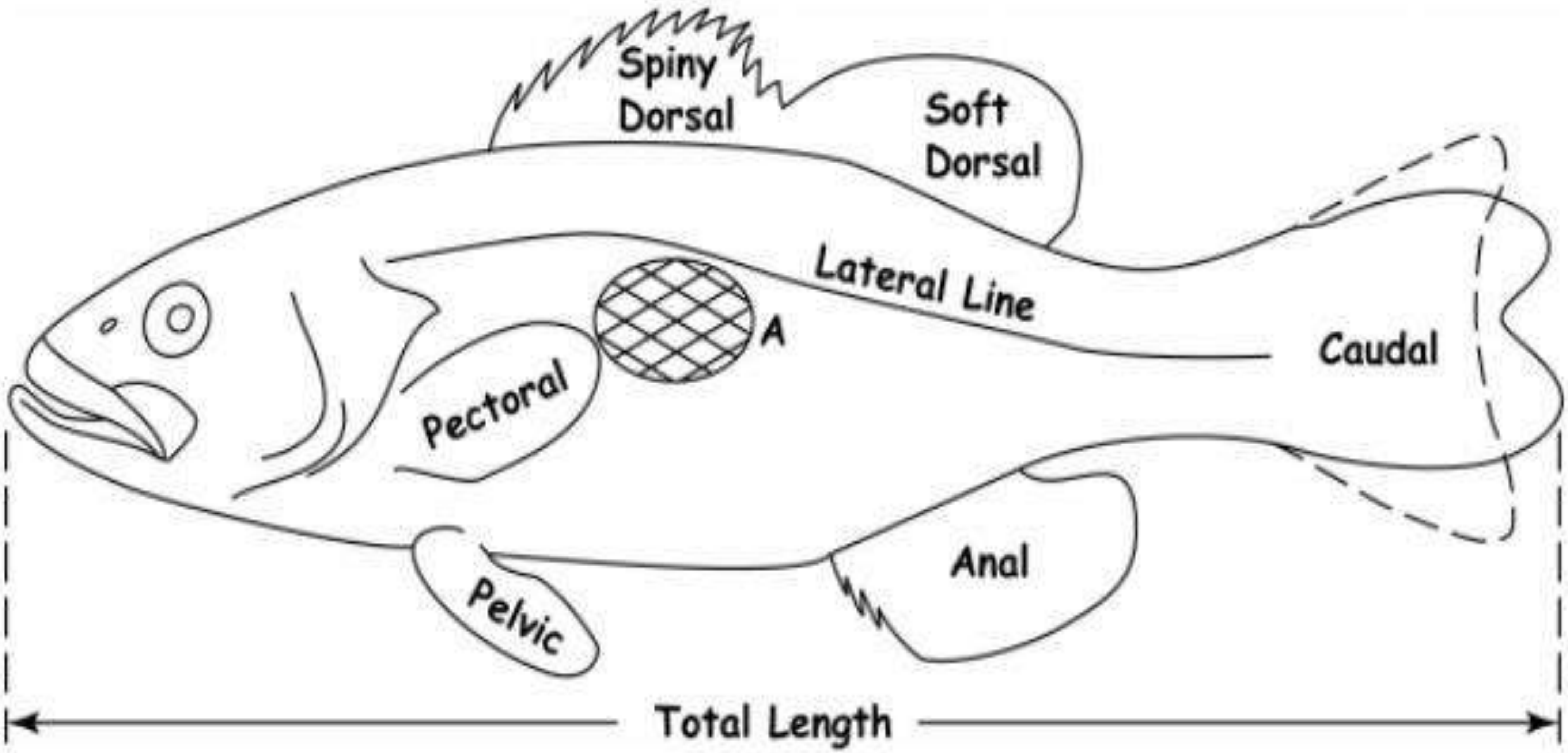



Figure 9.2–Area for taking scale samples from a spiny-rayed fish.

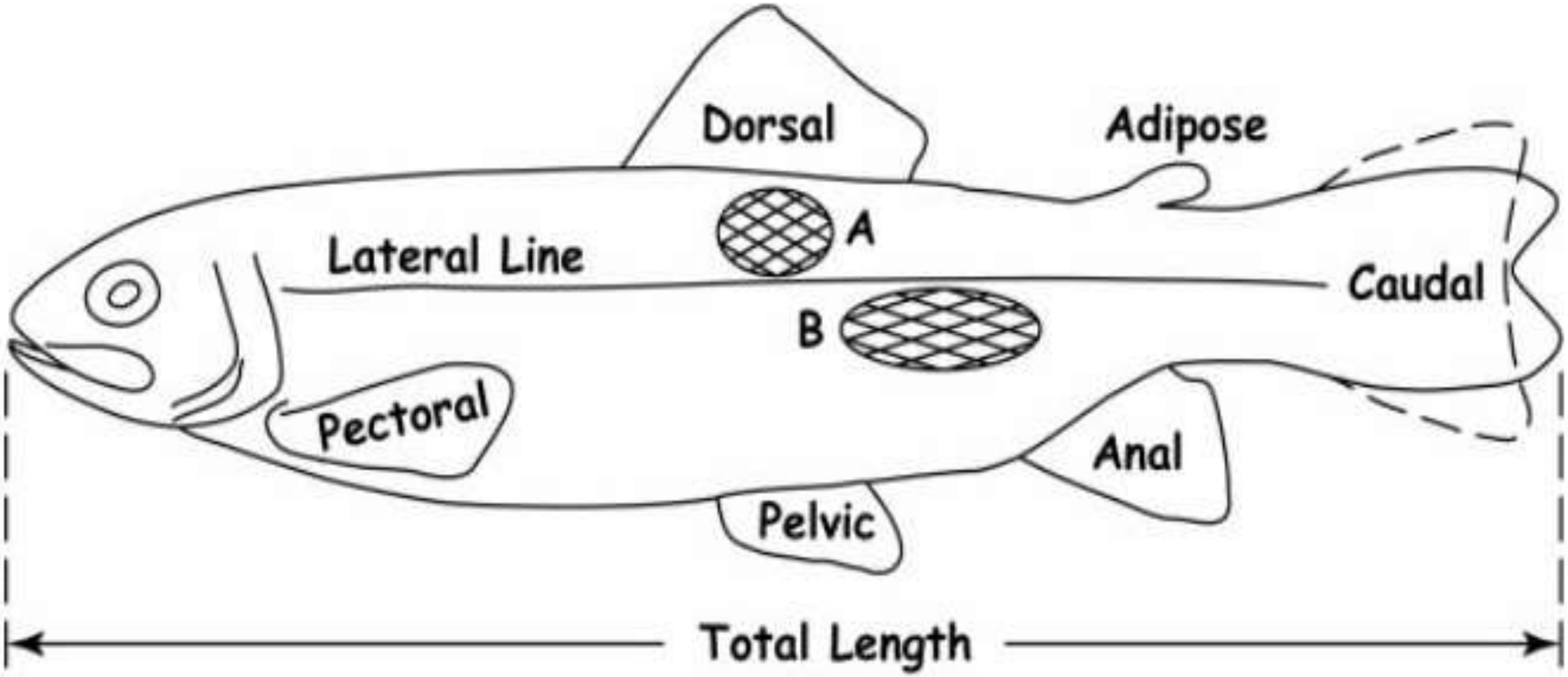



Figure 9.3–Areas for taking scale samples from most soft-rayed fish (A) or trout (B).

# A well-developed scale has the following structures:

**1. Focus:**

It is a clear area in the center, but may be shifted from the center due to irregular growth of anterior or posterior parts of scale caused by unusual overlapping of scales.

**2. Circuli:**

These are concentric rings present around the focus, they run parallel at regular intervals or distances. They appear as ridges.

**3. Grooves:**

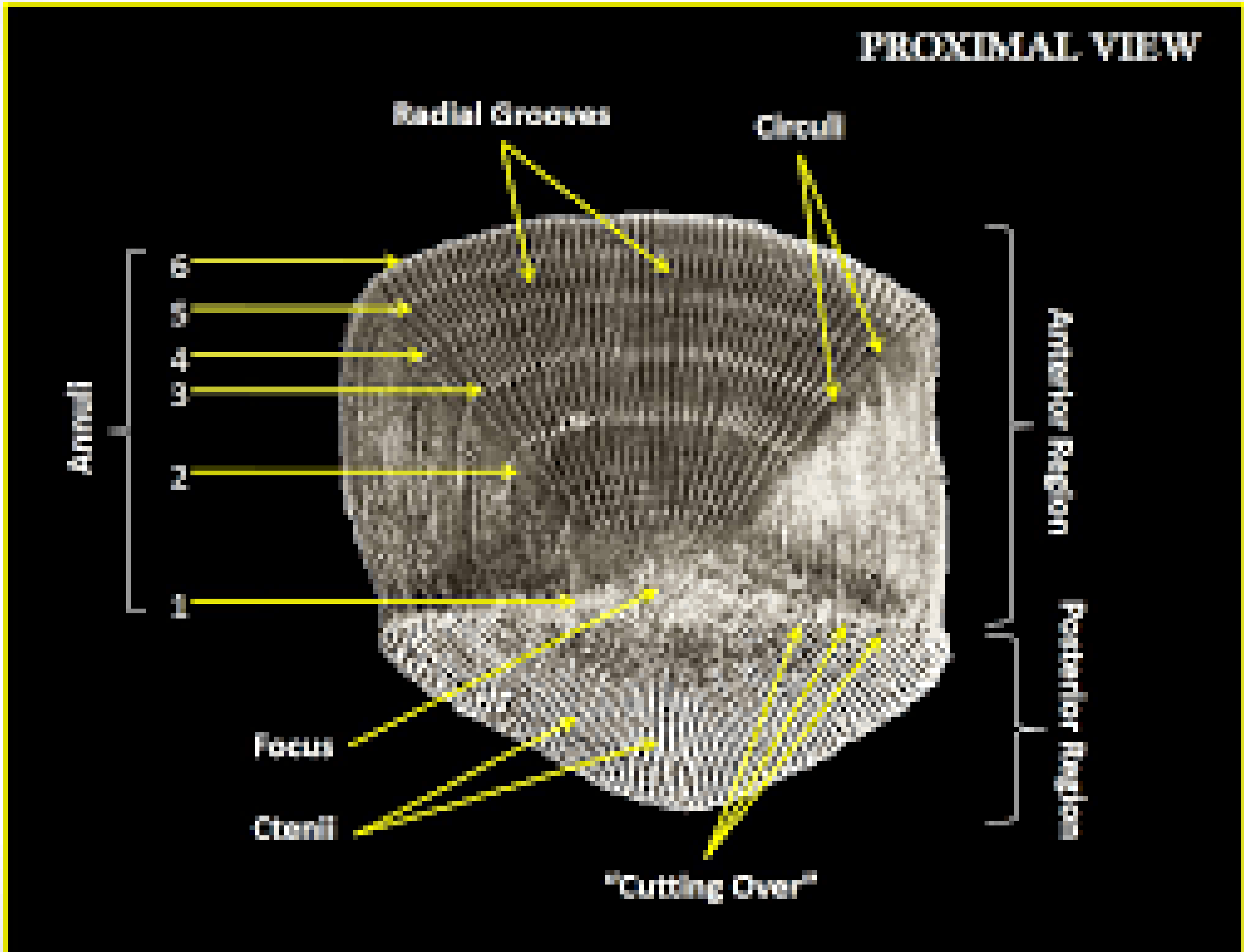
The grooves are found between the ridges of circuli and they are responsible for maintaining the regular space between them.

**4. Radii:**

These are grooves found radially, viz., they run from focus to margin of scale. Radii cut the circuli present in their path.

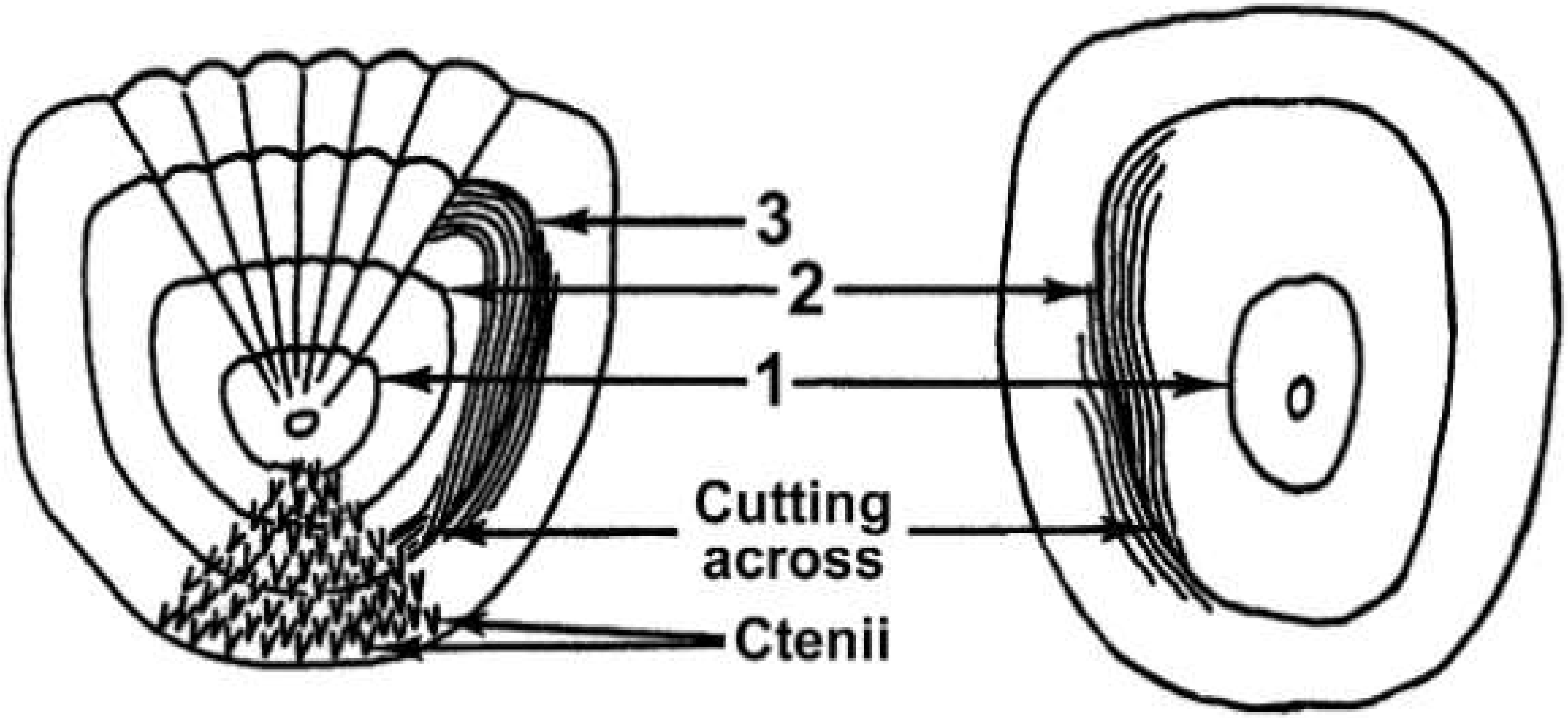
**5. Annuli:**

These are wide circular troughs found in aged fish over one year. Each trough contains a few incomplete and narrow circuli different from the circuli outside it, which are complete and more widely spaced. The number of annuli represents age of a fish in years.



PROXIMAL VIEW
Radial Grooves
Circuli
6
5
4
3
2
1
Annuli
Anterior Region
Posterior Region
Focus
Ctenii
"Cutting Over"

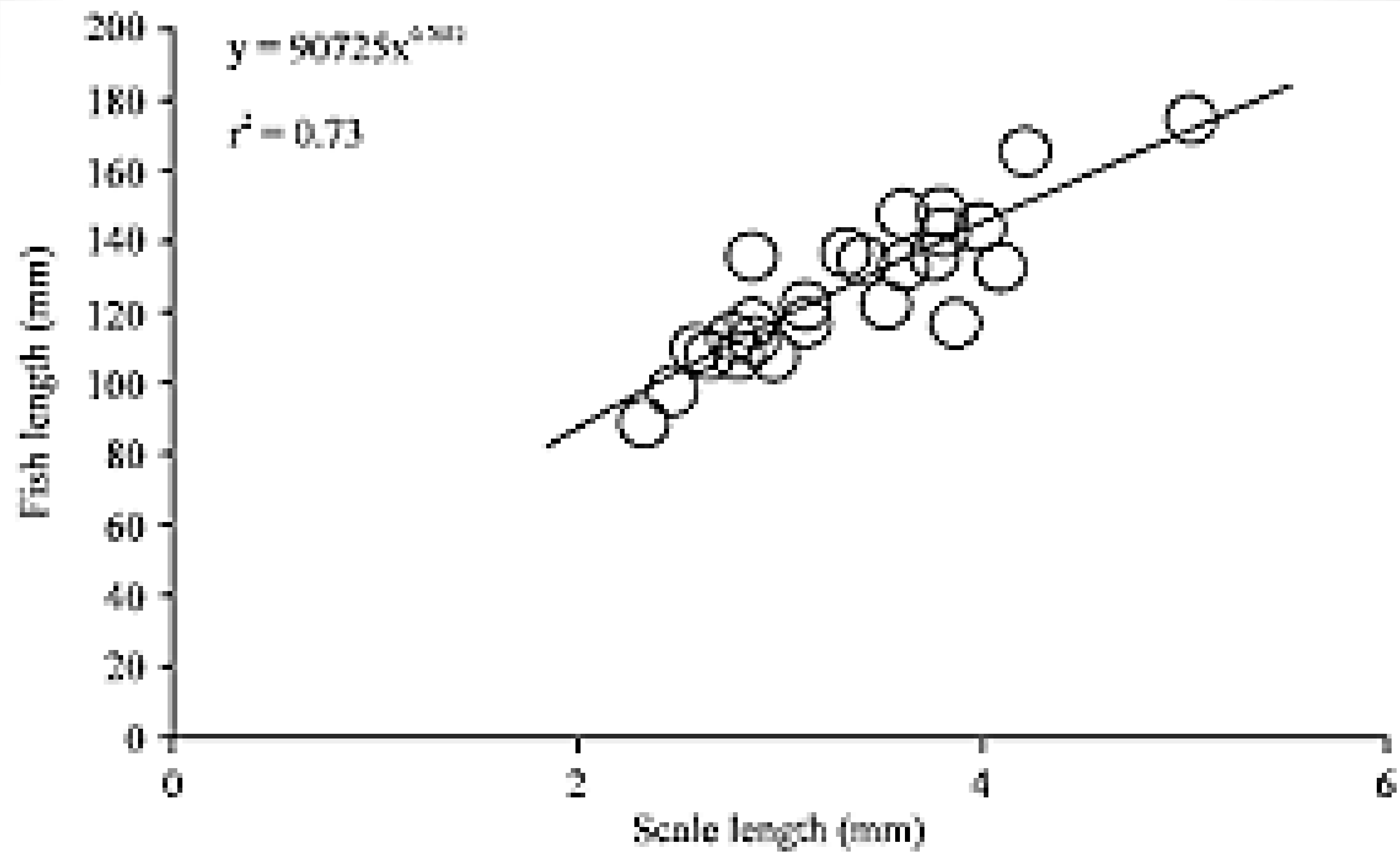
# Scales



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.

**Log L: log c + n log S**

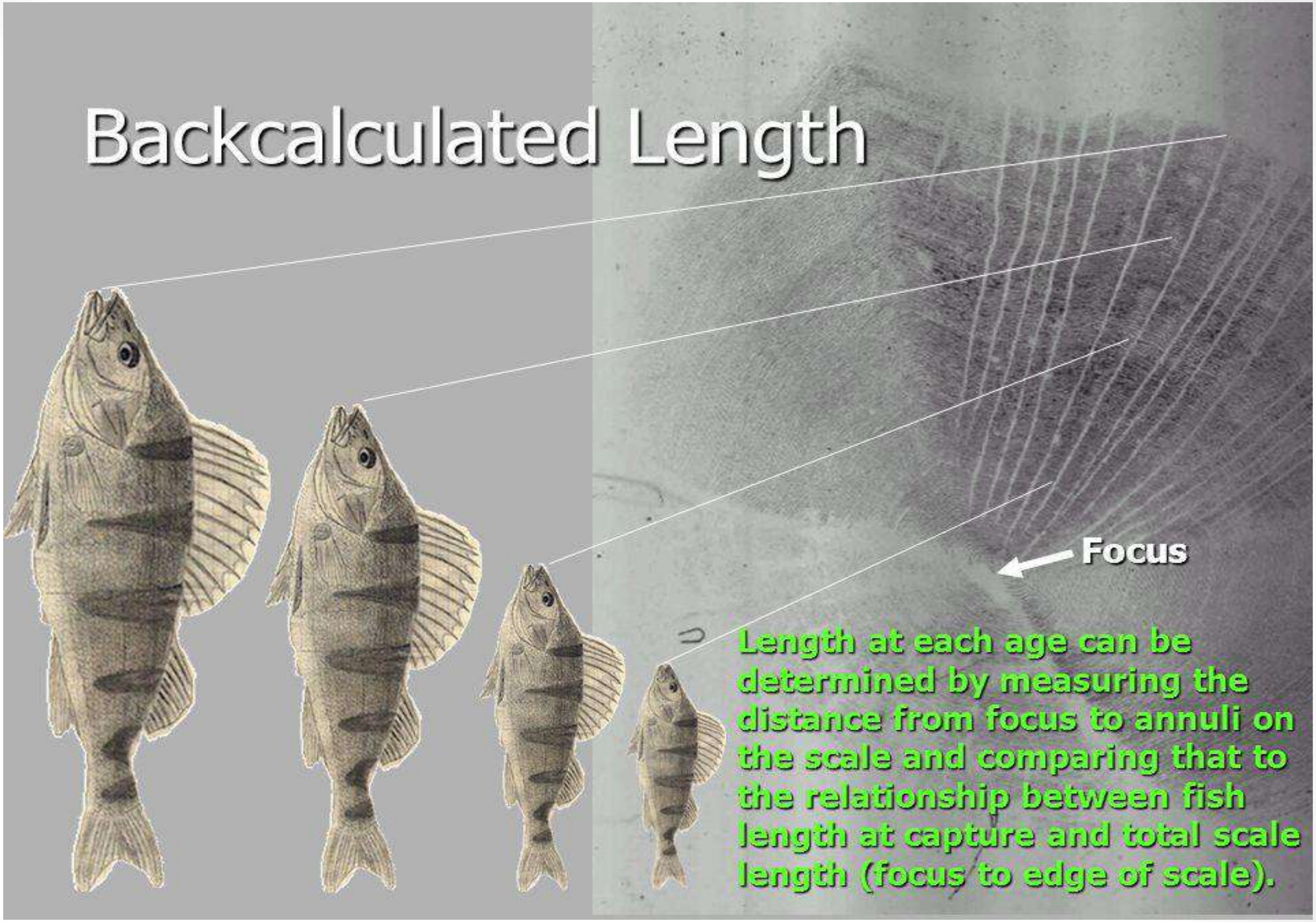
L: body length S= scale length c= intercept on the line on the axis of ordinate n: slope



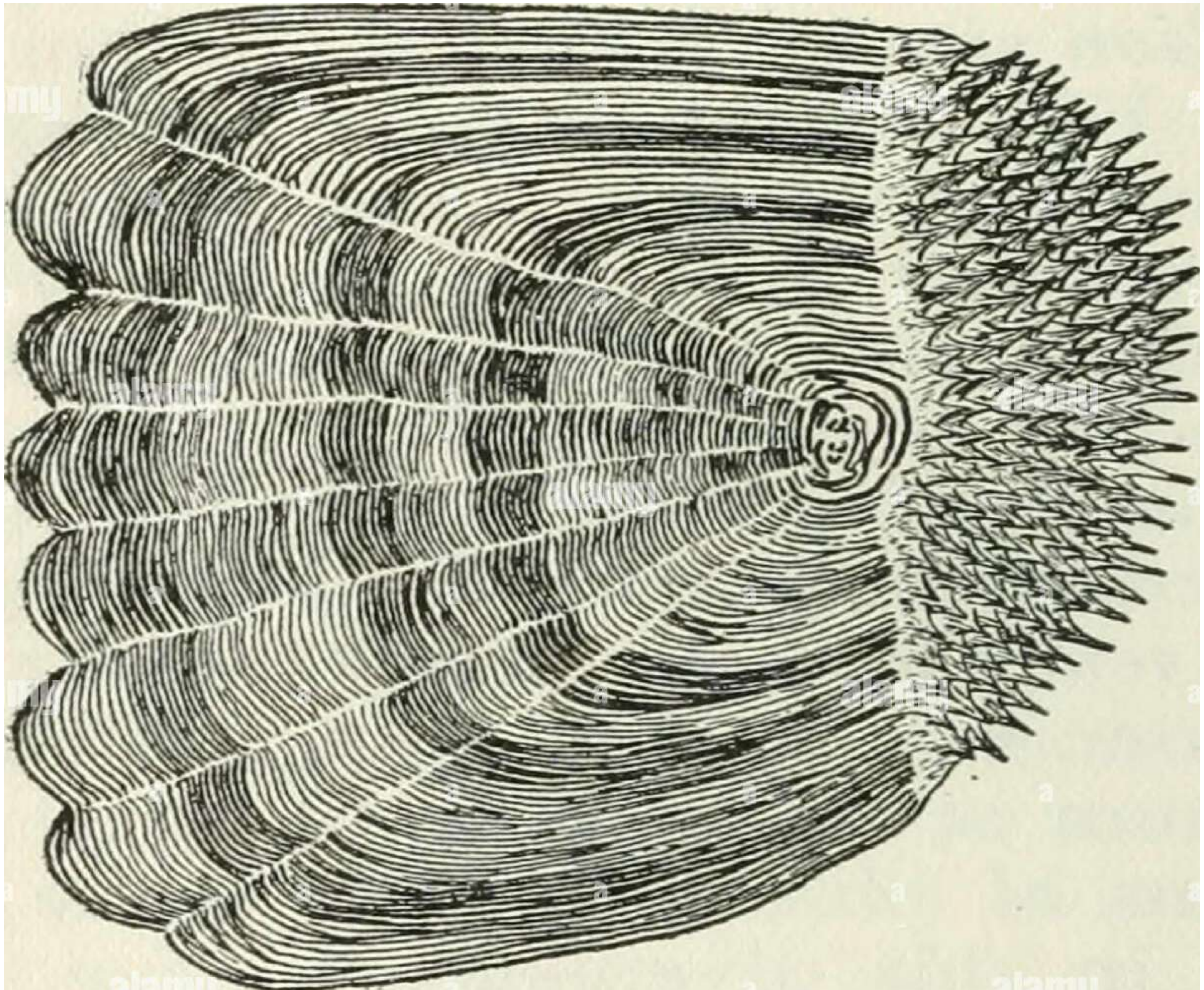
y = 90725x
r² = 0.73
Fish length (mm)
Scale length (mm)
0
20
40
60
80
100
120
140
160
180
200
0
2
4
6

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

# Backcalculated Length




Length at each age can be determined by measuring the distance from focus to annuli on the scale and comparing that to the relationship between fish length at capture and total scale length (focus to edge of scale).



$$L_n = a + (L-a)(V_n)/V_r$$

Ln= calculated length of the fish at n year

L: length of the fish at the time of capture

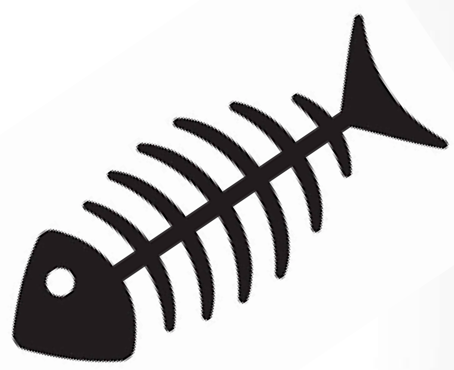
Vn= radius (distance from the focus to the nth annulus)

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 6

# 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.

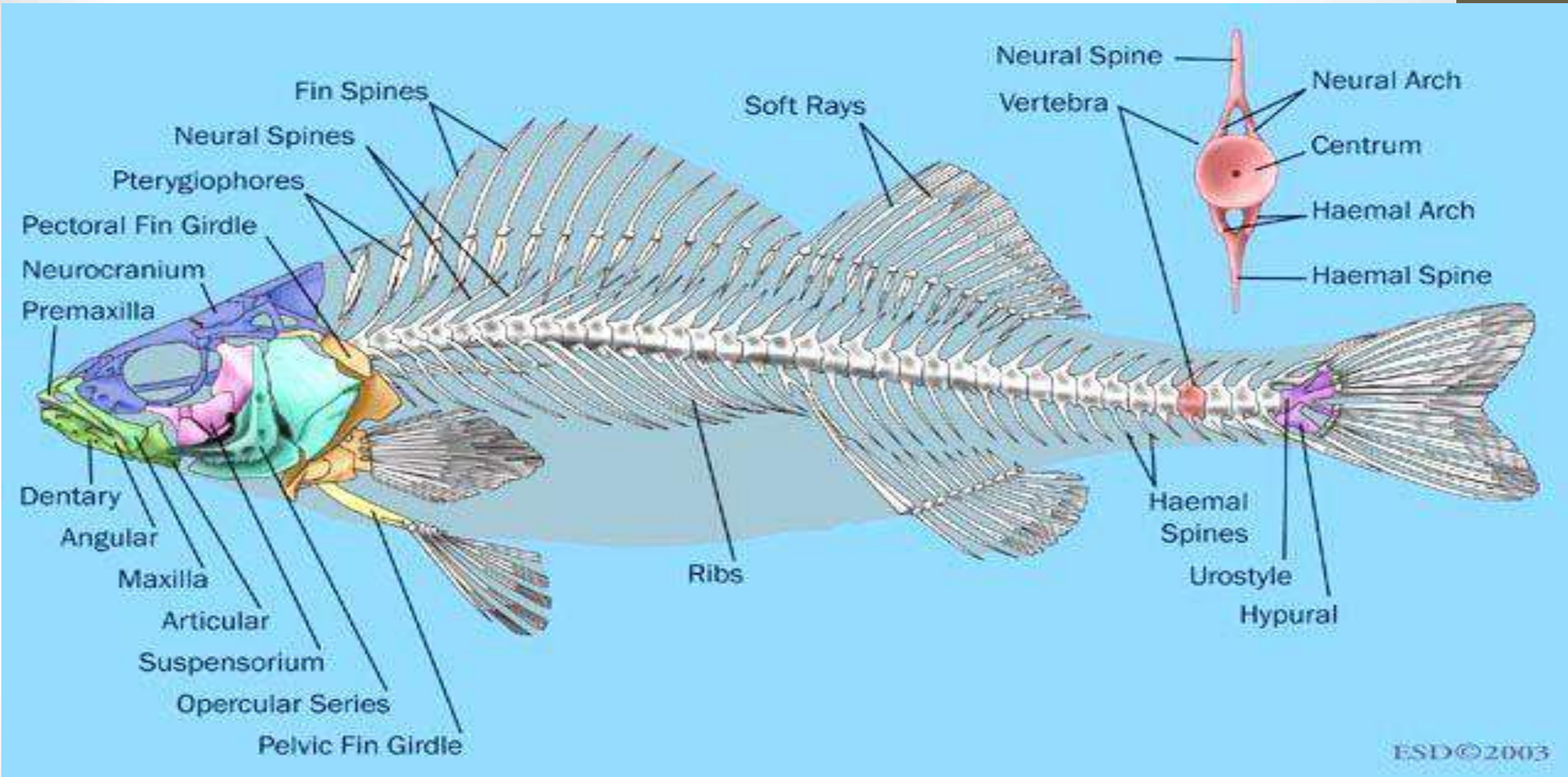
# Axial skeleton

Its containing:

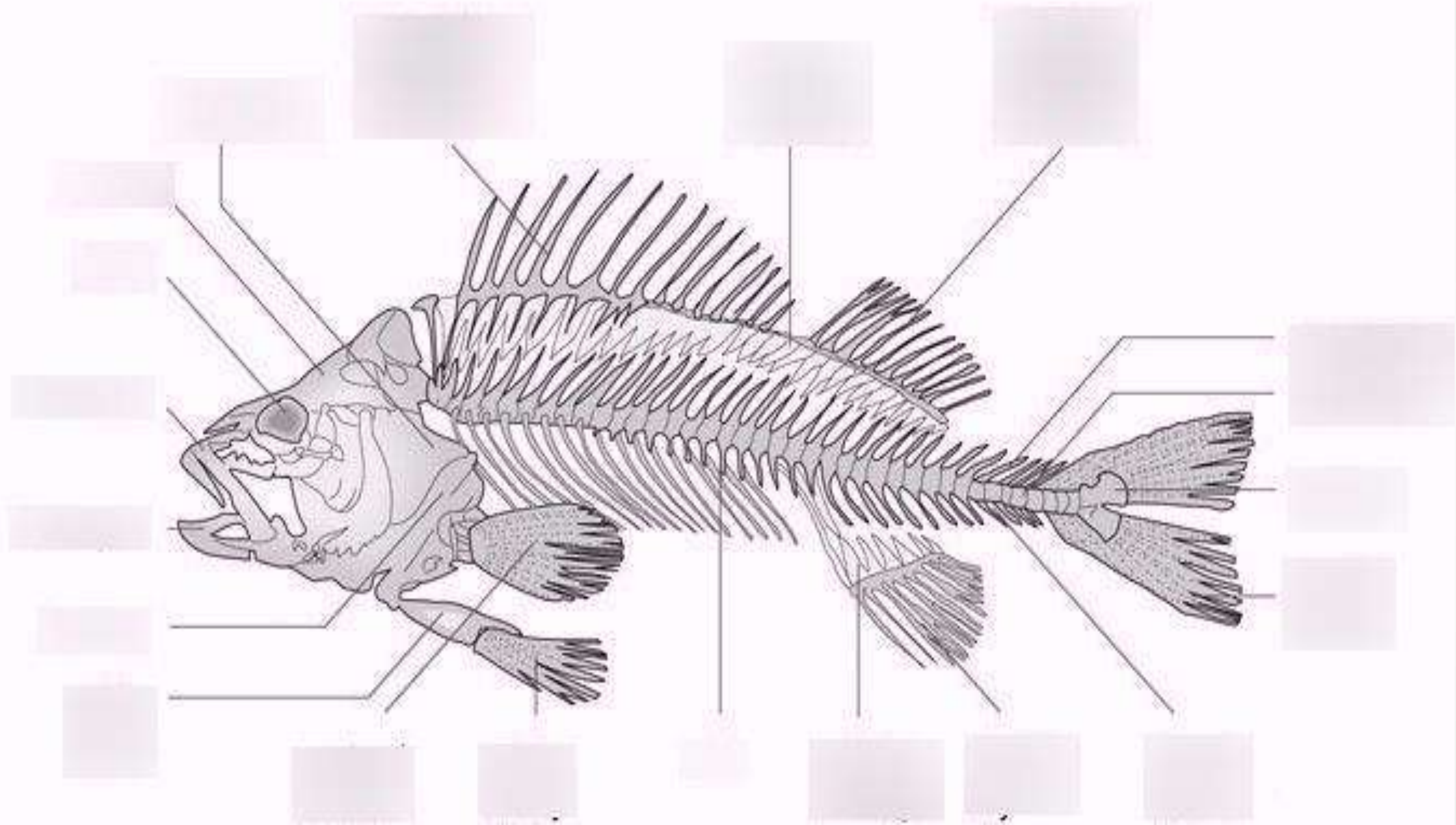
1- Skull

2- Vertebral column

3- Ribs



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



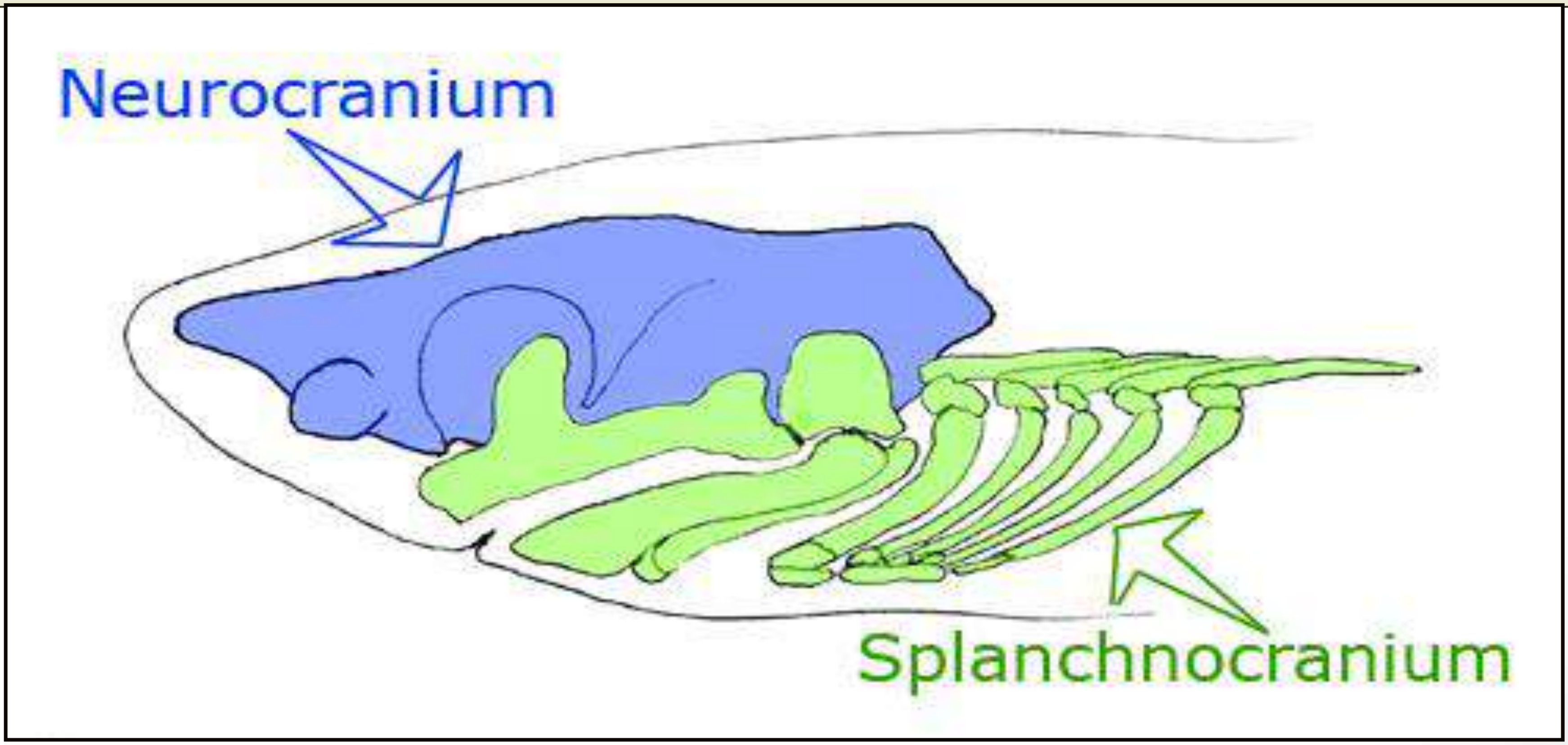
# The head skeleton of living chondrichthian fish

