FISH & FISHERIES BIOLOGY (BIOL 458)

BY

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UNIT TWO
FUNCTIONAL ANATOMY OF FISHES

Unit 2: Functional anat.: ILOs.

- **Know** & **understand** how the body shape & external features of fishes affect their locomotion, way of life, survival, & other diverse functions;

- **Know** & **understand** how the structure of the various organ systems in fish functions to enable them successfully live in their diverse water env't;
  - **Respiration, blood circulation, feeding & digestion, reproduction, nervous system, hydromineral balance, behavioural adaptations**

Unit 2, 1: Form & Movement in Fishes

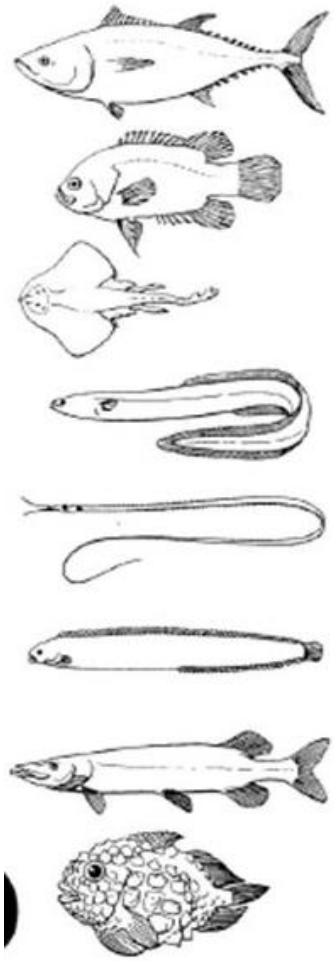
UNIT 2: FUNCTIONAL ANAT. FISH.

- The great ecological diversity of fishes is reflected in the variety of **body shapes** & means of **locomotion** they possess..

- Much is learnt about fish ecology by examining its anatomical features/watching movement in water.

- These features also form the basis for most schemes of classification & identification.

UNIT 2: FUNCTIONAL ANAT. FISH.



Fusiform (Tuna)

Compressiform (Tautog)

Depressiform (Skate)

Anguilliform (Eel fish)

Filiform (Pipe fish)

Taeniform (Ribbon fish)

Sagittiform (Snake head)

Globiform

BODY SHAPE

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

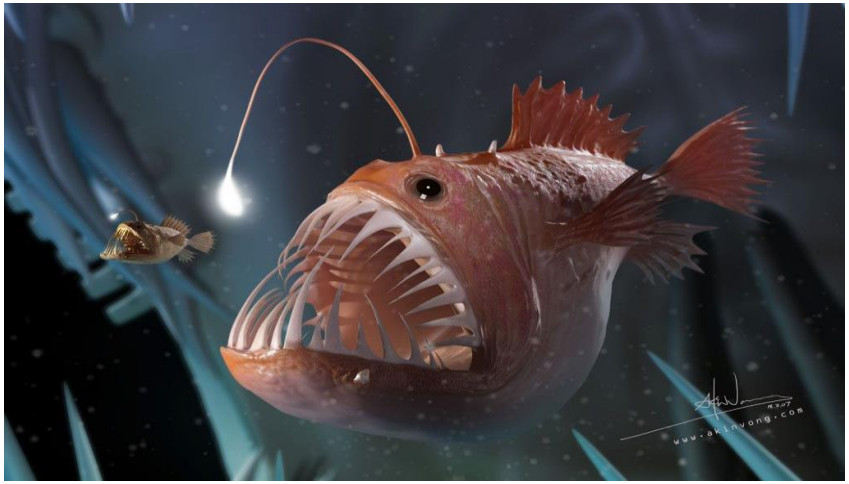
UNIT 2: FUNCTIONAL ANAT. FISH.

- Success of fishes despite constraints of living in water

- This results in many unlikely forms e.g. seahorses, anglerfishes, pufferfishes, lumpfishes, etc….

- But more fish-like species are placed in functional categories based on their **body shape**, **scales**, **fins**, **mouth**, **gill openings**, **sense organs**, etc**.**

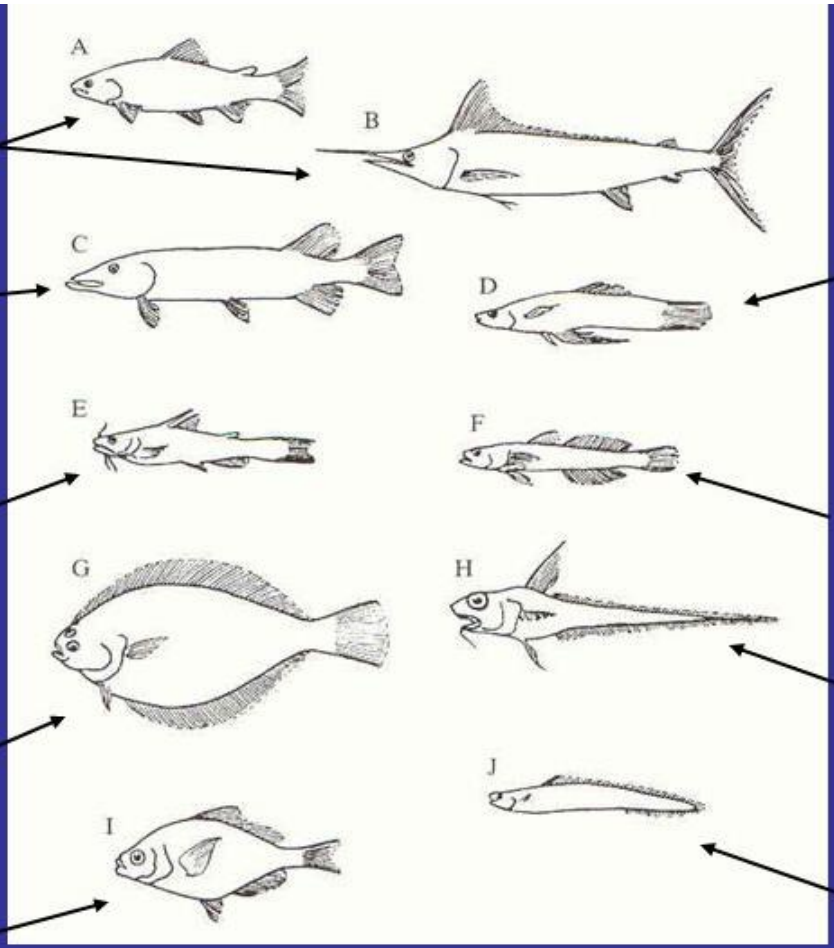
UNIT 2: FUNCTIONAL ANAT. FISH.



UNIT 2: FUNCTIONAL ANAT. FISH.

- Most fishes fall into one of 6 broad categories based on body shape or configuration:
  - (1) **rover predator**,
  - (2) **lie-in-wait predator**,
  - (3) **surface-oriented fish**,
  - (4) **bottom fish**,
  - (5) **deep-bodied fish**, &
  - (6) **eel-like fish**…

UNIT 2: FUNCTIONAL ANAT. FISH.



Rover-predator
Tuna, swordfish, bass, trout

Lie-in-wait
Pikes, barracuda, gars

Bottom rover
Catfishes, sturgeons

Flatfish

Deep-bodied
Perch,

Surface-oriented
Four eyed fish, killifish

Bottom clinger
Sculpins, gobies, clingfishes

Rattail
Chimeras, brotulas

Eel-like

UNIT 2: FUNCTIONAL ANAT. FISH.

- **i) *Rover-predators***
  - body shape is streamlined (***fusiform***)…
  - has pointed head with a terminal mouth…
  - has narrow caudal peduncle with a forked tail…
  - fins are more or less evenly distributed about body,
  - they typically are constantly moving & searching out prey, which they capture through pursuit,
  - E.g. many species of minnows, tuna, mackerel, etc

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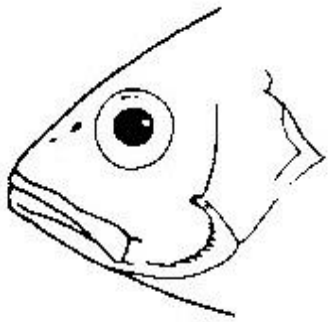
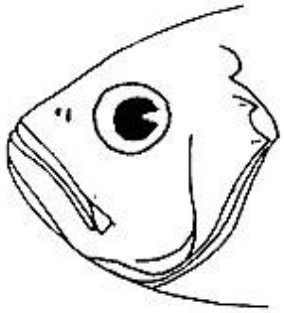
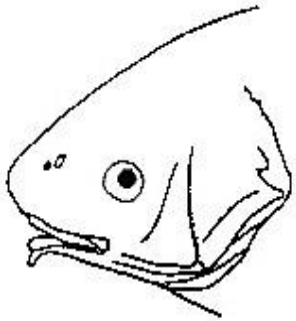


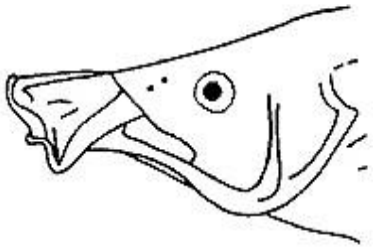
terminal



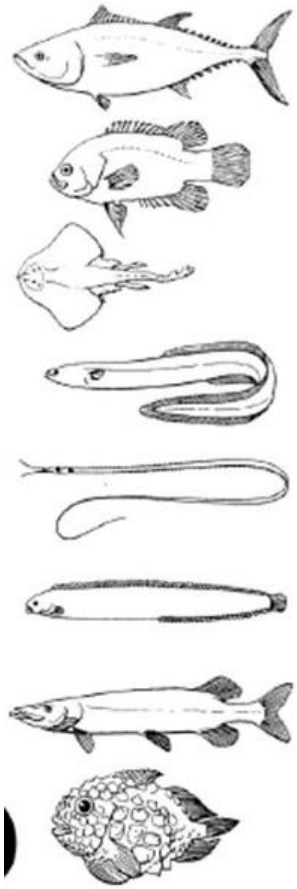
superior



inferior



protrusible



Fusiform (Tuna)

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Depressiform (Skate)

Anguilliform (Eel fish)

Filiform (Pipe fish)

Taeniform (Ribbon fish)

Sagittiform (Snake head)

Globiform

UNIT 2: FUNCTIONAL ANAT. FISH.

- **ii)** ***Lie-in-wait predators***
  - body is **fusiform**, also elongate, often torpedo-like;
  - **head** is flattened & equipped with a large mouth with pointed teeth & long, pointed snout
  - **caudal** fin is large & the **dorsal** & **anal** fins are placed far back on the body, in line with each other;
  - mainly ***piscivores*** with morphology well suited for the ambushing of fast-swimming prey;
  - their cryptic coloration & secretive behaviour makes them less visible to their prey

UNIT 2: FUNCTIONAL ANAT. FISH.

- **iii) *Surface-oriented fish***
  - a **fusiform** to deep body,
  - have an upward-pointing **mouth** (superior) & a dorsoventrally flattened **head** with large eyes,..
  - are typically small in size & stocky-bodied,
  - a **dorsal fin** placed toward the rear of the body;
  - **morphology** suited for capturing plankton & small fishes near surface of water or insects that land on the surface.

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- **iv) *Bottomfish***
  - possess a wide variety of body shapes, all adapted for a life in nearly continuous contact with the bottom..
  - In most of them, the **swim-bladder** is reduced or absent; &
  - most are flattened in one direction or another

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- **iv) *Bottomfish***
- Bottom fish can be divided into 5 overlapping types:
  - (1) **bottom rovers**,
  - (2) **bottom clingers**,
  - (3) **bottom hiders**,
  - (4) **flatfish**, &
  - (5) **rattails**

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- **v) *Deep-bodied-fish***
  - laterally flattened (**compressiform**)…
  - **body depth** usually a 3rd of the standard length
  - **dorsal** & **anal** fins are typically long, **pectoral** fins are located high on the body, with the **pelvic** fins immediately below
  - mouth is usually small & **protrusible**,

UNIT 2: FUNCTIONAL ANAT. FISH.

- **v) *Deep-bodied-fish* (cont)**
  - Large **eyes** & short **snout**
  - Well-adapted for manoeuvring in tight quarters e.g. in coral reefs, dense beds of aquatic plants, etc
  - well adapted for picking small invertebrates off the bottom or out of the water column;

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- **v) *Deep-bodied-fish* (cont)**
  - most have **stout spines** in **fins**, having sacrificing speed for manoeuvrability & developing spines for protection from predators
  - most are closely associated with the bottom, but many open-water plankton feeders (*planktivores;* e.g., herring) are also moderately deep-bodied

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- **vi)** ***Eel-like fish***
  - have **elongate bodies**,
  - **blunt** or **wedge-shaped** heads,
  - **tapering** or **rounded** tails
  - if paired fins are present, they are small, but their **dorsal** & **anal fins** are typically quite long

UNIT 2: FUNCTIONAL ANAT. FISH.

- **vi) *Eel-like fish* (cont)**
  - **scales** are small & embedded or absent
  - in cross-section, their bodies can range from compressed to round
  - well **adapted** for entering small crevices & holes & for making their way through beds of aquatic plants, or for burrowing into soft bottoms

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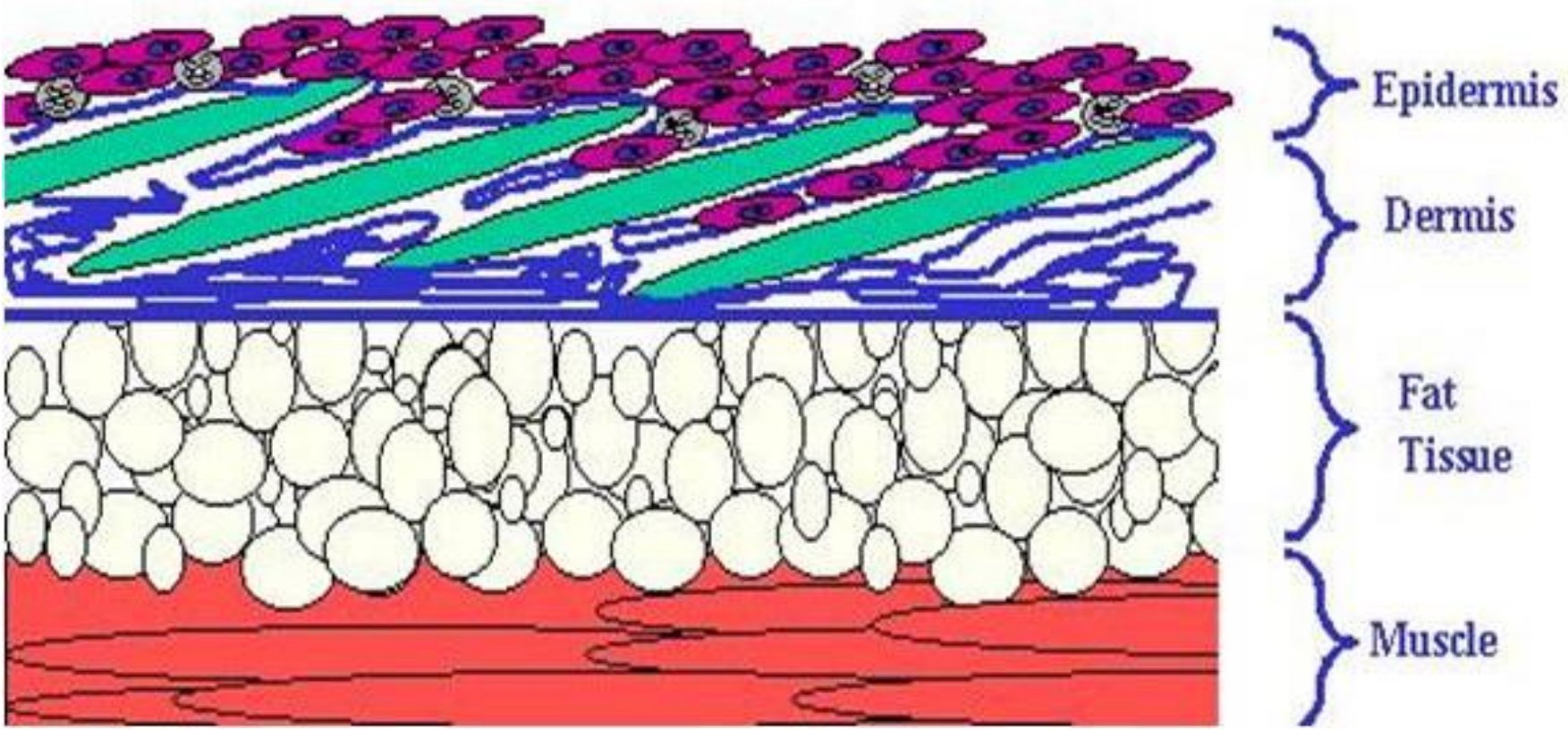
- **vi) *Eel-like fish***
  - A surprising number found in open ocean, so this body shape is useful for other purposes as well
  - E.g.s of this group are many eels (Anguilliformes), loaches (Cobitidae), & gunnels (Pholididae).