The head skeleton of living chondrichthian fish consists of

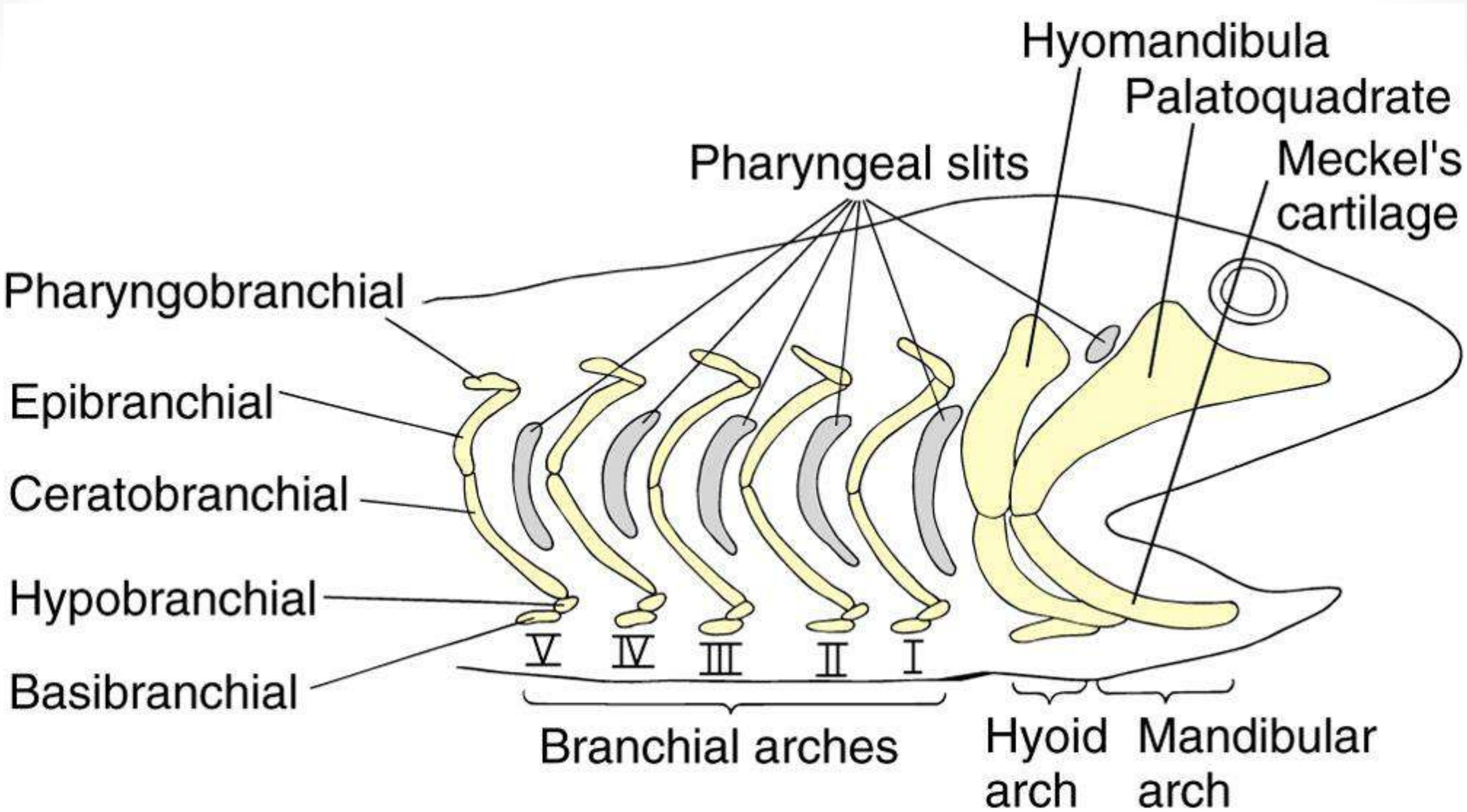
A)- a highly developed neurocranium,

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

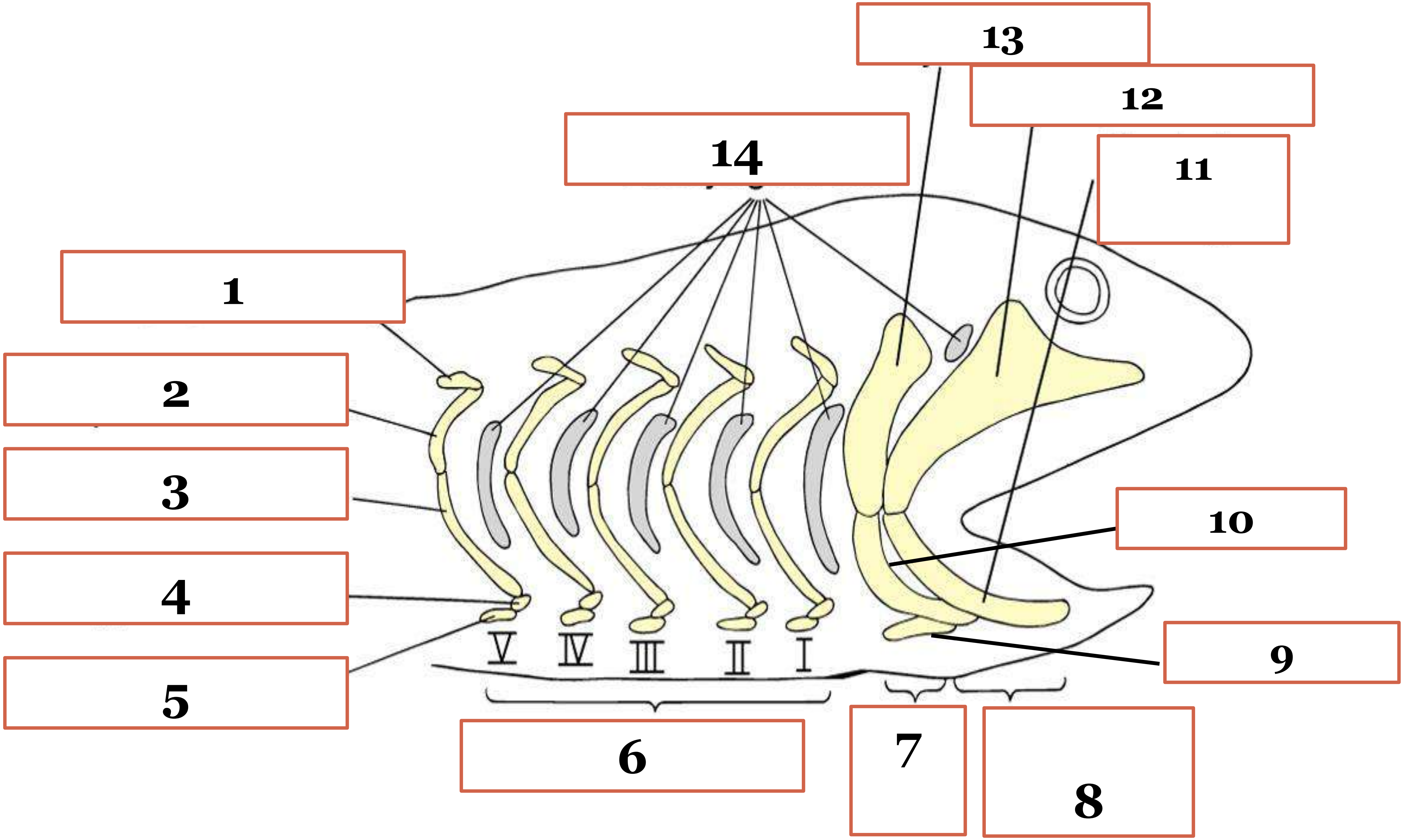
- The visceral arches of bony fishes resemble that of sharks except that bone is added.

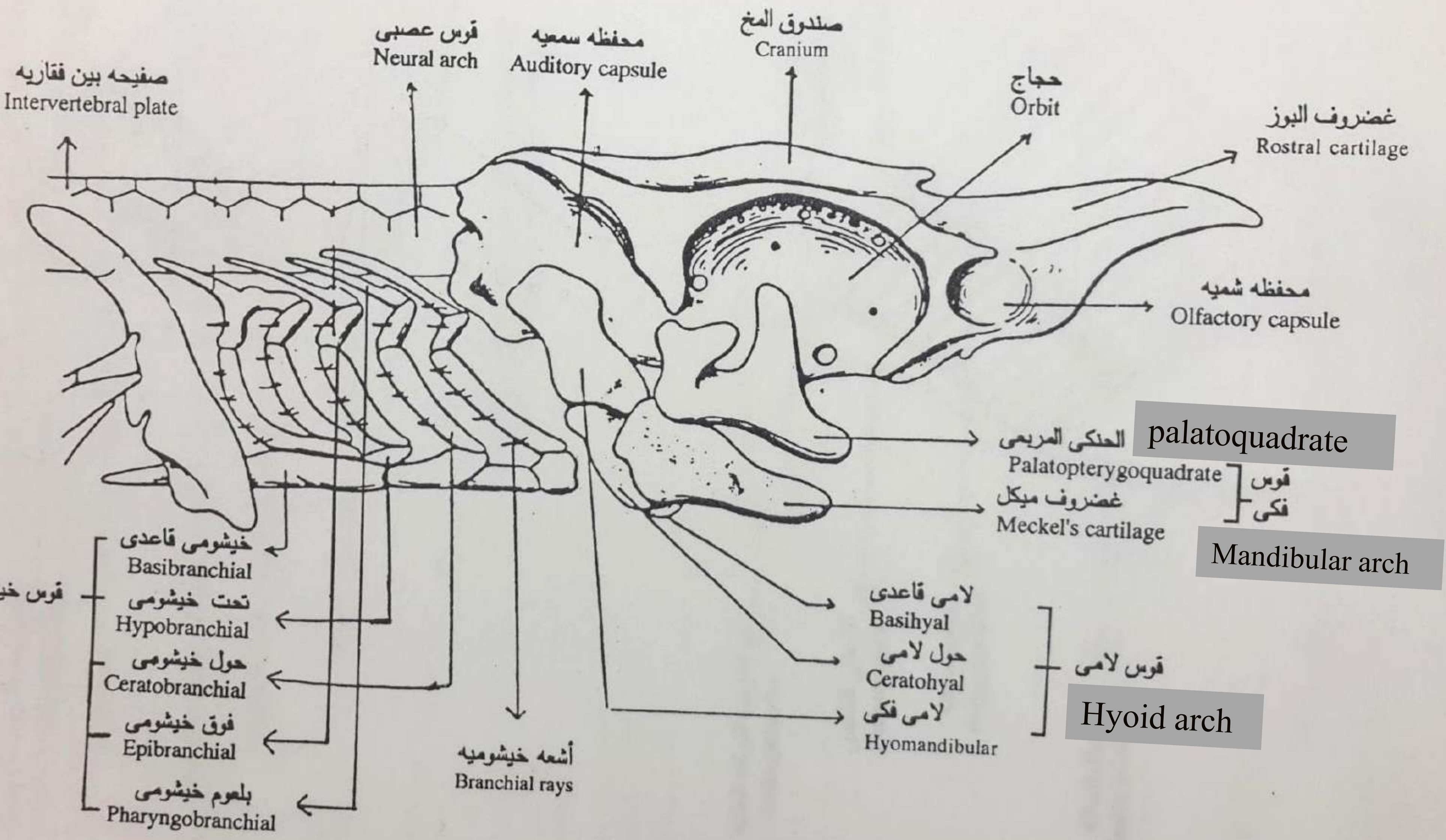


- Splanchnocranium (Visceral arches): are pieces of cartilages or bones that support the mouth and the pharyngeal region of vertebrates and also help attach the jaws with the skull.
- There are typically 7 pairs of visceral arches in vertebrates which modify in different groups depending upon the presence 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 branchial arches, 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.

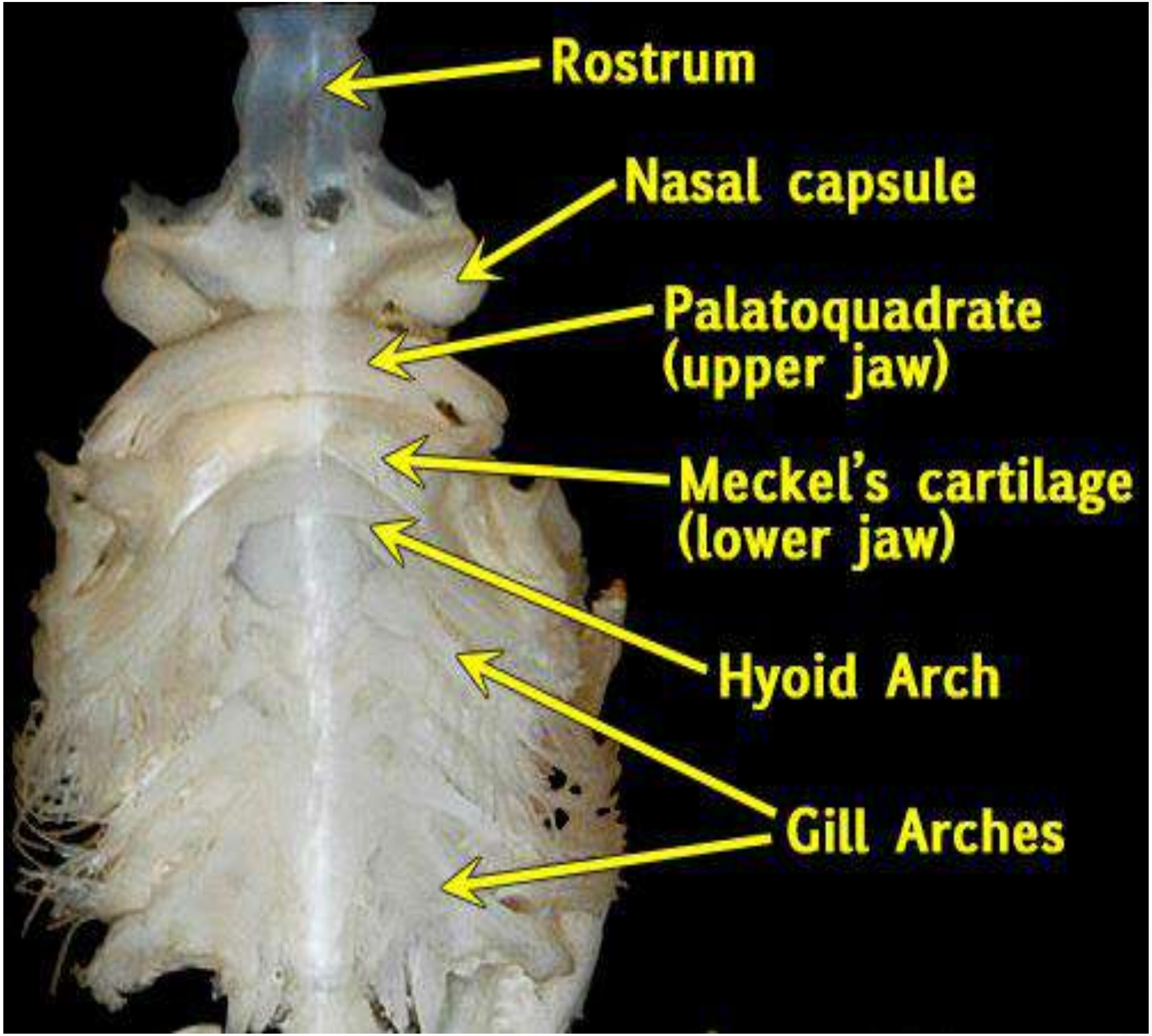


Hyomandibula
Palatoquadrate
Pharyngeal slits
Meckel's cartilage
Pharyngobranchial
Epibranchial
Ceratobranchial
Hypobranchial
Basibranchial
V
IV
III
II
I
Branchial arches
Hyoid arch
Mandibular arch


13
12
14
11
1
2
3
4
5
10
9
V
IV
III
II
I
6
7
8

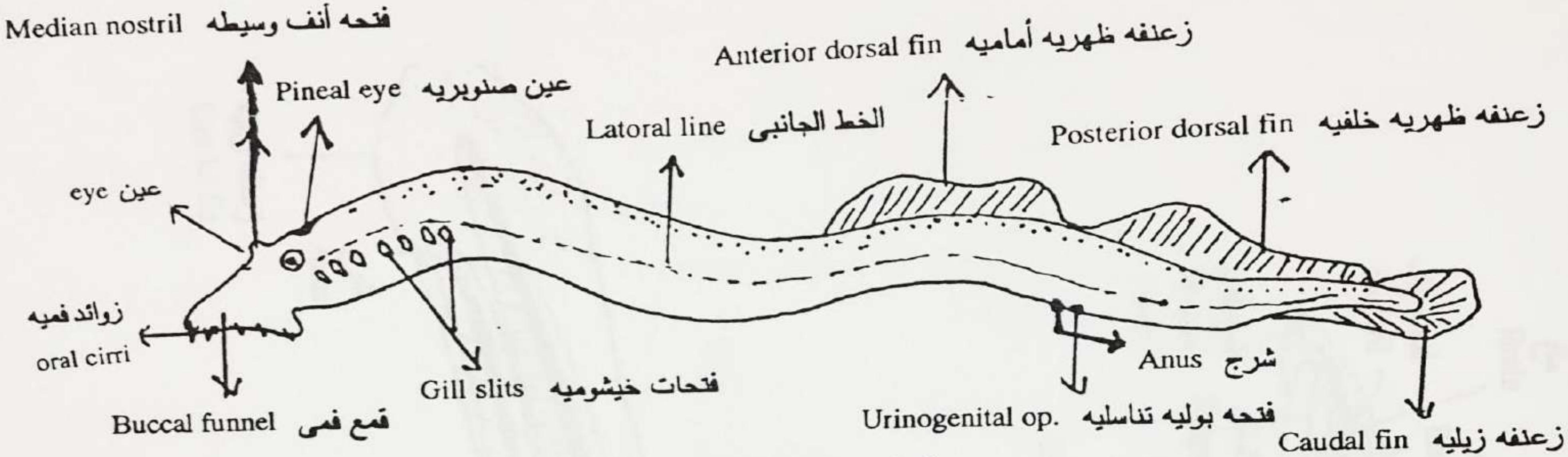


كلب السمك: الهيكل الحشوى
Dogfish. Splanchnocranium or visceral skeleton, Lateral view

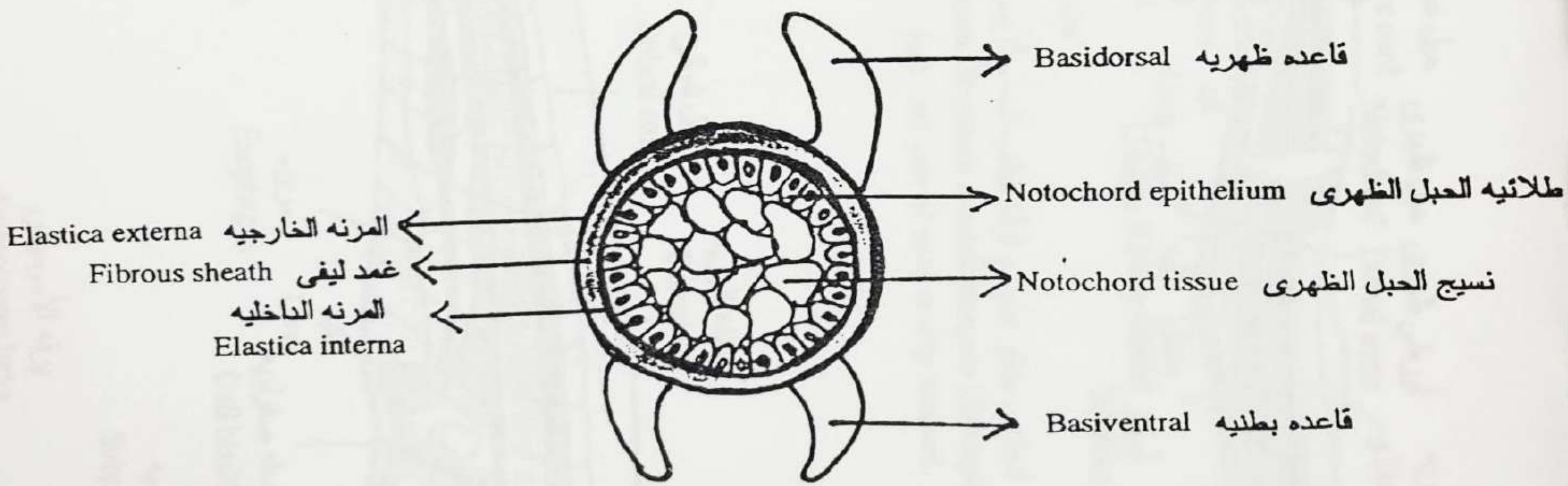

Rostrum
Nasal capsule
Palatoquadrate
(upper jaw)
Meckel's cartilage
(lower jaw)
Hyoid Arch
Gill Arches

# 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.

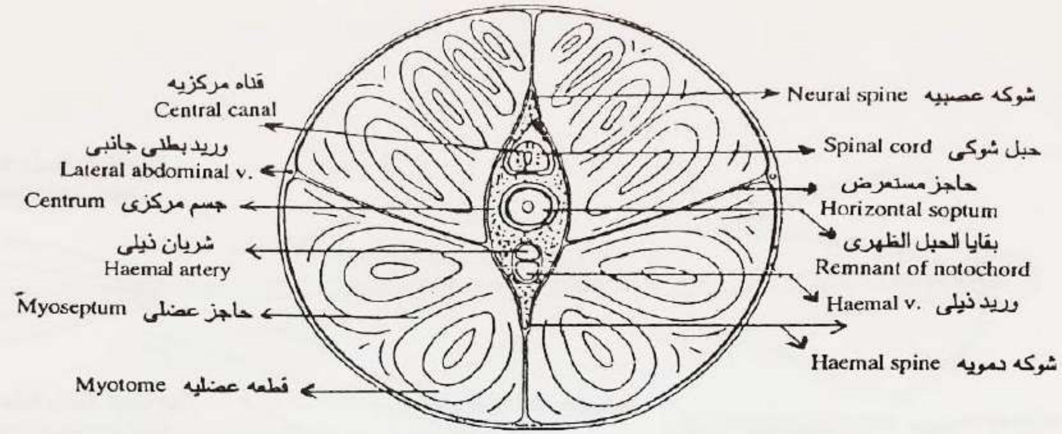



الجلكى: ق. ع. فى الحبل الظهرى
Petromyzon: T. S. of the notochord.

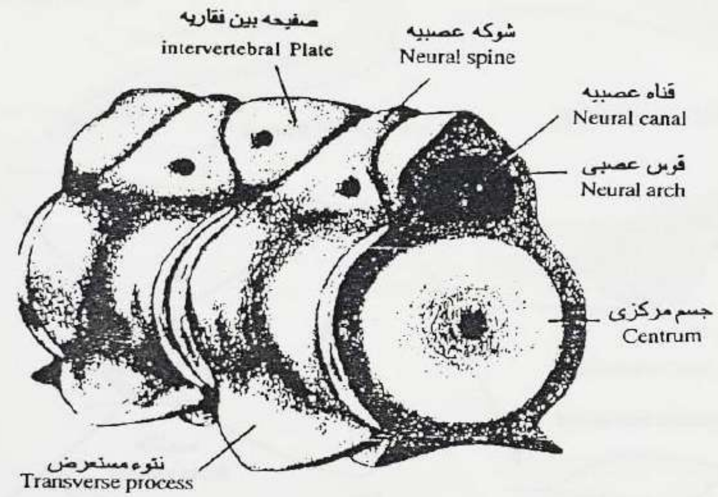
# 1)- The cartilaginous fishes

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.

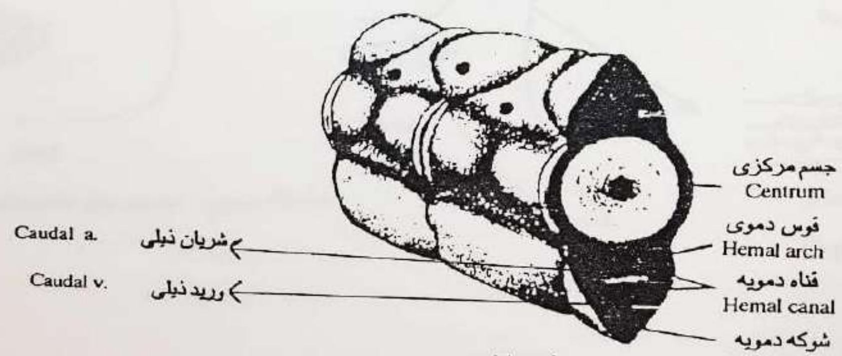
The vertebrae are amphicoelous.



كلب السمك: قطاع عرضي في الذيل
Dogfish shark: Cross section through tail



فقره جزعيه
Trunk vertebra



فقره ذيليه
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.

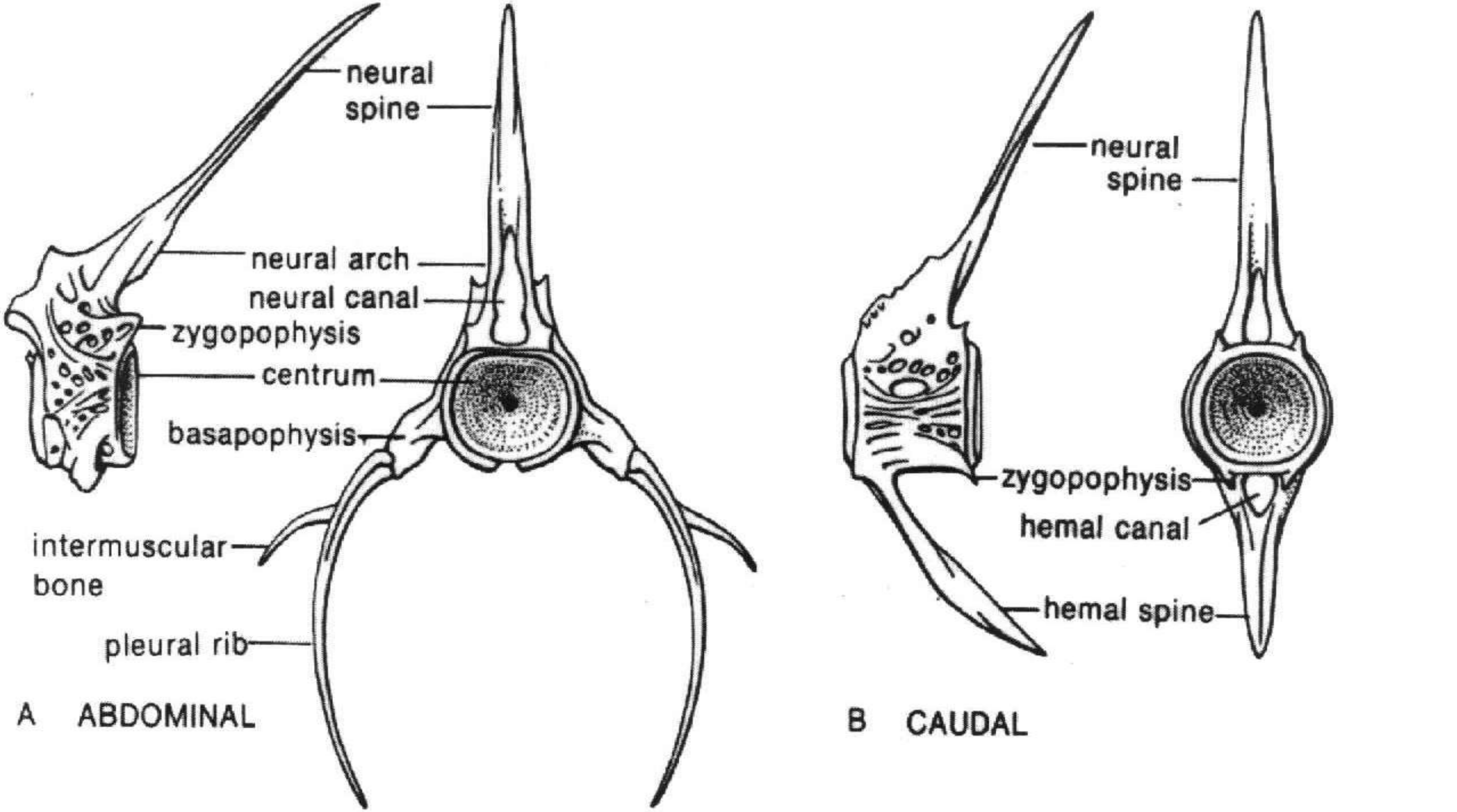
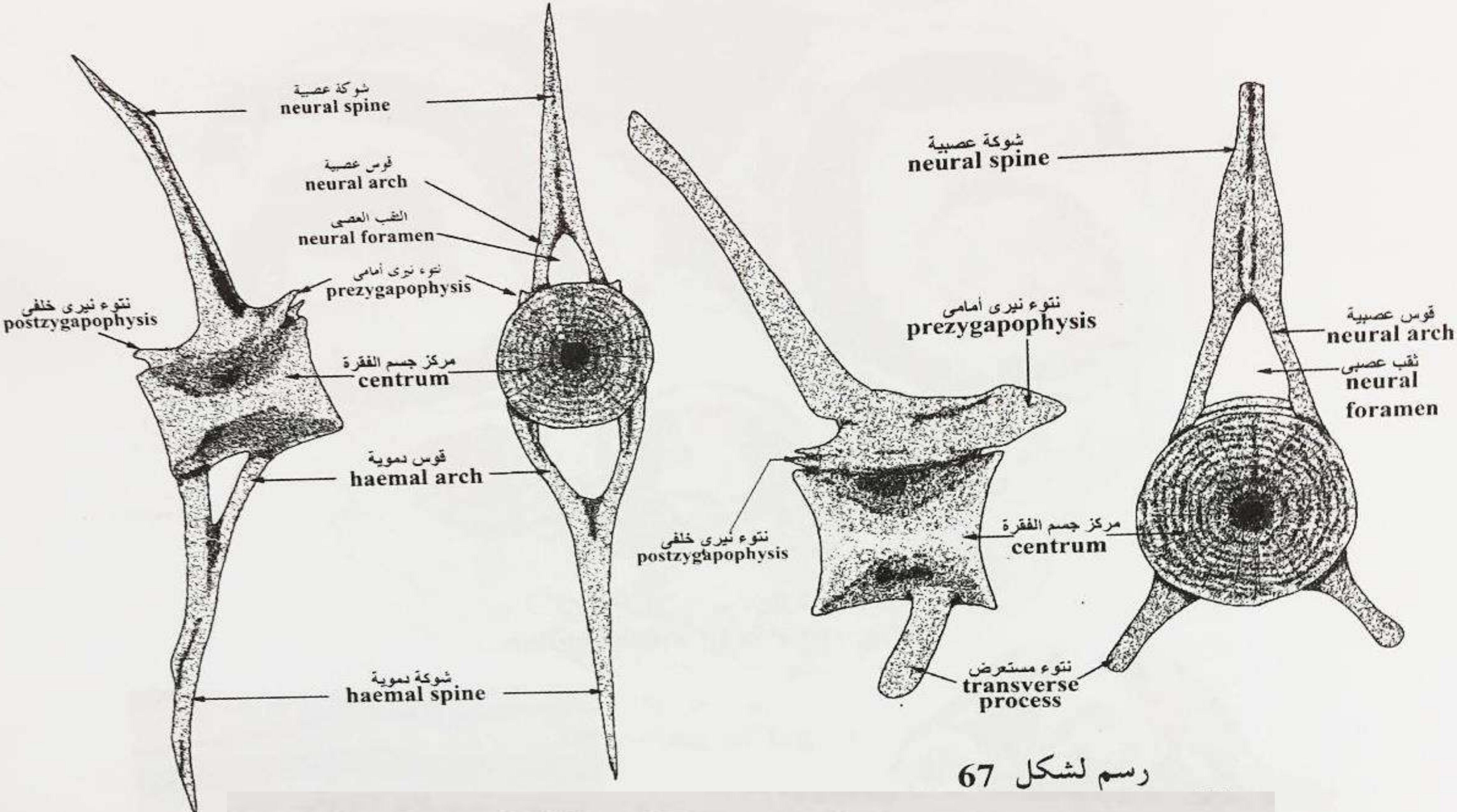



**FIGURE 3–8.** Vertebrae of teleost. *A*, lateral and posterior views of abdominal vertebrae; *B*, lateral and posterior views of caudal vertebrae.




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**

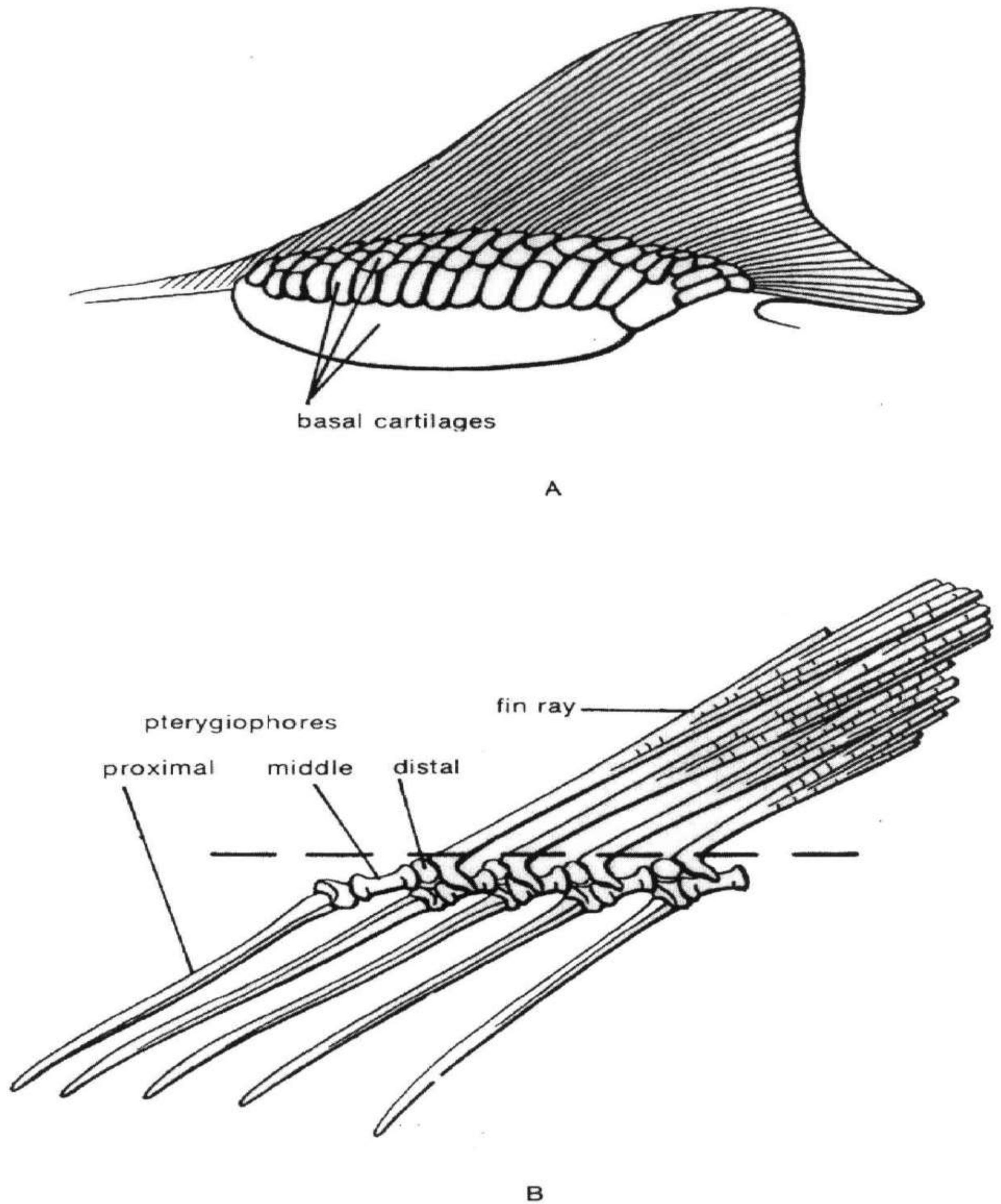



FIGURE 3–9. Skeletal supports of dorsal fin. *A*, Shark; *B*, bony fish (dashed line shows approximate body contour). (*A* based on Goodrich, 1930.)

# B- The paired fins

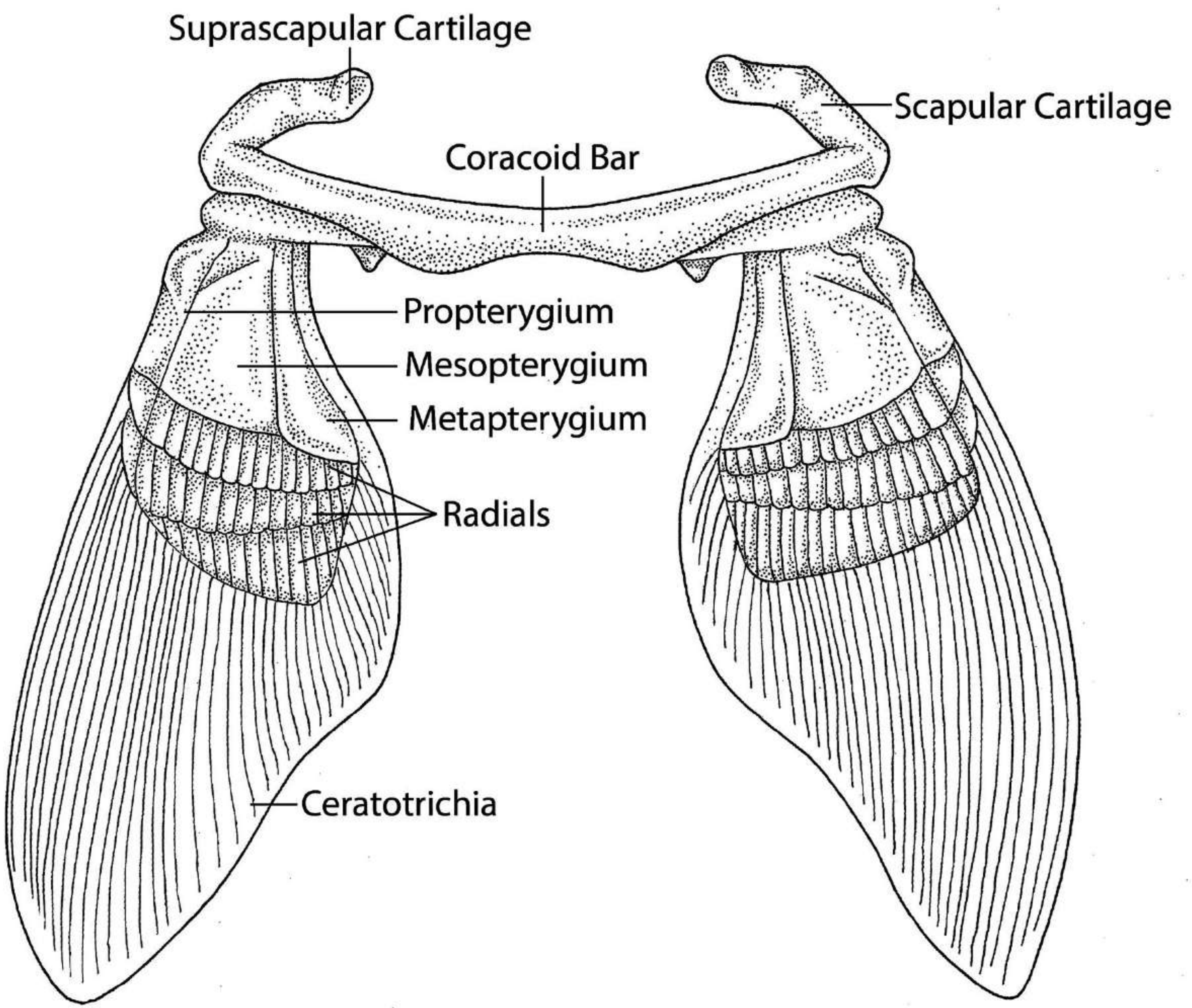
## 1)- The cartilaginous fishes:

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

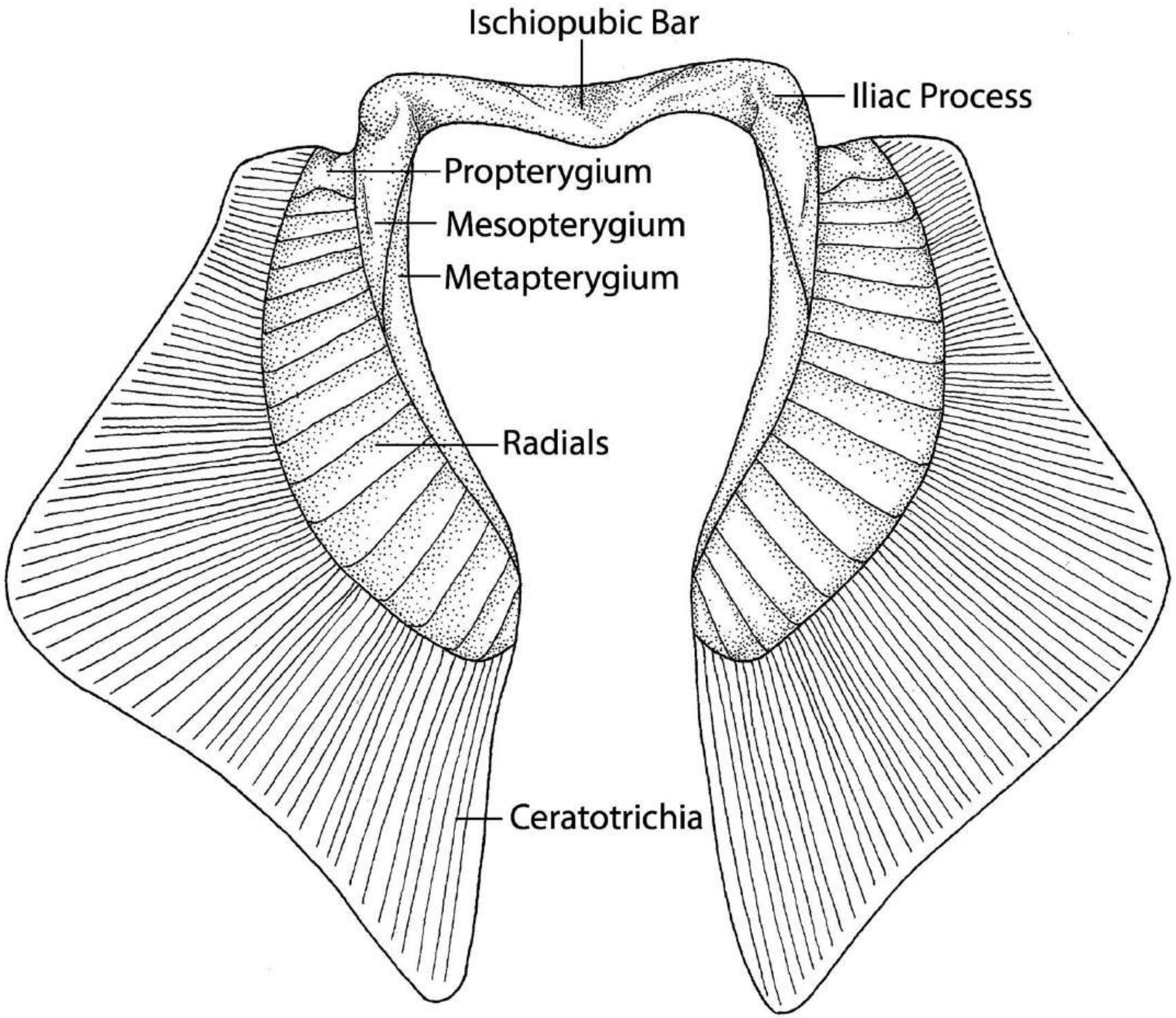
  - an upper section, or scapula
  - a lower coracoid piece.

- The pelvic fins of elasmobranchs are supported by a bar of cartilage crossing the ventral midline.

# Skeletal supports of the pectoral fin of elasmobranchs

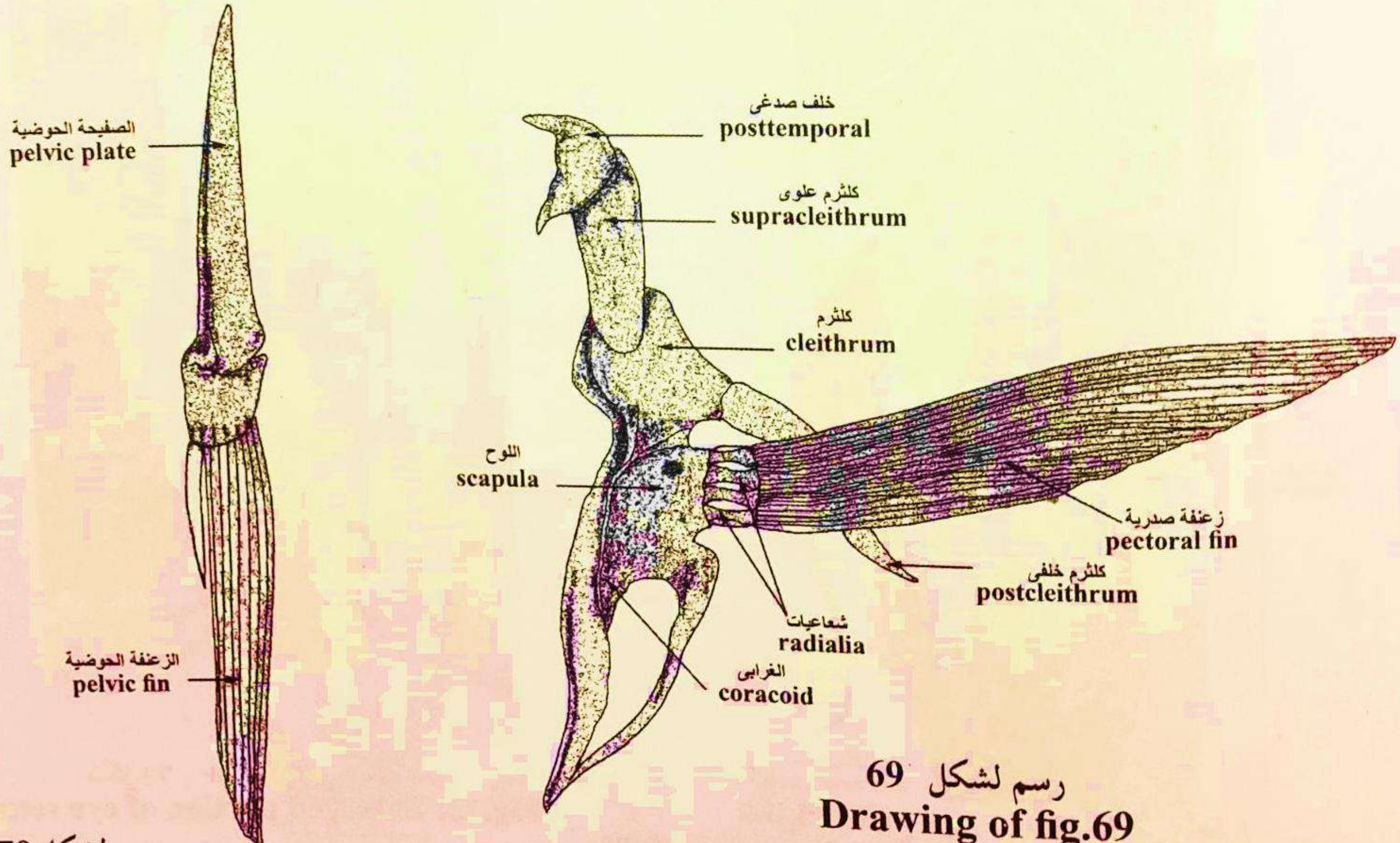


# Skeletal supports of the pelvic fin of elasmobranchs



## 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.




رسم لشكل 69
**Drawing of fig.69**

رسم لشكل 70
**Drawing of fig.70**

لثرينس لينتيجان (الشعرى)
***Lethrinus lentjan***

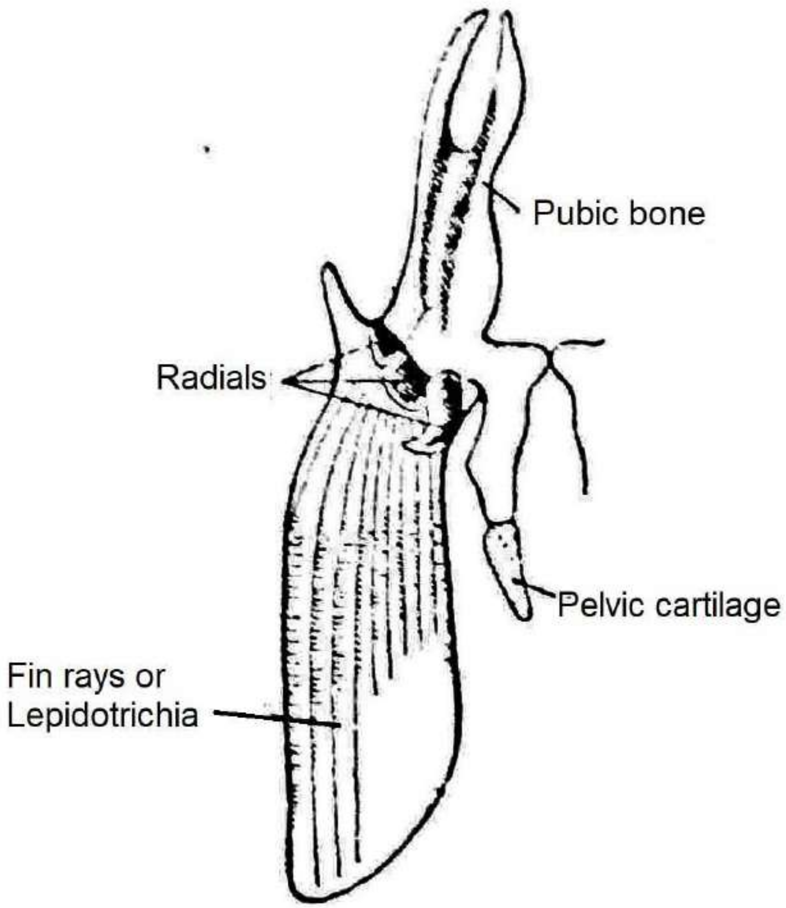
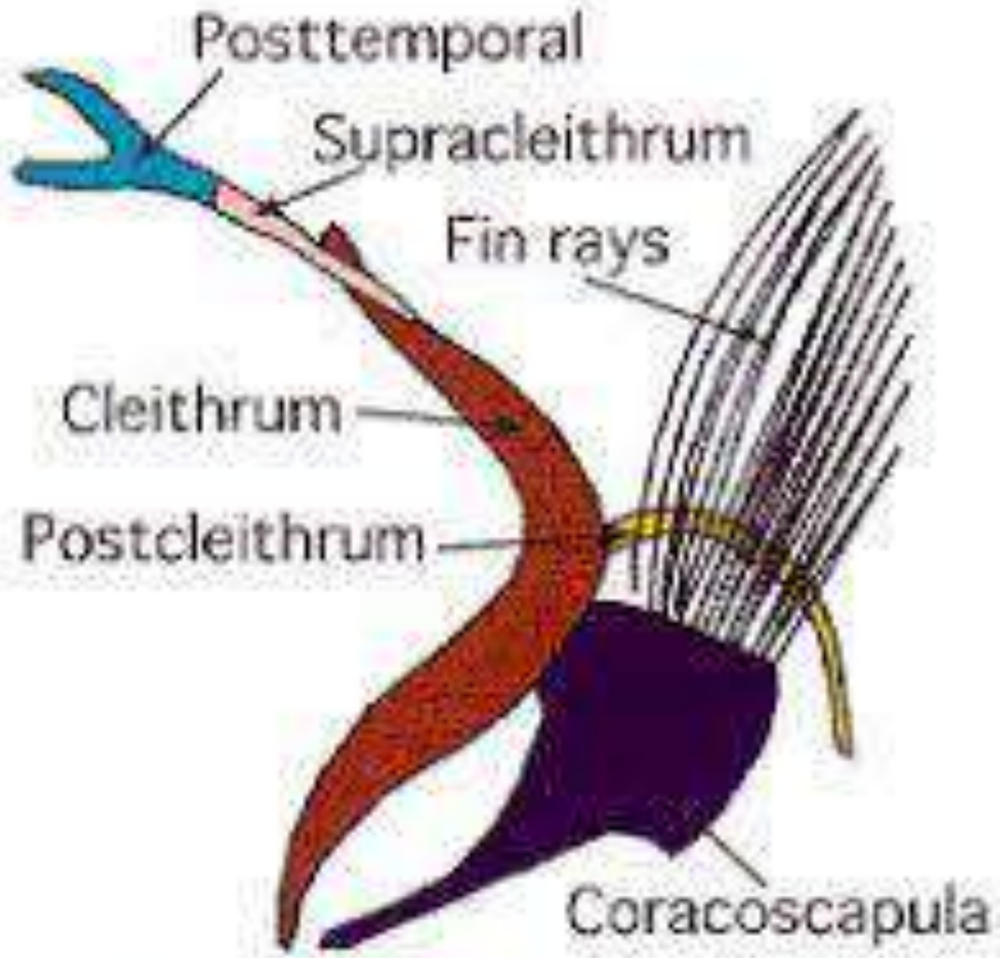
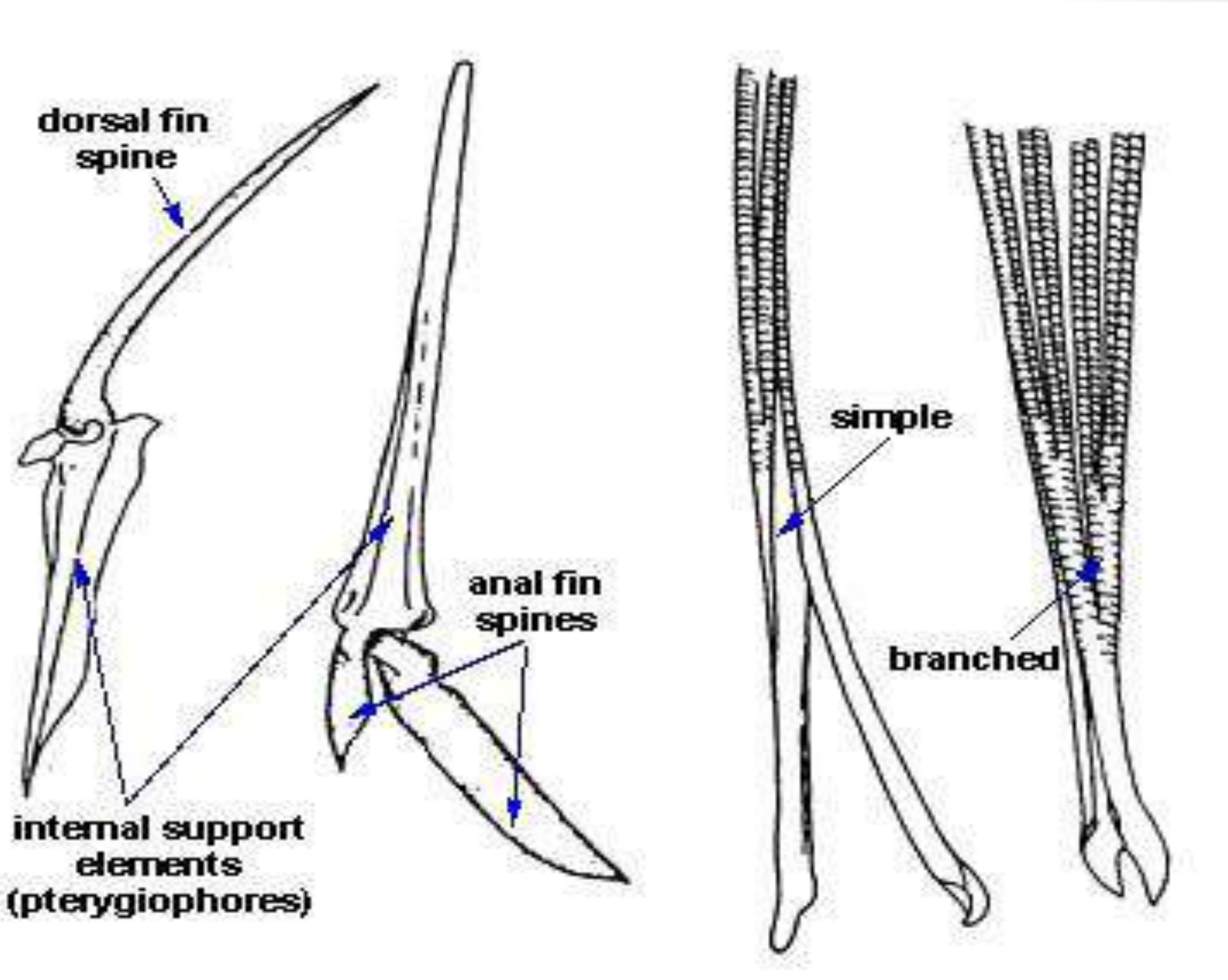



Fig. Pelvic girdle and pelvic fin




Teleost pectoral girdle and fin
(left half)


dorsal fin spine
anal fin spines
internal support elements (pterygiophores)
simple
branched

# 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**

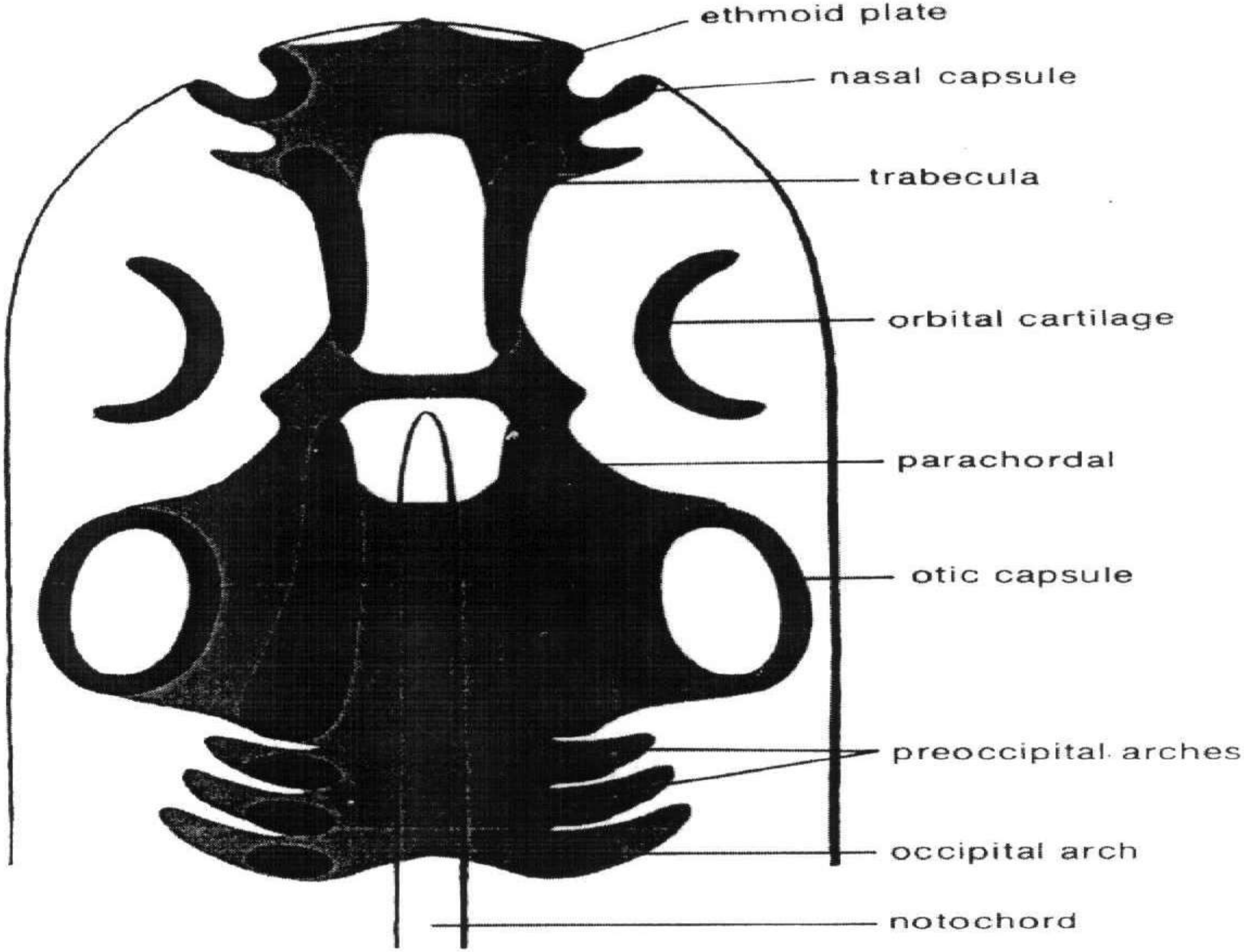



**FIGURE 3–1.** Generalized diagram of early stages of development of chondrocranium. *In black*, separate cartilages; *in gray*, the formation of ethmoid and basal plates.

# 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

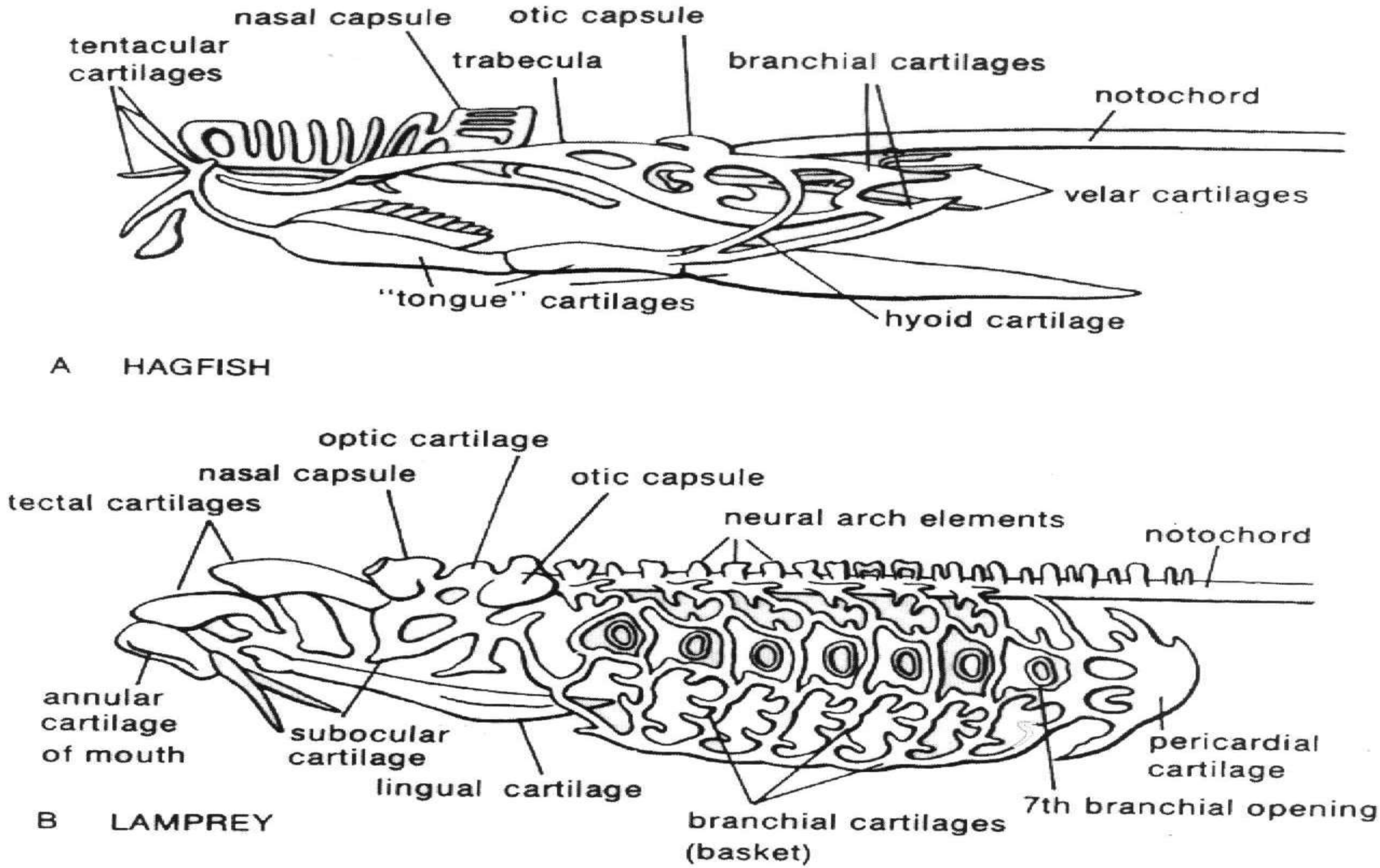


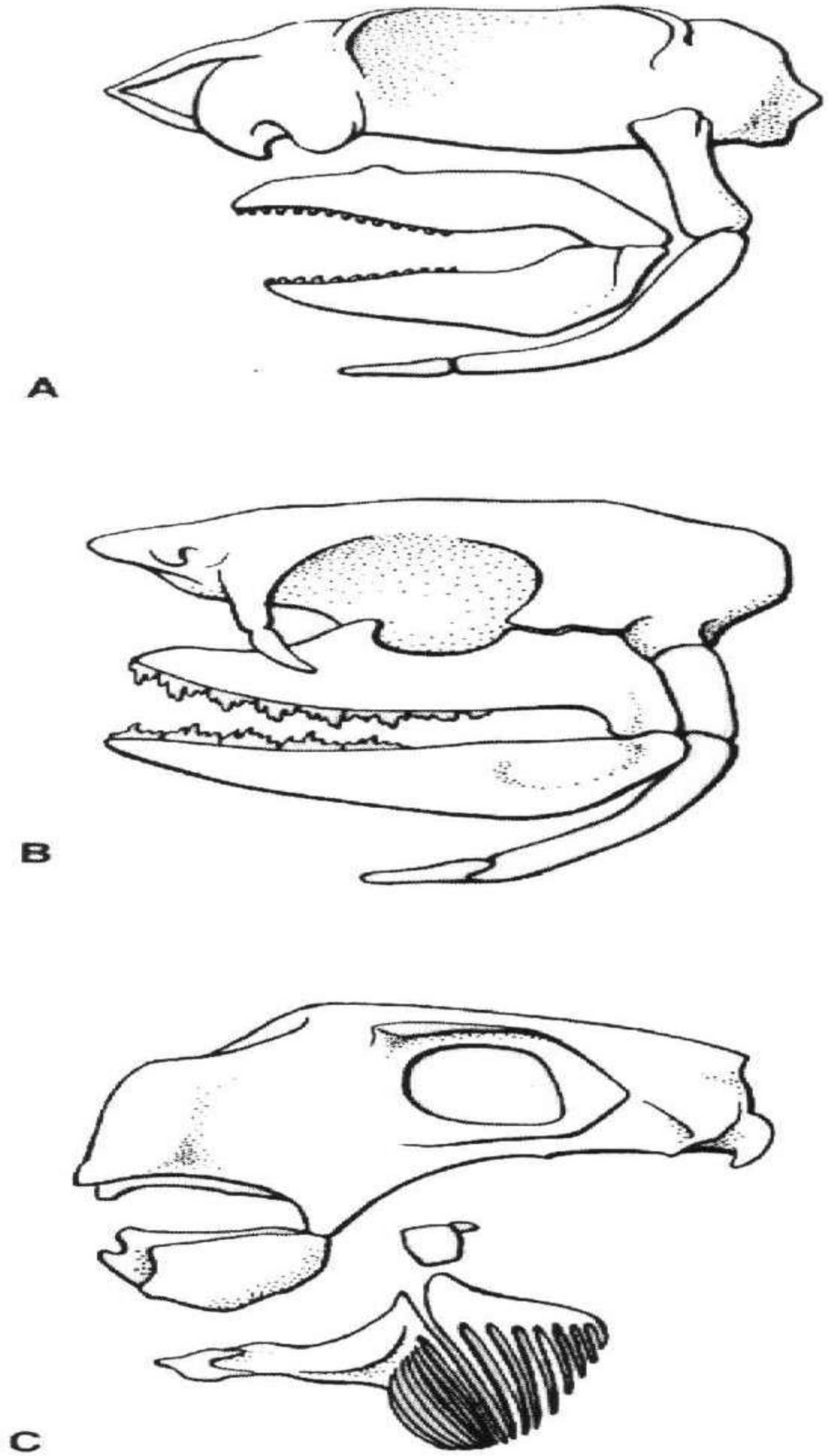

**FIGURE 3–2.** Diagrams of skulls of living agnaths. *A*, Hagfish; *B*, lamprey. (Based on Goodrich, in Lankester, 1909.)