Unit 2: Functional anat.: skin & scales

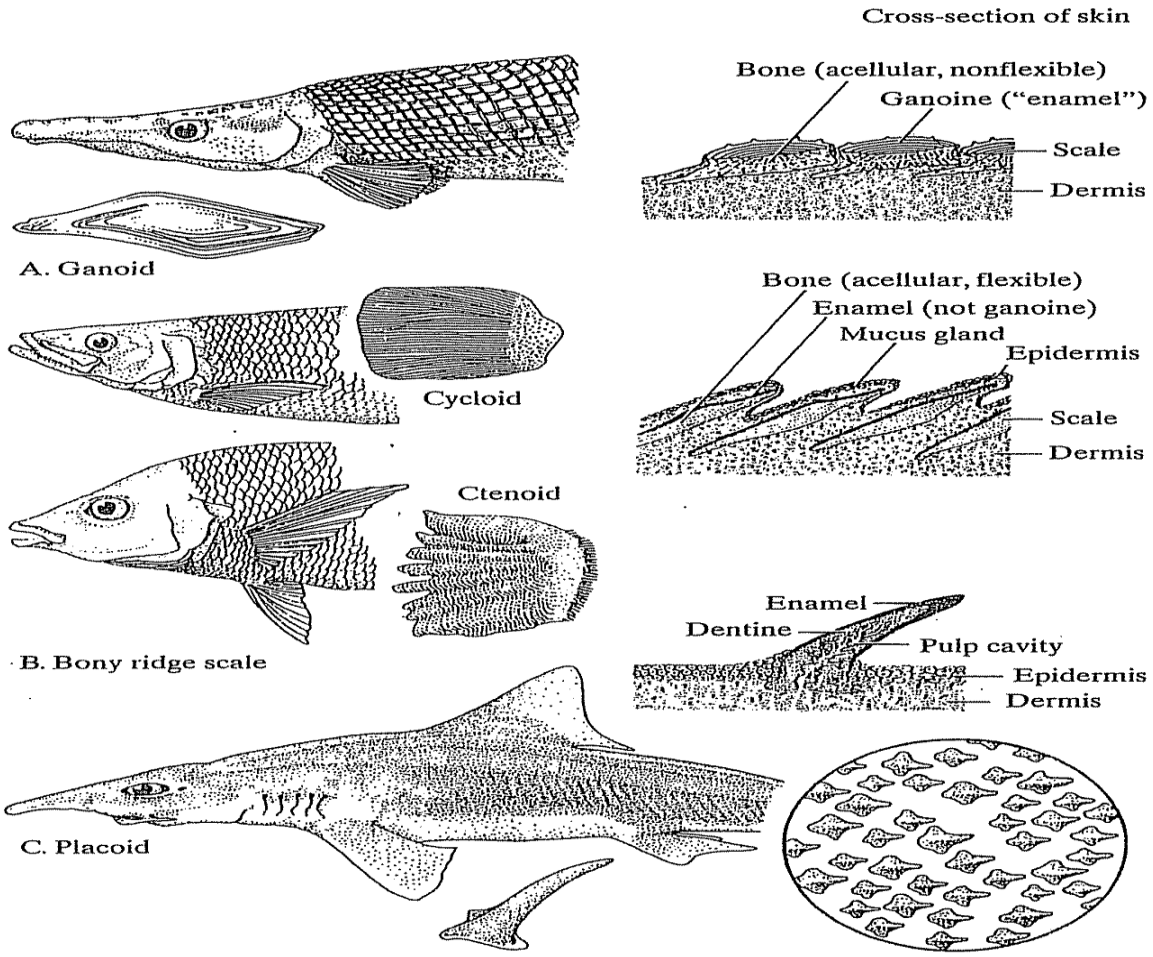
- Fish skin is structured into different layers:
  - an outer mucous layer of glycoproteins called mucins which protects it against *mechanical wear* & contains a number of *antimicrobial components*;..
  - the epidermis consists of mucosal cells & *keratocytes* & form the outermost layer;
  - the dermis provides the skin with *strength* & *elasticity*; it has *more blood vessels*, *strengthening fibres*, & *pigmented cells*; *scales* originate from here

Unit 2: Functional anat.: skin & scales



Structure of Fish Skin

Unit 2: Functional anat.: skin & scales



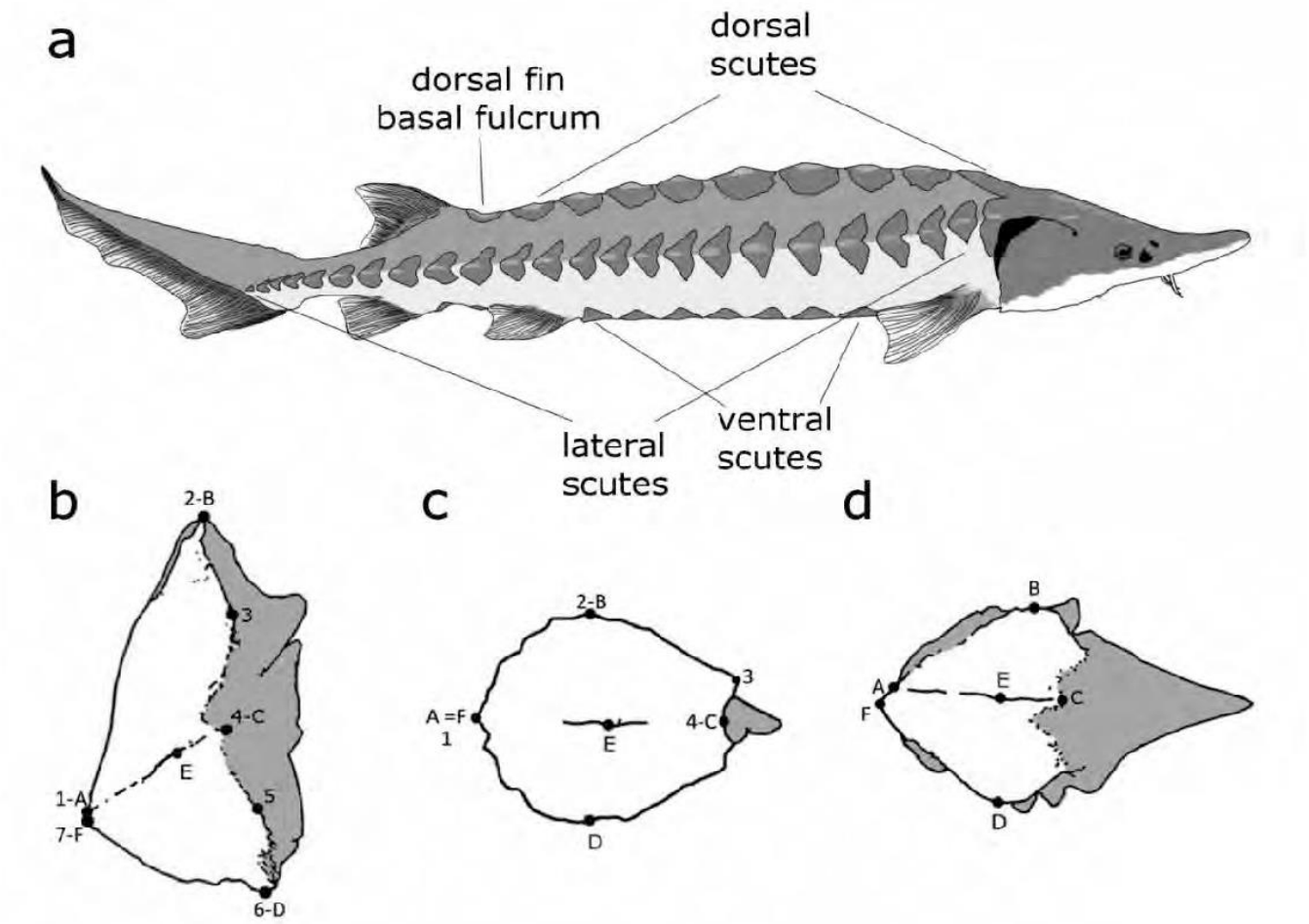
E.g.s of **ganoid** scales on gar, **cycloid** scales on sardine, **ctenoid** scales on snapper, & **placoid** scales on a shark.

Unit 2: Functional anat.: skin & scales

- Some are covered by **scutes** instead of *scales* but others have just a few that are modified for other purposes….

- Such fish are by & large
  - bottom dwellers in moving water
  - fish that frequently hide in caves, crevices, & other tight places; or
  - fast-swimming pelagic fish

Unit 2: Functional anat.: skin & scales



Unit 2: Functional anat.: skin & scales

- Many that appear *scaleless* have a complete coating of deeply embedded scales e.g. most tunas, etc..

- Several bottom-oriented, slow moving fishes have large, modified scales or **bony plates** as armour.

- Most free-swimming fish are covered by scales that provide protection from predators but do not weigh them down.

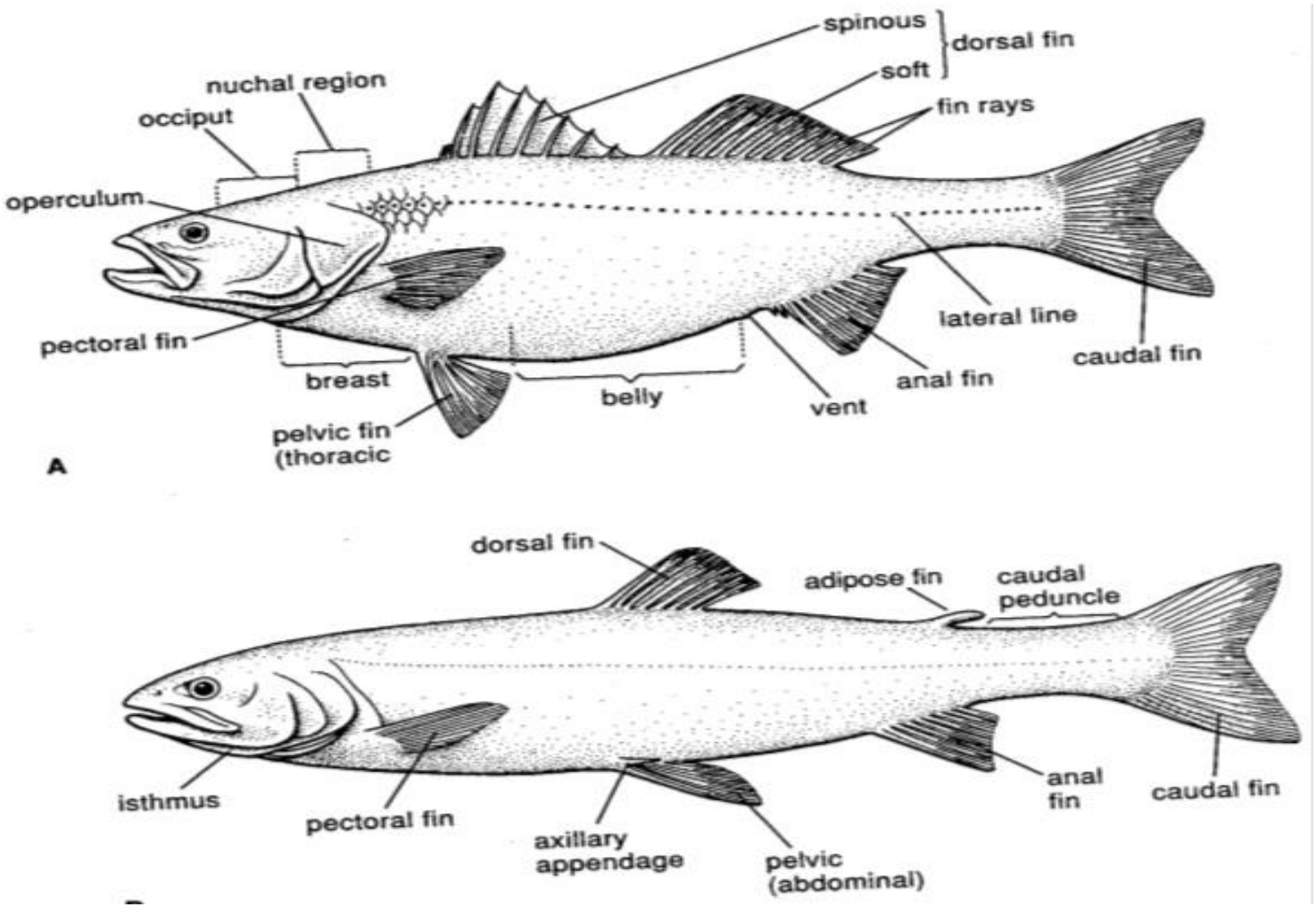
Unit 2: Functional anat.: fins

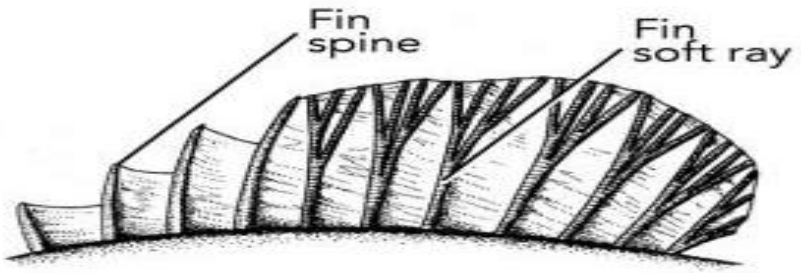
- Another key morphological feature of fishes are the **fins**.

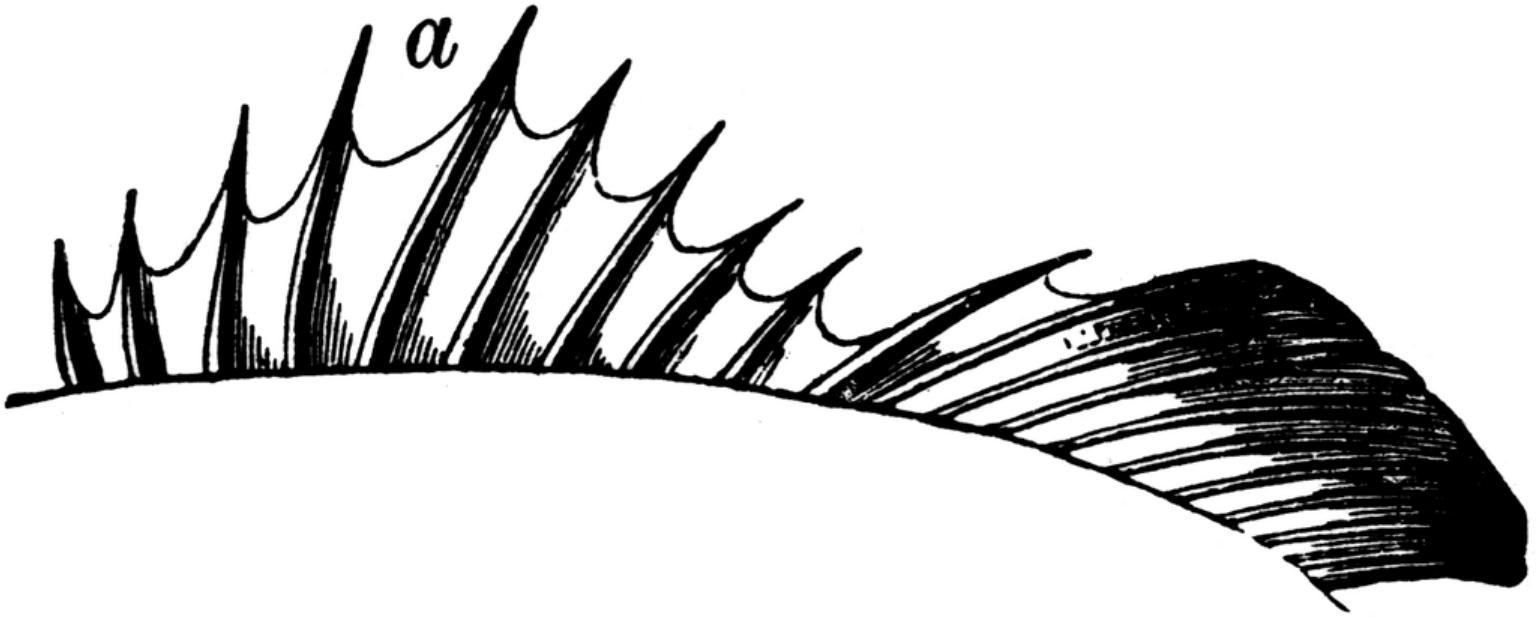
- In fishes (cartilaginous & bony), fins are supported internally by sturdy **fin rays**…

- Chondrichthyes fin rays are called ***ceratotrichia*** & are fairly stiff, unbranched, & unsegmented but bony fish fin rays called ***lepidotrichia*** are flexible, segmented, & branched…