# Types of jaw suspensions

**A) Hyostylic**

**B) Amphystylic**

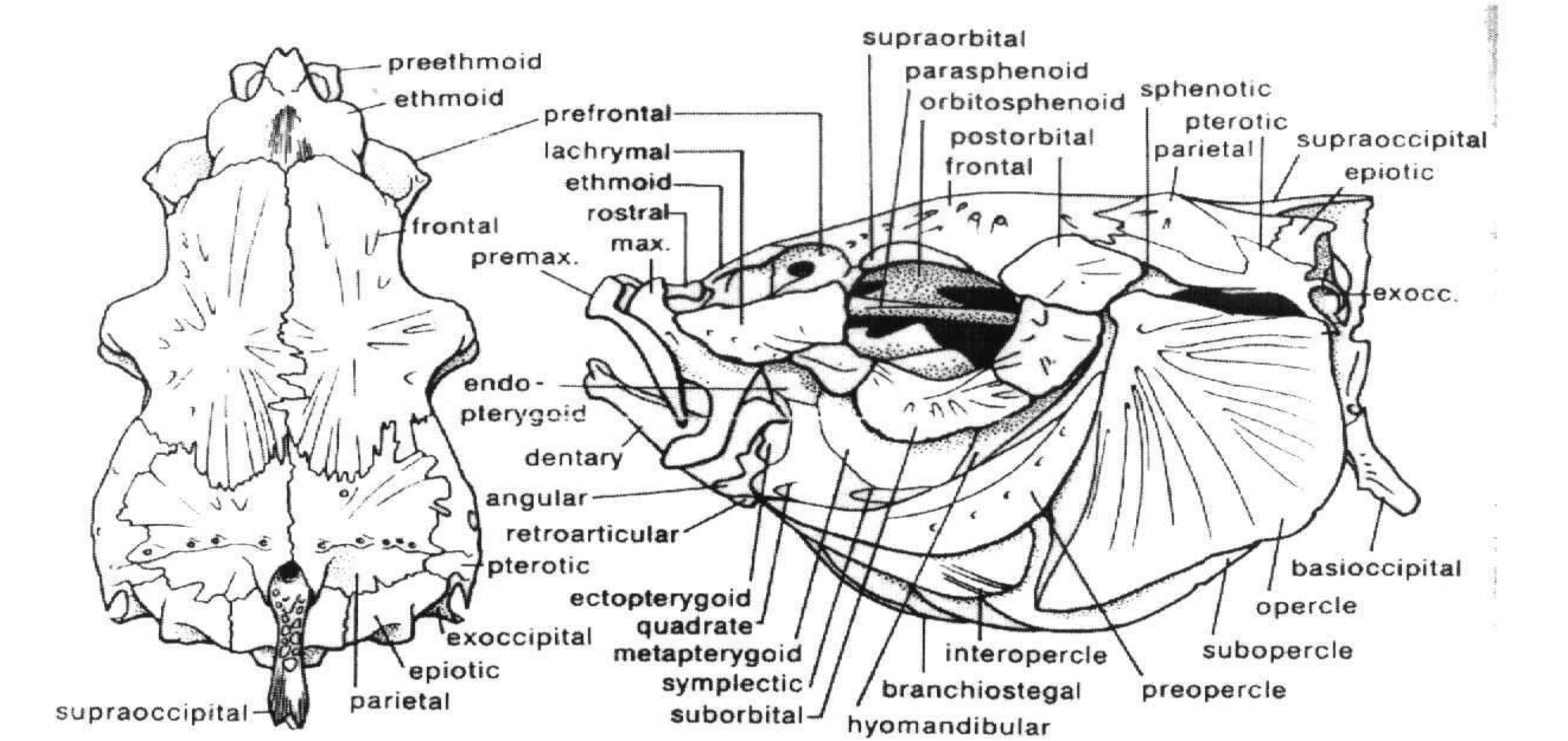
**C) Holostylic**




Where?

**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

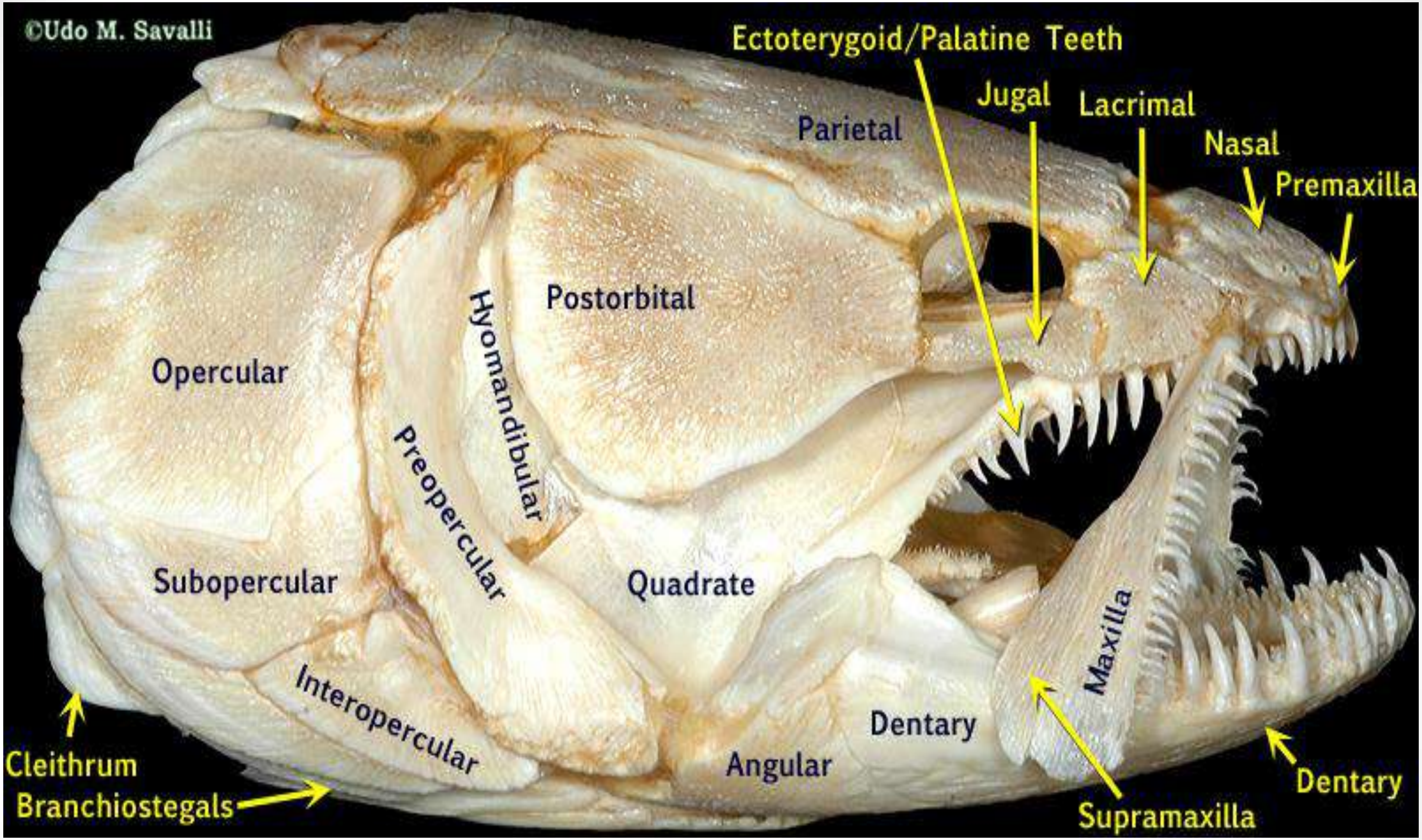


In ray-finned fishes, there has also been considerable modification from the primitive pattern.

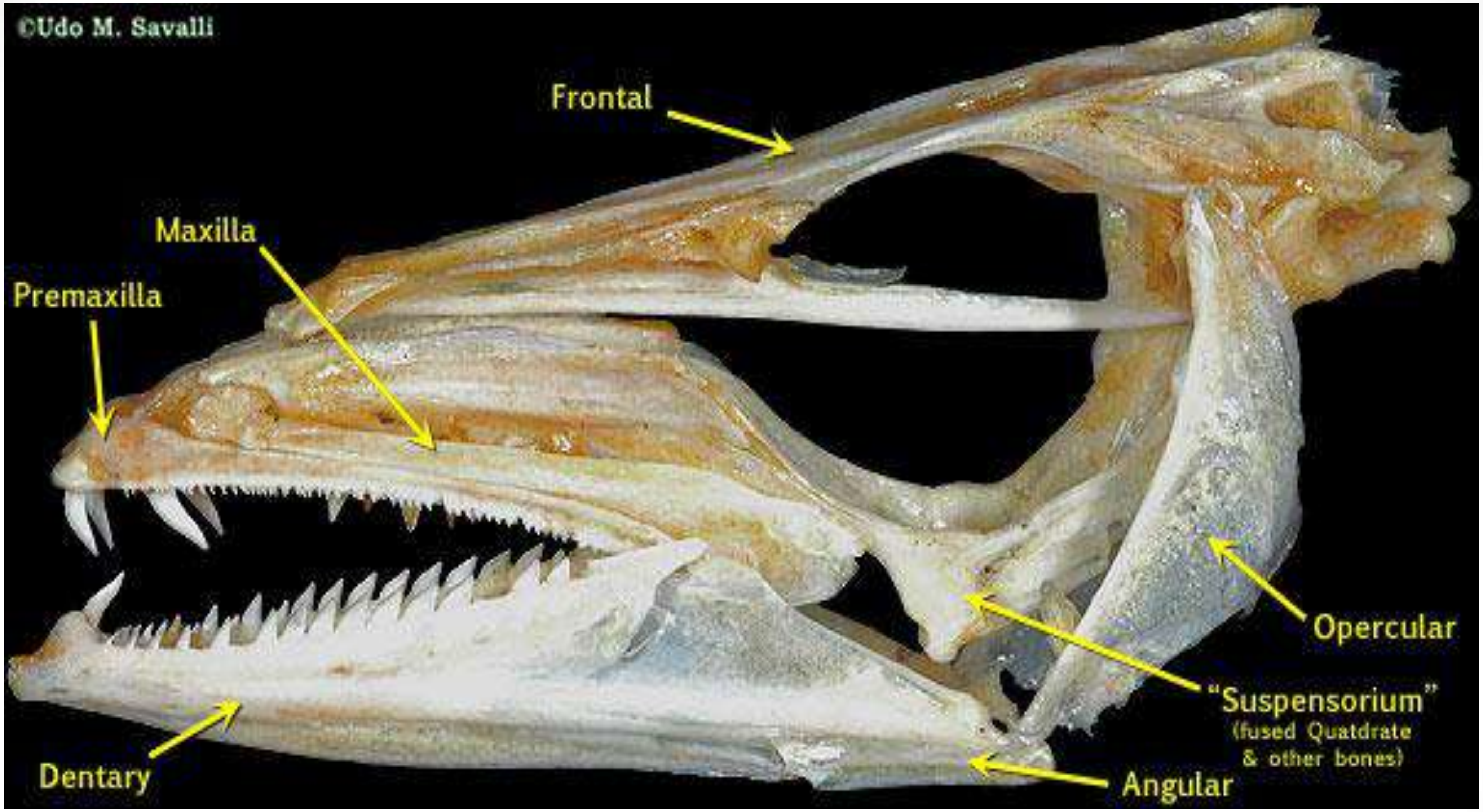
The **roof of the skull is generally well formed**, and although the exact relationship of its bones to those of tetrapods is unclear, they are usually given similar names for convenience.

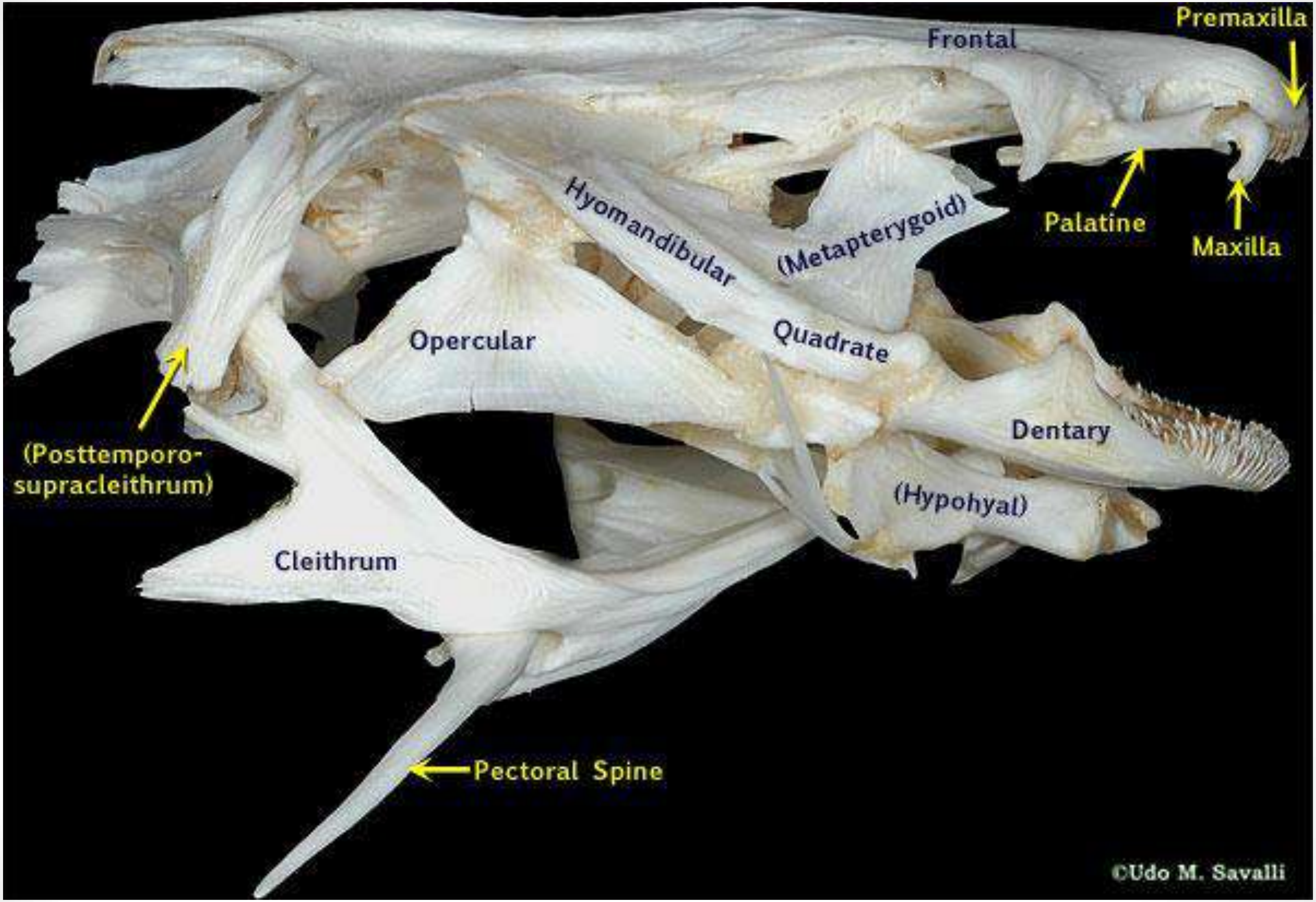
Other elements of the skull, however, may be reduced; there is little cheek region behind the enlarged orbits, and little, if any bone in between them.

**The upper jaw is often formed largely from the premaxilla**, with the maxilla itself located further back, and an additional bone, the **symplectic,** linking the jaw to the rest of the cranium.



©Udo M. Savalli
Ectoterygoid/Palatine Teeth
Jugal
Lacrimal
Nasal
Premaxilla
Parietal
Postorbital
Hyomandibular
Opercular
Preopercular
Subopercular
Quadrate
Maxilla
Interopercular
Dentary
Angular
Cleithrum
Branchiostegals
Supramaxilla
Dentary


©Udo M. Savalli
Frontal
Maxilla
Premaxilla
Opercular
"Suspensorium"
(fused Quatdrate
& other bones)
Dentary
Angular


Premaxilla
Frontal
Palatine
Maxilla
Hyomandibular
(Metapterygoid)
Quadrate
Opercular
Dentary
(Posttemporo-
supracleithrum)
(Hypohyal)
Cleithrum
Pectoral Spine
©Udo M. Savalli

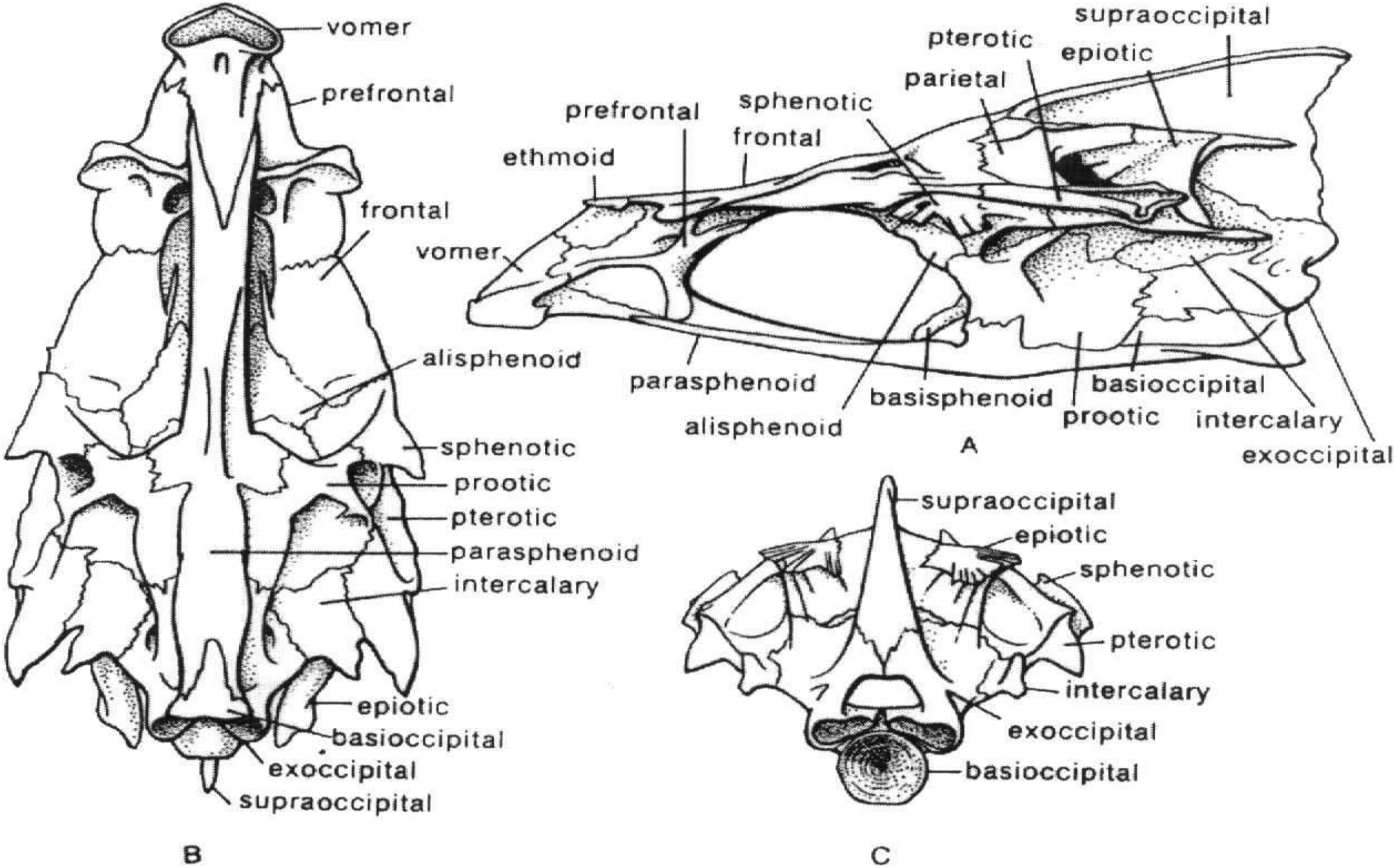



**FIGURE 3–7.** Neurocranium of percoid (based on *Morone saxatilis*). *A*, Lateral view; *B*, ventral view; *C*, posterior view.


*DEEP BREATH*
TRUE

# Lecture 7

# Sensory Organs of Fishes

# Introduction

- Fish have many well developed senses some such as **sight, smell** and **taste** 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.


subterranean characins

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.**
- 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.**

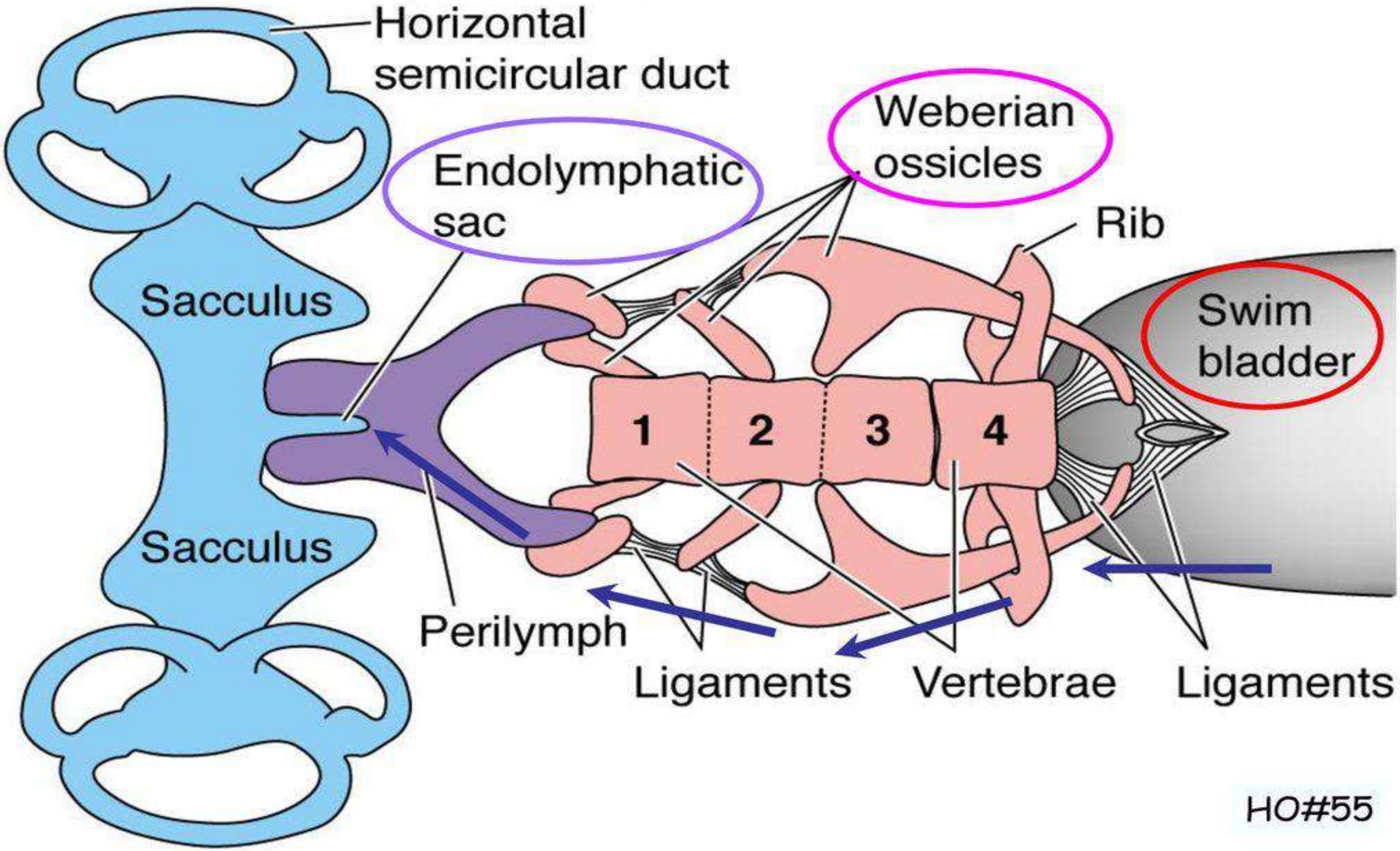



# Hearing

*Aulonocara* eht ni deirub yerp rof netsil ot daeh rieht dnuora serop yrosnes esu *araconoluA* rehto lla ekil 'euboC'
neddih eb yliranidro dluow yerp yeht erehw etartsbus

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.**

# 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.** .ecnatsid a ta "leef" ot hsif eht swolla ylevitceffe sihT eht llet ot elba si hsif eht erop hcae ni ecnereffid eht gnileef yB dna ecnabrutsid eht fo ecruos eht morf ecnatsid dna noitcerid meht no pu kaens ot gniyrt rotaderp yna fo meht nraw lliw siht .ti ees t'nod yeht fi neve

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

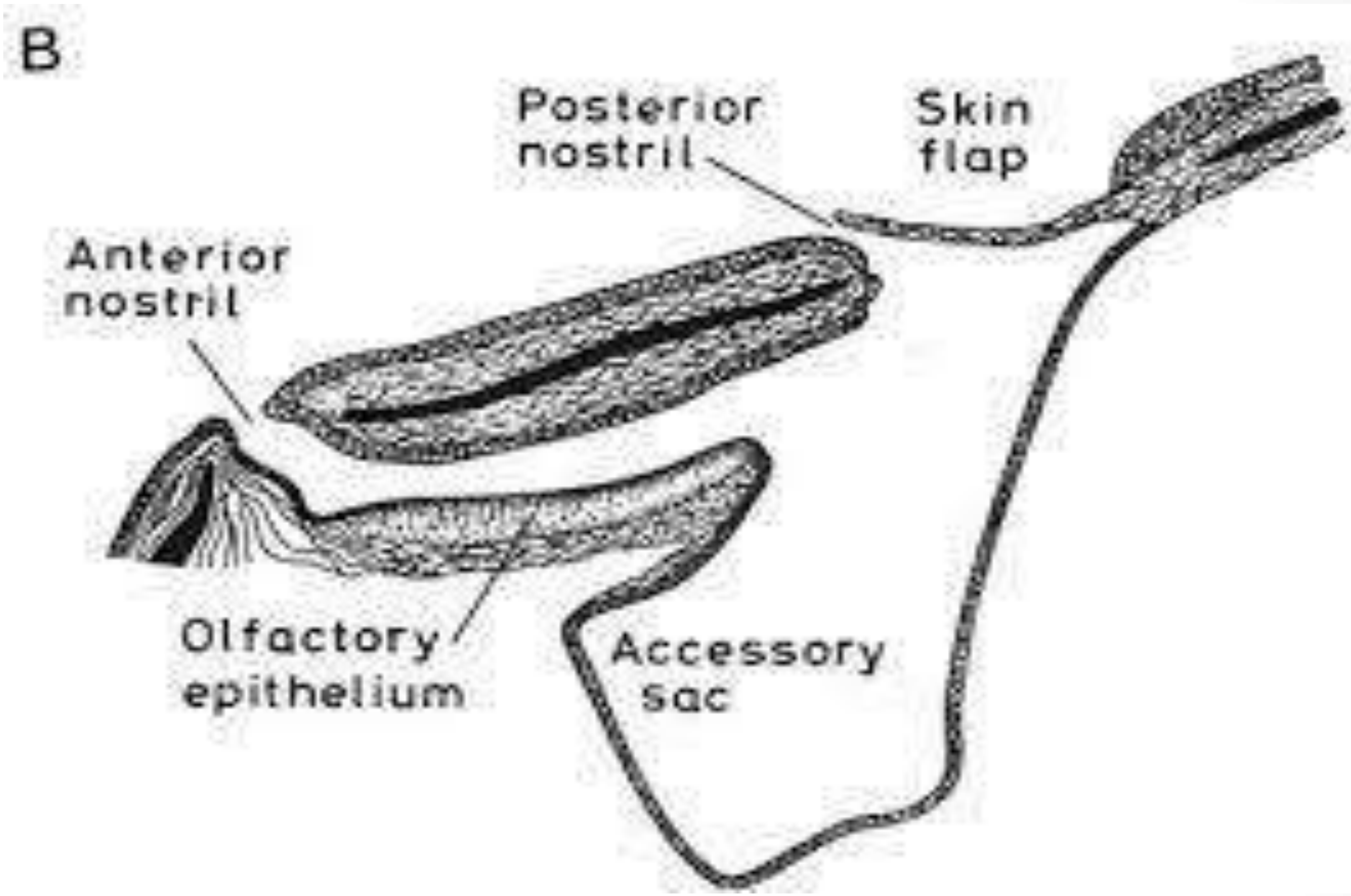
The sense of smell is very well developed in some fish and is better not only than ours but it is **better than in most mammals.** Other species of fish like the family Tetraodontidae have completely abandoned the sense of smell altogether.

**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.




The olfactory organs

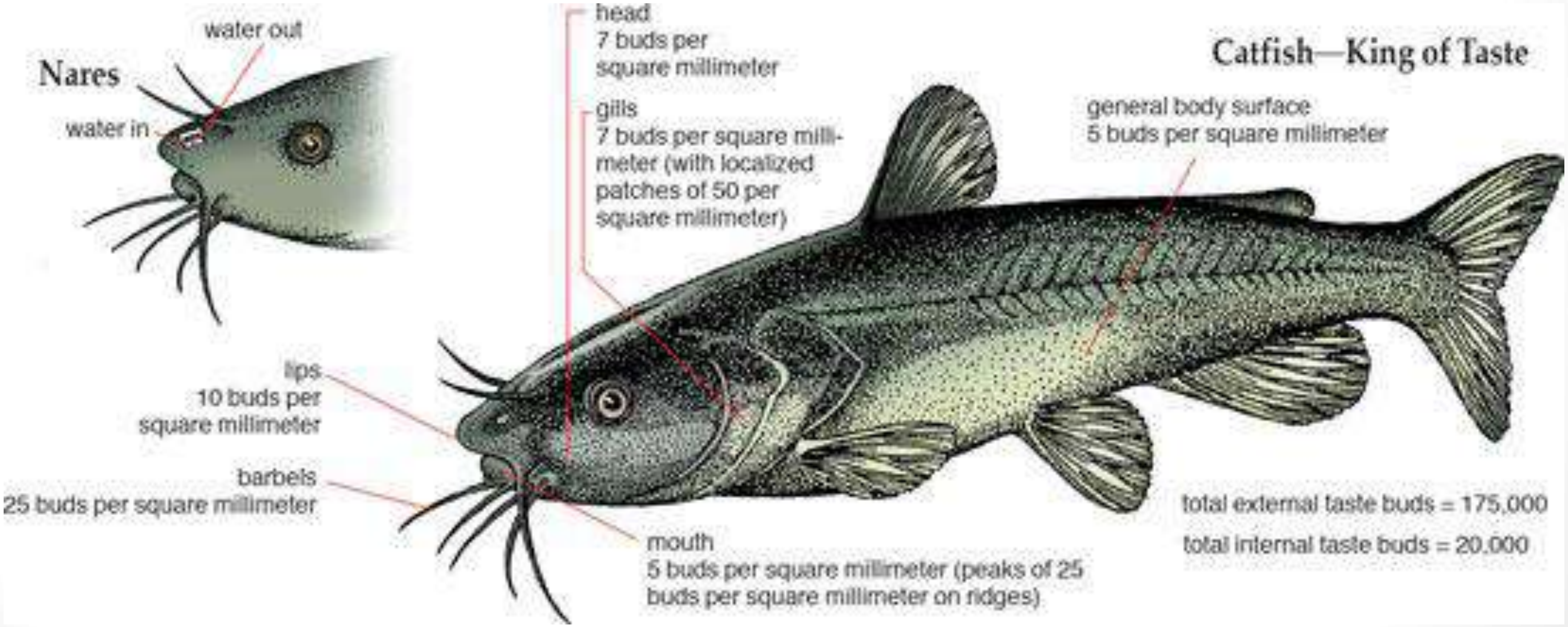
Like some other gouramis the **pearl gourami** has some **taste buds** on their long **pelvic fins** and they can often be observed touching various items in the tank using these fins.

Most fish have **taste buds located in their mouth** but these taste buds are not exclusively found in the mouth .

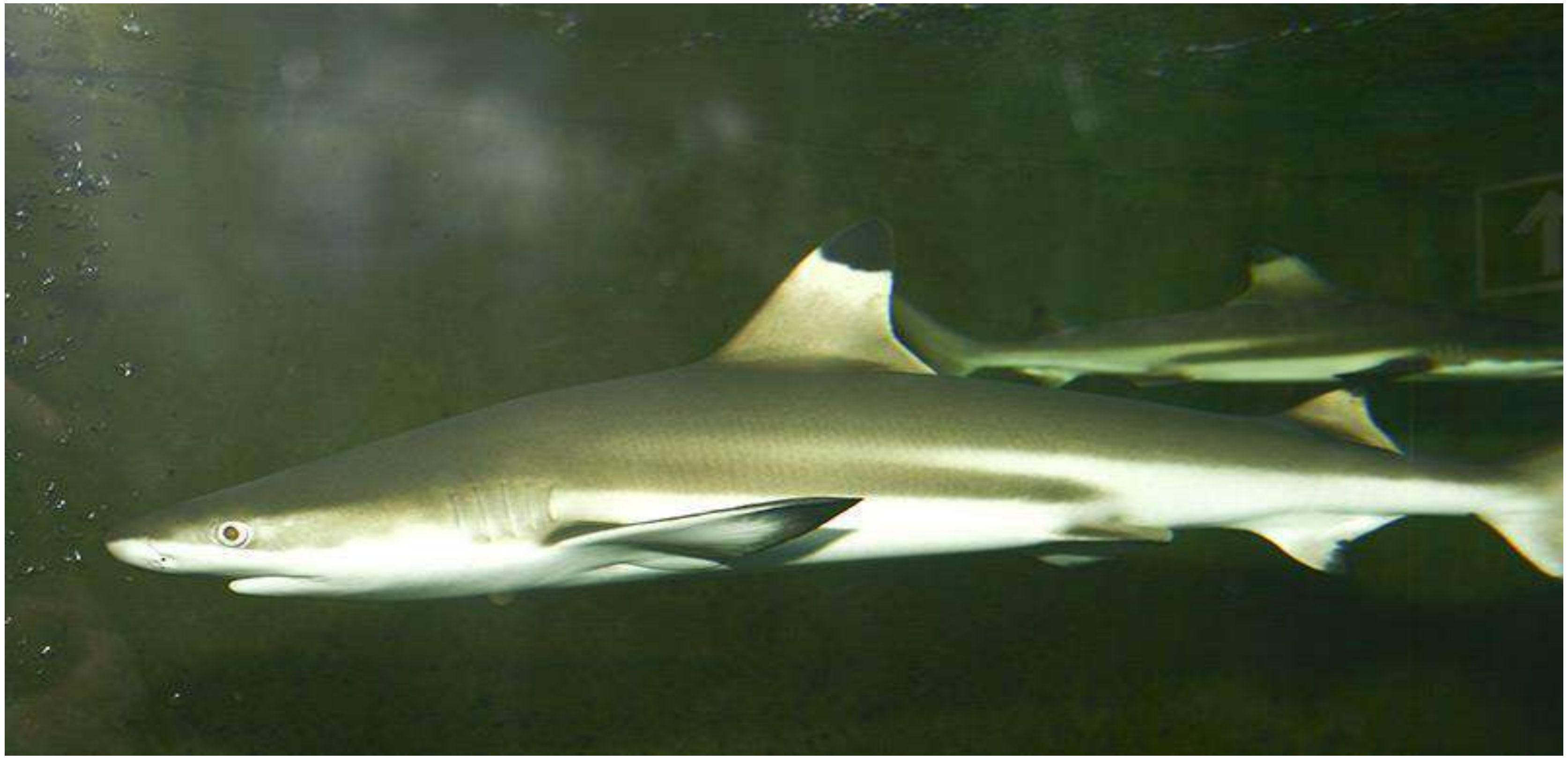
Taste buds are found on the gill arches, gill rakers, barbels and even some fins but they are **absent on the fish's tongue .**

# pearl gourami

In **cyprinids and siluriformes** sdub etsat
ot pu htiw hsif eht fo ydob eritne eht revoc300
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.