Unit 2: Functional anat.: fins




Fin
spine
Fin
soft ray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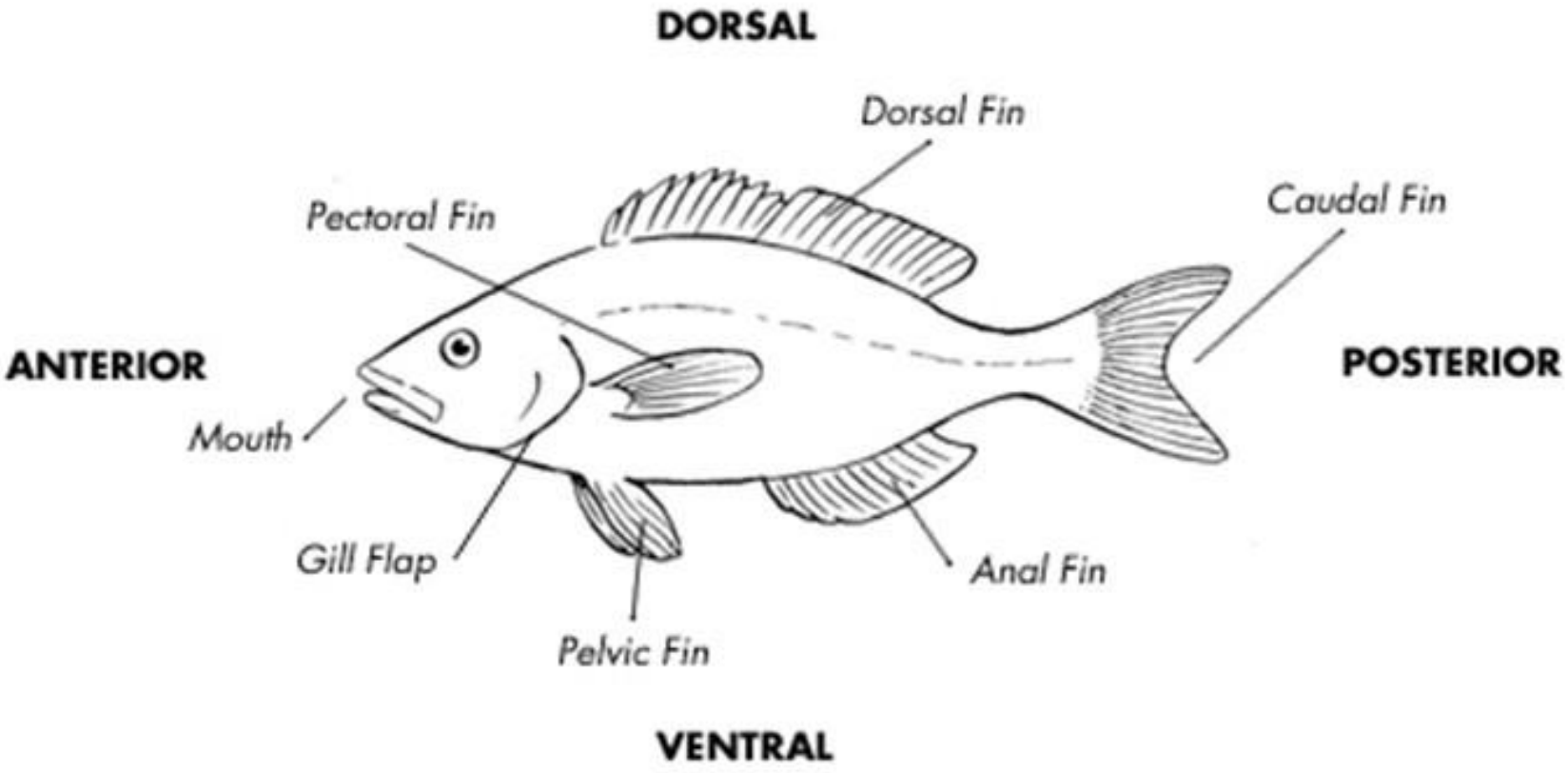
Unit 2: Functional anat.: fins

- Various combinations of location, size, & shape of fins are associated with the different **body shapes**.

- The **paired** fins (pectorals & pelvics) & the **unpaired fins** (dorsal, anal, caudal, & adipose) evolved together as a system that simultaneously,
  - propels,
  - stabilizes, &
  - helps fish to do manoeuvers…

Unit 2: Functional anat.: fins



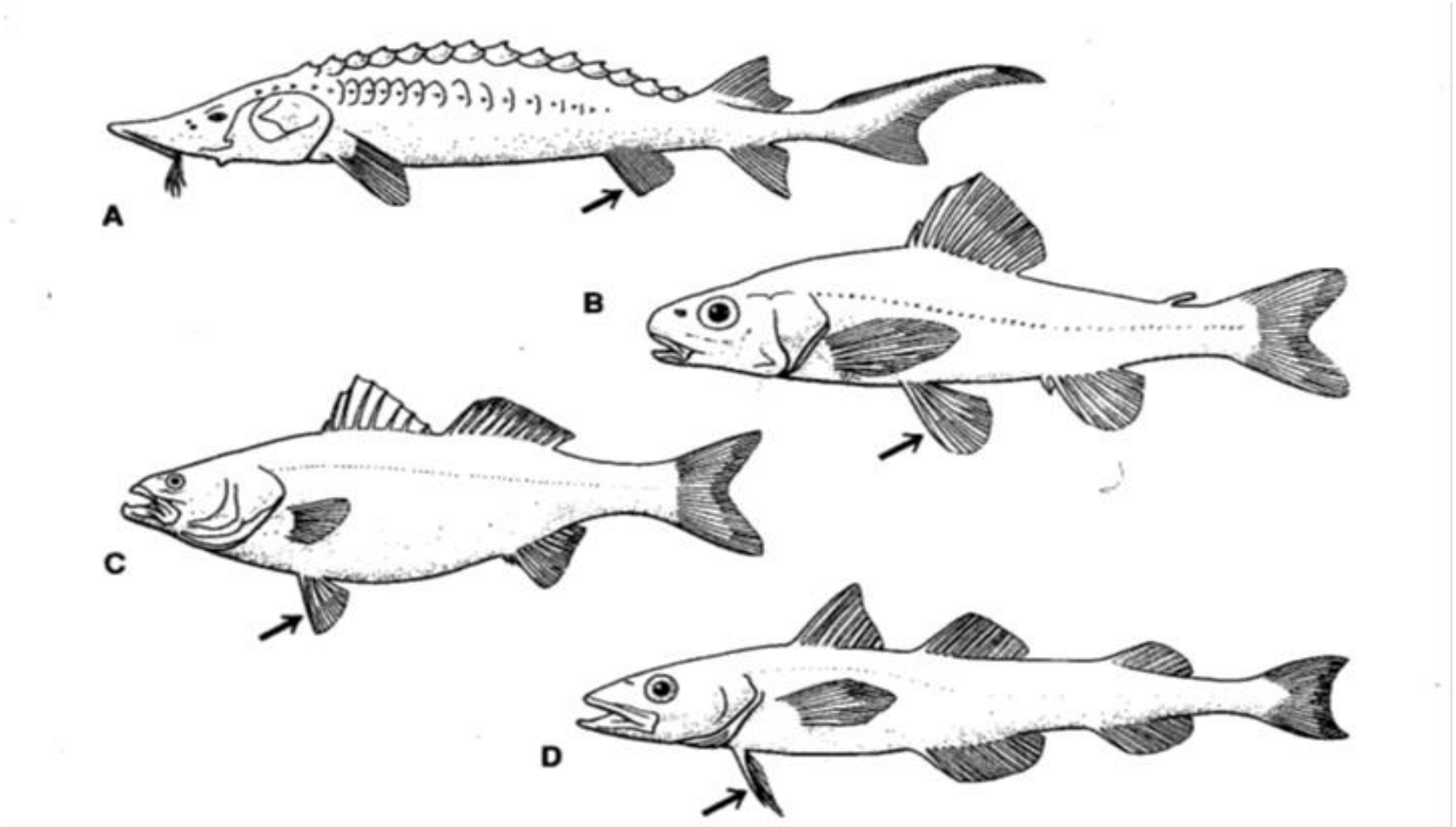
Unit 2: Functional anat.: fins - pelvic

- The most variable of the fins in terms of position.

- In ancestral bony fishes & sharks (cartilaginous), pelvic fins are located ventrally, toward the rear of the fish (*abdominal position*)….

- Most of these fishes have rover-predator body shapes, & the fins assist in **steering** & **braking**.

Unit 2: Functional anat.: fins - pelvic



A= abdominal; B= subabdominal; C=thoracic; D= jugular

Unit 2: Functional anat.: fins - pelvic

- In advance, deep-bodied **teleosts**, the pelvics are anterior, below pectoral fins (*thoracic position*) or may even be in front of pectorals (*jugular position*)…

- In eels & eel-like fish, they are absent or greatly reduced in size, so as to squeeze through tight places.

- In **bottom-dwelling** fish, they're frequently modified into organs for holding on to the substrate.

Unit 2: Functional anat.: fins - pectoral

- Generally located high up on sides of **deep-bodied** fish, which depend on precise mov't for picking prey from the bottom or water column.

- In **rover-predators**, these fins are more toward or below the midline of the fish.

- Very **fast-swimming** & **deep-bodied** fishes that picks prey from substrate they tend to be long & pointed.

Unit 2: Functional anat.: fins - pectoral

- Slower-moving **rover-predators** tend to have more rounded pectoral fins.

- Those of **bottom resting bony fishes** are broad, rounded, ventral in position, & spread out laterally.

- Enlarged pectoral fins are also used for gliding (flying fish) or, in many rays "flying" in the water.

Unit 2: Functional anat.: fins - pectoral

- Some fishes use it mainly in **display**, to startle predators when opened or to signal predators (& conspecifics) to stay away from poisonous spines.

- They are rigid in sharks & can be moved but not collapsed serving basically as stabilizers.

Unit 2: Functional anat.: fins – dorsal & anal

- Are normally long on **rover-predators** & **deep-bodied** fish to provide stability while swimming…

- In fast-swimming pelagic fish e.g. tuna the rearmost parts are often broken up into numerous finlets.

- When swimming at high speed, the forward part of dorsal fin fold into a dorsal slot to reduce resistance.

Unit 2: Functional anat.: fins – dorsal & anal

- Teleosts lacking this feature collapse dorsal & anal fins & fold back pectoral & pelvic fins when speeding

- Sharks don't have this way of reducing drag but, they are capable of swimming at high speeds.

- Eels have long dorsal & anal fins that run most of the body & may unite with the caudal fin & such arrangement is necessary for anguilliform mov't.

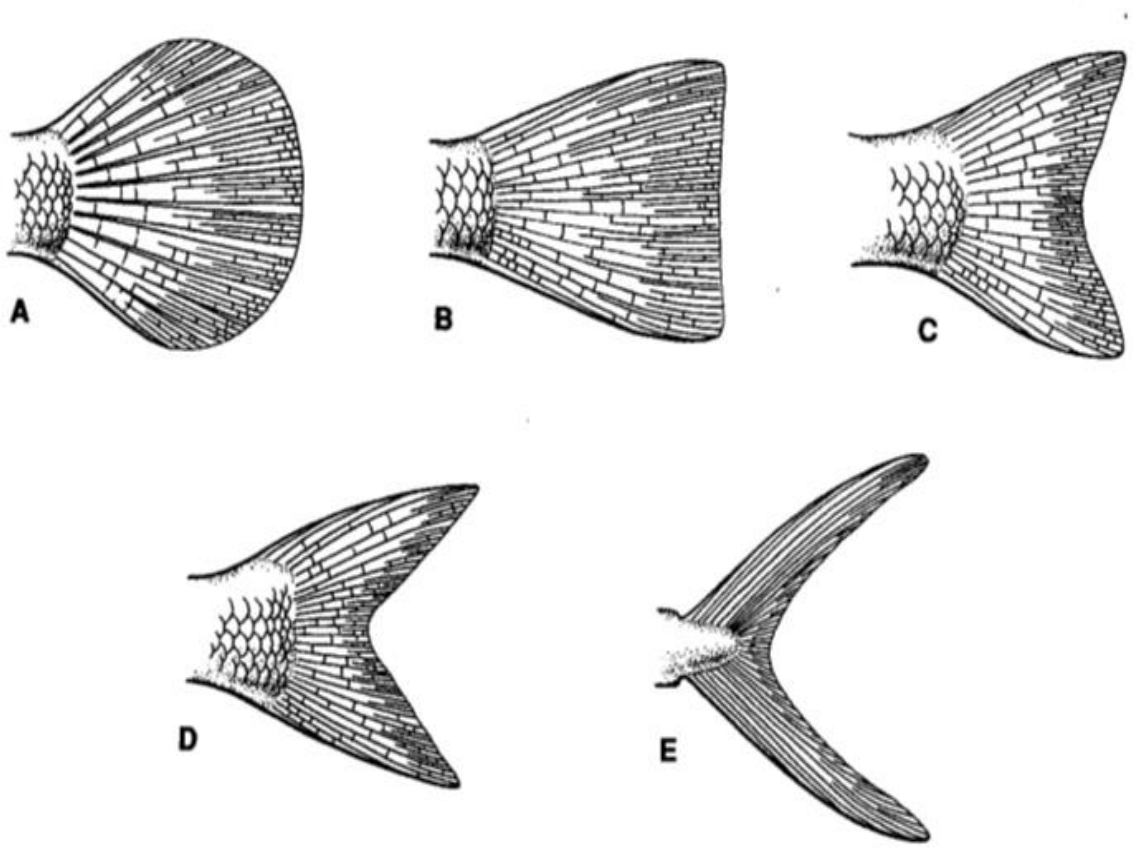
Unit 2: Functional anat.: fins – caudal

- Have shapes strongly related to normal swimming speed of a fish…

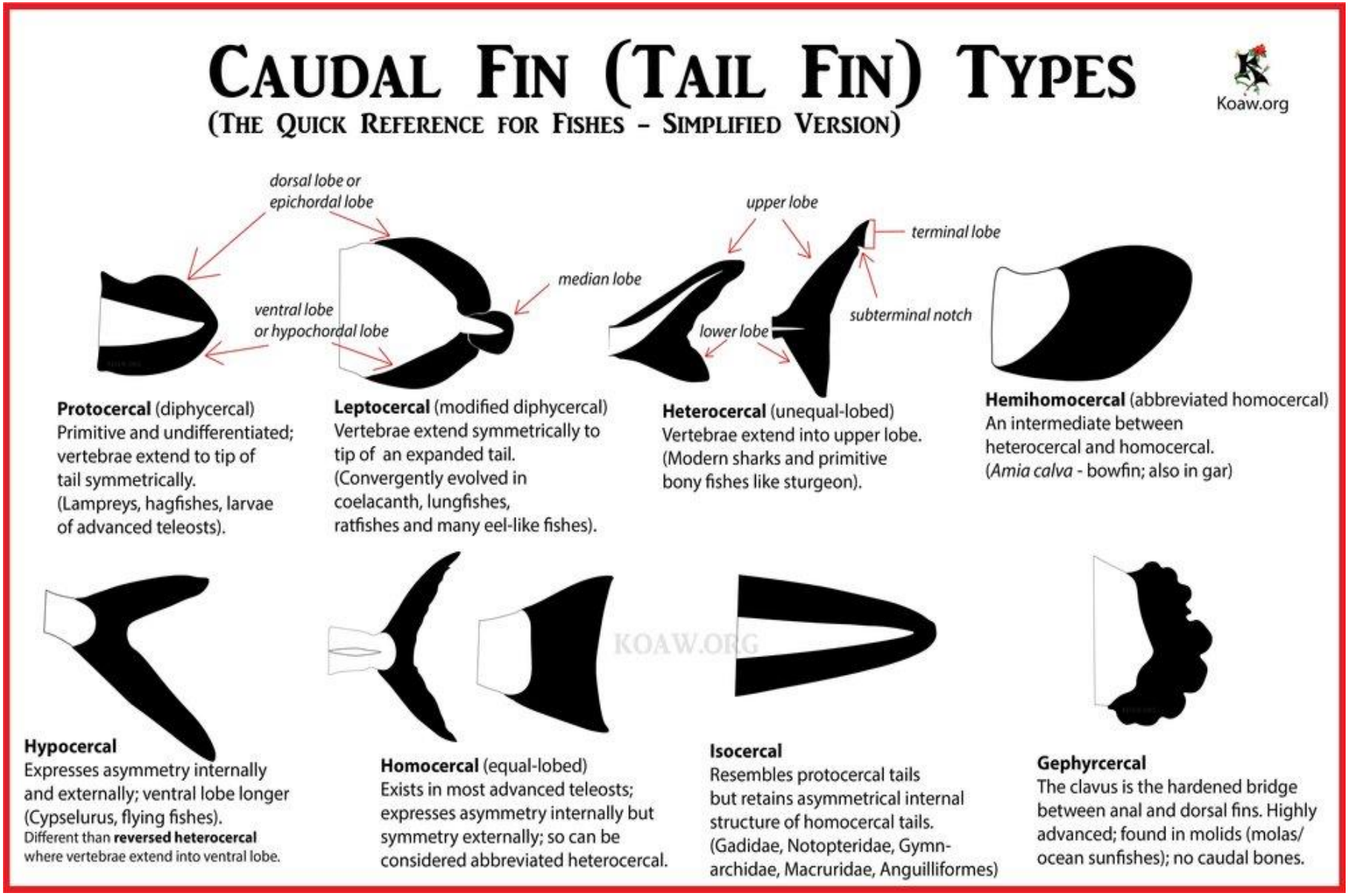
- The tails of most bony fish are ***homocercal***…, with upper & lower lobes being about the same size.

- Homocercal tails are of different types e.g. fastest-swimming fish have a stiff, quarter-moon-shaped fin (lunate) attached to a narrow caudal peduncle….