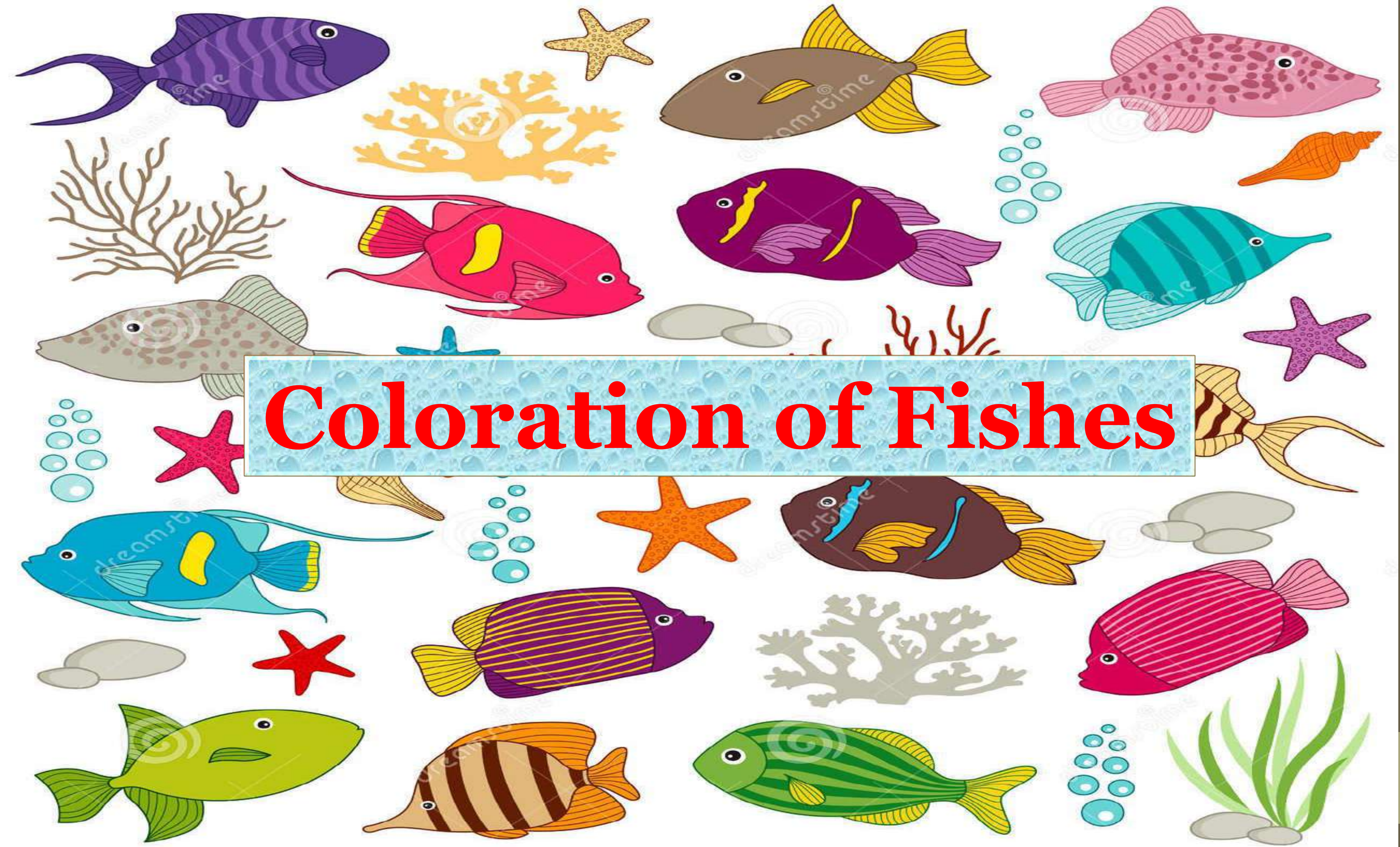
- The Ampullae of Lorenzini can pick up **minute changes in voltage**.
- So sensitive is it that a difference in voltage of just 0.000,000,005 of a volt can be sensed.
- **Sharks and rays** use this sense to find prey which has buried itself in to the substrate in an attempt to hide.
- All living things 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.**


*DEEP BREATH*
TRUE

https://www.youtube.com/watch?v=TxCOliJgc74

https://www.youtube.com/watch?v=ryRcPeOM1sY

# Coloration of Fishes



## 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.
- The bottom dwellers are often strongly and intricately coloured above and pale below.
- However, some fishes have uniform colouration as found in the gold fish, **Carassius,** which has brilliant colour all over the body.

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.




**Mahseer (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**.

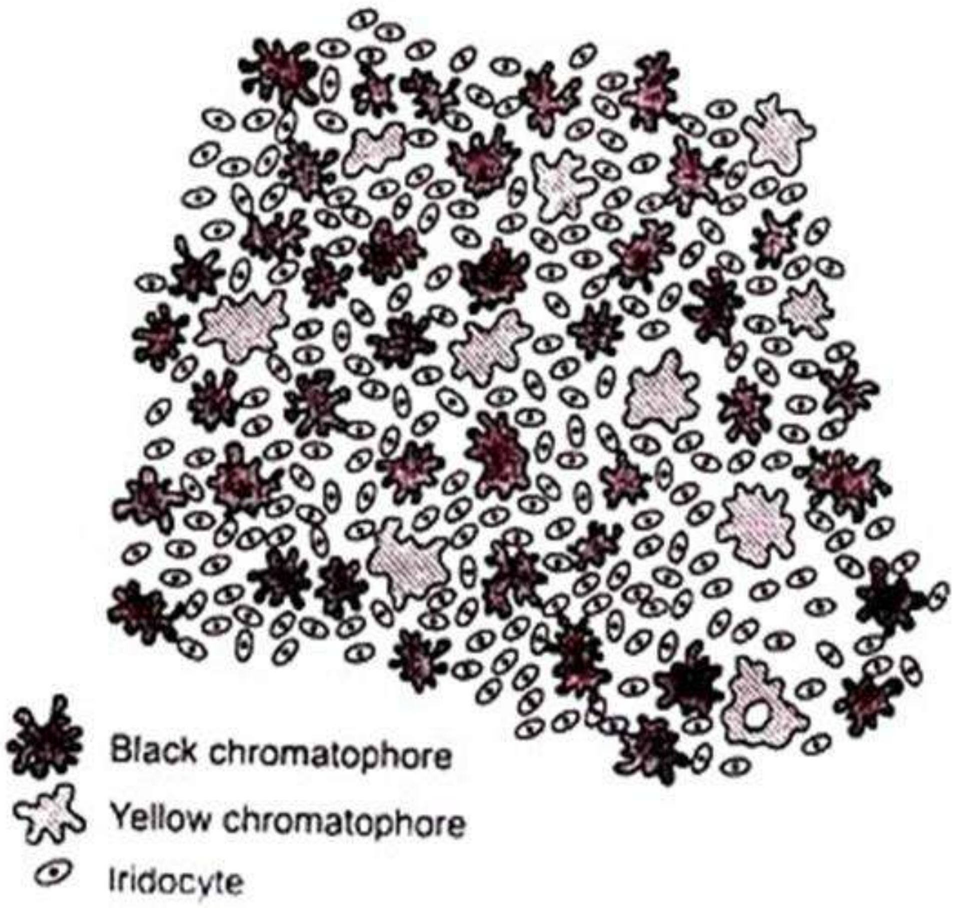


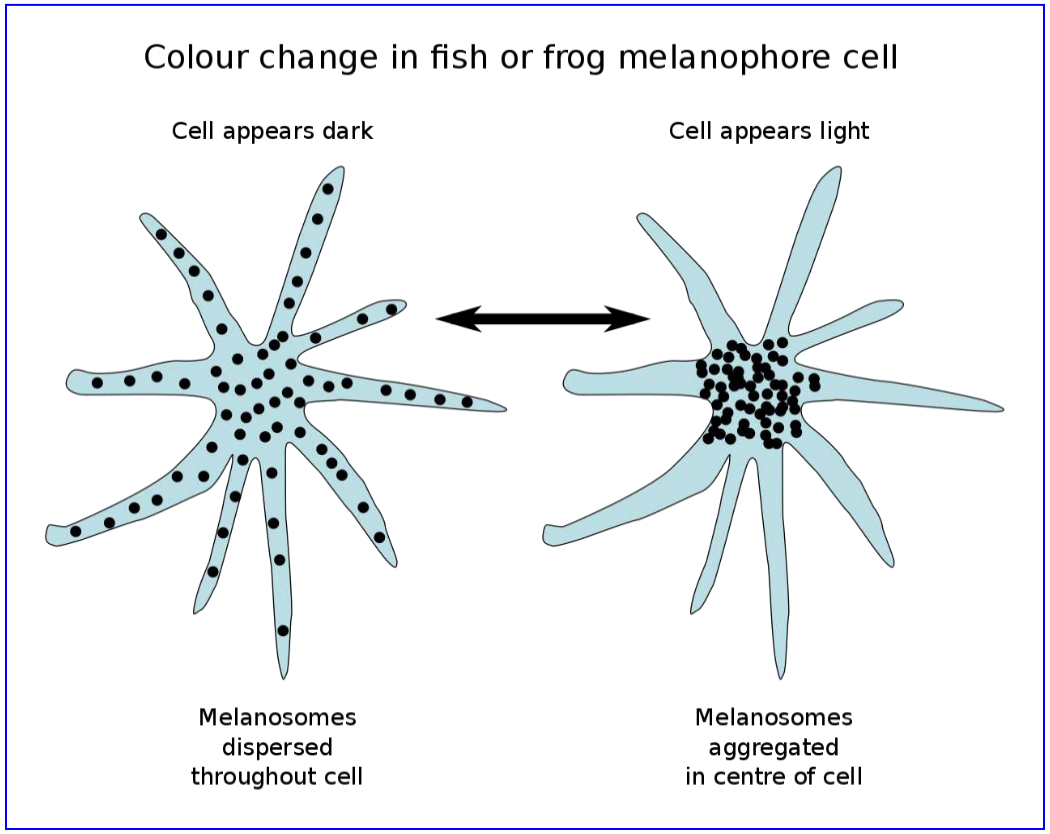

Fig. 16.1 : Coloration elements in the skin of the upper side of a flounder (*Platichthys*) (After Norman)

## I) The Chromatophores:

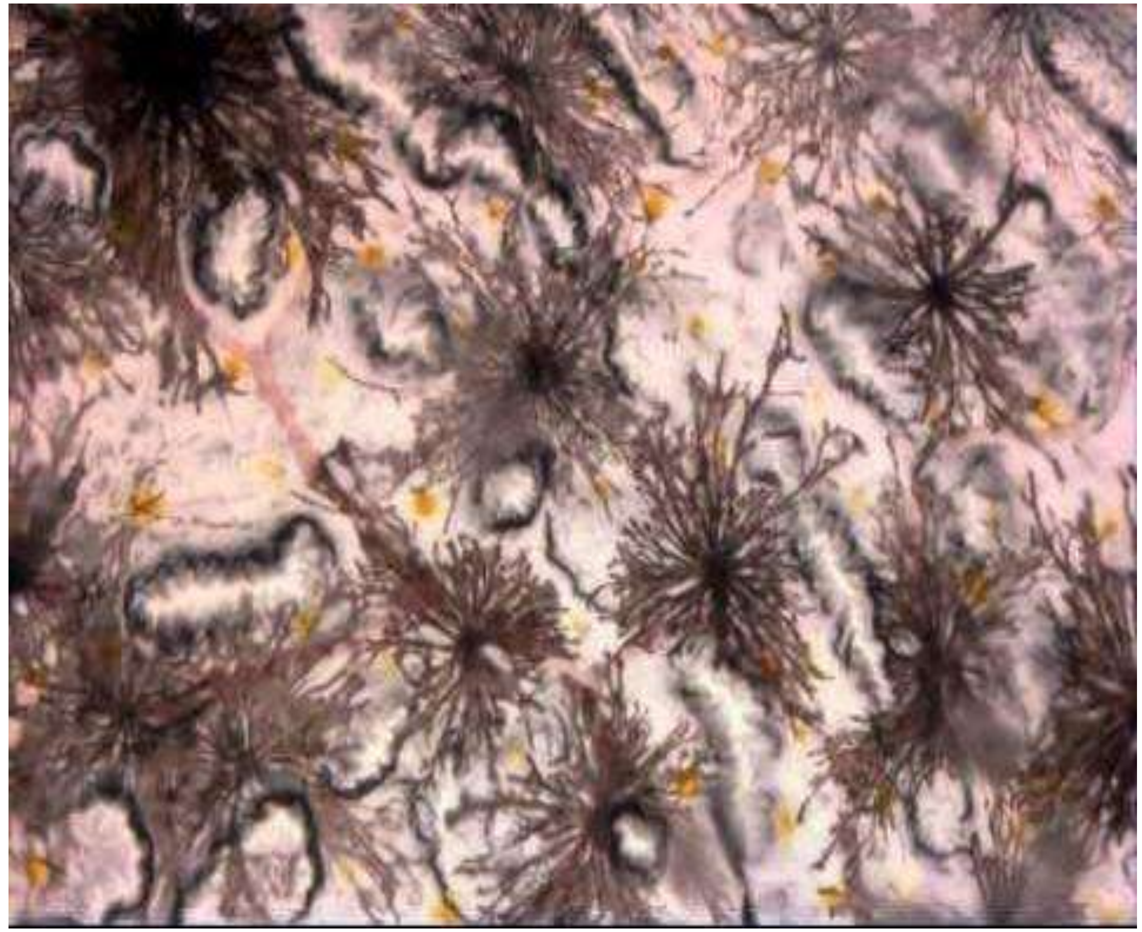
- They are large and branched specialized cells .
- They are mostly present in the dermis, just beneath the epidermis or scales .
- They are also present around the brain and spinal cord.
- Chromatophores may be monochromatic, viz., and possess only one type of pigment, di or polychromatic.

- Cytoplasm of chromatophores contains different **pigment granules** rof elbisnopser era hcihw , .ruoloc
- Amalgamation of different chromatophores produces a wide range of colour, thus **yellow and black**
- 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.

- 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).



Colour change in fish or frog melanophore cell
Cell appears dark
Cell appears light
Melanosomes dispersed throughout cell
Melanosomes aggregated in centre of cell

- 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.

# 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**.

## **Pteridines:**

- 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.**


*DEEP BREATH*
TRUE

# 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**.eye eht laecnoc ot ,

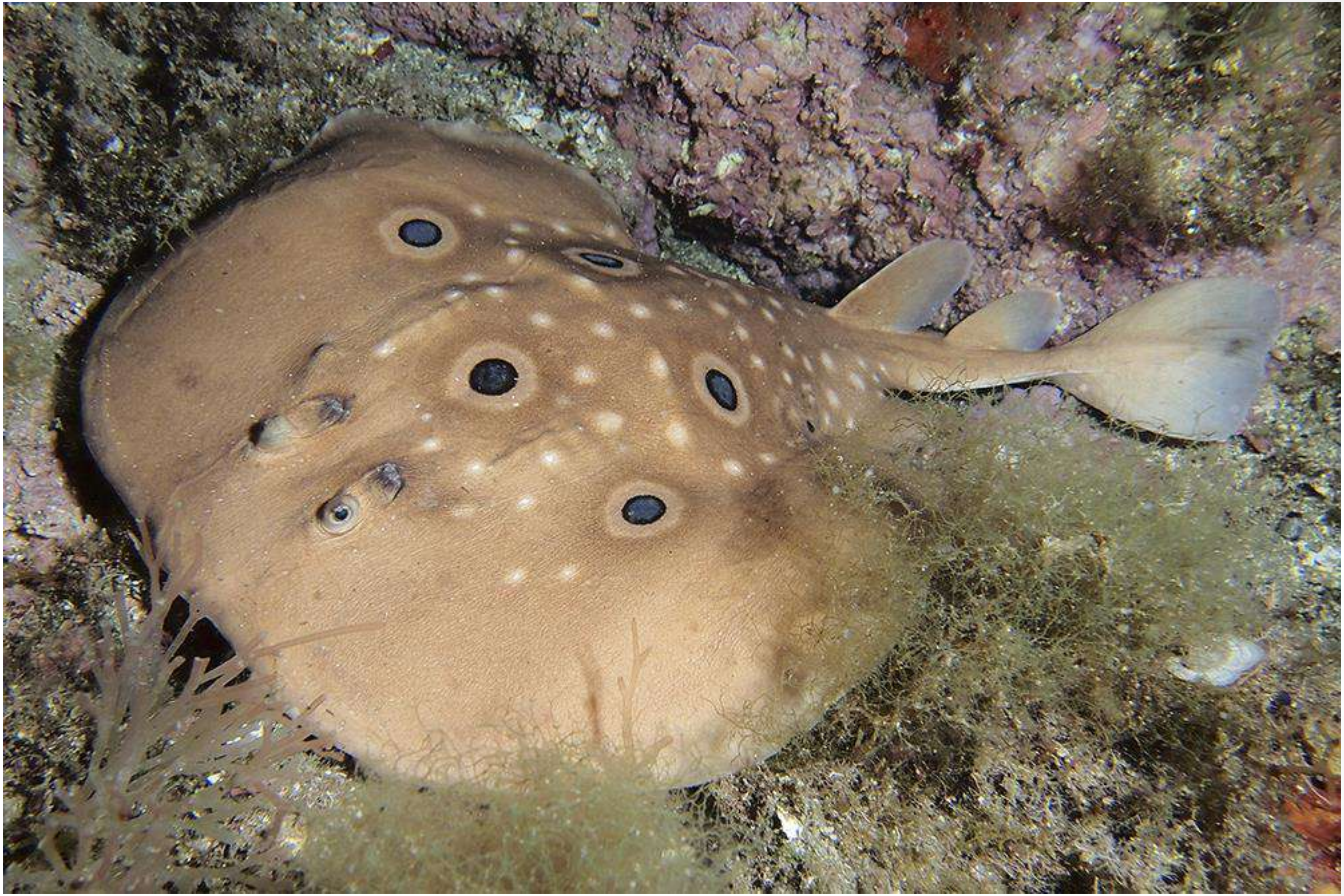
## (iii) Sematic or Warning Colouration:

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 has a prominent spot on electric organ for this purpose.**



**Torpedo ocellata**

## 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** era hcihw elbisnopser**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.

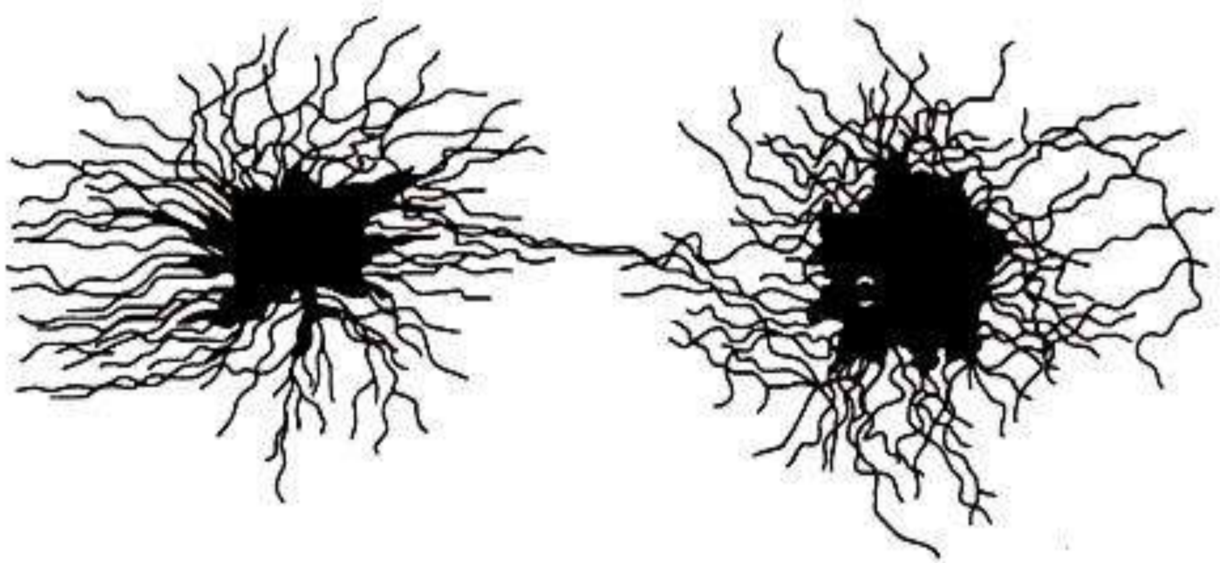


Fig. 16.2 : Nerves of the melanophores of a perch (From Ballowitz)

## 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 استئصال 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),** causes darkening and the **melanin-aggregating hormone (MAH)** 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.

- **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.

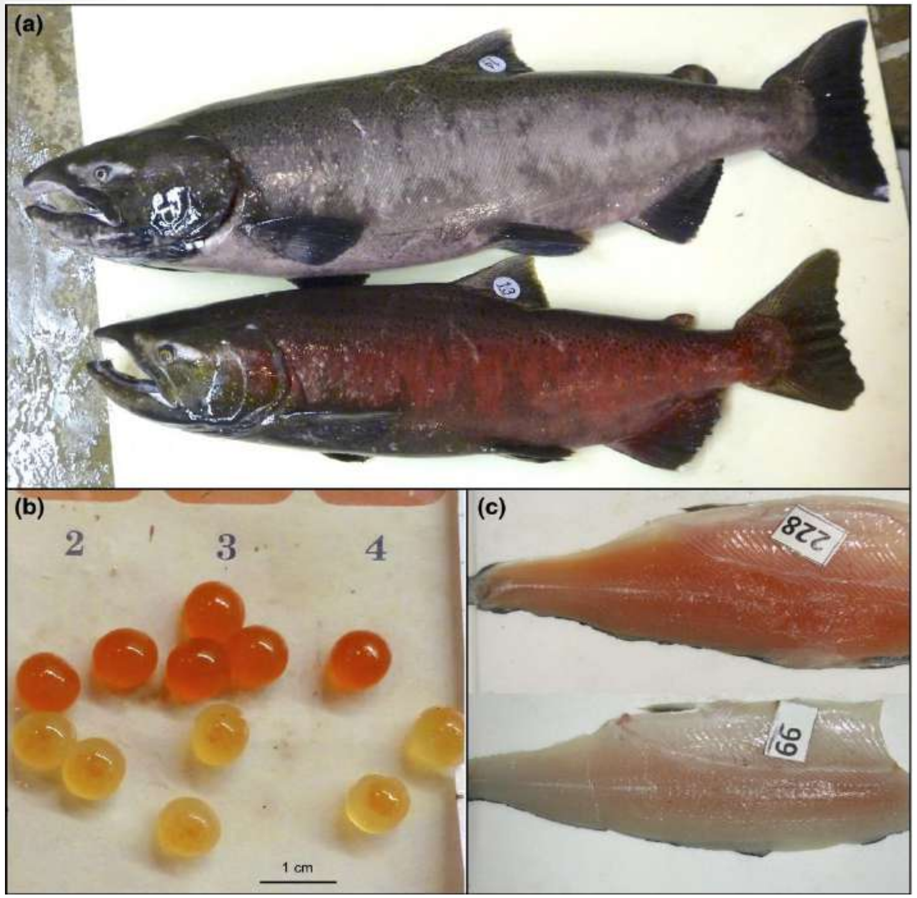
**External stimuli** like tactile or psychic type also influence colouration of fish.

## Effect of Diet on Colouration:

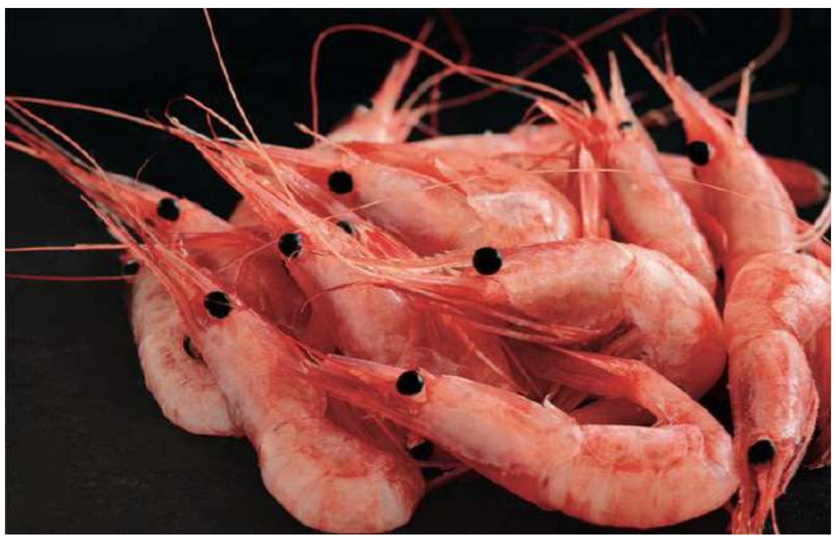
The colour of many fishes is also depends on their diets. Such types of diets may contain additional natural pigments to enhance colours of **ornamental fishes.** The carotenoid pigment found in most marine and a few freshwater invertebrates is **astaxanthin**.

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.**

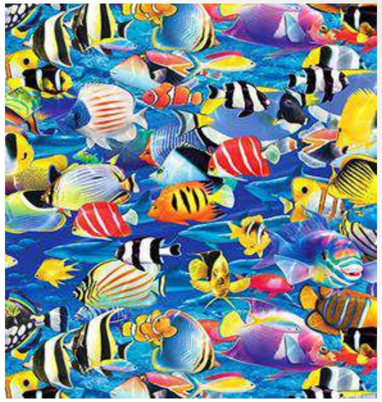

(a)
(b)
2
3
4
1 cm
(c)


flesh of salmon



# 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**.



# 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 milliosmoles = 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)

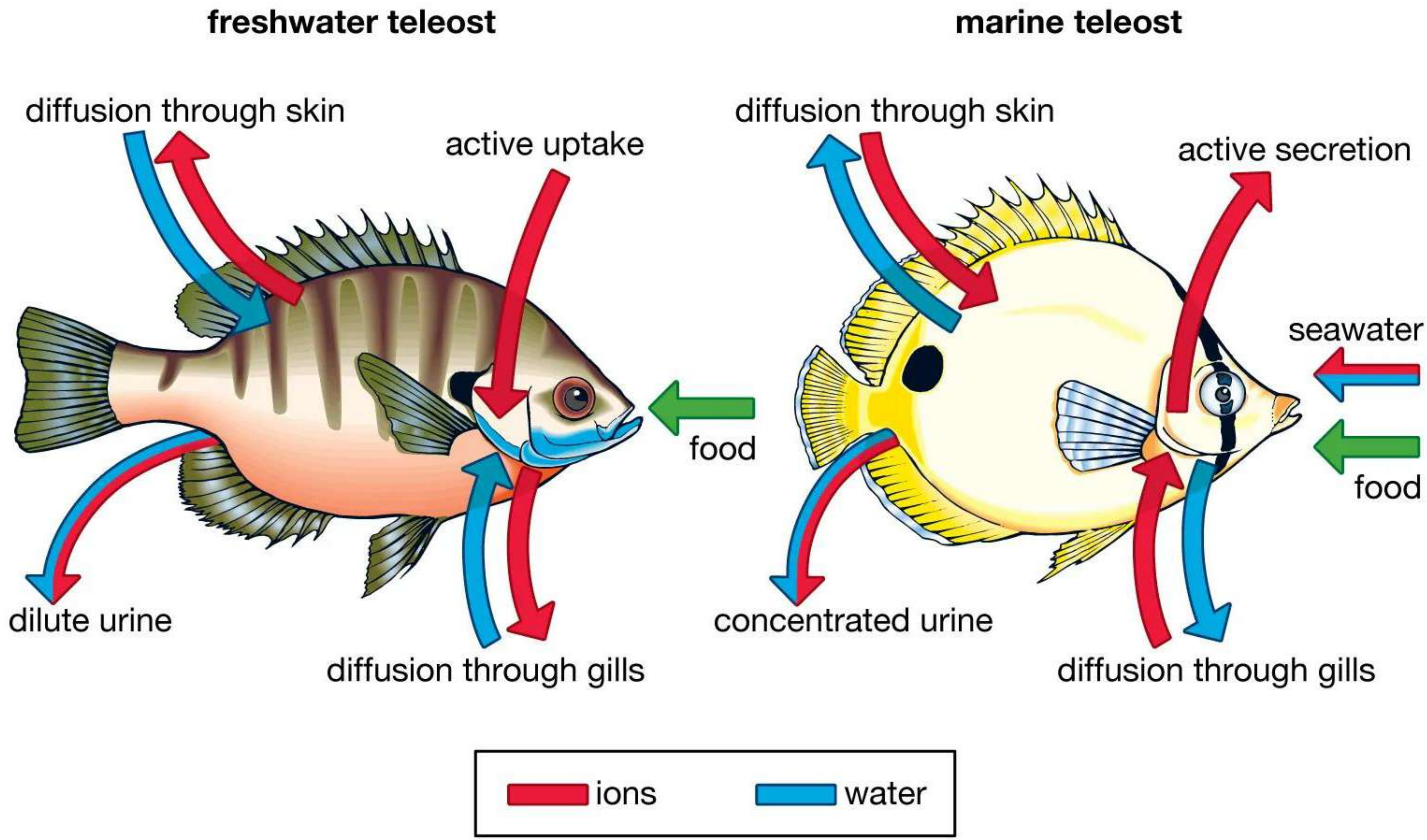
# Osmotic regulation by marine teleosts

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

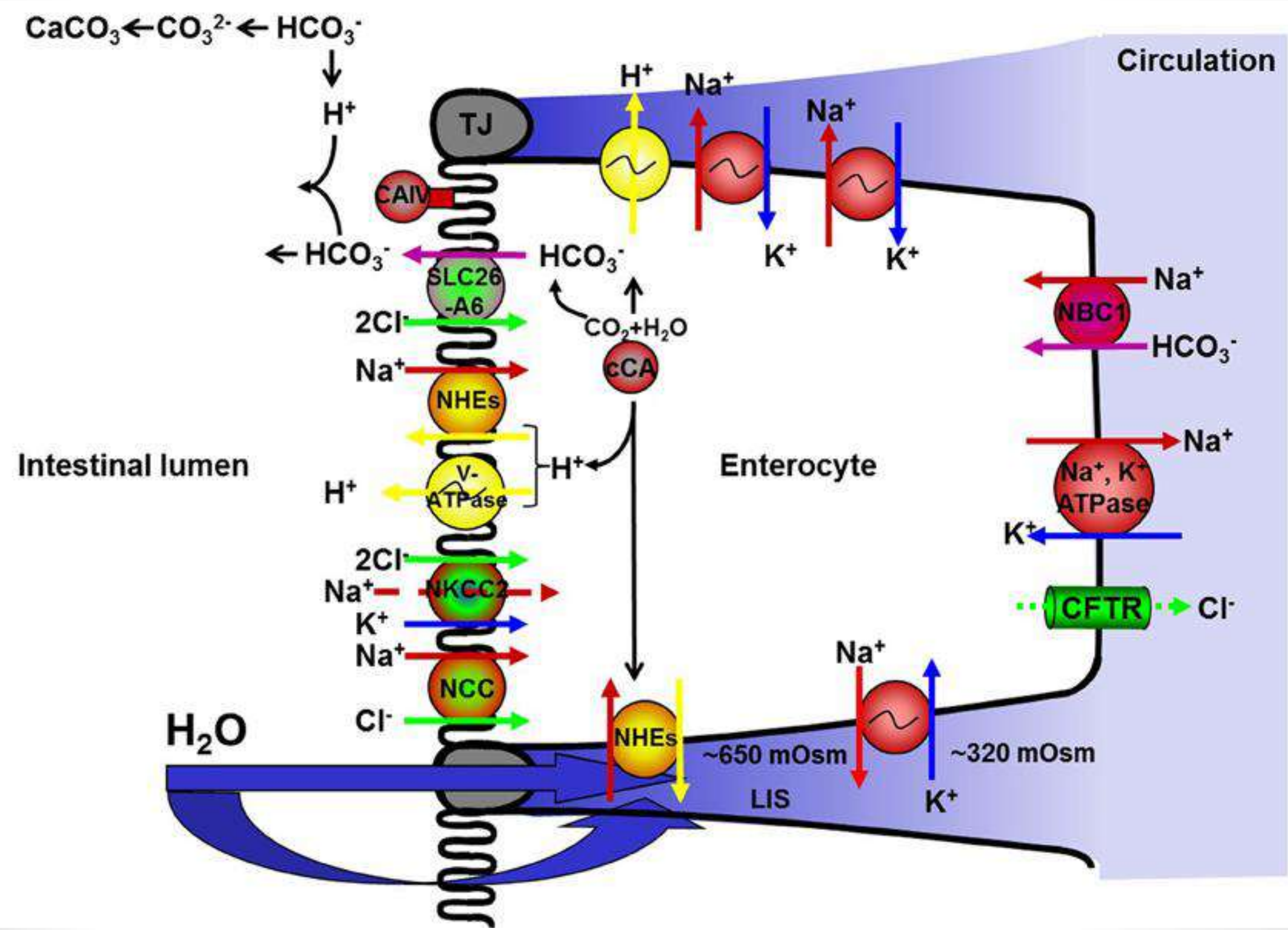
1. Oral ingestion:
2. Extrusion/secretion mechanism of salts/ions in gills
3. Absorption and secretion of salts/ions by kidney and urinary Bladder


freshwater teleost
marine teleost
diffusion through skin
active uptake
food
dilute urine
diffusion through gills
diffusion through skin
active secretion
seawater
food
concentrated urine
diffusion through gills
ions
water

# 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.



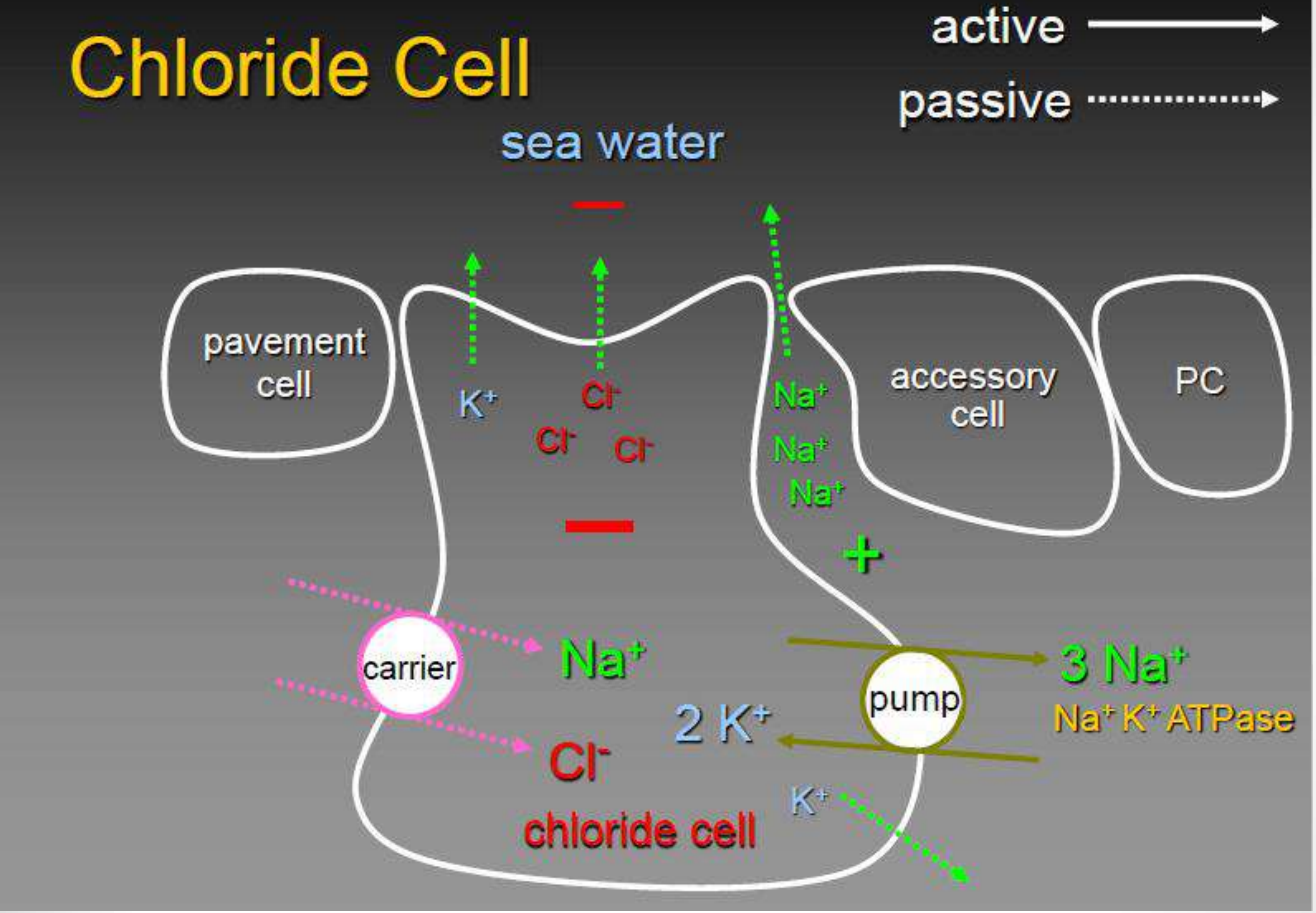
CaCO3 ← CO3 2- ← HCO3-
H+
CAIV
← HCO3-
SLC26-A6
HCO3-
CO2+H2O
cCA
2Cl-
Na+
NHEs
H+
V-ATPase
H+
Intestinal lumen
Enterocyte
Circulation
TJ
H+
Na+
Na+
K+
K+
Na+
NBC1
HCO3-
Na+
Na+, K+ ATPase
K+
CFTR
Cl-
2Cl-
Na+
NKCC2
K+
Na+
NCC
Cl-
H2O
NHEs
~650 mOsm
LIS
Na+
~320 mOsm
K+