Unit 2: Functional anat.: fins – caudal



Unit 2: Functional anat.: fins – caudal



Unit 2: Functional anat.: fins – caudal

- Fish whose survival depends on frequent, sustained swimming have forked tails, with the deepest forks occurring on the most active fish…

- **Deep-bodied** fish, most **surface**, & **bottom** fish have square, rounded, or only slightly forked tails…

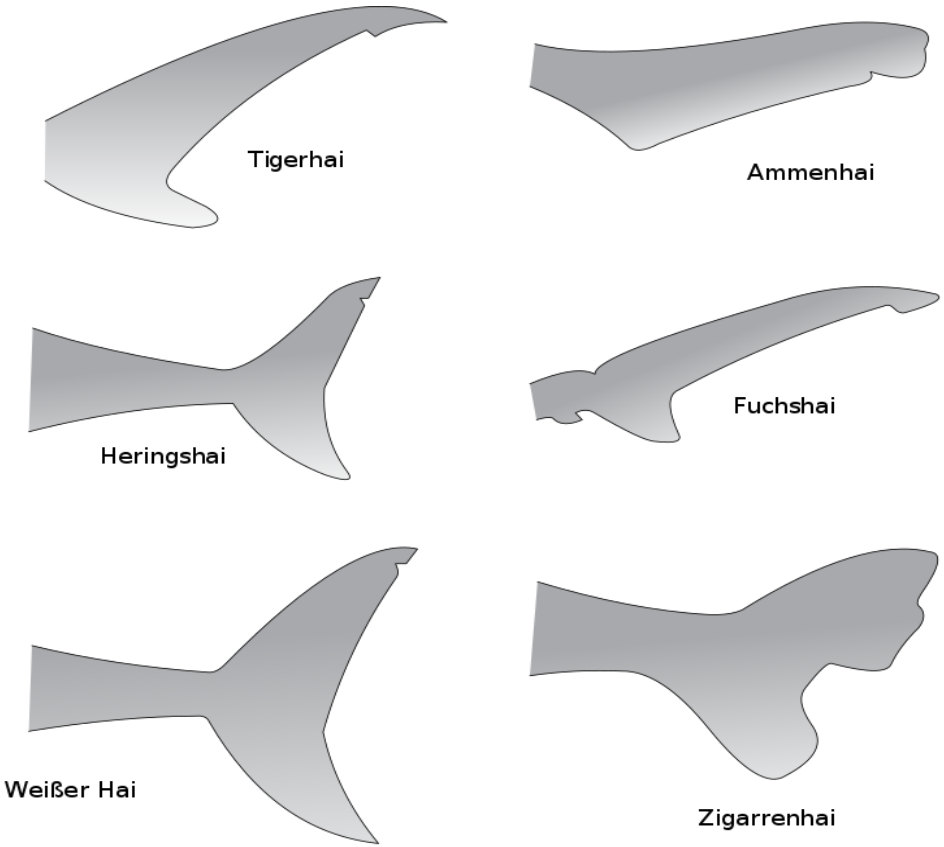
- When a homocercal tail lacks well-defined lobes, it is referred to as ***isocercal***….

Unit 2: Functional anat.: fins – caudal

- Chondrichthyes usually have ***heterocercal*** tails, with the upper lobe being longer than the lower one….

- In homocercal tails, the vertebral column ends in modified vertebrae that support the fan-like tail…

- In heterocercal tails, the vertebral column actually extends into the upper lobe of the tail….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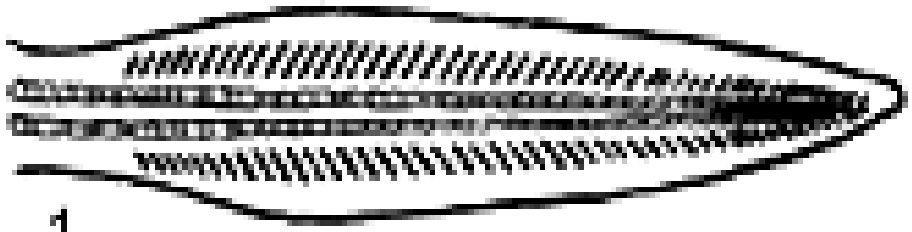
Weißer Hai
Zigarrenhai



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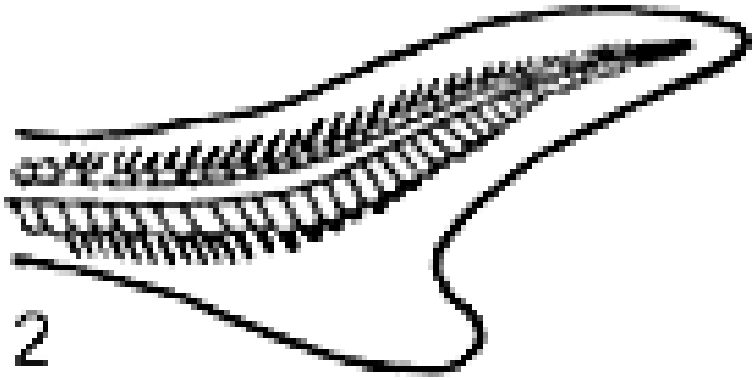

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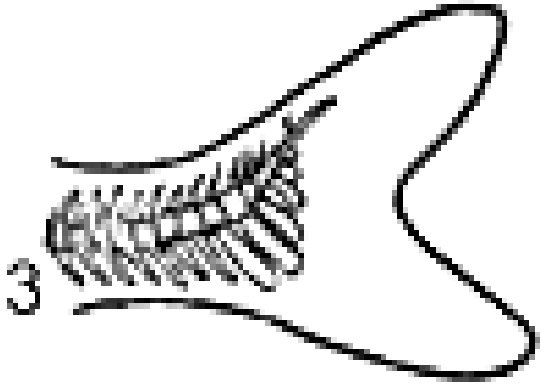

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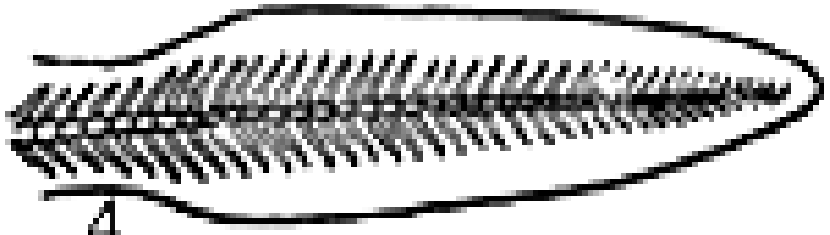

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Unit 2: Functional anat.: fins – adipose

- Is a fleshy, dorsal appendage between dorsal & caudal fins in some fishes.

- Its small size & lack of stiffening rays make its function a mystery..

- It may function in fish swimming during post-larval stage of dev't, when other fins are poorly developed.

Unit 2: Functional anat.: fins – rays & spines

- Fish fins also show the presence or absence of ***spines*** on the dorsal, anal, & pectoral fins…

- In spiny-finned teleosts (Acanthopterygii), spines are solid bony structures without any segmentation, unbranched & round in cross-section.

- Others have stiffened, thickened rays, which are segmented, dumbbell-shaped in cross-section, & often branched.

Unit 2: Functional anat.: fins – rays & spines

- Spines are an effective & lightweight means of protection against predators regardless of structure.

- *Dorsal*, *pectoral*, & *opercular* spines are often located at the fish's centre of mass, the usual target point of piscivorous fish.

- Spines are uncomfortable for a predator to bite on, & greatly increase the effective size of a small fish.

Unit 2: Functional anat.: fins – rays & spines

- Once the *dorsal*, *anal*, & *pectoral* spines are locked into place, the fish can be grabbed only by a predator that can get its mouth around the spines.

- By increasing its effective size through spines, a small fish reduces the number of predators that can eat it.

- So, well-developed spines are found mainly in small to medium-sized fishes that forage for their food.

Unit 2: Functional anat.: fins – rays & spines

- Also, many spines have *poison glands* associated with them e.g. scorpionfish, some catfish, & stingrays.

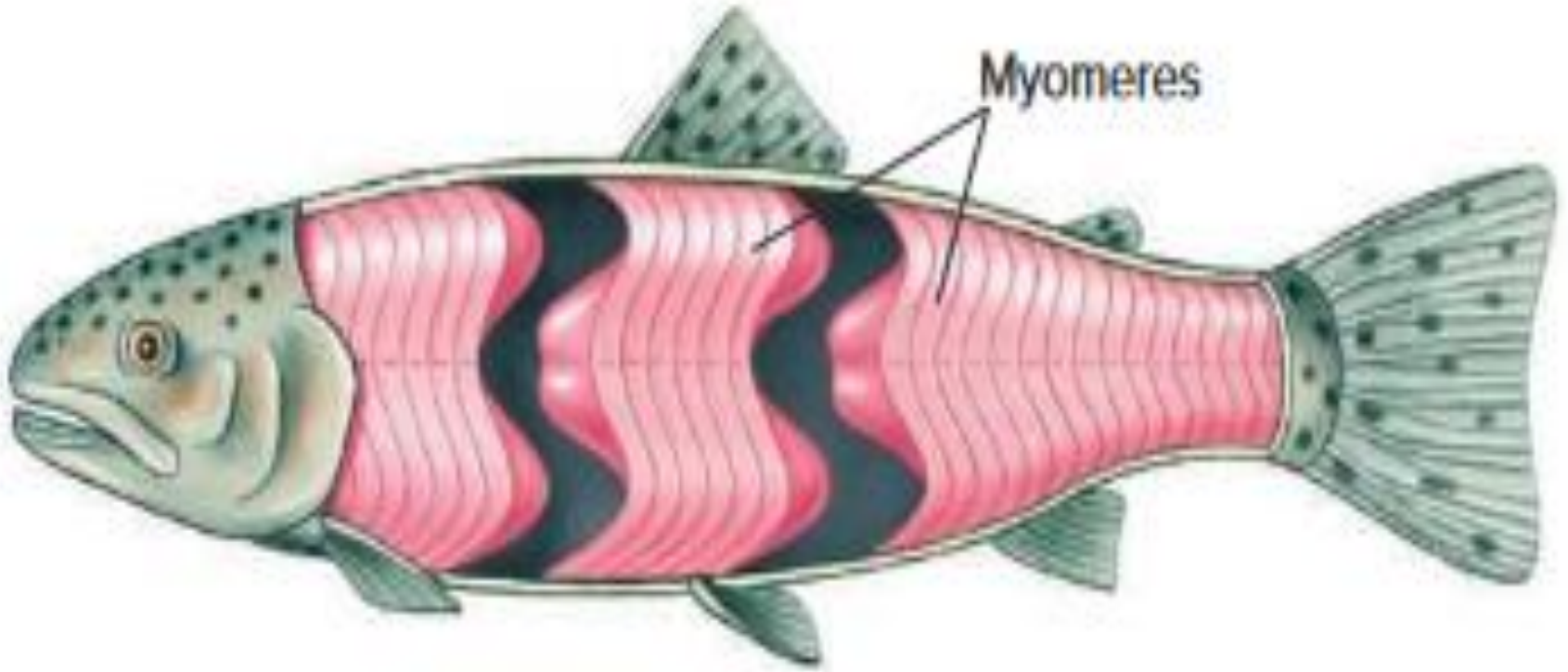
Unit 2: Functional anat.: muscular system

- The large muscles of the body & tail comprise the majority of the body mass of a fish.

- Body muscles are divided vertically along the body into sections called the ***myomeres*** or ***myotomes*** separated by sheets of connective tissue….

- The myomeres are W-shaped on its side, so that they fit into one another like a series of cones….

Unit 2: Functional anat.: muscular system



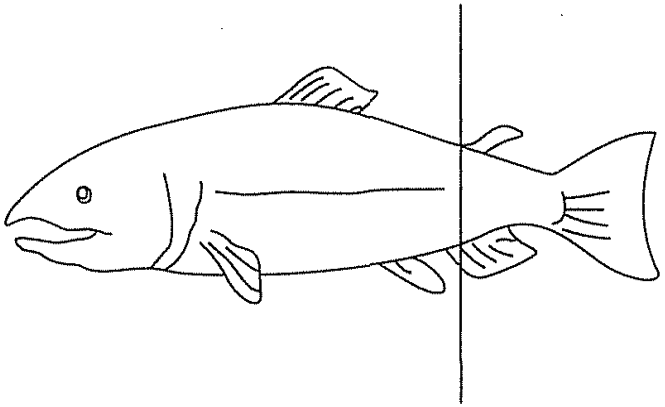
Unit 2: Functional anat.: muscular system

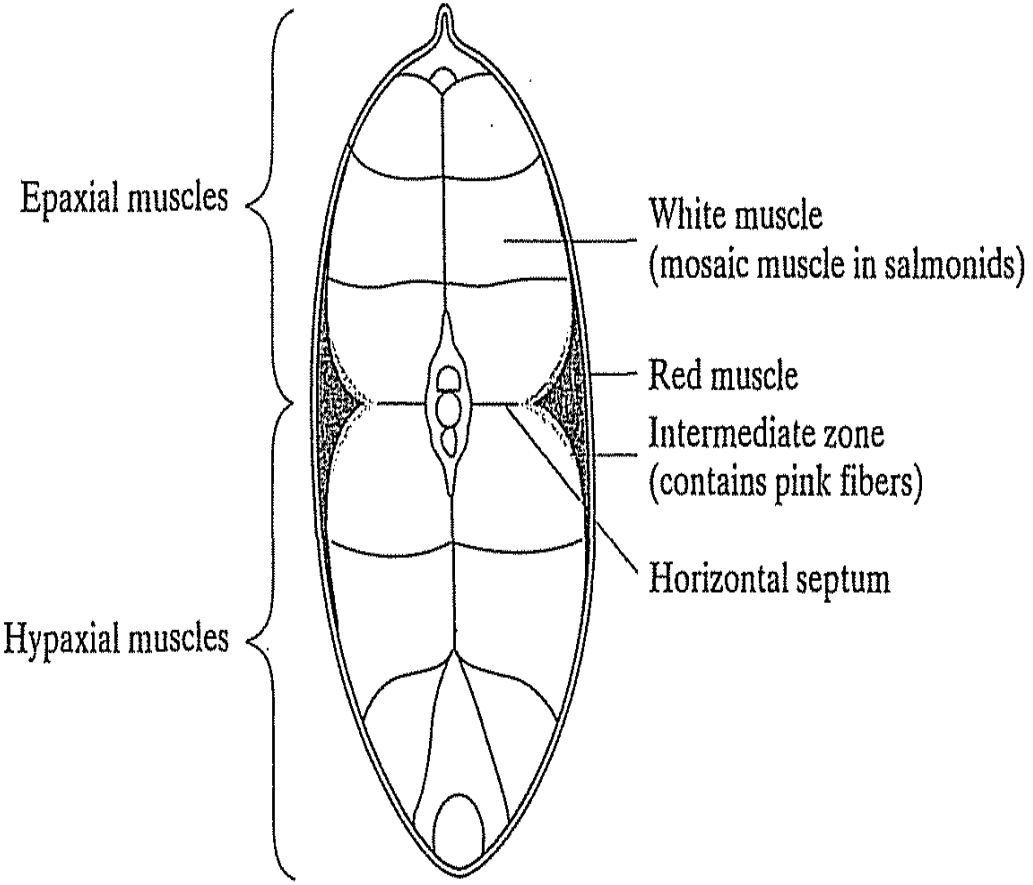
- The myomeres on the right & left halves of the body are separated by a vertical ***septum…***

- A horizontal septum separates the muscle masses on the **upper** & **lower** halves of the body.

- The upper muscles are called the ***epaxial muscles*** & the lower muscles the ***hypaxial muscles…***

Unit 2: Functional anat.: muscular system





Unit 2: Functional anat.: muscular system

- Fish muscles are generally of 3 types – skeletal, smooth, & cardiac or heart.

- In the locomotory system, fish muscles can often be divided into red, white, & pink ….

- ***Red muscles*** are capillaries-rich & appears red due to high levels of red, O_2-binding haemoglobin & in the muscle tissue itself, myoglobin.

Unit 2: Functional anat.: muscular system

- *High capillary density* & *pigments* ensure red muscle receives adequate O_2 for its mitochondria to digest fat to sustain high continuous (*aerobic*) swimming.

- Hence, in continuously active fish, a large proportion of their muscle mass is red muscle.

- Fish of "intermediate" activity have the lateral band of muscles, which is always red in colour & well developed.

Unit 2: Functional anat.: muscular system

- These fishes may also have red muscle fibres within white muscle that makes up most of the body mass.

- In some cases, the position of the red bands within the body also reflects swimming ability.

- E.g. the fastest-swimming fishes e.g. tunas carry red muscles deep within body core to aid the stiff-body & permits conservation of metabolic heat for faster muscular contractions & higher swimming velocities.

Unit 2: Functional anat.: muscular system

- At low temperatures, red muscle shows **increased**:
  - capillary densities (enhancing blood flow through muscle tissues),
  - cellular mitochondrial densities (increasing aerobic potential), &
  - lipid droplet densities (which may accelerate O_2 flux via increased O_2 solubility)

- These help maintain swimming speeds during slowed metabolic & chemical processes at low temperatures.

Unit 2: Functional anat.: muscular system

- ***White muscle*** fibres are
  - thicker than that of red muscles,
  - have a poorer blood supply, &
  - lack red, O_2-carrying pigments such as myoglobin..
- Their contraction isn't dependent on O_2 supply.
- They usually converts glycogen to lactate via anaerobic pathways.

Unit 2: Functional anat.: muscular system

- White muscle is most useful for short bursts of swimming & dominates muscle mass of moderately active to "sluggish" swimmers.

- ***Pink muscles*** fibres are intermediate in nature to white & red muscles & is typically used at swimming velocities too high for red muscle to sustain but too low for the effective use of white muscle.

Unit 2: Functional anat.: muscular system

- In some fish, pink muscle is used in a similar manner to red muscle at slow velocities whereas in other fish, it is used for swimming at fairly high velocities.

- Hence, swimming power of a fish rarely is strictly a matter of red & white-or even pink.

- The different kinds of muscle fibres are typically used in concert as fish change swimming speed.

Unit 2: Functional anat.: locomotion

- Fish move by a variety of means –
  - simplest is **passive** drift of many larval forms,
  - but drifters quickly change into forms capable of **active**, directed mov't.

- Fishes have evolved abilities to burrow, walk, crawl, climb, glide, & leap, or even fly, but **swimming** is by far the most important means of locomotion.

Unit 2: Functional anat.: locomotion

- Swimming involve rhythmic undulations, oscillations of part or all of a fish **body** or **fins**.

- Sideways/lateral flexures of the body muscles/fins at the appropriate angle of attack propels a fish forward

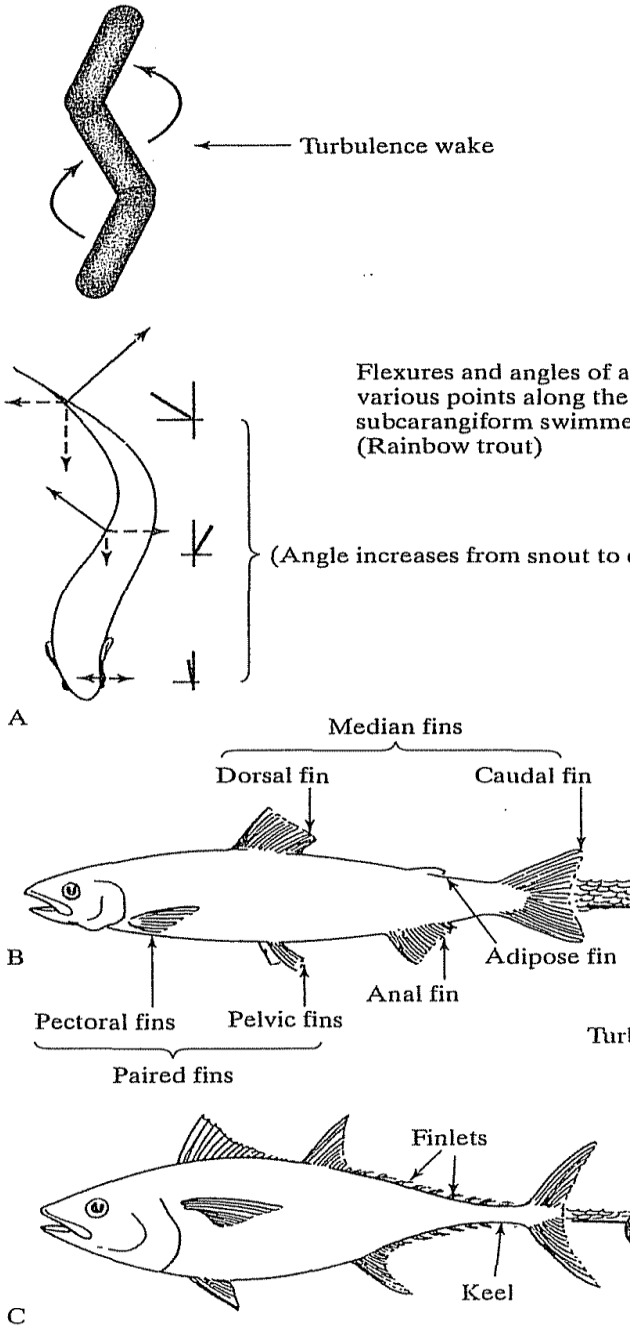
- Body movt involves alternate contraction & relaxation of **myomeres** on the sides a fish resulting in the body pushing back the water & moving forward.

Unit 2: Functional anat.: locomotion

- As this propulsive wave/flexure moves backwards, the water adjacent to the fish is pushed backward & is shed at the caudal fin pushing it forward.

- The greater the undulatory or oscillatory waves, the more power the fish can generate.

- If **drag** on body is held constant, fish that generate more power, accelerate more quickly & swim faster.


Turbulence wake
Flexures and angles of a
various points along the
subcarangiform swimme
(Rainbow trout)
(Angle increases from snout to
A
Median fins
Dorsal fin
Caudal fin
Adipose fin
Anal fin
Pectoral fins
Pelvic fins
Paired fins
B
Finlets
Keel
C

Unit 2: Functional anat.: locomotion

- Variations in this basic swimming approach of fishes exists & result in the dev't of a general classification of swimming modes/types.

- The key features of each type is how much of & which parts of the body are involved in propulsion & whether the body or the fins undulate or oscillate.

- 4 basic swimming types & their modifications- fins alone, anguilliform, carangiform, & ostraciform.

Unit 2: Functional anat.: form & movt

LOCOMOTION BY TRUNK AND TAIL					
	Anguilliform	**Subcarangiform**	**Carangiform**	**Thunniform**	**Ostraciform**
Examples	Eels, dogfishes, etc	Salmon, trout, cod	Jacks, herrings	Tunas, billfish	Torpedo rays, elephantfishes
Propulsive force	Most of body	Posterior half of body	Caudal region	Caudal region	Caudal peduncle
Propulsive form	Undulation	Undulation	Oscillation (limited to caudal tail region)	Undulation	Oscillation
Max. speed	Slow-moderate	Moderate	Fast	Very fast	Slow
Body shape	Elongate	Fusiform	Variable		

Unit 2: Functional anat.: form & movt

LOCOMOTION BY FIN ALONE					
	Tetraodontiform /balistiform	**Rajiform**	**Amiiform**	**Gymnotiform**	**Labriform**
Examples	Triggerfishes, ocean sunfishes	Skates, rays	Bowfins, seahorses	Knifefishes	Wrasses, parrotfishes
Propulsive force	Dorsal & anal (flap)	Pectoral	Dorsal	Anal	Pectoral (row)
Propulsive form	Oscillation	Undulation	Undulation	Undulation	Oscillation
Max. speed	Slow	Slow	Slow	Slow	Slow

Unit 2: Functional anat.: locomotion

- Despite these variations in locomotion, most fishes are ***locomotor generalists*** rather than ***locomotor specialists***.

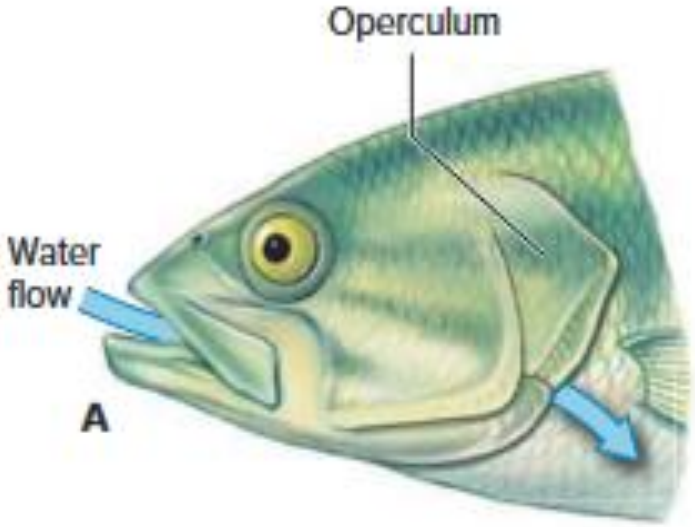
- Many switch between modes depending on whether fast or slow swimming or hovering is needed.

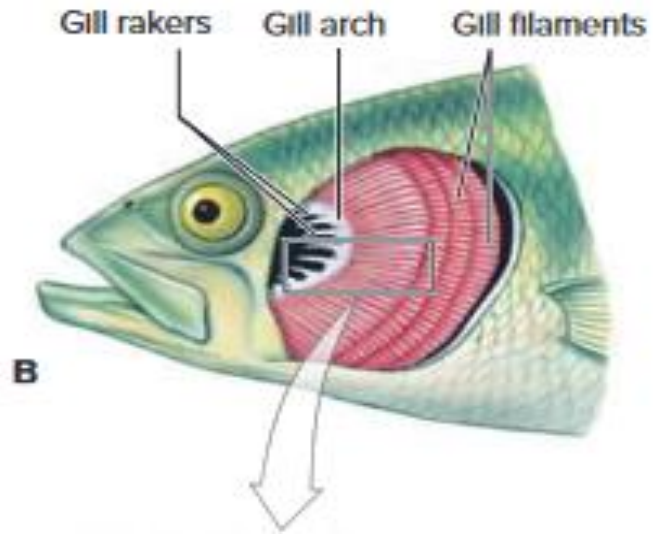
Unit 2, 2: Ventilation & Respiration in Fishes

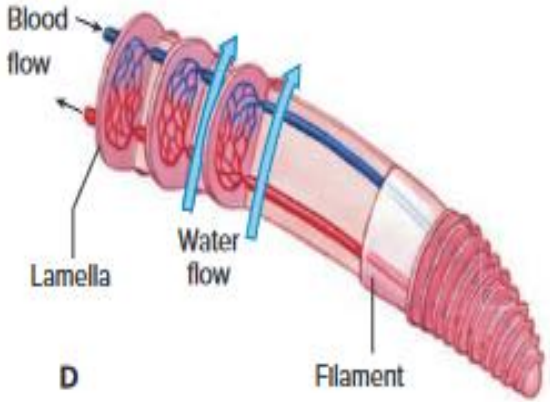
Unit 2: Funct. anat.: ventilation & respiration

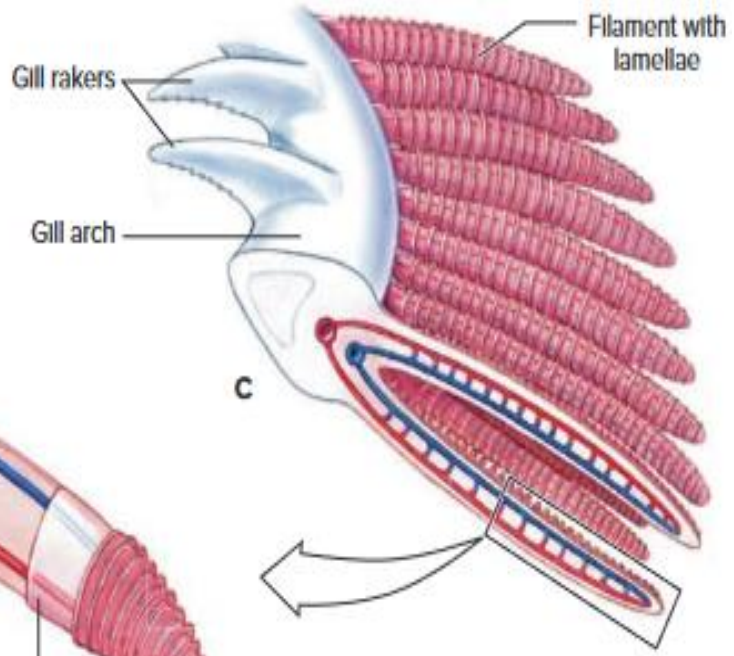
- Water as a respiratory env't.
  - The challenges of acquiring O_2 from water

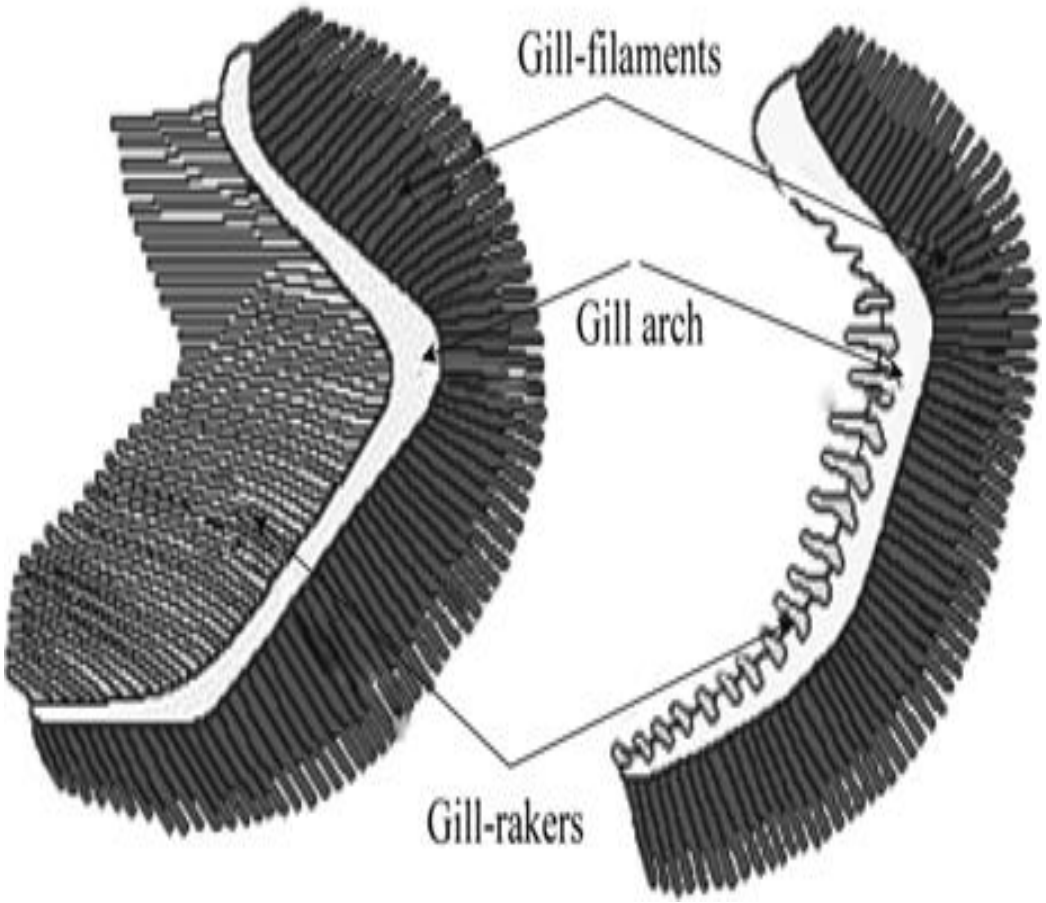
- **Aquatic breathing**
  - Structure of the **gill** - main respiratory organ (located in the pharyngeal/branchial cavity) …
  - **Features of the gill**
    - large surface area,
    - thin epithelia membranes of 2° lamellae,
    - flow of blood in 2° lamellae in the opposite direction of water flow in the gills – *countercurrent flow*.

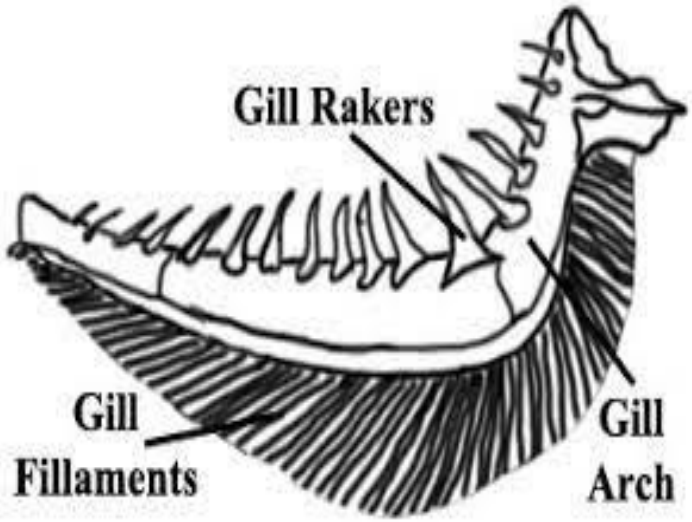

Operculum
Water flow
A

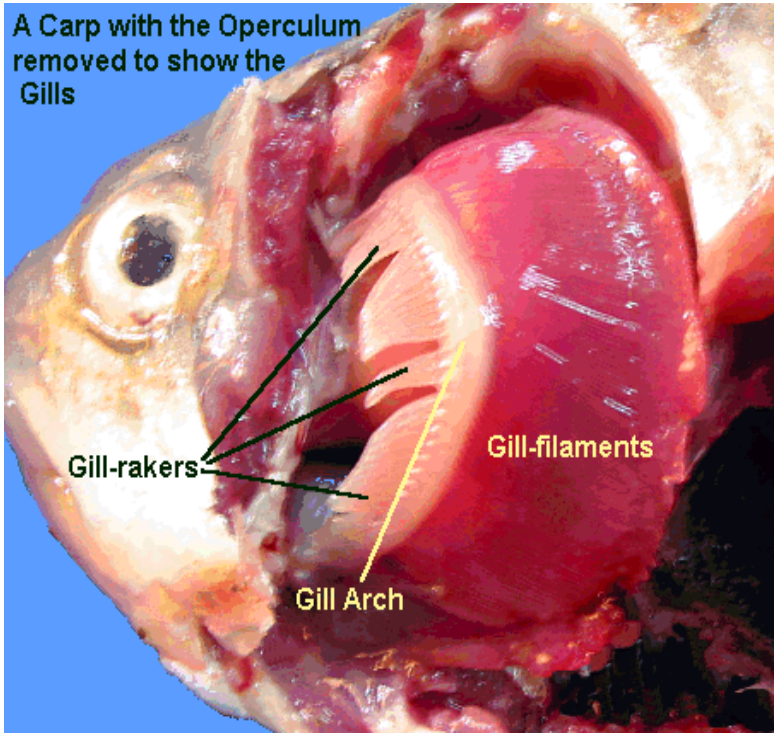

Gill rakers
Gill arch
Gill filaments
B


Blood flow
Lamella
Water flow
Filament
D


Filament with lamellae
Gill rakers
Gill arch
C


Gill-filaments
Gill arch
Gill-rakers


Gill Rakers
Gill
Fillaments
Gill
Arch


A Carp with the Operculum removed to show the Gills
Gill-rakers
Gill-filaments
Gill Arch

Unit 2: Funct. anat.: ventilation & respiration

- Efficient functioning of gills – anterior-posterior flow
  - **gill pumping mechanism**
  - **ram ventilation**

- Ventilation in Agnathans
  - **Hagfishes** use a muscular, scroll-like flap or *velum* to move water in through a single nostril & over the gills
  - **Lampreys** expand & contract branchial area causing water to flow in & out through multiple gill openings

Unit 2: Funct. anat.: ventilation & respiration

- **Air-breathing fishes**
  - Most are bimodal breathers
    - **facultative**
    - **obligate** (aquatic surface respiration)
    - **amphibious** air breathers
  - Air-breathing organs of fishes are of 3 categories
    - those derived from the **gut** e.g. lungs, gas bladder, stomach, intestine;
    - structures of the **head & pharynx** e.g. gill modifications (labyrinth organ & respiratory tree), mouth, pharynx, etc
    - well vascularized **skin** (cutaneous)

Unit 2: Funct. anat.: ventilation & respiration

- **Aquatic cutaneous respiration**
  - Any thin surface in contact with the respiratory medium is a potential site of gas exchange.
  - So skin respiration is important in fishes with well-vascularized skins e.g. young fish with immature gills.
  - Most juvenile & adult fishes use the skin for some aquatic gas exchange but early life-history stages e.g. larvae use it almost exclusively for respiration.