## Osmoregulation by marine teleost continued…….

### 2. Extrusion mechanism in gills

- Large acidophilic cells, the chloride secreting cells or chloride cells 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

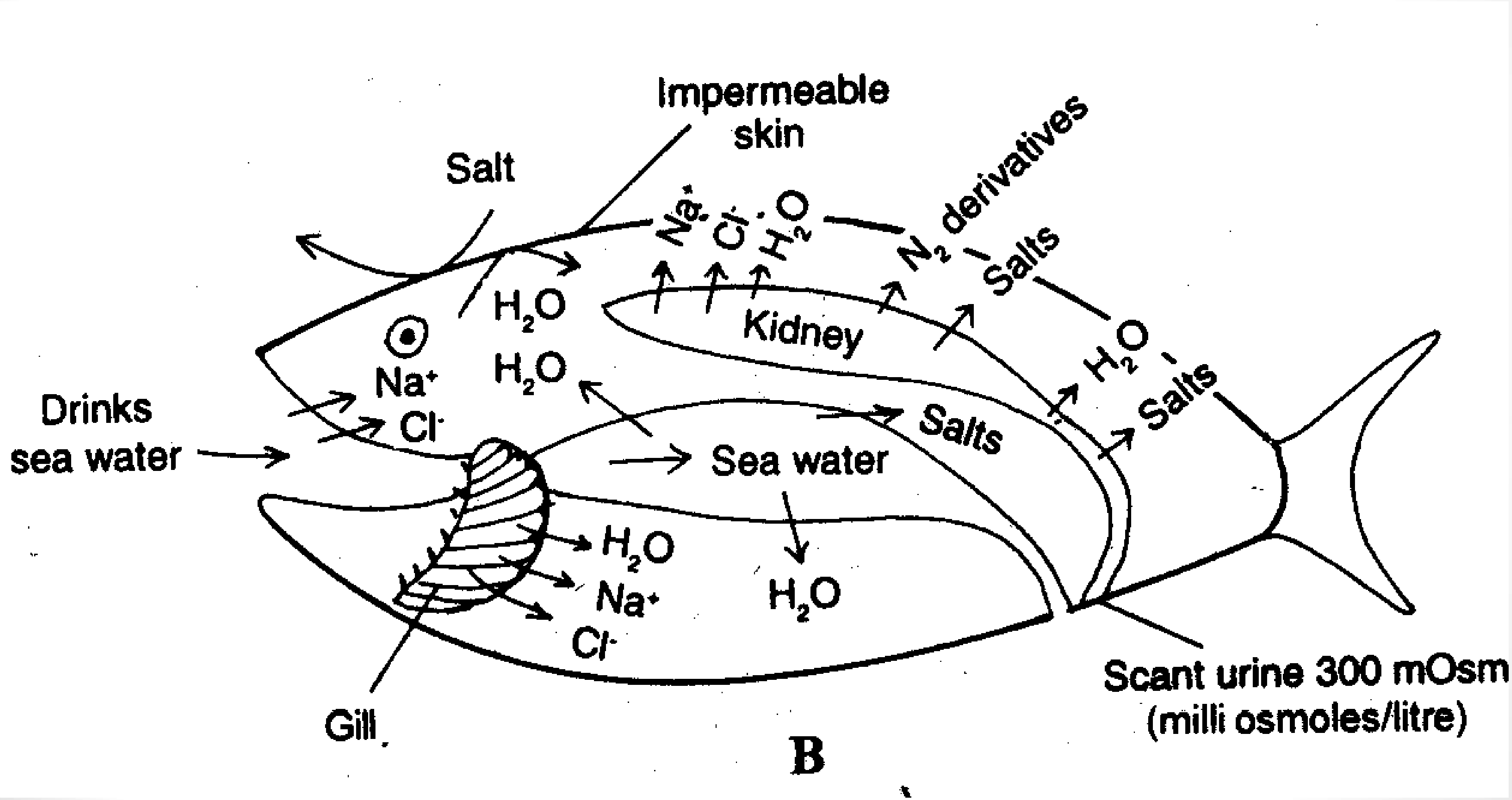


# Osmoregulation by marine teleost continued…

## 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 (Flow glomerular rate) 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

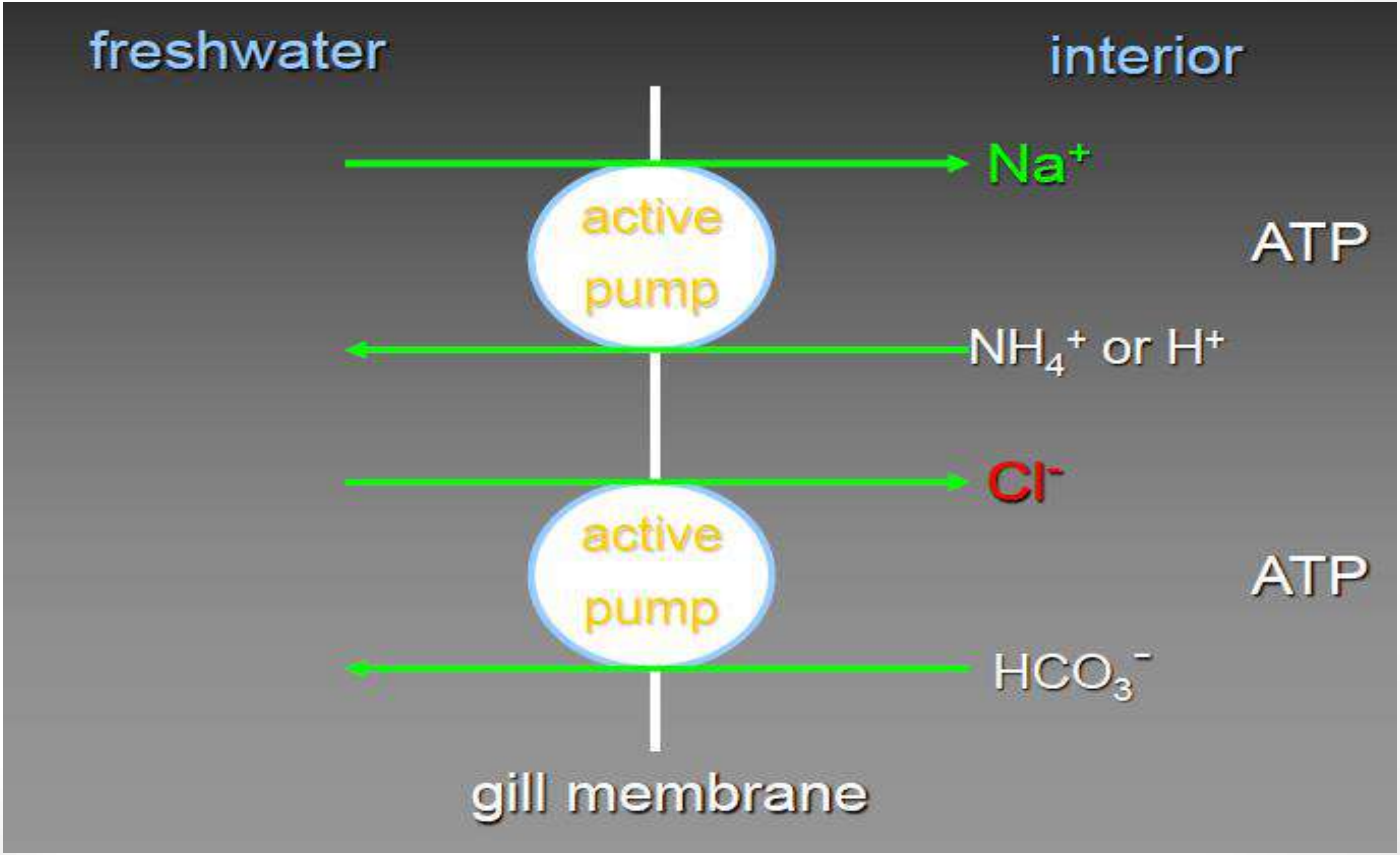
## Osmoregulation by Freshwater teleosts

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 bicarbonate ($HCO_3^-$ ) and uptake of $Na^+$ is effected by Amonia ($NH_4^+$) 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**

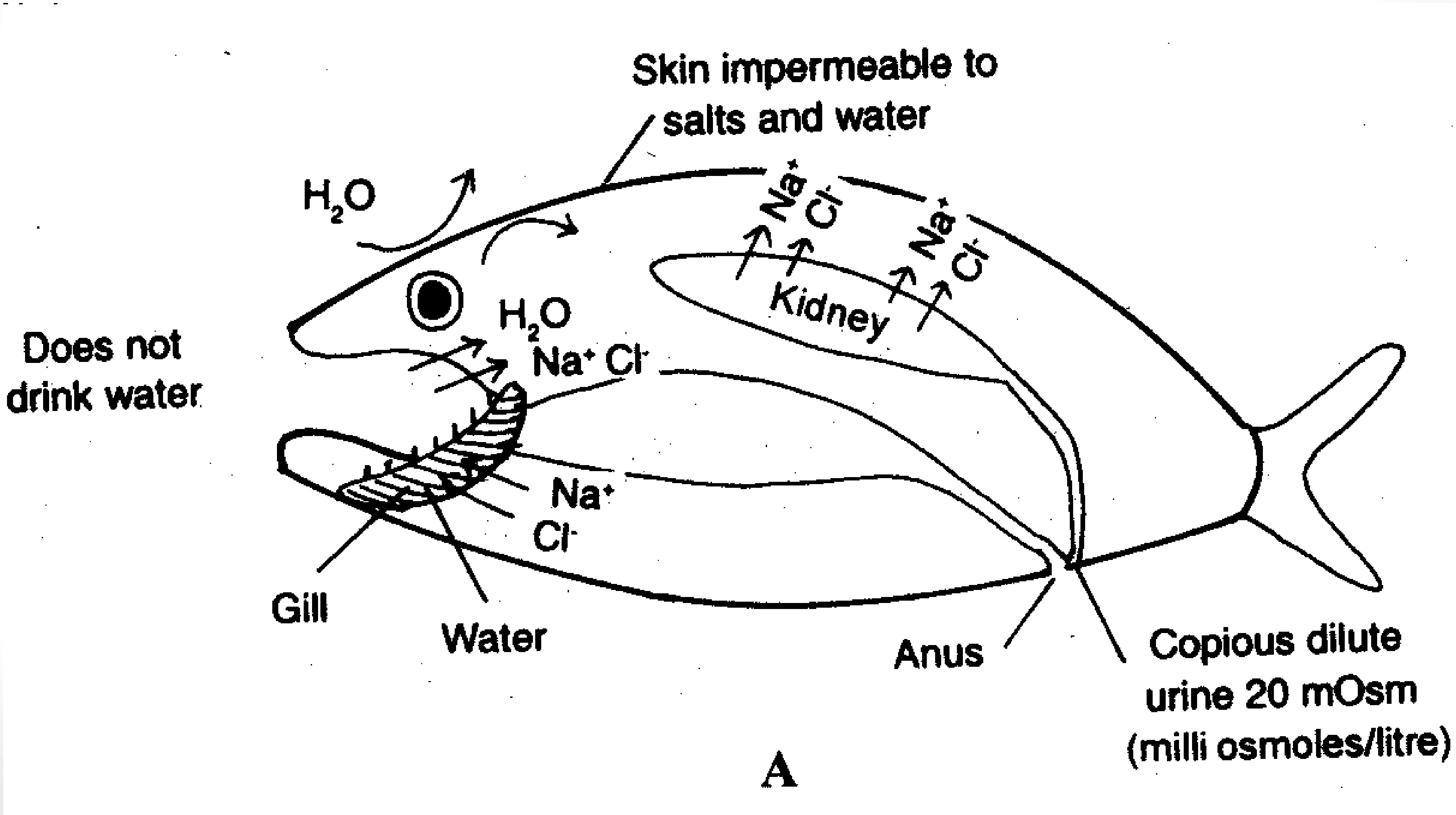
Kidney of these fishes have very large number of well developed glomeruli which has proximal tubule segment I and II, an intermediate segment, distal tubule and collecting duct.

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 faeces 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 these 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 secret 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

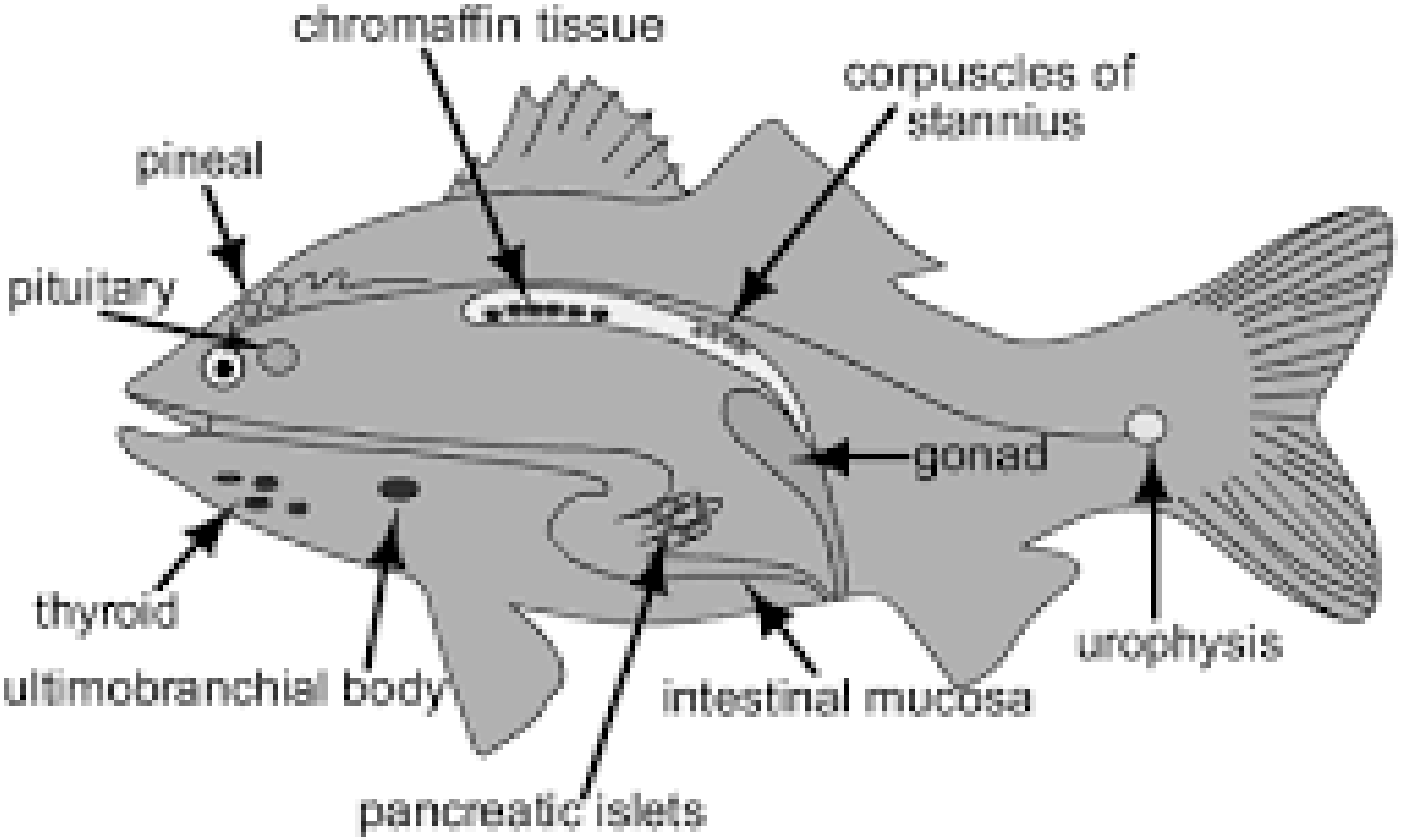
- The glands that secrete their products into the bloodstream and body tissues along with the central nervous system to control and regulate many kinds of body functions are known as endocrine gland.

- 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
- Urophysis
- Pancreatic islets
- Pineal gland


chromaffin tissue
corpuscles of
stannius
pineal
pituitary
gonad
thyroid
urophysis
ultimobranchial body
intestinal mucosa
pancreatic islets

## 1. The pituitary gland or Hypophysis:

### Location:

Ventral surface of brain below optic chiasma.

### Origin:

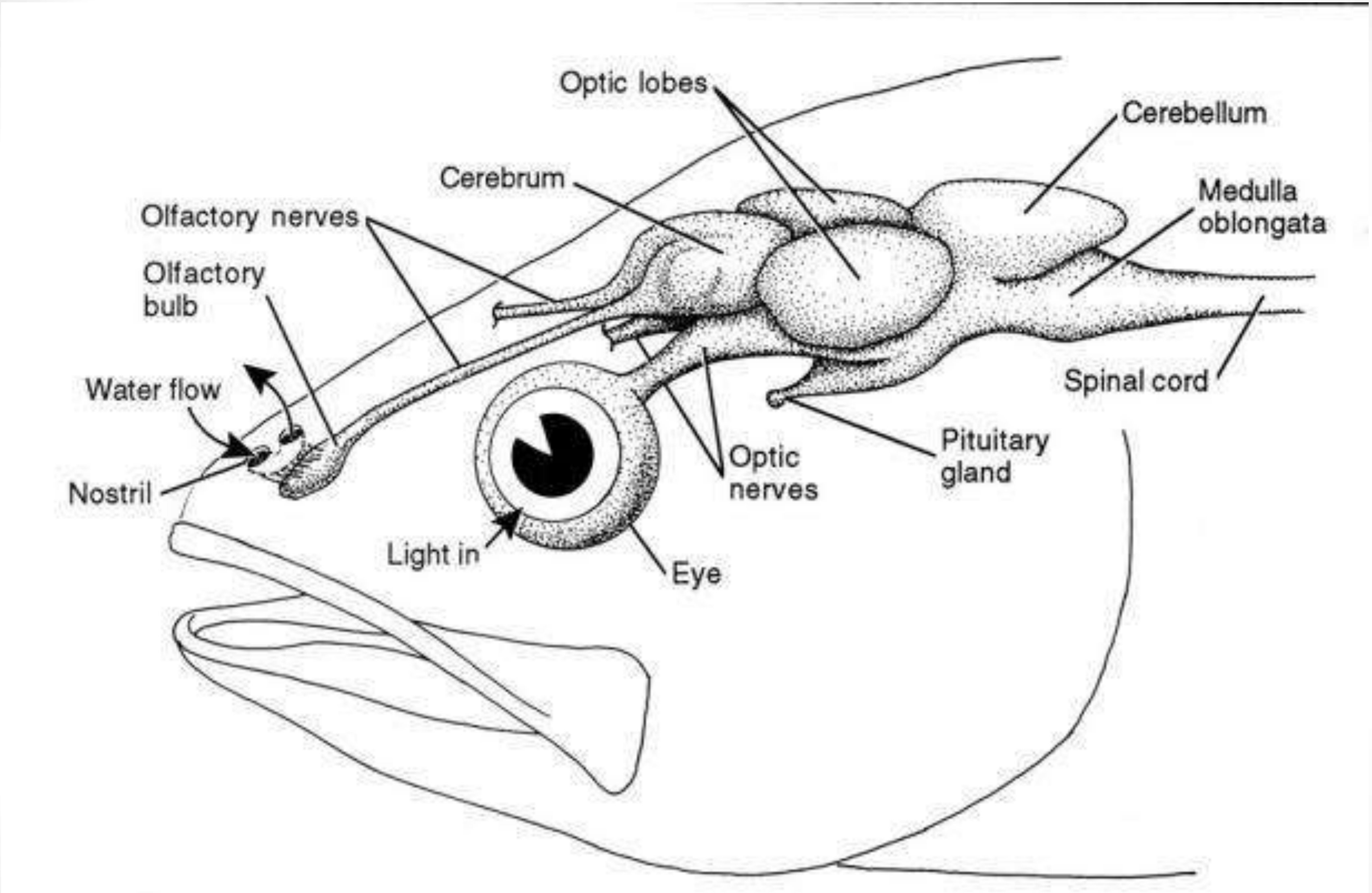
Two parts of pituitary gland are derived from two different components.

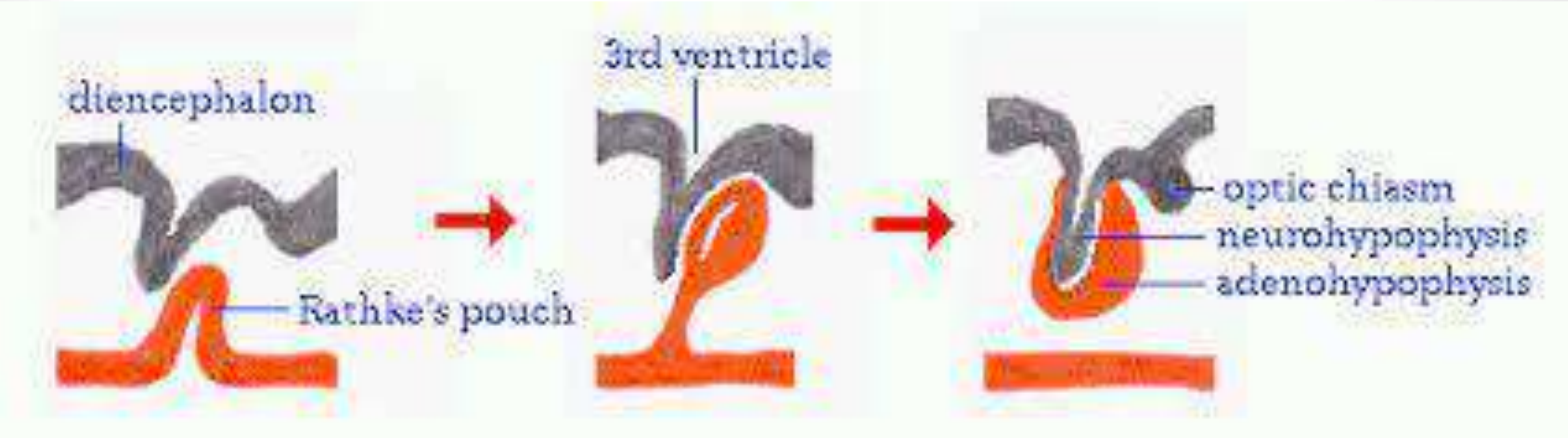
Neurohypophysis develops from the floor of the embryonic diencephalons.

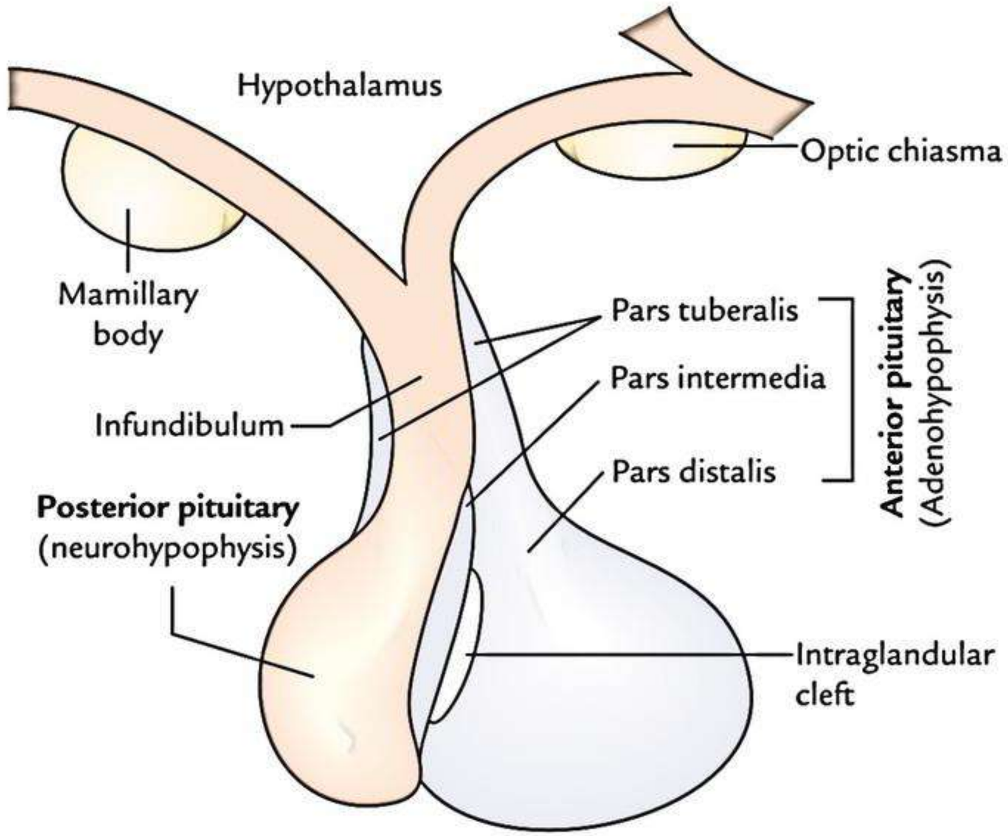
Adenohypophysis developes from the dorsal evagination of the ectodermal part of buccal cavity called Rathke's pouch.

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.


Optic lobes
Cerebellum
Cerebrum
Medulla oblongata
Olfactory nerves
Olfactory bulb
Water flow
Spinal cord
Pituitary gland
Optic nerves
Nostril
Light in
Eye


diencephalon
Rathke's pouch
3rd ventricle
optic chiasm
neurohypophysis
adenohypophysis


Hypothalamus
Optic chiasma
Mamillary body
Pars tuberalis
Pars intermedia
Pars distalis
Anterior pituitary (Adenohypophysis)
Infundibulum
Posterior pituitary (neurohypophysis)
Intraglandular cleft

**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 $1^{st}$ 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 (lung fish), 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.
- 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.

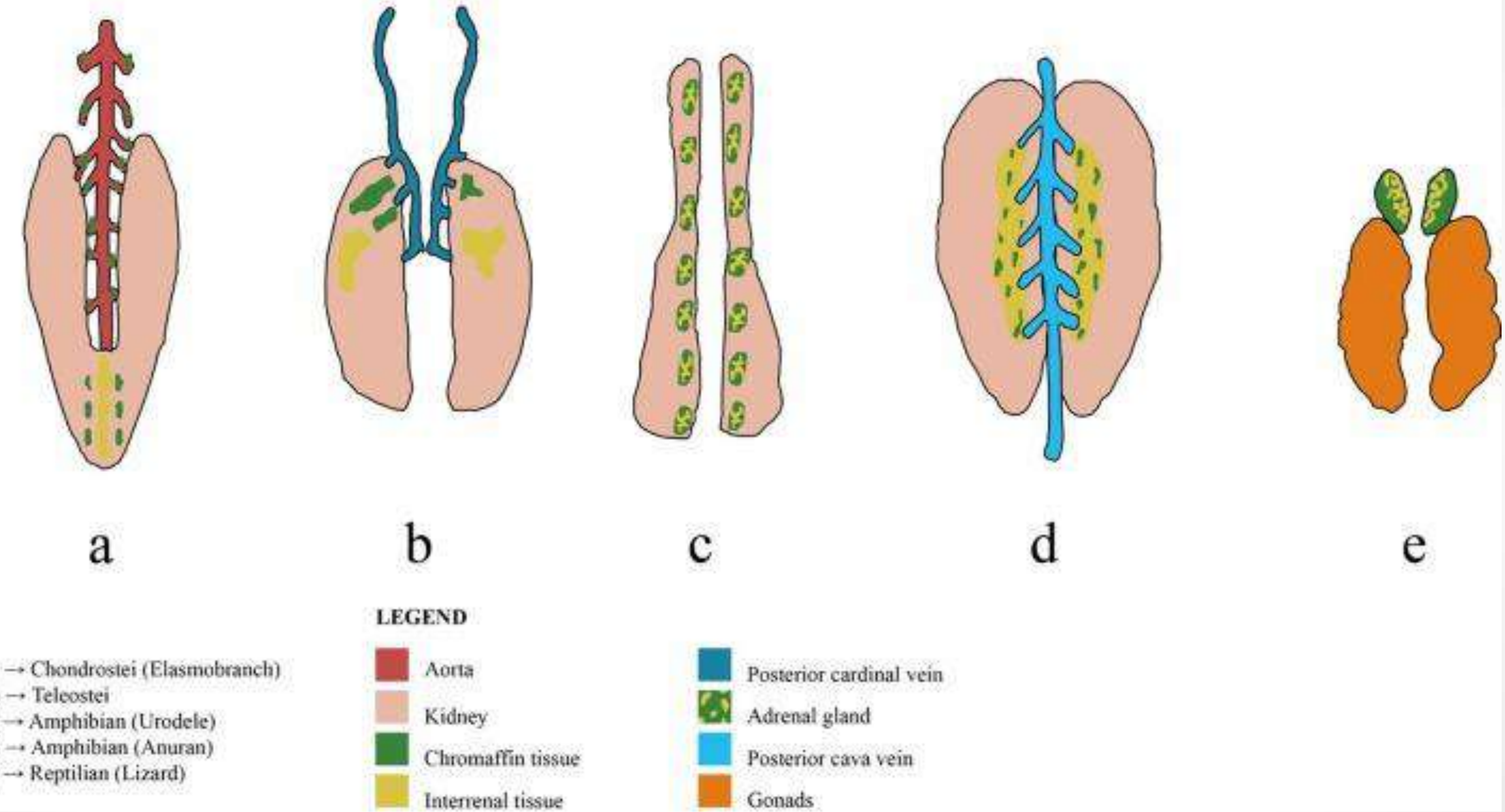
**Origin:** Mesodermal layer of embryo

**Secretion:** Adrenaline, Cortisol

## Function:

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

# Adrenal gland structure




**a** → Chondrostei (Elasmobranch)
**b** → Teleostei
**c** → Amphibian (Urodele)
**d** → Amphibian (Anuran)
**e** → Reptilian (Lizard)

## 4. The Corpuscles of Stannius:

**Location:**

Attached to or embedded in kidneys of holosteans and teleosts

**Origin:**

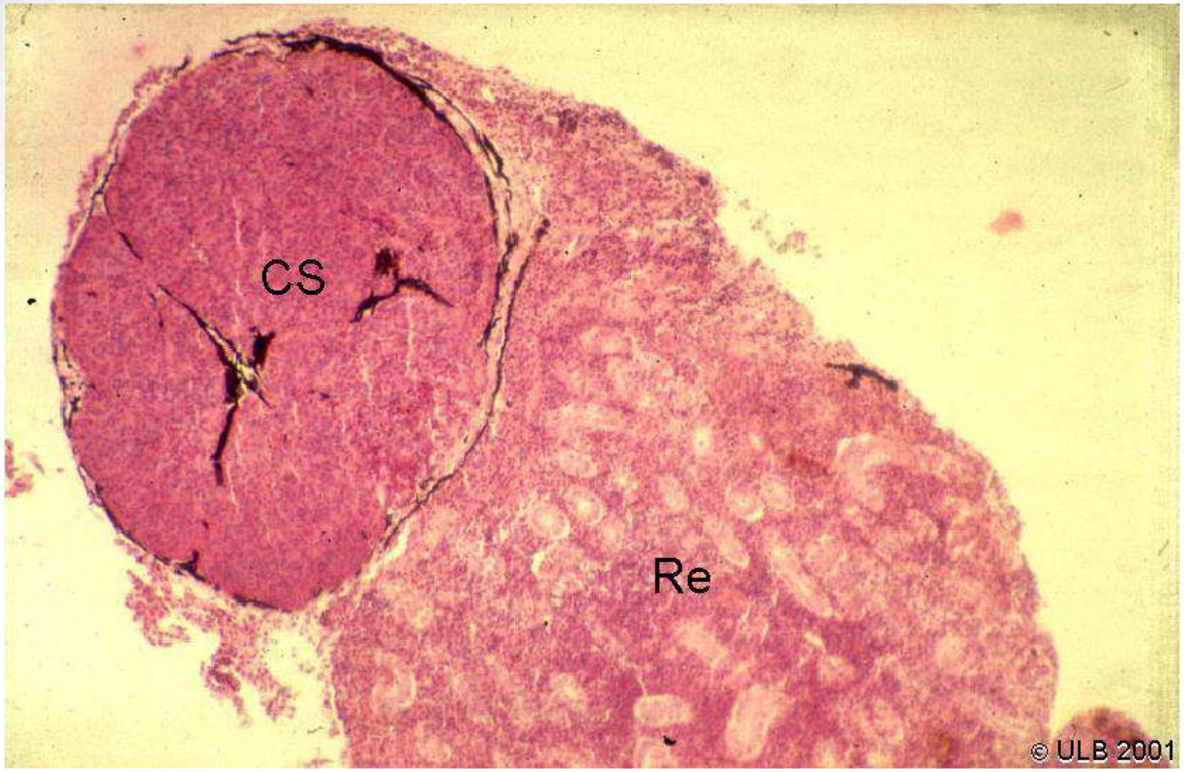
the corpuscles of stannius orginate as outgrowths from the pronephric or the mesonephric duct of the kidney.

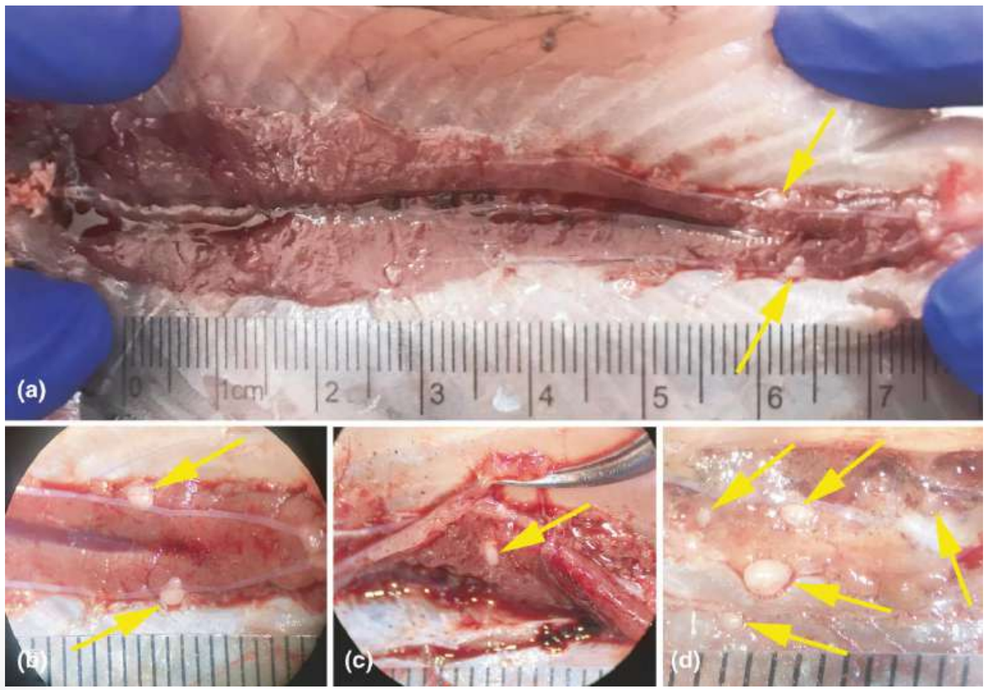
**Nature:** Proteinous

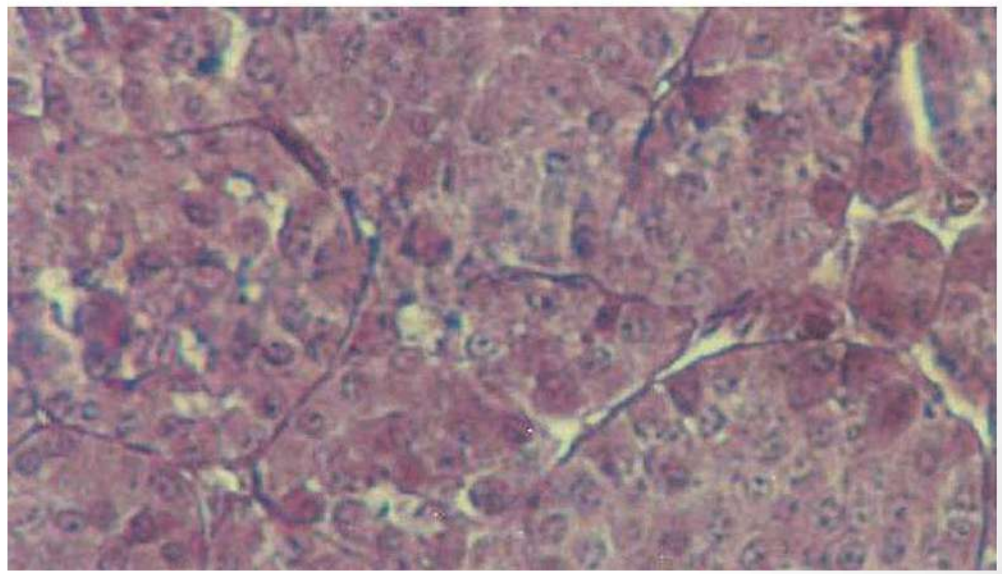
**Secretion:** Hypocalcin

**Colour:** Pink or white

**Function:** Regulates calcium balance


CS
Re
© ULB 2001


(a)
1cm
(b)
(c)
(d)



## 5. The Ultimobranchial Glands:

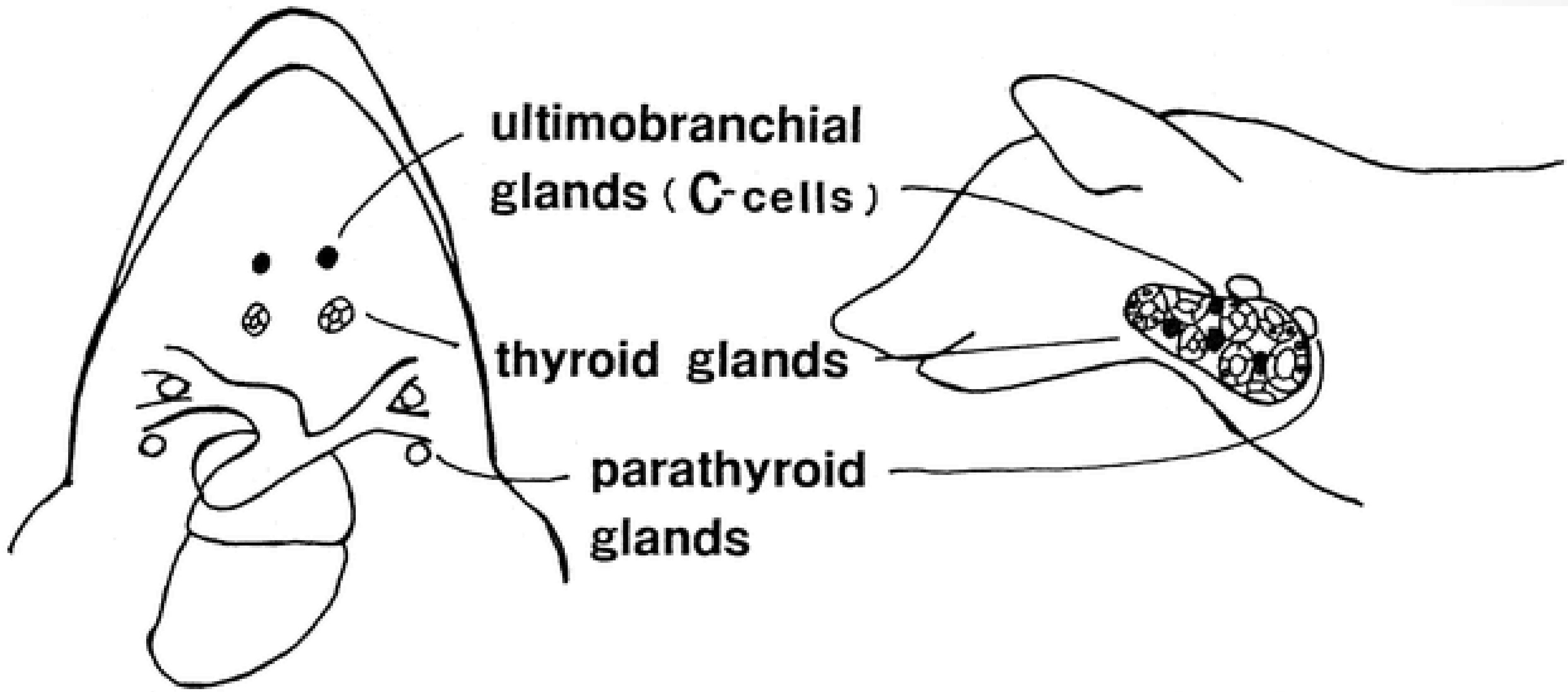
It is also known as post-branchial bodies or suprapericardial bodies or ultimobranchial bodies.

**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.




In non-mammals, those glands are independent.

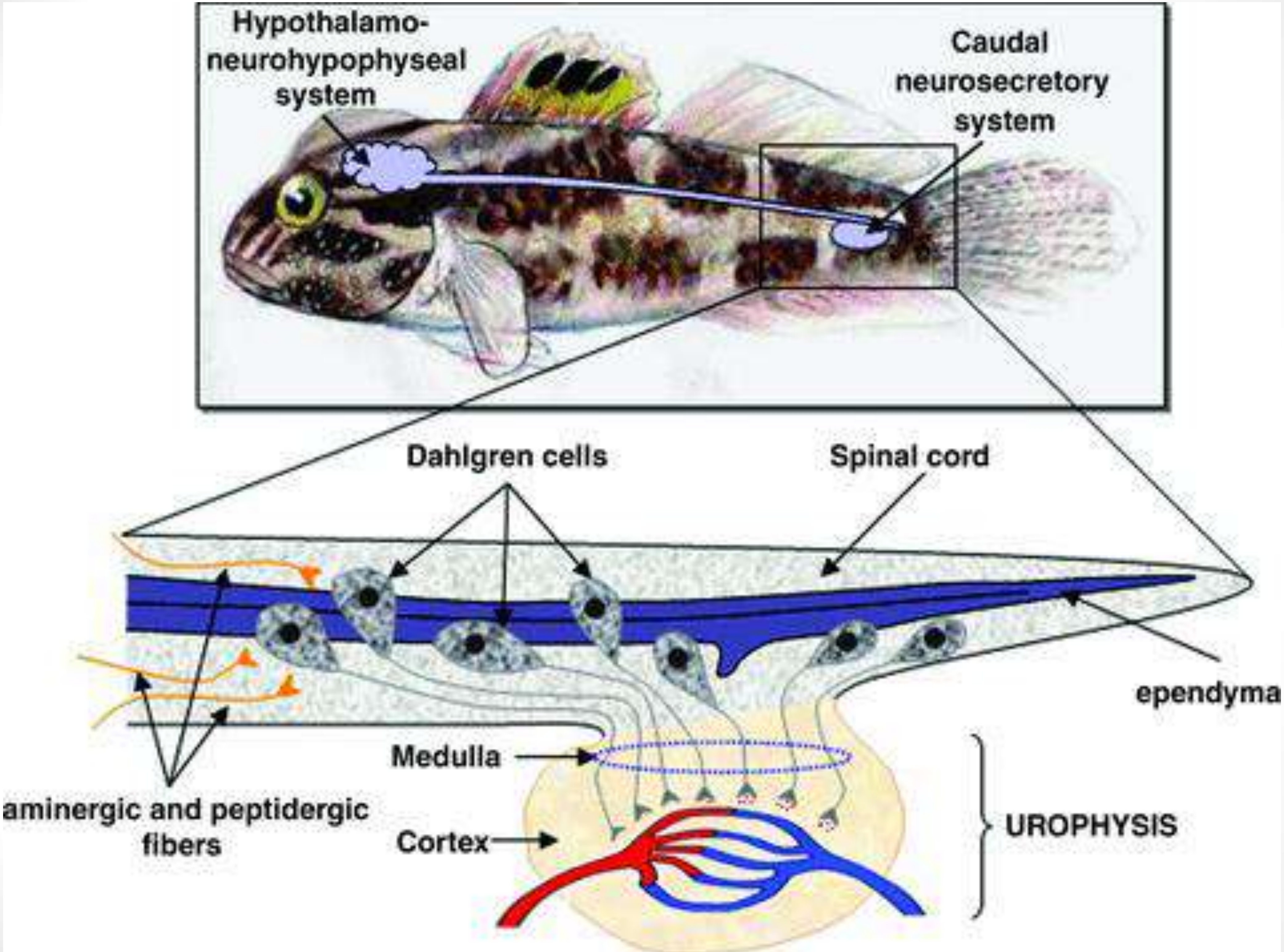
In mammals, those glands are united.

**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.


Hypothalamo-
neurohypophyseal
system
Caudal
neurosecretory
system
Dahlgren cells
Spinal cord
ependyma
Medulla
aminergic and peptidergic
fibers
Cortex
UROPHYSIS

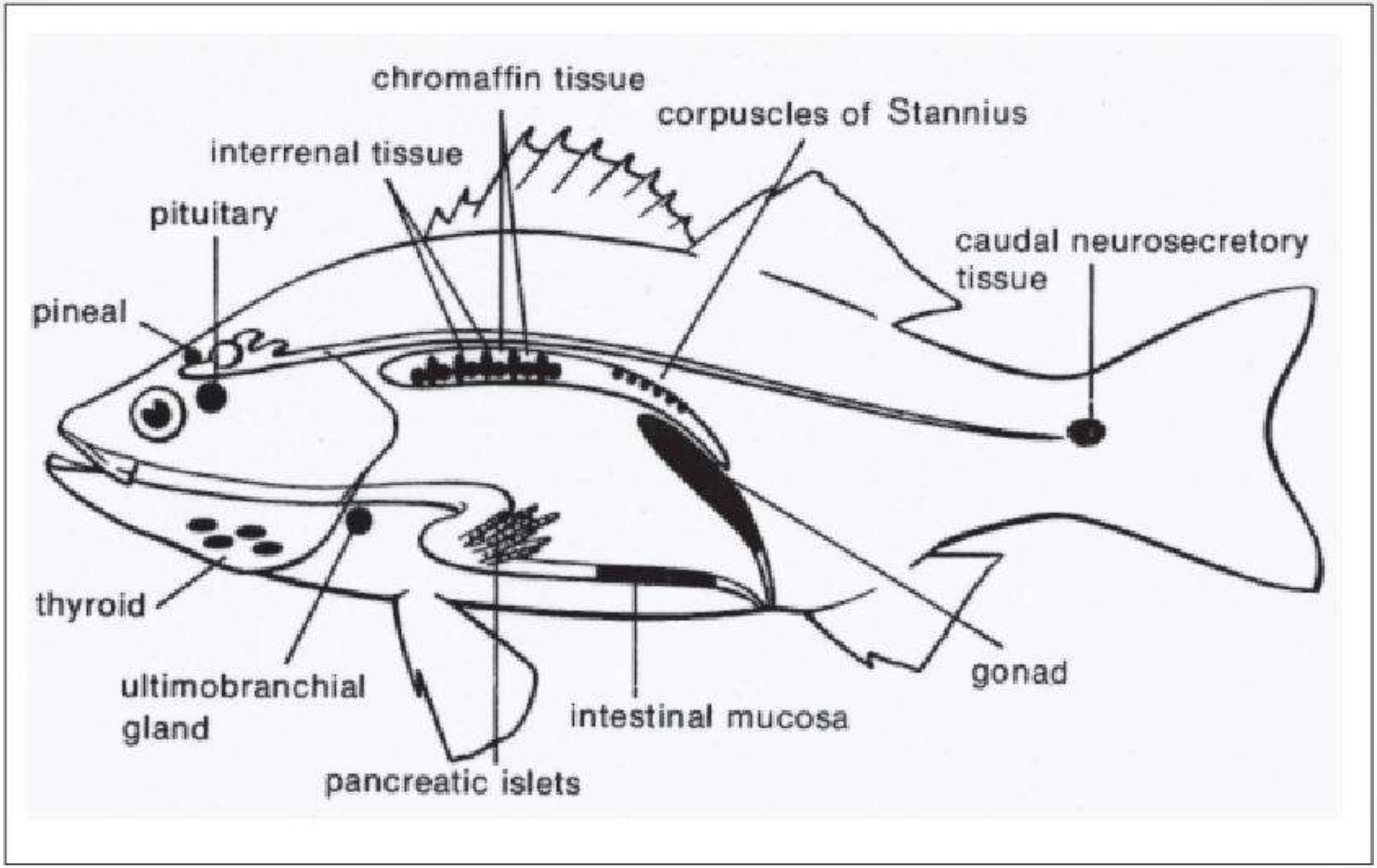
## 7. Pancreatic islets:

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

**Embryonic Origin:** Mesoderm

**Secretion:** Insulin

**Function:** Carbohydrate metabolism

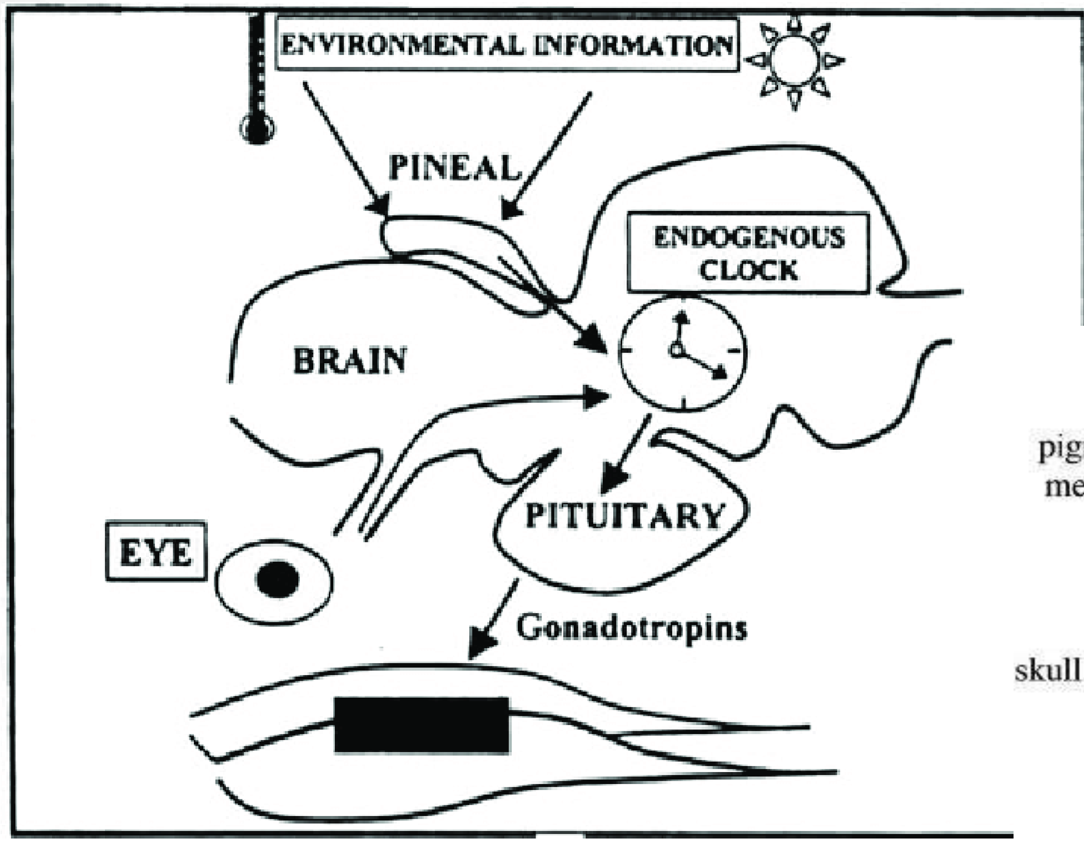

chromaffin tissue
corpuscles of Stannius
interrenal tissue
pituitary
caudal neurosecretory tissue
pineal
thyroid
ultimobranchial gland
pancreatic islets
intestinal mucosa
gonad

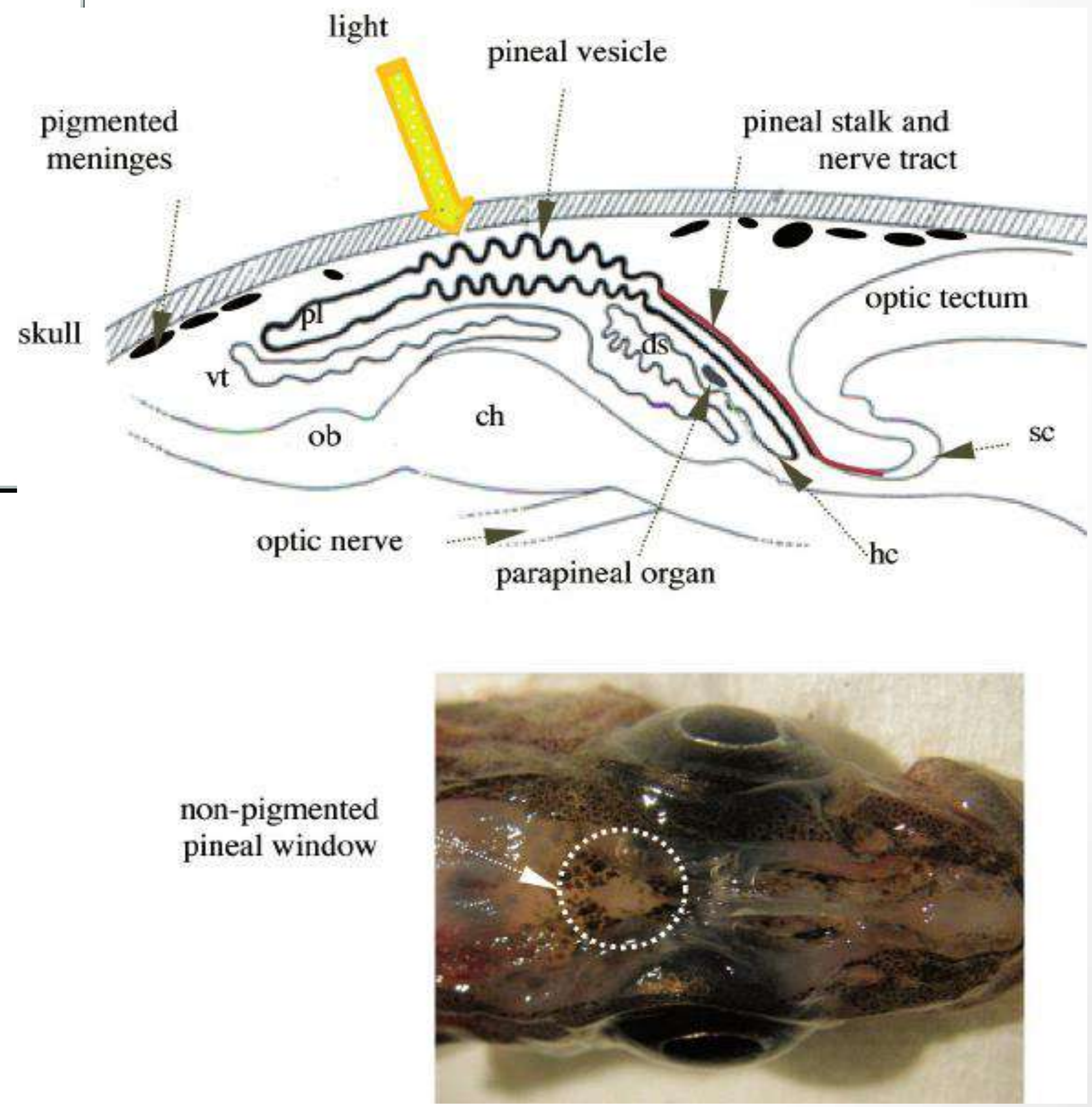
## 8. Pineal gland:

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

**Secretion:** Melatonin

**Function:** Photosensory and secretory function


ENVIRONMENTAL INFORMATION
PINEAL
ENDOGENOUS CLOCK
BRAIN
PITUITARY
EYE
Gonadotropins


light
pineal vesicle
pigmented meninges
pineal stalk and nerve tract
skull
pl
vt
ds
optic tectum
ch
ob
sc
optic nerve
parapineal organ
hc
non-pigmented pineal window

# 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 **external fertilization**
  - less time and energy in courtship, pair bonding
  - increases number of potential mates
  - greater fecundity

- **internal 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

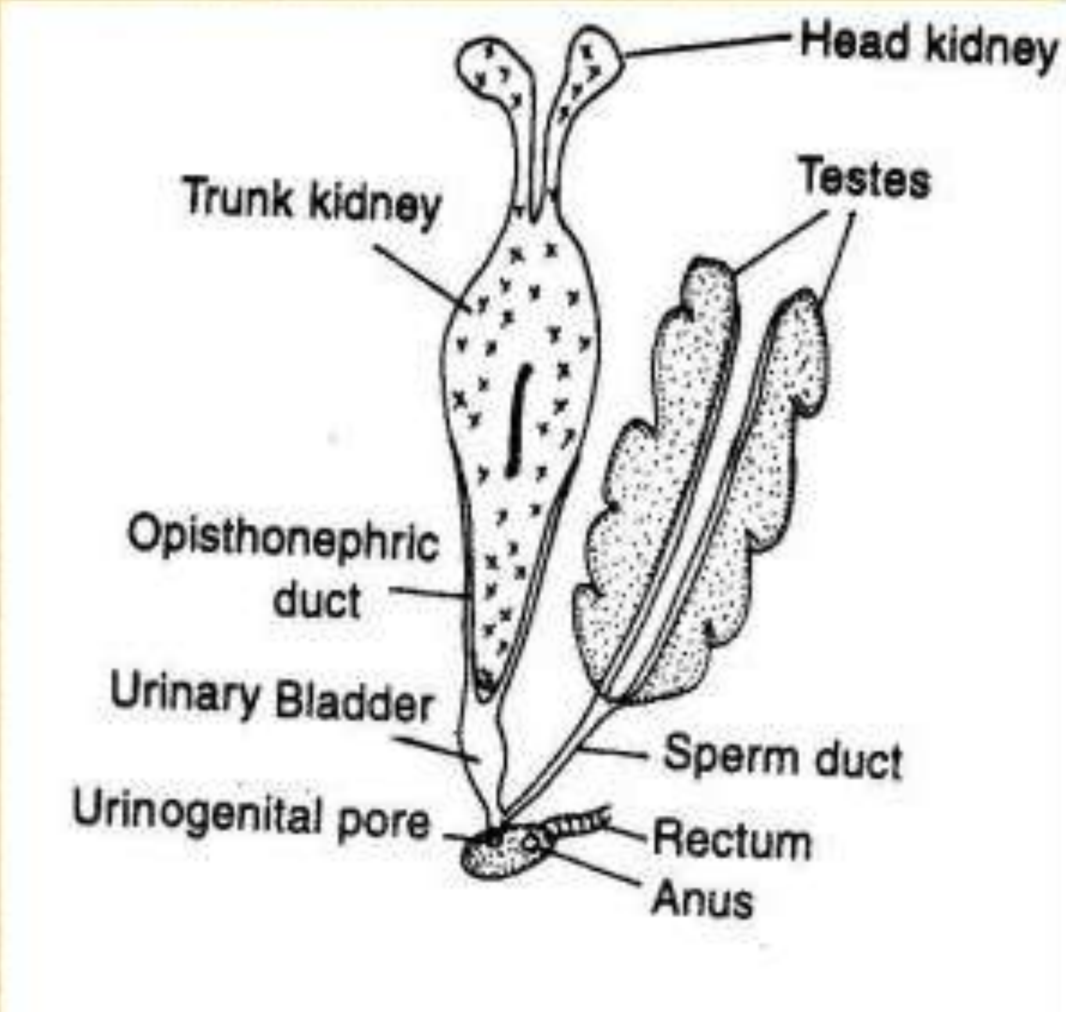
**Male reproductive organ Composed of**

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

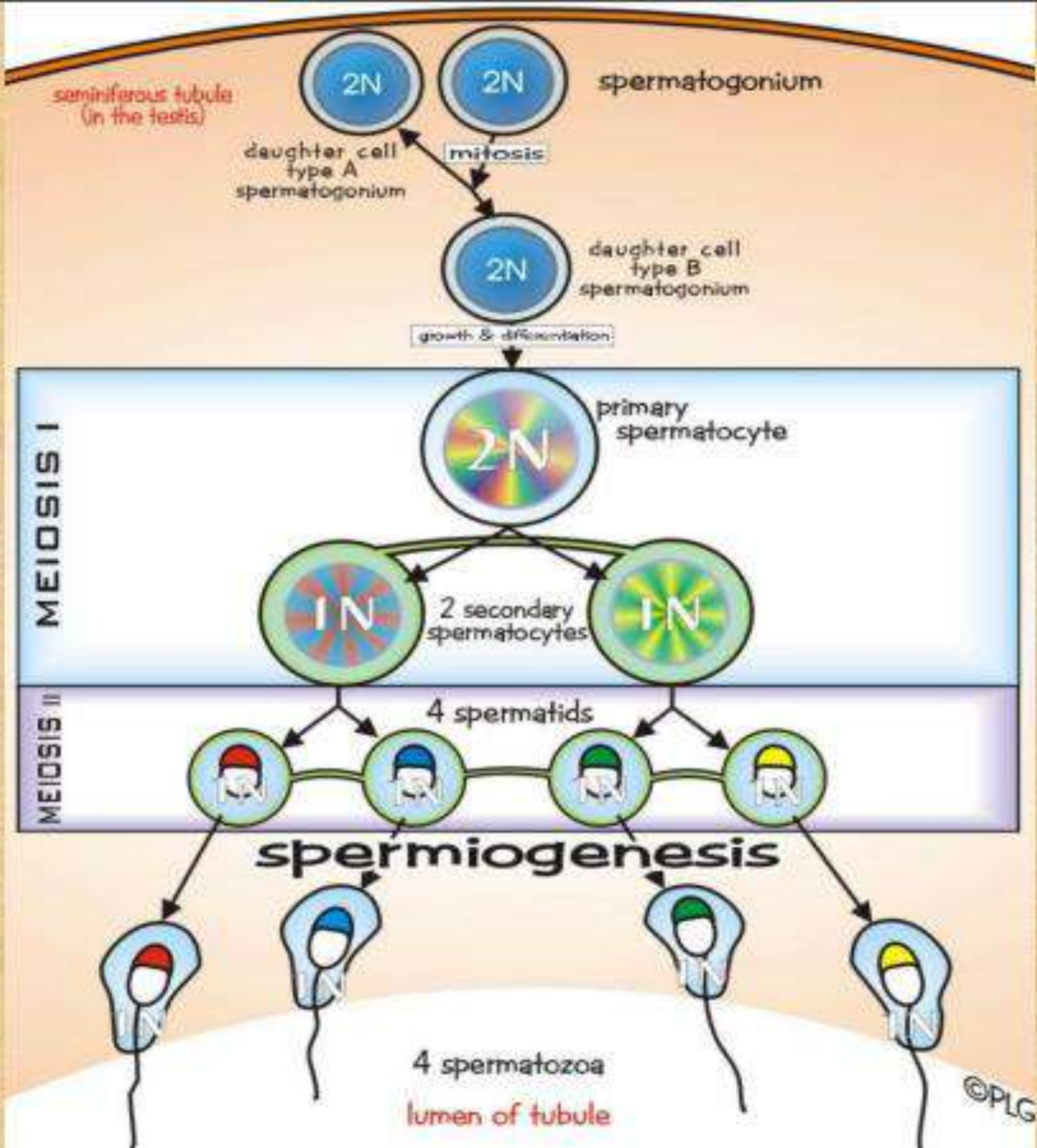
In most cases, testes are a pair of elongated structures composed of numerous seminiferous tubules embedded in the stroma.

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**

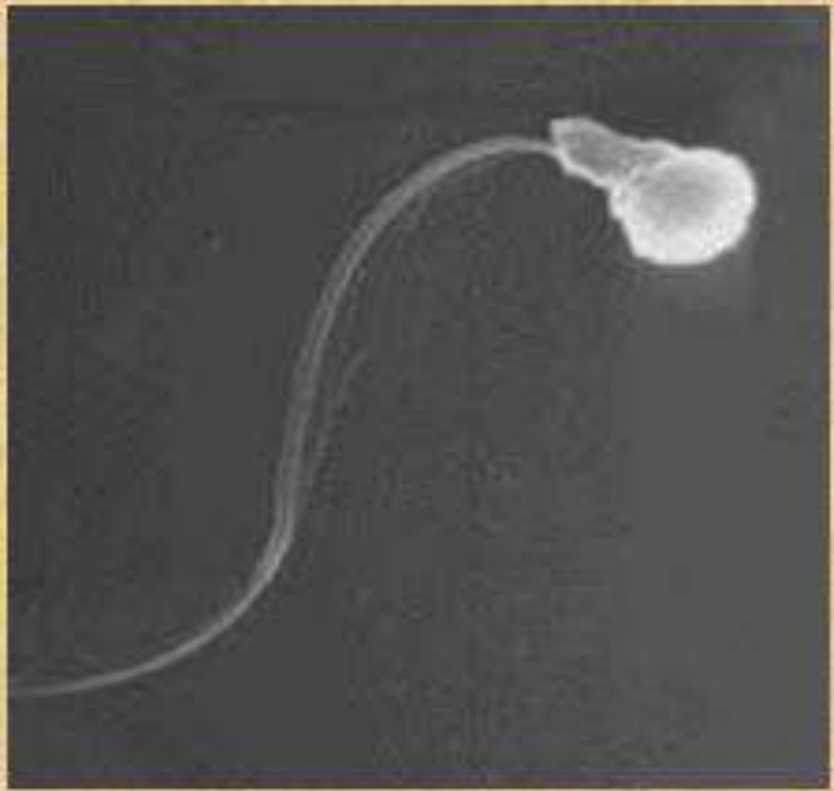
**Spermatids undergo metamorphosis to produce sperm and this process is called spermiogenesis**