- **Aquatic cutaneous respiration (cont)**
  - Significant cutaneous respiration have also been found in some adult fishes.

Unit 2: Funct. anat.: ventilation & respiration

- **Gas Transport**
  - Fish RBCs have *haemoglobin*, an O_2-carrying protein that increases overall capacity of the blood to transport it.
  - Fishes with higher affinities for haemoglobin are better adapted to low O_2 env'ts & vice versa.
  - Different haemoglobins also show different sensitivities to temperature & pH.

- **Gas Transport (cont)**
  - Also, blood takes ups the CO_2 produced in cellular metabolism & transport it back to the gills for release to the env't.

- **Metabolic rate**
  - Definition.
  - rate of O_2 use as an index of aerobic metabolic rate assuming no significant anaerobic metabolism.
  - Factors that influence metabolic rate of fishes
    - **age, reproductive status, food in the gut, physiological stress, env'tal temperature, level of activity, season, etc**

- **Metabolic rate (cont)**
  - Standard & routine metabolic rates.
  - Metabolic scope & its significance.
  - O_2 use vs temperature & swimming velocity.
  - Potential underestimate of true metabolic cost at high speeds due to use of anaerobic respiration of muscles during high speed swimming.

Unit 2, 3: Blood Circulation in Fishes

Unit 2: Funct. anat.: circulatory system

- Have a **closed** circulatory system.

- It consists of a single heart as a pump which lines up with the *branchial* (gill) & *systemic* (body) capillary beds connected by arteries & veins.

- The **main role** of the circulatory system is to transport: *respiratory gases*, *nutrients*, *metabolic waste products*, *endocrine factors*, *heat*, etc

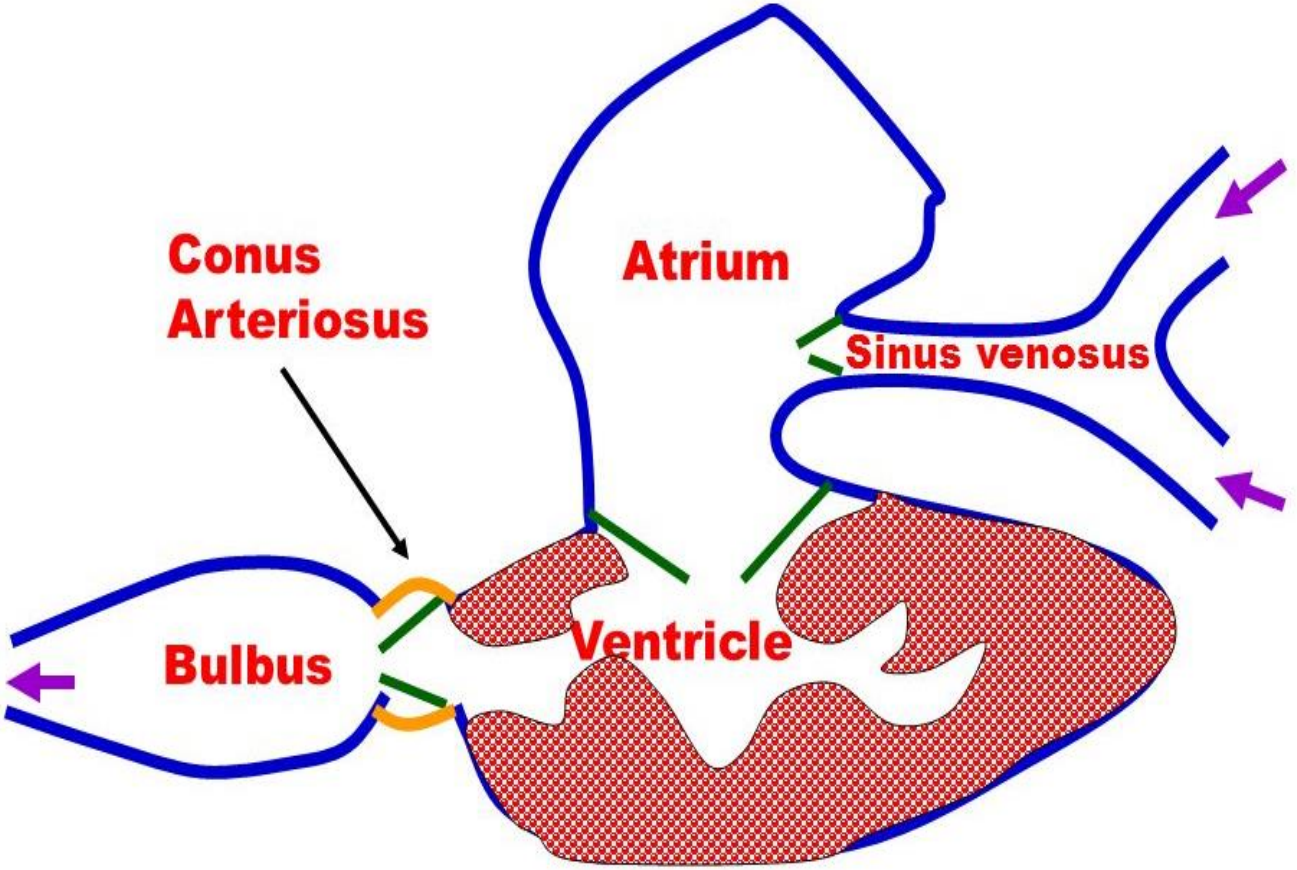
Unit 2: Funct. anat.: circulatory system

- The structure of a fish's heart…

- Sequential arrangement of the heart chamber.
  - ***sinus venosus*** - thin-walled sac with some cardiac muscle collects deoxygenated blood from body from incoming hepatic & cardinal veins & directed to atrium through the *sinoatrial valve*.

  - ***atrium*** is a thick-walled, muscular chamber sends blood to the more thicker-walled ventricle via the *atrioventicular valve*.

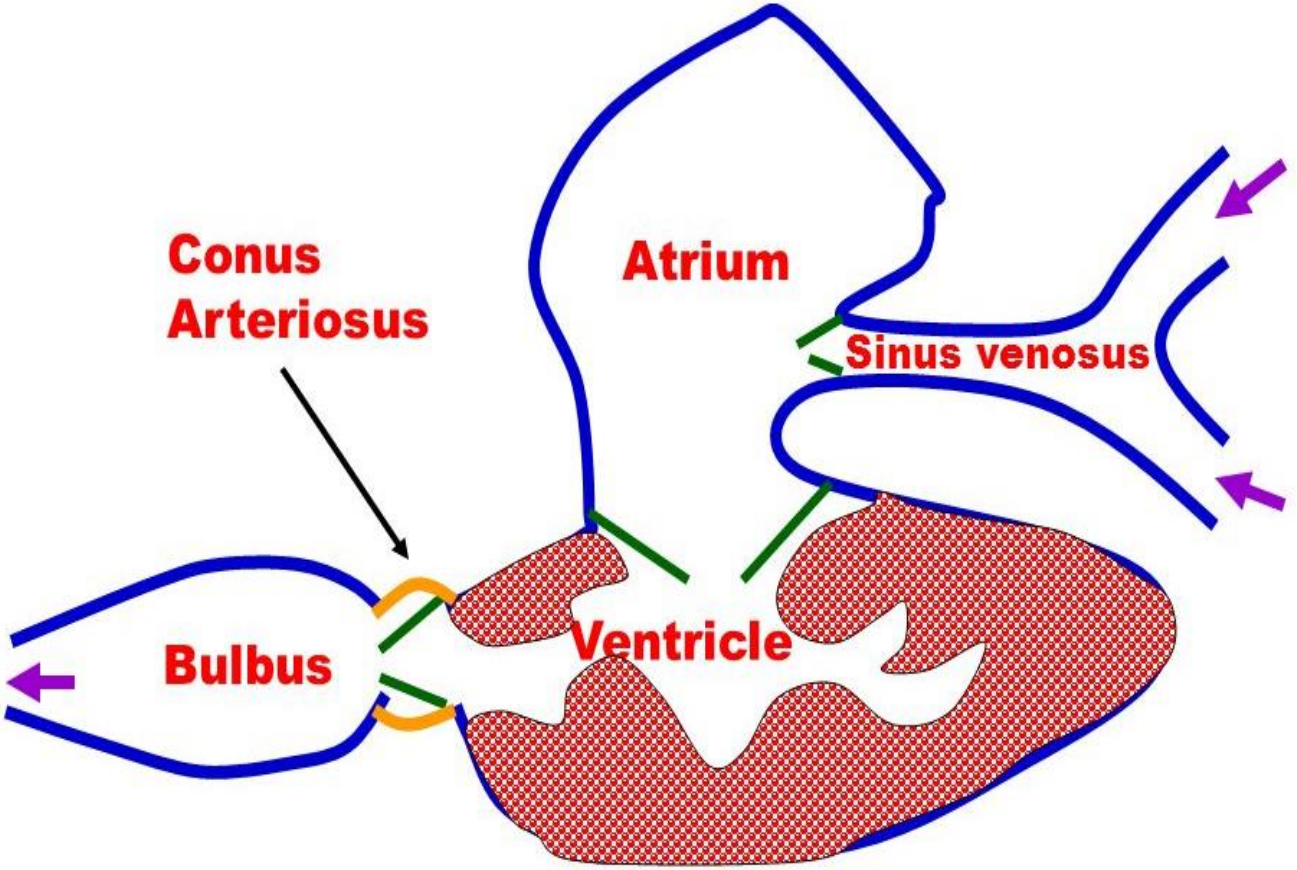
Unit 2: Funct. anat.: circulatory system



Unit 2: Funct. anat.: circulatory system

- Sequential arrangement of the heart chamber.
  - ***ventricle*** pumps blood to the 4th part (outflow tract)
  - It is made of 2 muscle layers:
    - a dense *cortex* that receives O_2 & nutrients from the coronary artery (compact myocardium) & is well developed in active fishes, &
    - the *spongy myocardium* consisting of a spongy mesh supplied with O_2 & nutrients by the venous blood that it pumps…

Unit 2: Funct. anat.: circulatory system



Unit 2: Funct. anat.: circulatory system

- Sequential arrangement of the heart chamber.
  - d). ***outflow tract (OFT)*** – enters the ventral aorta & consists of the tubular *conus arteriosus* (elasmobranchs, lampreys, hagfishes, & holosteans), *bulbus arteriosus* (teleosts) or both…
  - OFT doesn't increase acceleration of blood but acts as elastic chamber dampening pressure pulses & intermittent flow from the ventricle into a more continuous flow to the ventral aorta & the gills.

Unit 2, 4: Feeding & Digestion in Fishes

Unit 2: Funct. anat.: Feeding & digestion

- Fish feeding habit – definition.

- Evolution of jaws & its impact on feeding.
  - mov't from passive-feeding to predation

  - dev't of necessary adaptations for predation e.g. stronger muscles, faster mov't, better balance, etc

- Thus feeding behaviour shape much of a fish's life,

Unit 2: Funct. anat.: Feeding & digestion

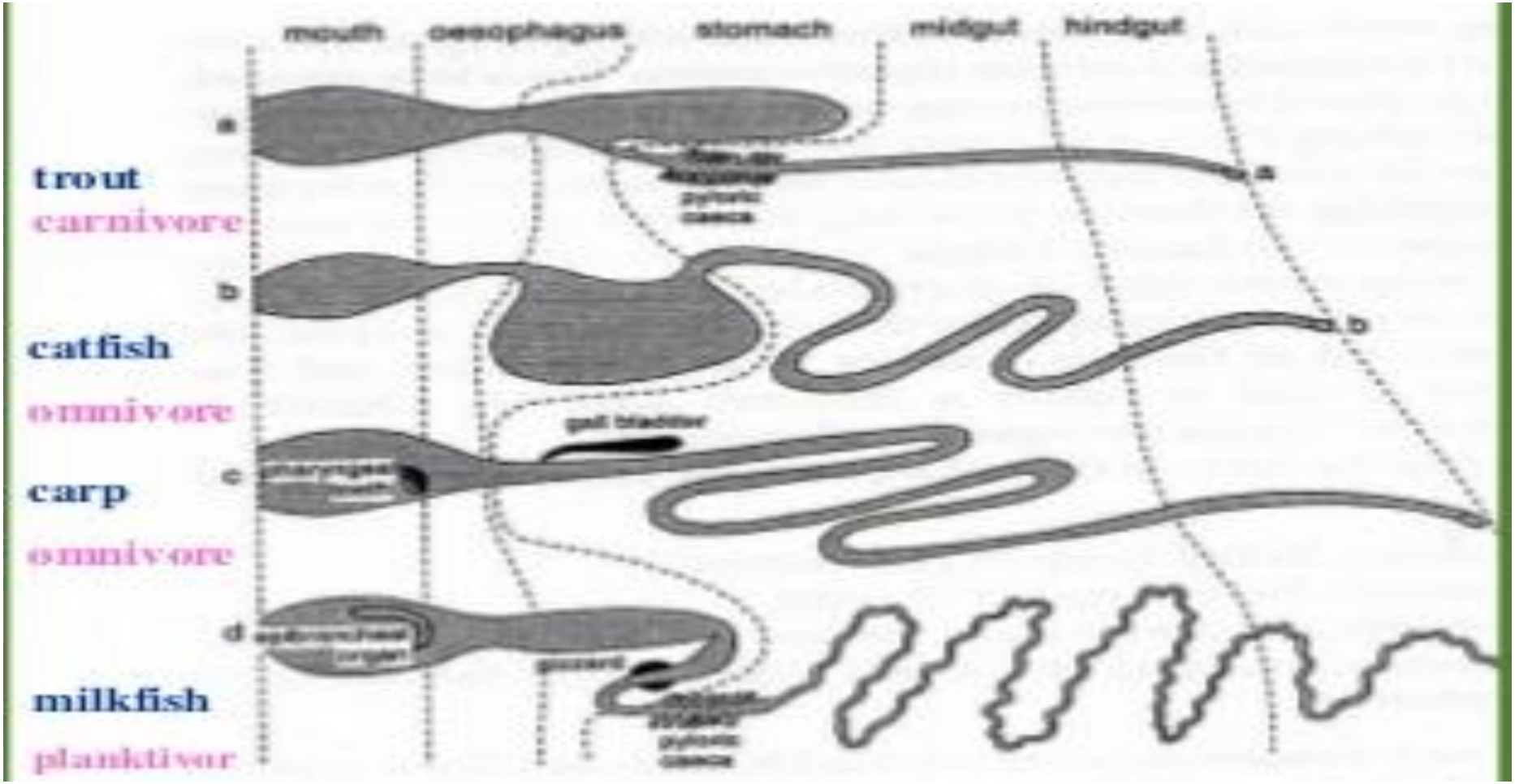
- Fish be grouped according to the materials they habitually eat into 5 types:
  - **carnivores** – feed exclusively on animal matter;
  - **herbivores** – feed exclusively on plant materials;
  - **omnivores** – feed on both plants & animals matter;
  - **planktivores** – feed on plankton;
  - **detritivores** – feed on decaying matter

- Food availability determines what is eaten by a fish & most fishes are highly adaptable in feeding habits.