## Structure of sperm

a) Head piece

b) Middle piece

c) Tail



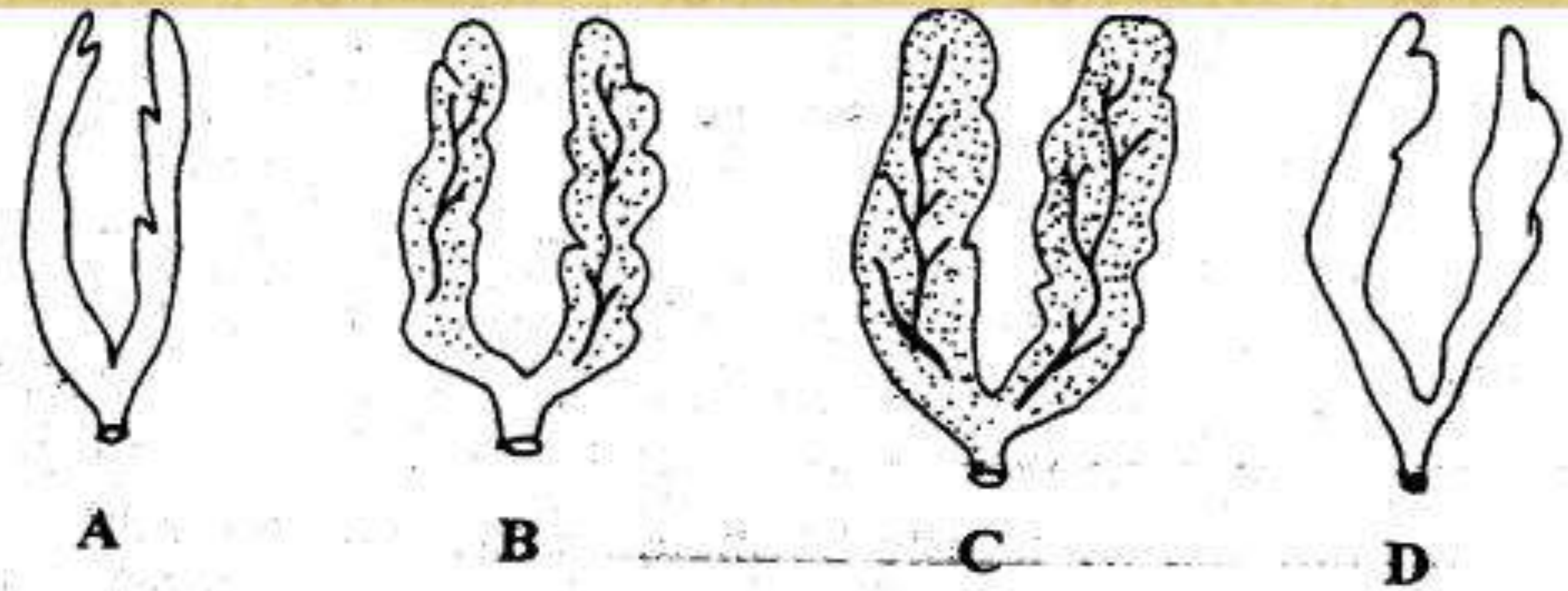
**In fish sperm, acrosomes are absent**

# 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**

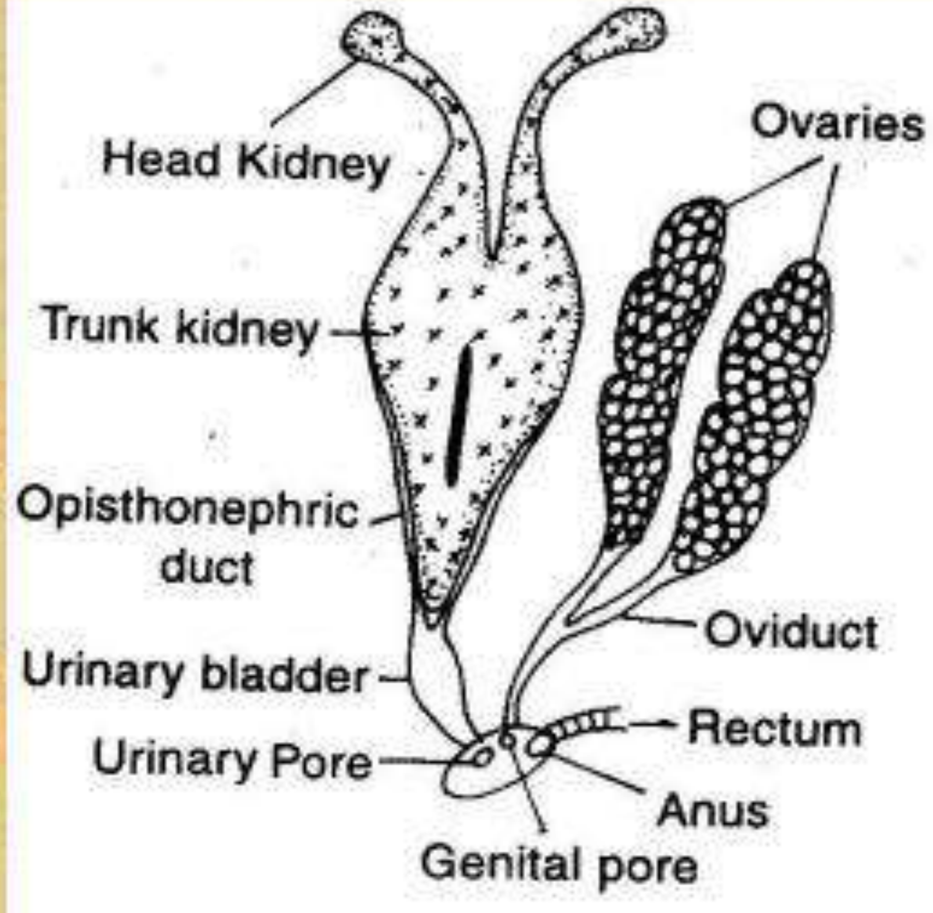
## ii) Oviduct

## 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*)



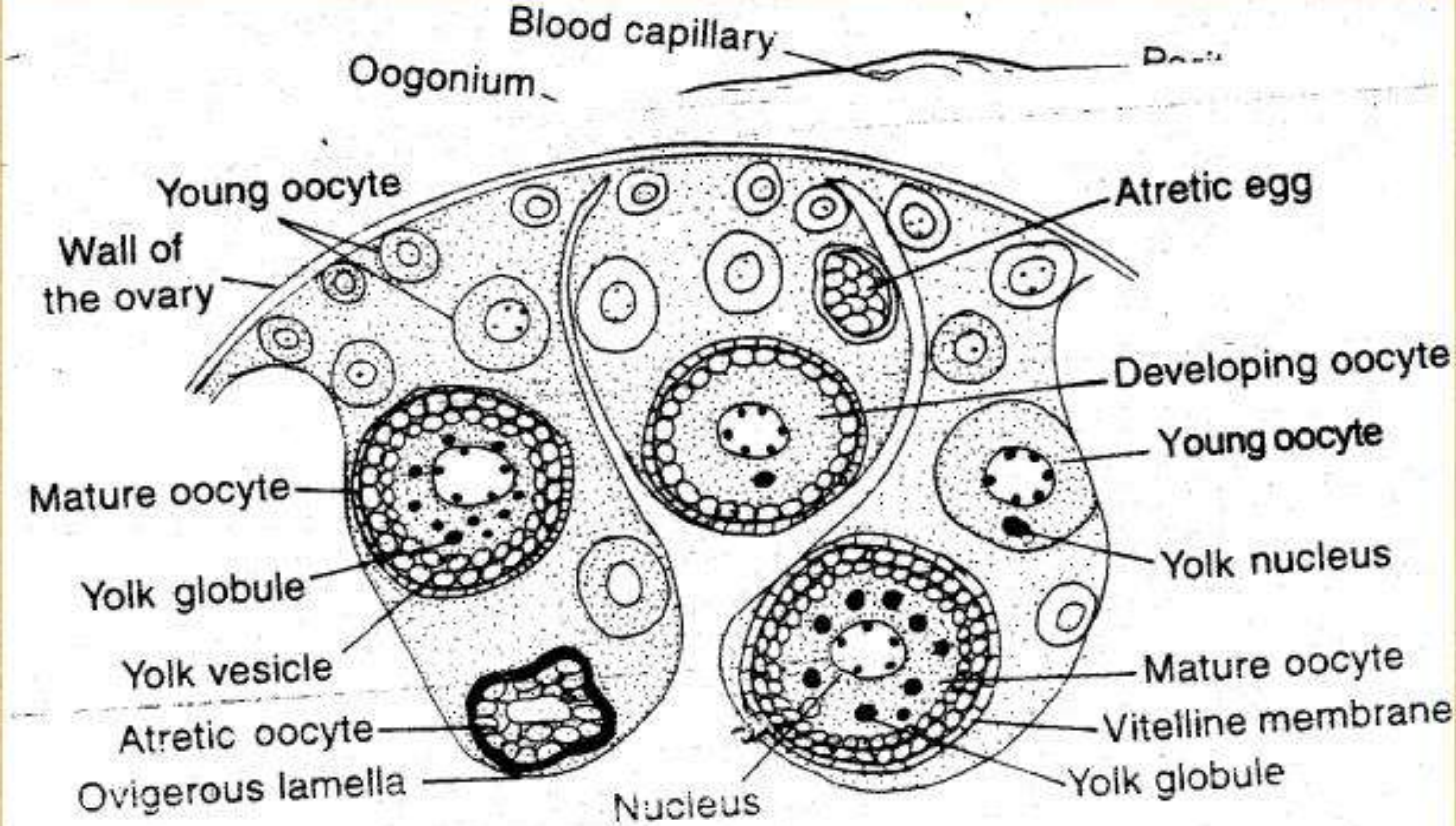
# Ovary

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

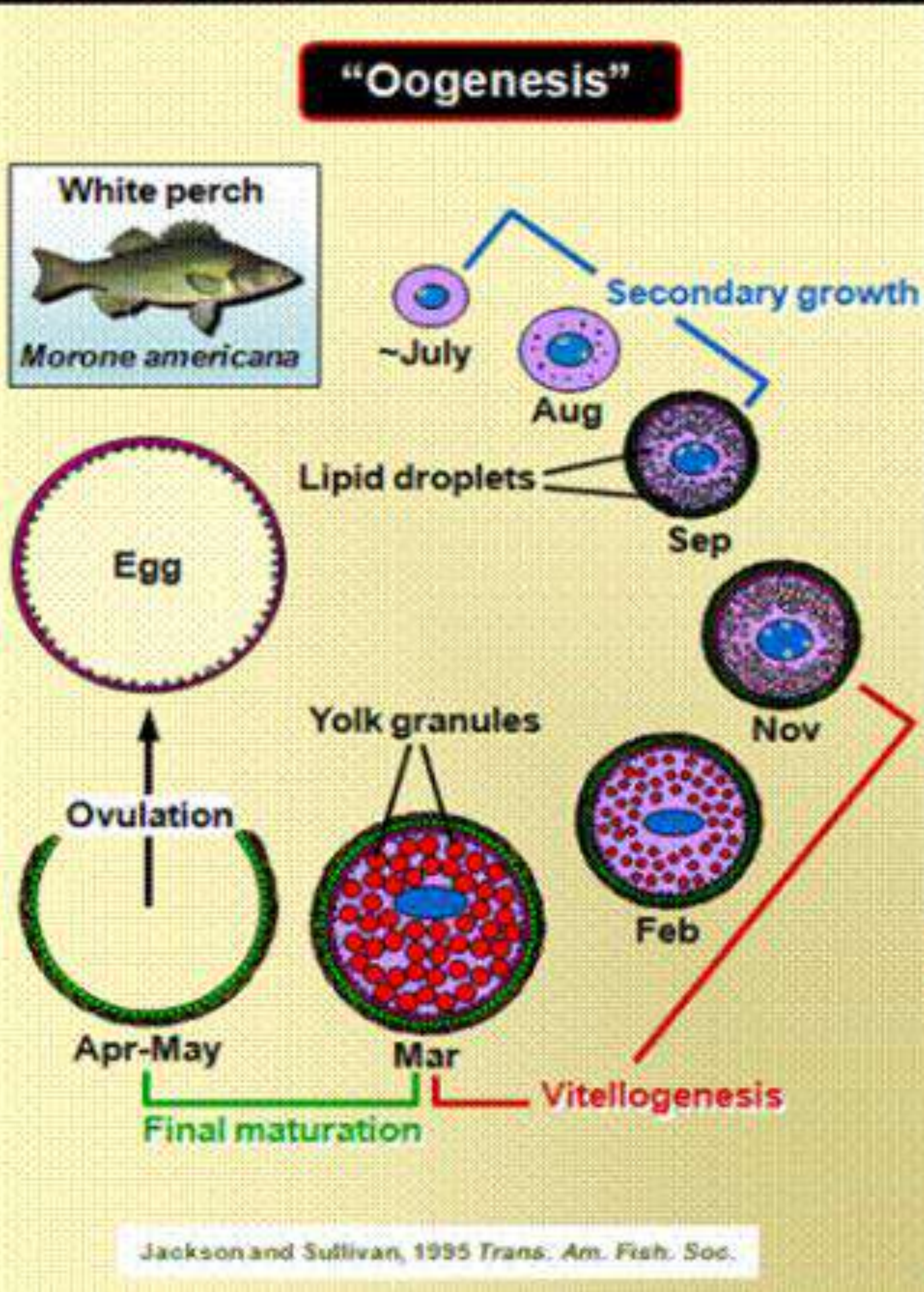
**The germ cells, oogonia (originate from germinal epithelium) multiply mitotically and get transformed into non-yolky primary oocytes**

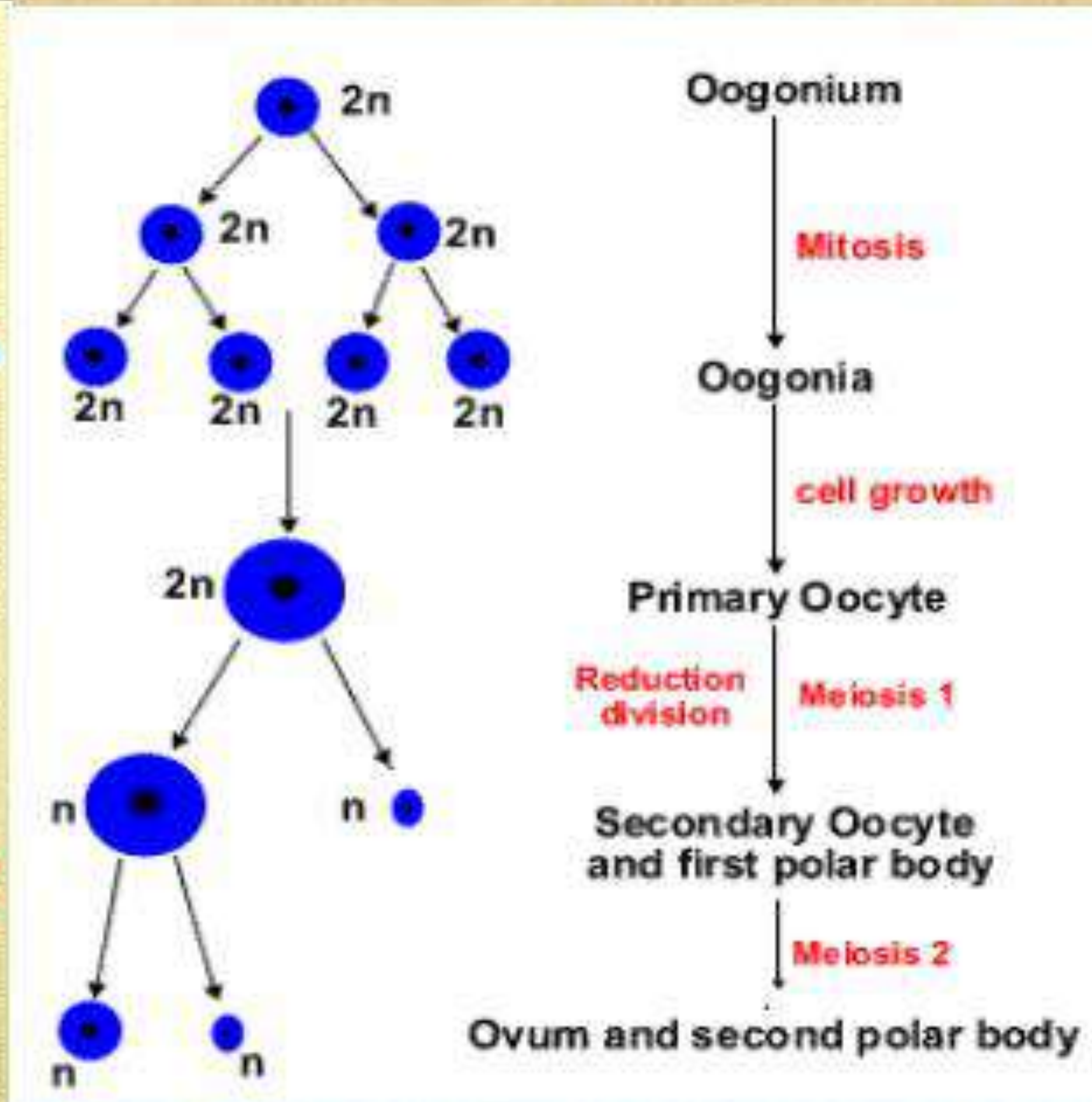
**Primary oocytes, covered generally by two layers of follicle cells, an outer thecal layer and an inner granulosa layer, undergo vitellogenesis when yolk is deposited in the ooplasm.**

**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**



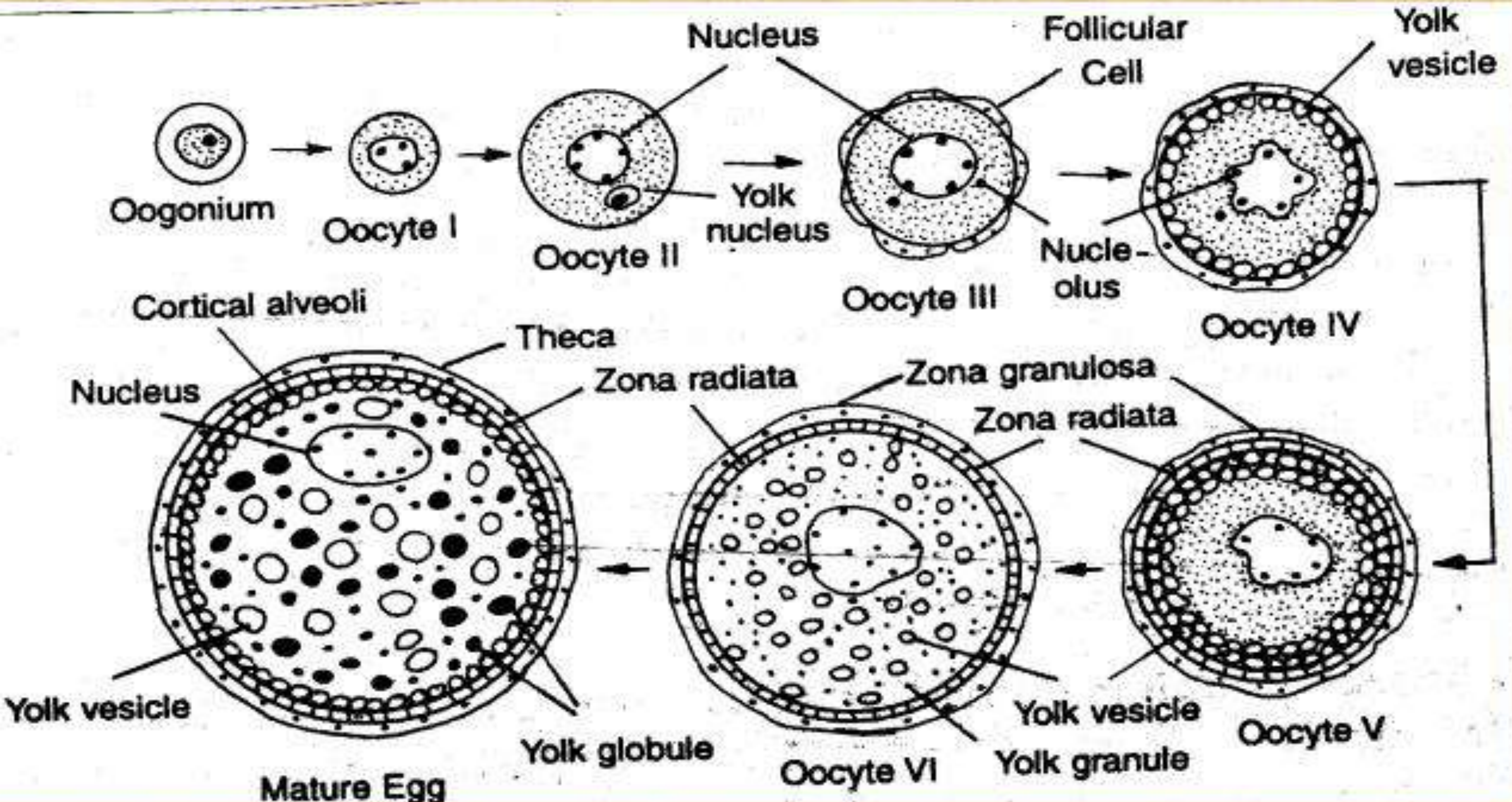

T.S. Mature ovary.




**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.

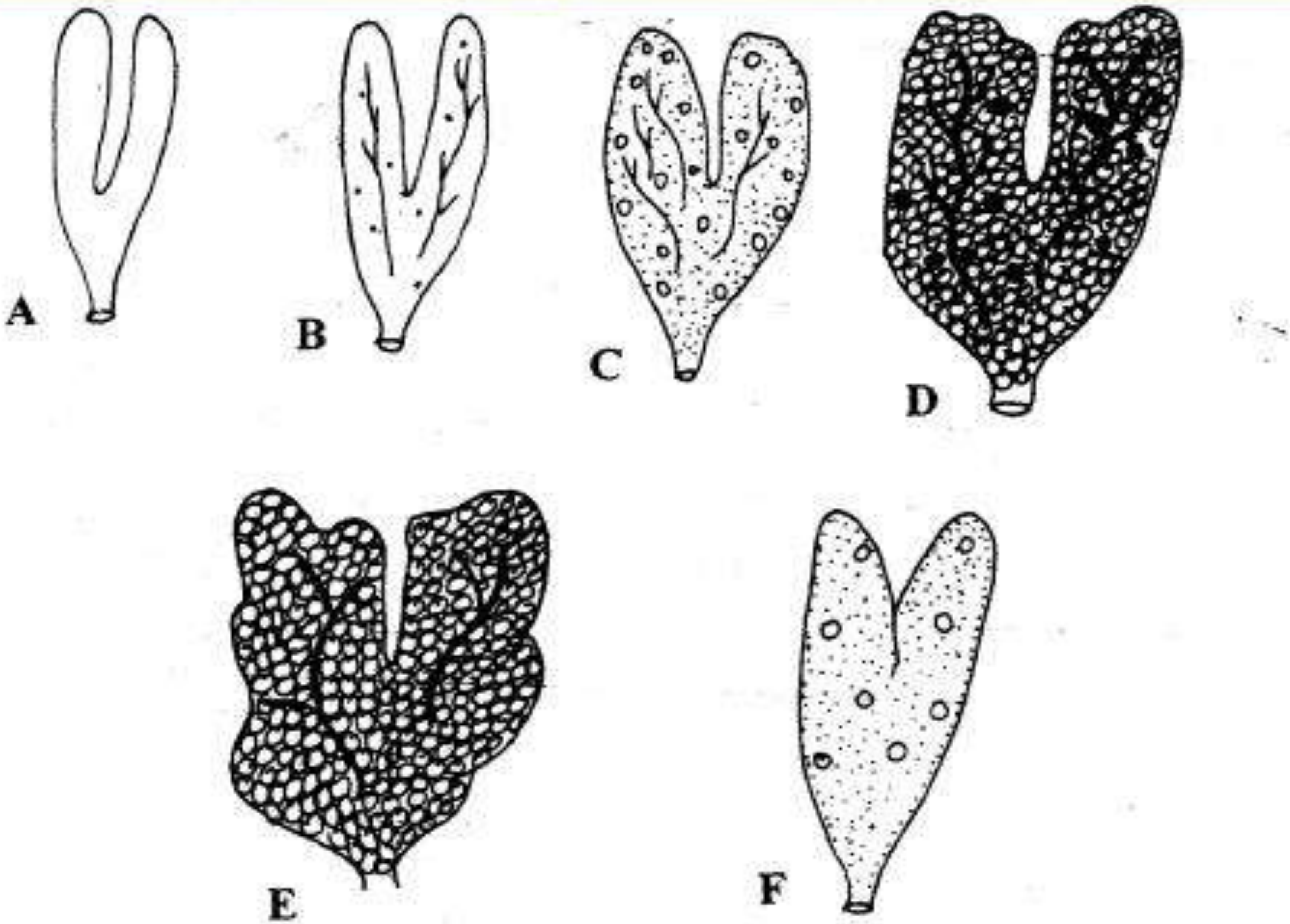
**2. Preparatory phase**: oocytes are in stage III. There is beginning of **vitellogenesis** in the oocyte cytoplasm. Oocyte envelops get differentiated with the thecal and granulosa layers assuming the steroidogenic function. Cells of granulosa layer **start producing female hormone, estradiol**.

**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. **1$^{st}$ 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

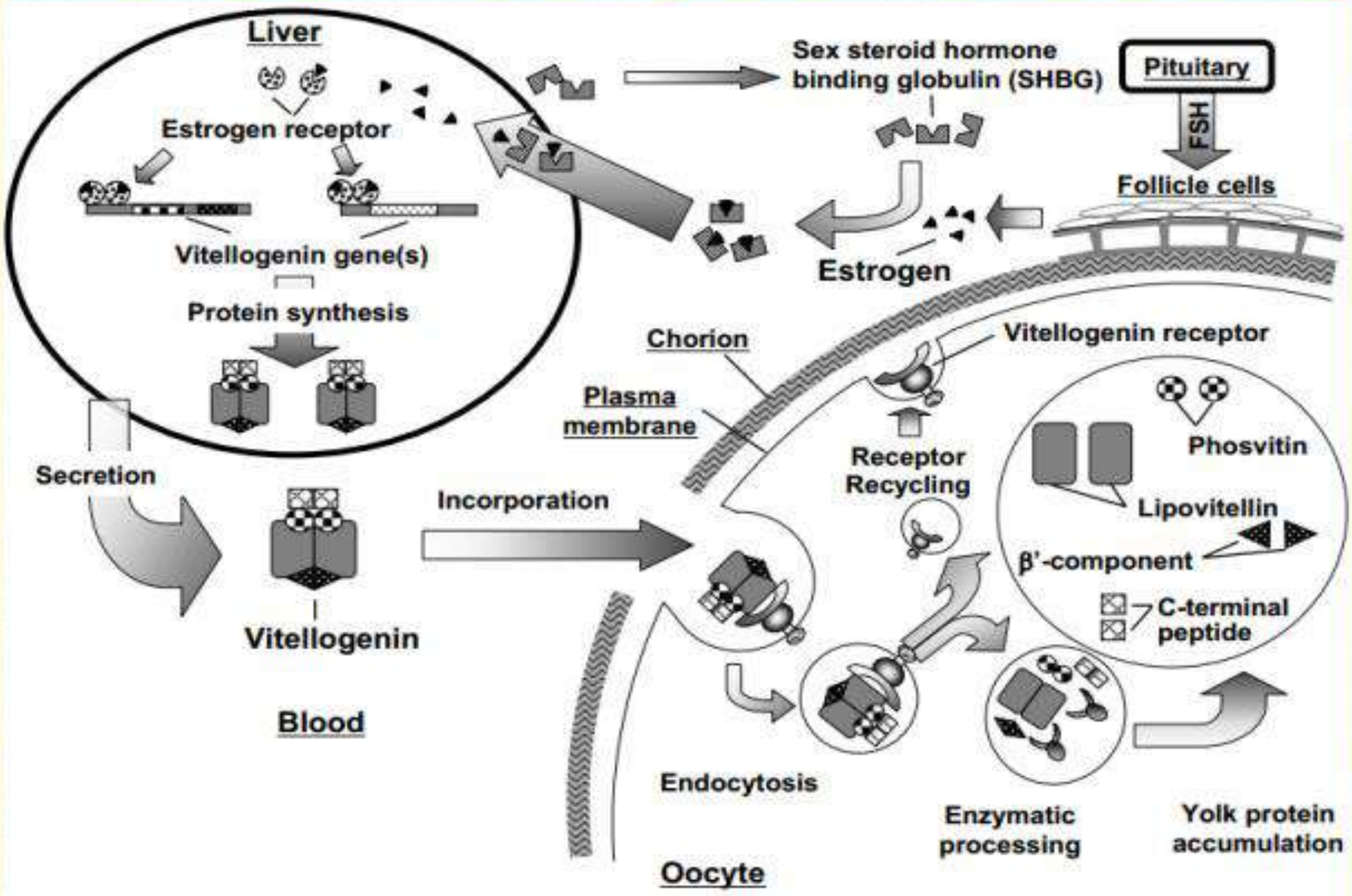
At the beginning there is no yolk. Blood of mature female contain a calcium binding lipophospoprotein called vitellogenin which is synthesized in the liver under the stimulation of female sex steroids. It passes from the plasma to oocyte and undergoes limited proteolysis give rise to yolk protein lipovitellin (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:**

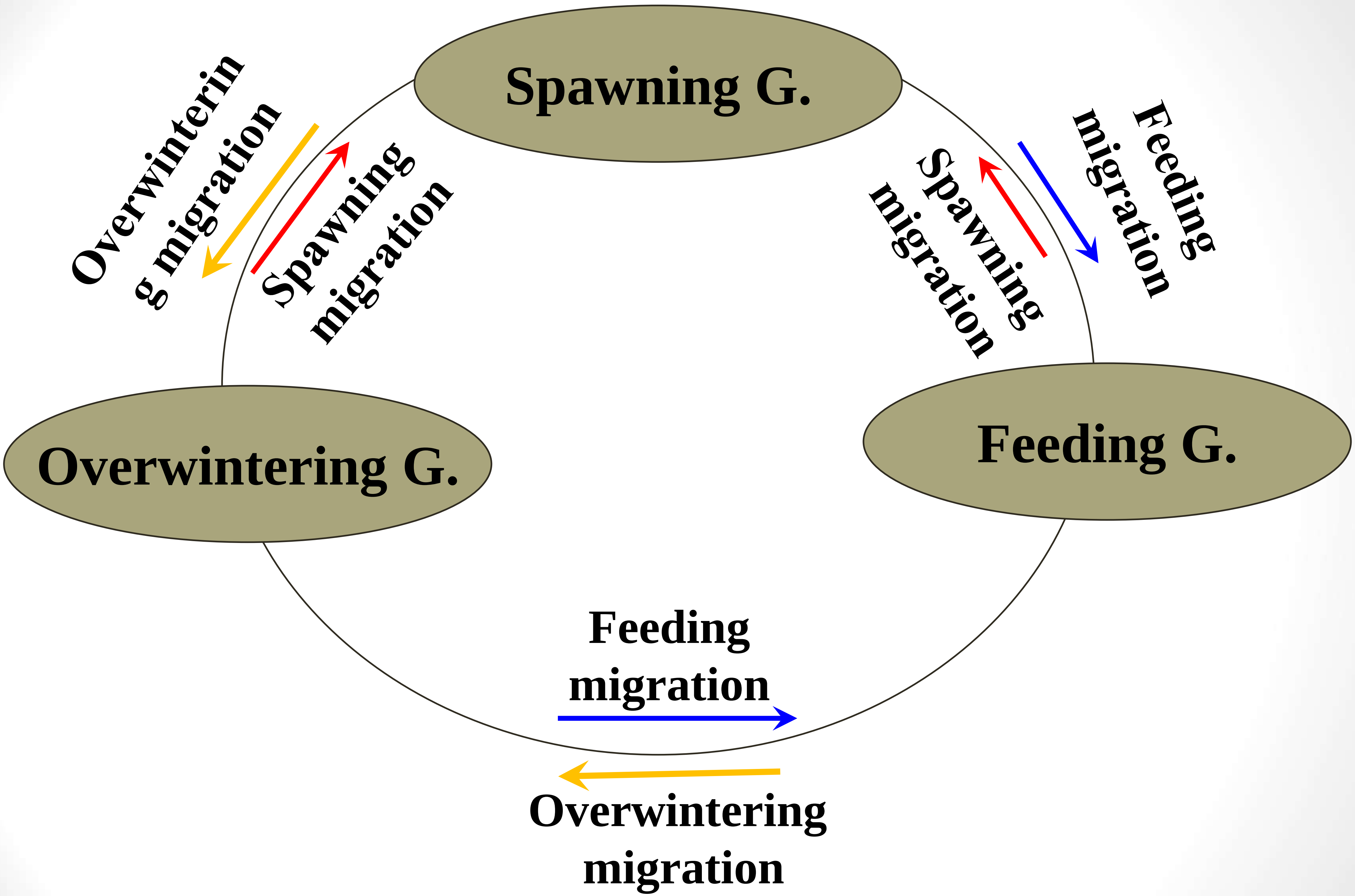
  The movement of fishes from the feeding or overwintering grounds to the spawning grounds.

- **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 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.

# 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.

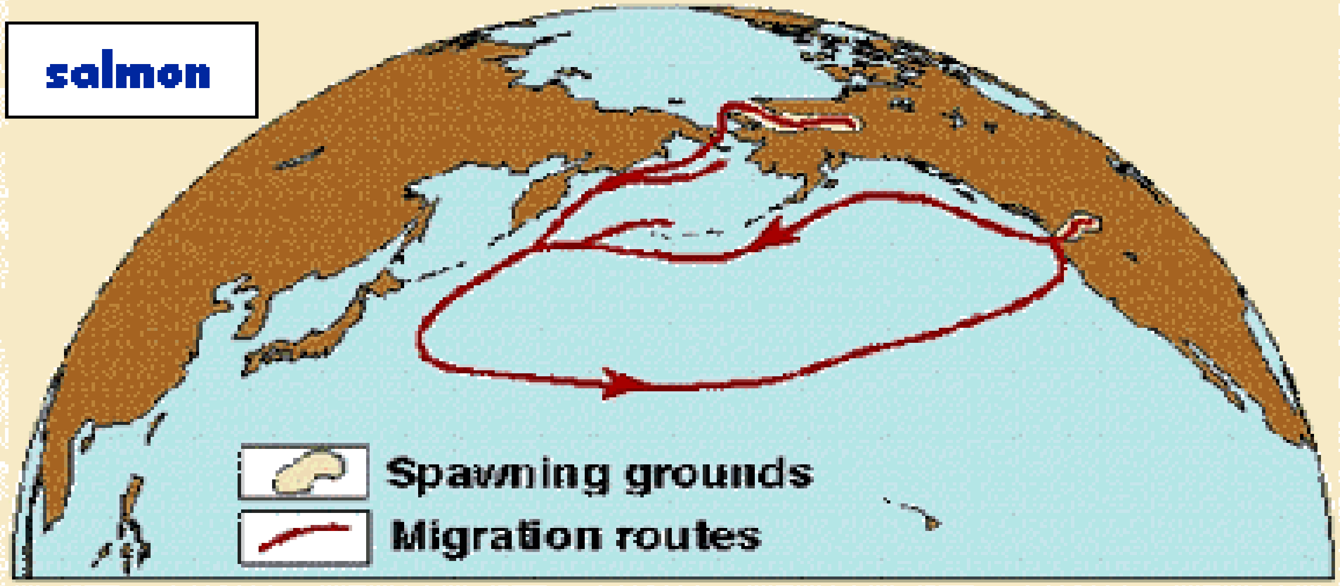
# Fish Migration:

- 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.

- During the course of its journey from its feeding ground in the European rivers to 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.

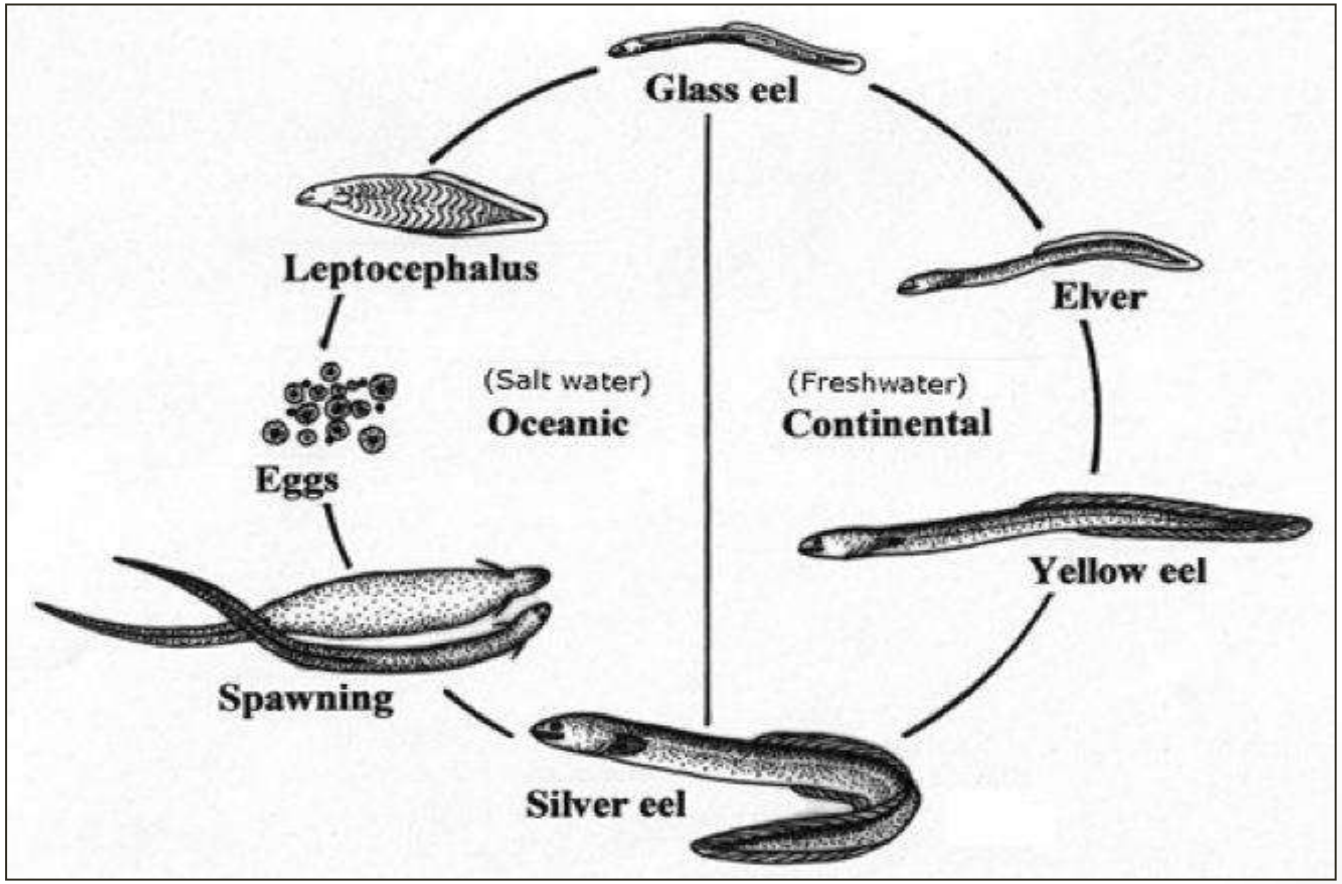
4- Expanded enormous amount of energy so become very thin.

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

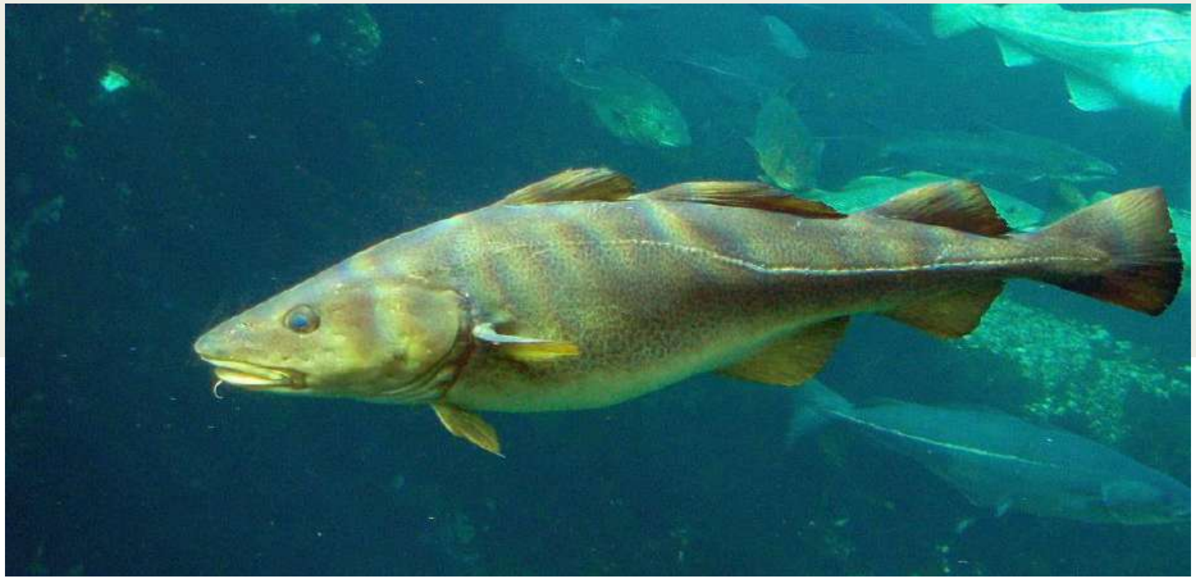
- Feeding migrations is a movement away from the the spawning or overwintering grounds to the feeding grounds and begins in the egg stage.
- The transport of the pelagic eggs and free embryos from the place they were spawned to the feeding grounds is a passive feeding migration.
- The passive feeding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