Unit 2: Funct. anat.: Feeding & digestion

	Carnivores[1]	Herbivores[2]	Omnivores[3]	Planktivores[4]	Detritivores[5]
Digestive tract; Relative gut length	Short; < 1	Very long; >3	Between carnivores & herbivores; 1- 3	Long, similar to herbivores; >3	Long, similar to herbivores; >3
Mouth	Large terminal or sub-terminal	Small inferior	Variable	Small	Inferior
Teeth type	Well-developed for grasping & biting	Rasping & nipping	Variable	No teeth except pharyngeal ones	Varied
Gill rakers devt	Absent or if present short & widely spaced	Short & widely spaced	Variable depends on primary food	Fine & tightly spaced	Variable depends on primary food

Unit 2: Funct. anat.: Feeding & digestion



Unit 2: Funct. anat.: Feeding & digestion

	Carnivores[1]	Herbivores[2]	Omnivores[3]	Planktivores[4]	Detritivores[5]
Stomach	Large & well developed	Generally absent	Shorter than carnivores	Absent or small	Small & muscular or absent
Pyloric caeca	Present	Absent or greatly reduced	Absent or greatly reduced	Absent or greatly reduced	Present
Length of intestine	Short & straight	Long & coiled	Variable	Long & coiled	Long & coiled
Feeding range	Stenophagic	Stenophagic	Euryphagic	Stenophagic	Stenophagic - euryphagic

Unit 2: Funct. anat.: Feeding & digestion

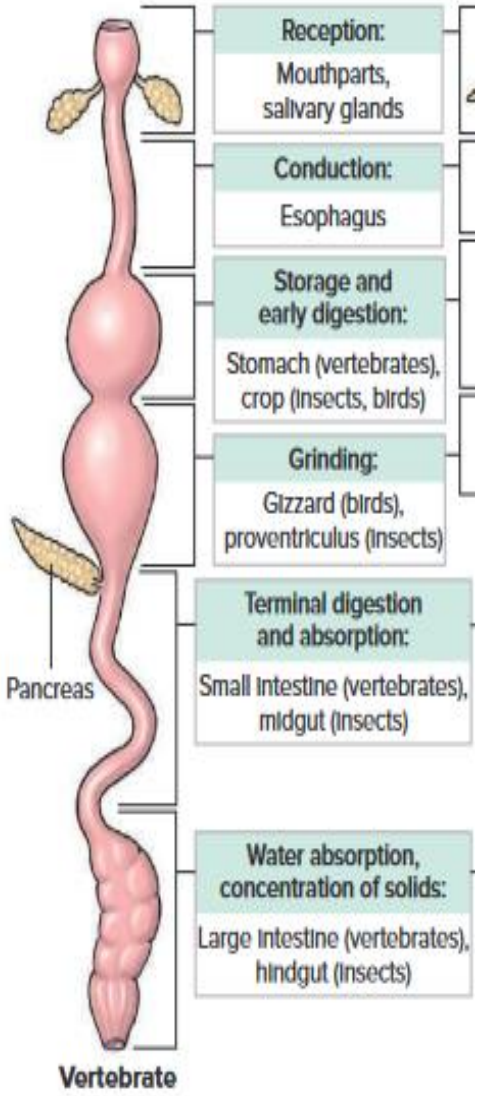
- Another classification of feeding behaviour is based on the manner of feeding:
  - **predators** – feed on big animals;
  - **grazers** – feed on bottom organisms/selected plankton;
  - **strainers** – filter organisms mainly plankton, & crustaceans;
  - **suckers** – suck in mud or food-containing material to obtain food;
  - **parasites** – by sucking body fluids of their host.

Unit 2: Funct. anat.: Feeding & digestion

- Food availability determines largely what a fish will eat with most fishes been highly adaptable in feeding habits with majority been *euryphagous*.

- Have complete alimentary canal like other vertebrates consisting of *mouth*, *buccal cavity*, *pharynx* (head gut), *oesophagus*, *stomach* (foregut), *intestine* (with *pyloric caeca* & related organs e.g. liver, gall bladder, pancreas – mid gut), *large intestines*, *rectum* & *anus* (hind gut)…

Unit 2: Funct. anat.: Feeding & digestion



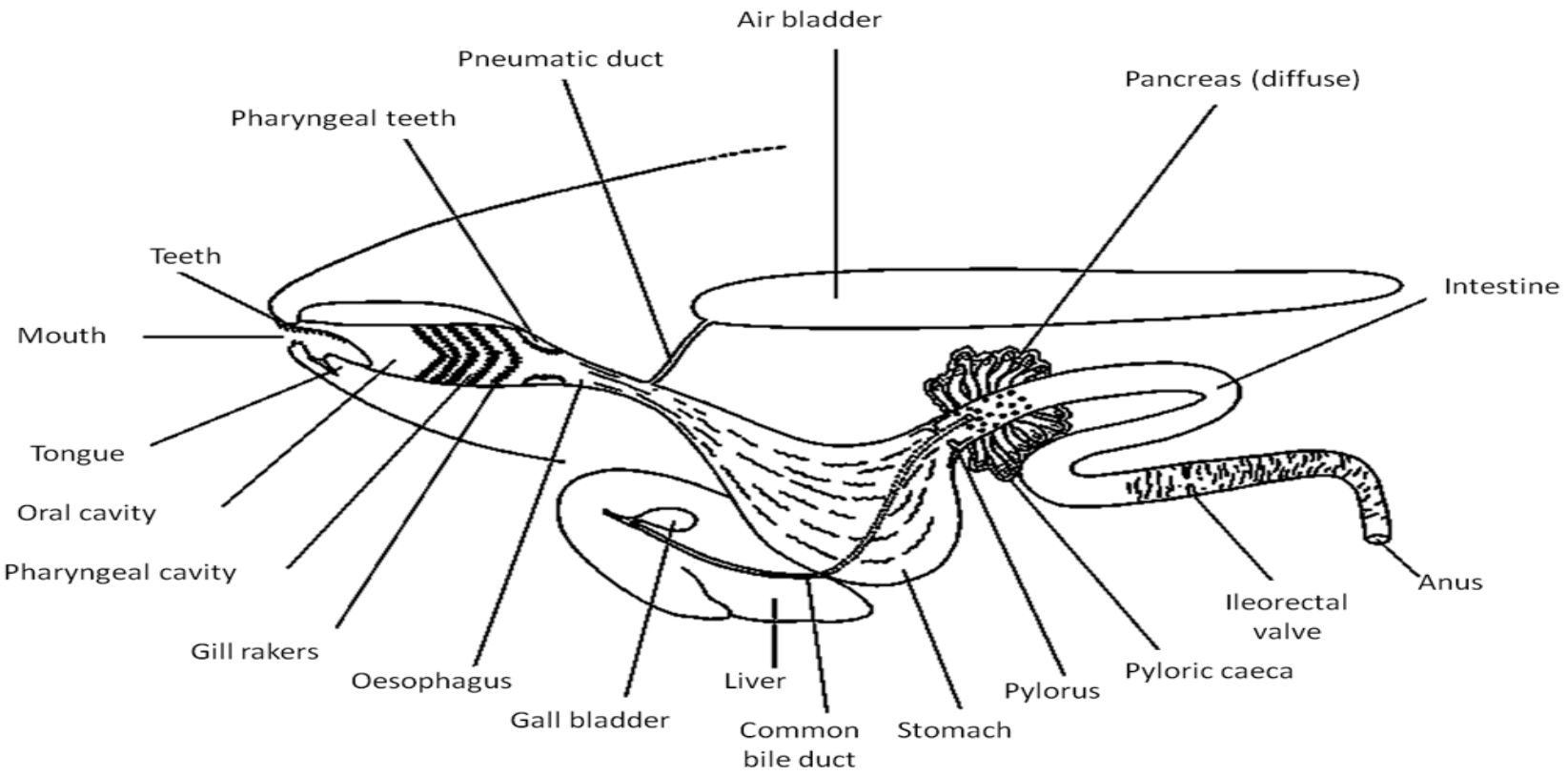
Unit 2: Funct. anat.: Feeding & digestion

	Head gut	Foregut	Mid gut	Hind gut
Parts	- Mouth & buccal cavity - Gills (branchial or pharyngeal cavity)	- Oesophagus - Stomach	- Small intestine - Pyloric caeca - liver, gall bladder, pancreas	- Large intestine - Rectum - Anus

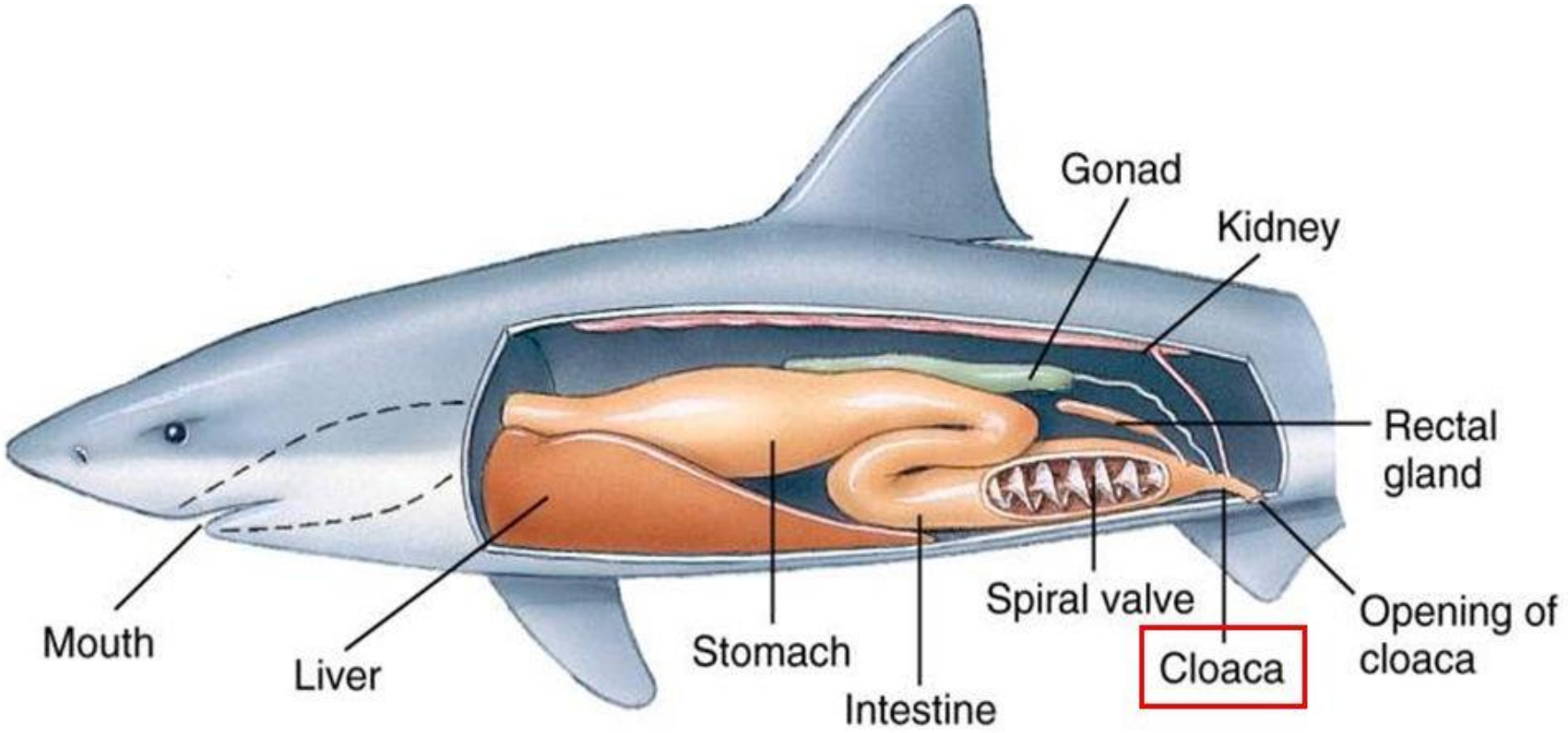
Unit 2: Funct. anat.: Feeding & digestion

	Head gut	Foregut	Mid gut	Hind gut
Functions	**M &** parts are used for; capturing, handling, sorting, crushing, biting, shredding	**O**: passage way, osmoregulation, passive & active transport of ions, presence of *salivary glands*. **S**: chemical digestion, stores & mixes food, crushing of materials (gizzard), HCl food hydrolysis, enzymatic activities -pepsin for proteins, chitinases for digestion of exoskeleton of crustaceans	**I:** Increases digestive surface area for absorption together with *scroll valve*.. in Chondrichthyes **PC:** accessory food reservoir, uptake of amino acids & sugars; **P:** secretes insulin, **L:** secretes bile (fat breakdown) & stores lipids & glycogen	- Continuation of digestion with reduced digestive & absorptive function - Voiding of undigested materials

Unit 2: Funct. anat.: Feeding & digestion



Unit 2: Funct. anat.: Feeding & digestion



Unit 2: Funct. anat.: Feeding & digestion

	Head gut	Foregut	Mid gut	Hind gut
Miscellaneous	Mouths may be *terminal, sub-terminal, ventral,* etc; More active feeders have strong jaws; Major types of teeth are *cardiform*, *villiform, canine, incisor,* & *molariform*	Some lack stomachs e.g. carps & other cyprinids	Longest part of the gut; all fishes have intestines; length varies from as low as 0.2 – 20 body length	

Unit 2, 5: Reproduction in Fishes

Unit 2: Funct. anat.: Fish Reproduction

- Fish show extraordinary variations on the basic theme of sexual reproduction.

- Most are ***dioecious***, with external fertilization & dev't of their eggs & embryos (***oviparity*** - the most common mode of reproduction in fishes

- Offspring are provided with egg yolk nutrients – a process called ***lecithotrophy*** & most energy is derived from yolk protein called ***vitellogen***.

Unit 2: Funct. anat.: Fish Reproduction

- Some are ***ovoviviparous*** & develop in the ovarian cavity of the mother, then are born.

- The eggs are fertilized in the female & remain so during dev't allowing for greater protection from predators & bad env'tal conditions.

- But, there is no direct nourishment by the mother.

Unit 2: Funct. anat.: Fish Reproduction

- ***Viviparous*** fishes give birth to live young, & the eggs develop in the mother whilst receiving nourishment from it.

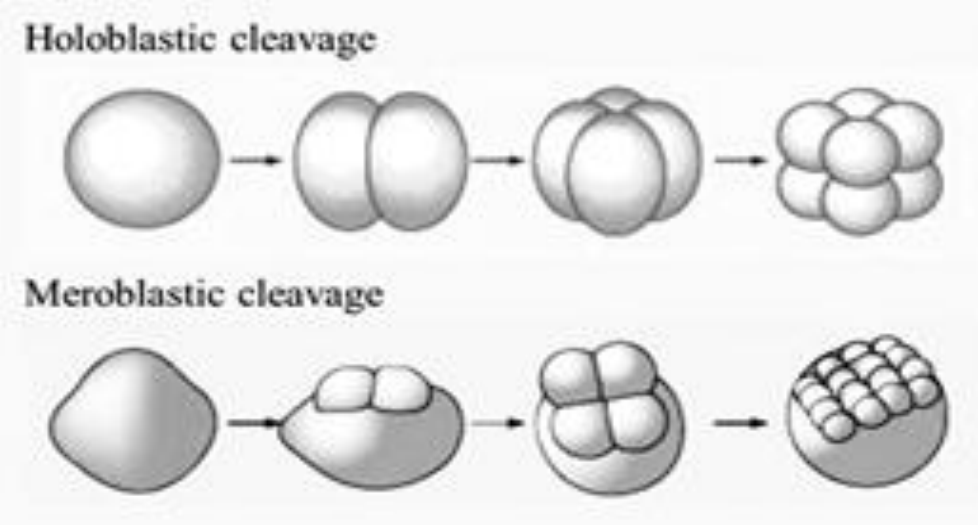
- Most develop a kind of placental attachment through which the young are nourished during gestation.

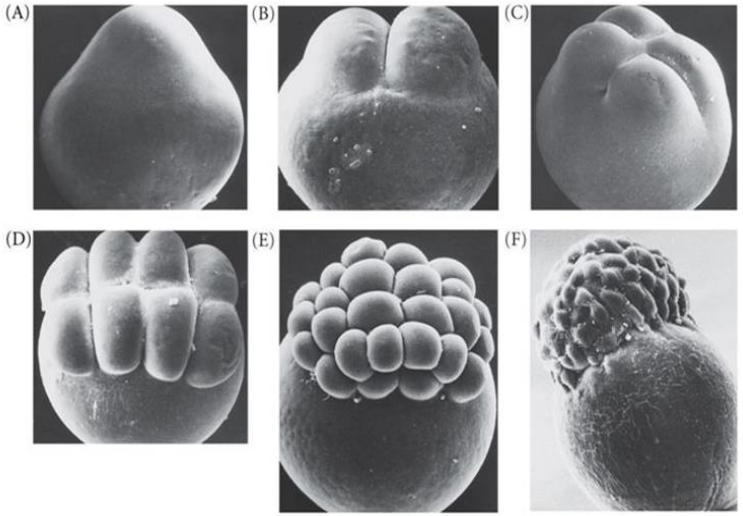
Unit 2: Funct. anat.: Fish Reproduction

- Most have ***megalecithal eggs*** with ***meroblastic cleavage***..

- Males & females come together in great schools & release vast numbers of gametes into the water to drift with currents.

Unit 2: Funct. anat.: Fish Reproduction





Unit 2: Funct. anat.: Fish Reproduction

- Pelagic marine teleost have minute, transparent buoyant, eggs but many near-shore/benthic spp have are larger, typically yolky, non-buoyant, & adhesive.

- Many benthic spawners guard their eggs & fight off intruders.

- Some **bury** their eggs, many **attach** them to vegetation, some **deposit** them in nests, & some even **incubate** them in their mouths.

Unit 2: Funct. anat.: Fish Reproduction

- Some provide no parental care & simply scatter their eggs among weeds or along the sediment.

- Fishes that provide egg care (e.g. cichlids), produce fewer, larger eggs with a better chance for survival.

- With increasing parental care from ***egg scatterers*** to ***brood hiders*** to ***external*** & ***internal bearers*** — the eggs become yolkier & less numerous.

Unit 2: Funct. anat.: Fish Reproduction

- Fishes also show several types of ***hermaphroditism***.
  - ***sequential hermaphrodites*** mature as one sex, & then change to the other sex
  - ***synchronous hermaphrodites***, have functional testes & ovaries at the same time (but only cross-fertilize).
- A few fish species consist only of females & reproduce ***parthenogenetically***.

Unit 2: Funct. anat.: Fish Reproduction

- E.g. the Amazon molly, *Poecillia formosa*, exhibits ***ameiotic parthenogenesis*** (*gynogenesis*) i.e. a sperm of a different species initiates egg dev't, but does not contribute genetic material.

- Most fishes undergo ***direct*** dev't except in *Anguilla* where dev't is ***indirect*** consisting of an elver (young eels) or leptocephalus larval form.

Unit 2: Funct. anat.: Fish Reproduction

- Most fishes hatch as larvae, with a semi-transparent yolk sac, that provides food supplies till the mouth & digestive tract have developed & larvae can self-feed.

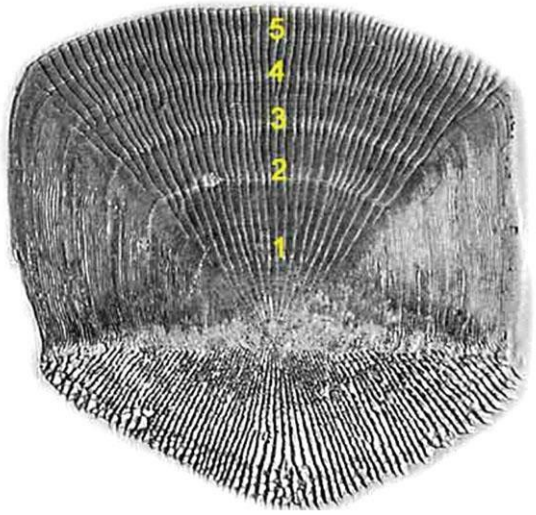
- After a period of growth larvae undergo ***metamorphosis***, especially dramatic in many marine spp. e.g. eels.

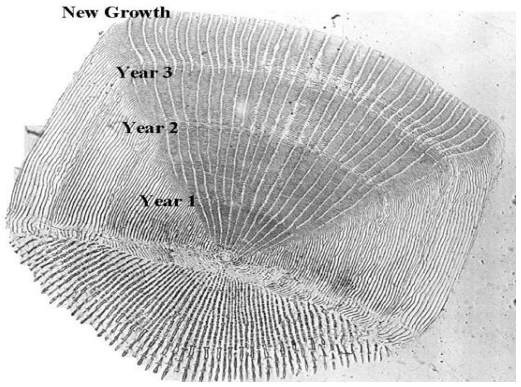
Unit 2: Funct. anat.: Fish Reproduction

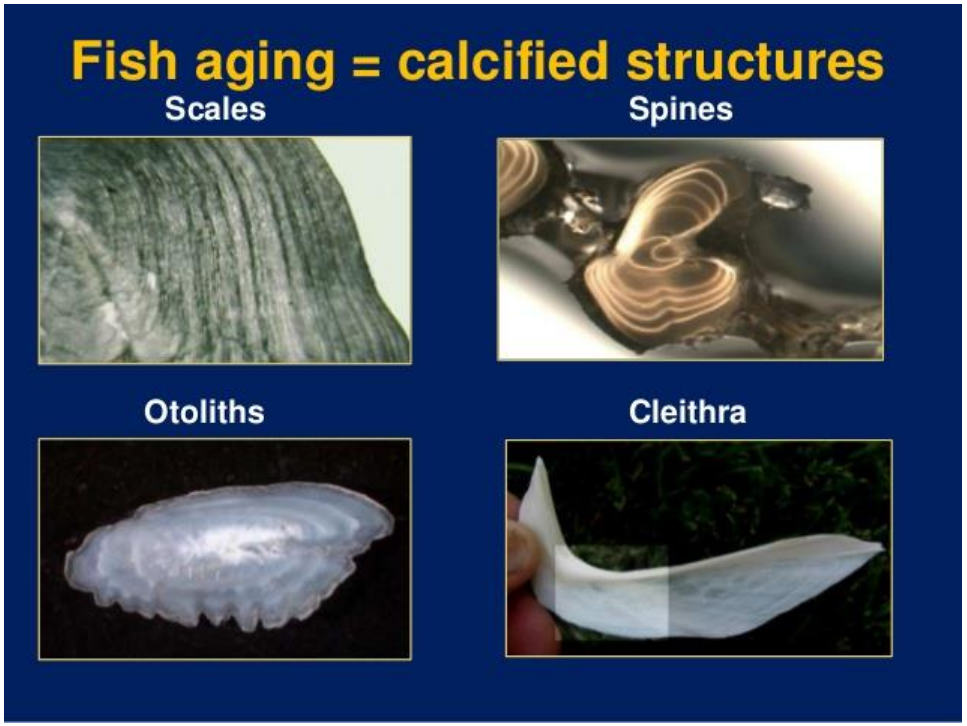
- **Growth** in fishes is temperature dependent & so fishes living in temperate regions grow rapidly in summer when food is abundant but nearly stop growing in winter.

- ***Annual rings*** in scales, otoliths, cleithrum, & other bony parts reflect this seasonal growth, a distinctive record of convenience to fishery biologists who wish to determine a ***fish's age***…

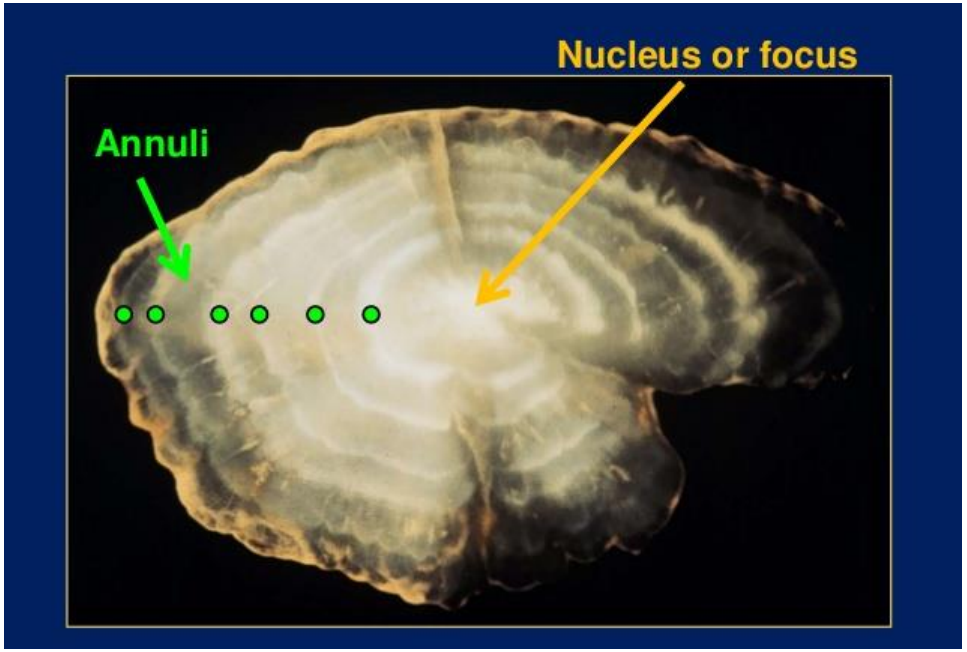
Unit 2: Funct. anat.: Fish Reproduction

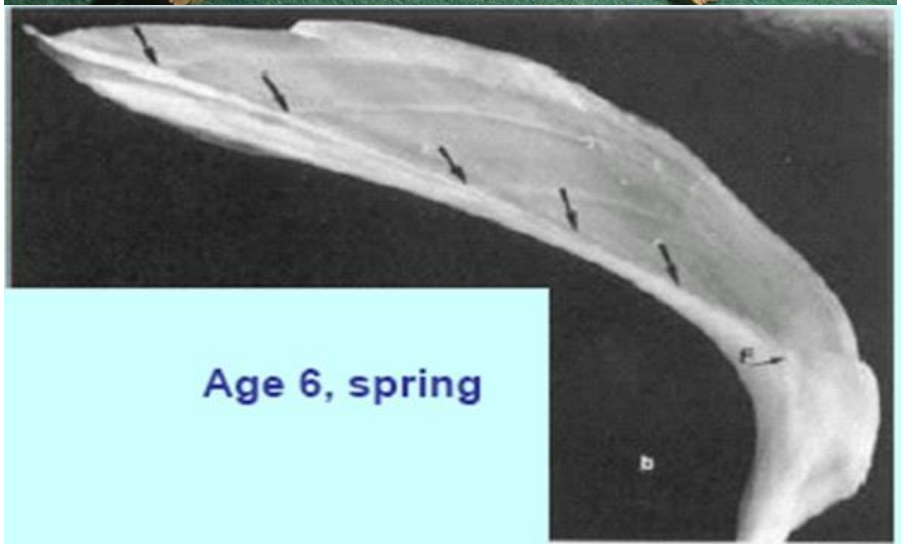




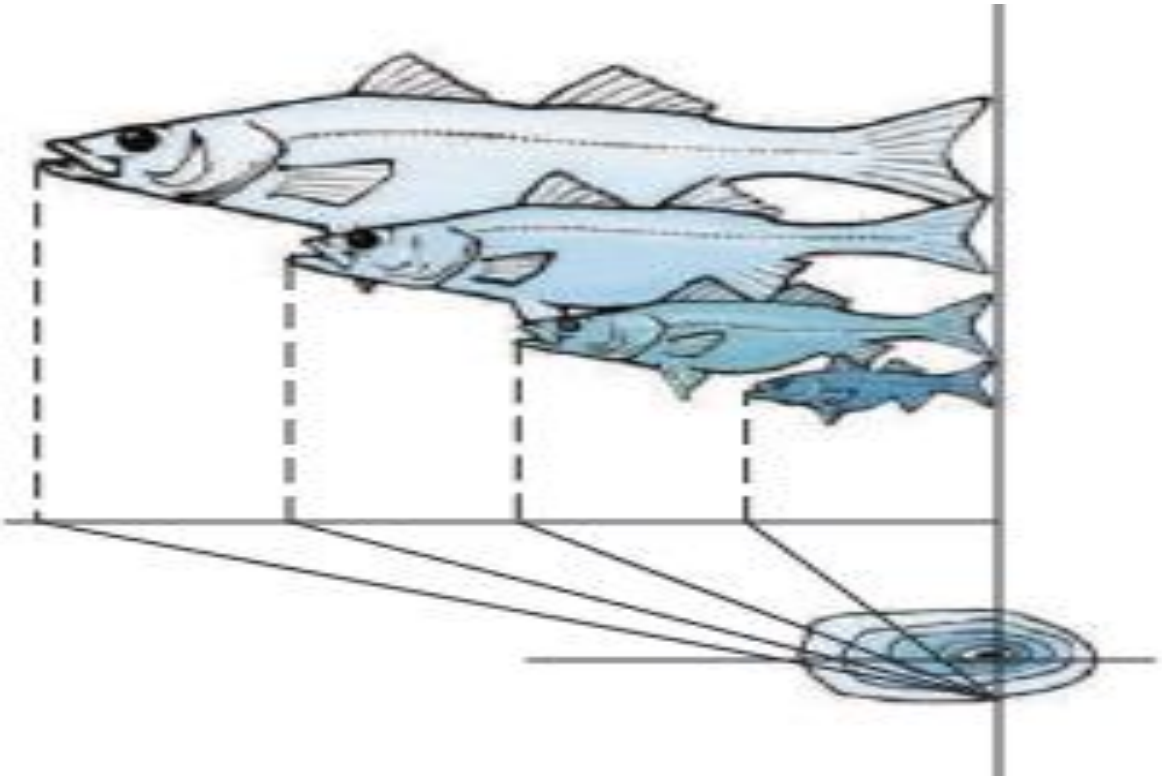


Unit 2: Funct. anat.: Fish Reproduction





Unit 2: Funct. anat.: Fish Reproduction



Unit 2: Funct. anat.: Fish Reproduction

- Fish lifespan vary from a year to over 150 years.

- Few die soon after a single spawning, a phenomenon termed *semelparity*, but most species normally produce for more than one season (*iteroparity*).

- Fewer than 1 % of fishes are semelparous, & these tend to be diadromous species.

Unit 2, 6: Nervous & Sensory System in Fishes

Unit 2: Funct. anat.: Nerv. & Sensory Syt.

- Fishes, though vertebrates, typically have small brains compared to other vertebrates e.g. birds, etc.

- Exception are found in the mormyrids (elephant fishes) & sharks with relatively large brains.

- Fish nervous system consists of a *central nervous system* (CNS), made up of brain & spinal cord & a *peripheral nervous systems* (PNS) made up of various nerves that branch off the spinal cord.

Unit 2: Funct. anat.: Nerv. & Sensory Syt.

- The CNS *coordinates* & *integrates* all bodily activities & *stores* information while the PNS allows the fish to delicately *sense* its watery env't.

- PNS have nerves found throughout the body that originate from the brain or spinal cord.

- They bring sensory messages from the skin surface (*somatic sensory*) & send messages outwards to move muscles (*somatic motor*).

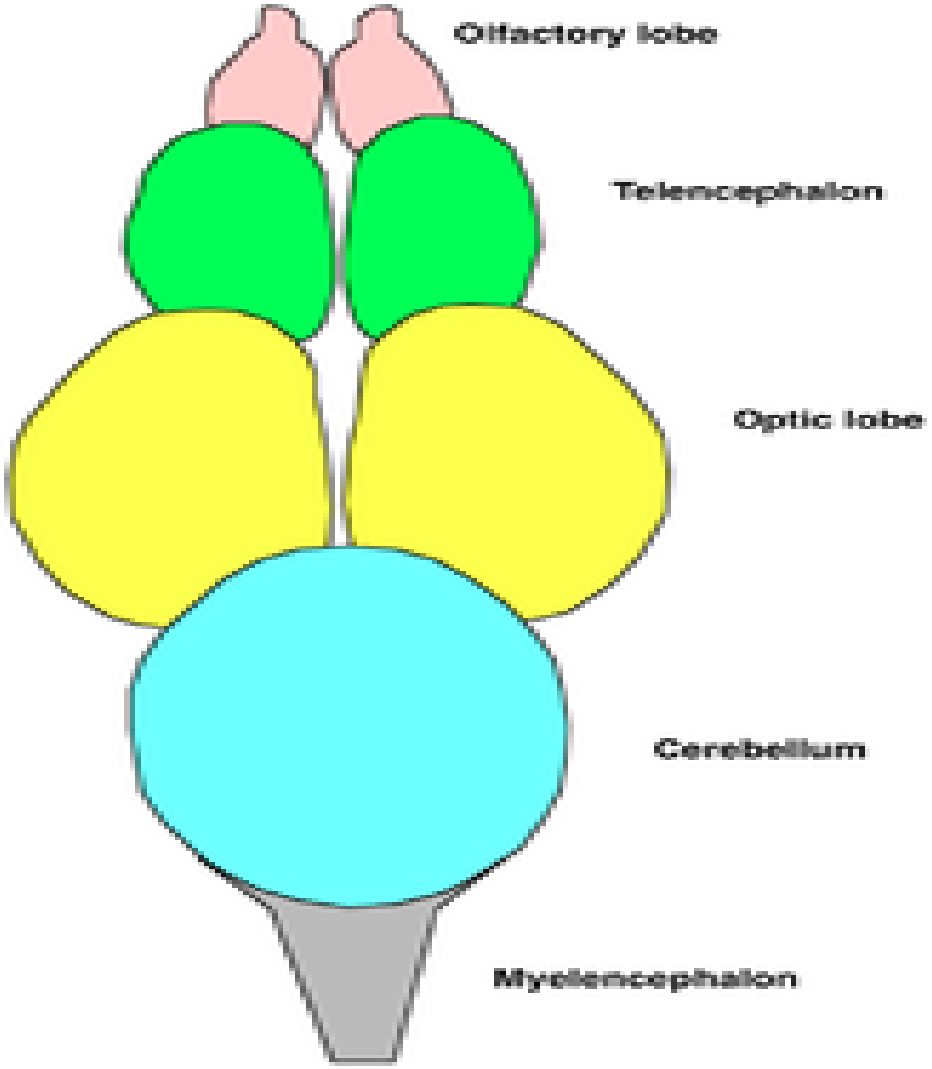
Unit 2: Funct. anat.: Nerv. & Sensory Syt.

- PNS also have *visceral sensory* & *motor nerves* connected to a fish's various organs.

- Information received by the CNS is sent to the brain in the form of nerve impulses.

- Functional anatomy of a fish's ***brain***.

Unit 2: Funct. anat.: Nerv. & Sensory Syt.



Unit 2: Funct. anat.: Nerv. & Sensory Syt.

	FOREBRAIN (FB) (telencephalon)	DIENCEPHALON	MIDBRAIN (MB) (mesecephalon)	HINDBRAIN (HB) (metencephalon)
Part(s)	-Olfactory parts (**OL**) - **cerebrum**	A connection between the **FB** & the **MB** & have a pineal body (**PB**); pituitary gland, etc	2 large optic lobes	- Cerbellum **(C)** - brain stem or myelencephalon (**M**)
Functions	-**OL** receives & process impulses from nostrils or smell - **cerebrum** is also involved in olfaction. - For detecting food, mates, predators, & to find homes e.g. salmons, etc	- **D** involved in hormonal balance & homeostasis - **PB** detects light, control colour changes, & maintain circadian rhythms	It is involved in processing visual information	- **C** helps in balance & swimming & - **M** connects spinal cord to brain; coordinates sensory information e.g. respiration & osmoregulation
Other features	It is very large in fish that <u>hunt primarily by smell</u> e.g. hagfish, sharks, catfish		Very large in species that hunt by sight e.g. cichlids, rainbow trout, etc	Hagfish & lampreys have small cerebella Mormyrids have massive ones.

Unit 2: Funct. anat.: Nerv. & Sensory Syt.

	FOREBRAIN (FB) (telencephalon)	DIENCEPHALON	MIDBRAIN (MB) (mesecephalon)	HINDBRAIN (HB) (metencephalon)
Other features	**Taste buds** used for smelling are located in the mouth, lips, fins, skin, barbels (e.g. goat fish)		- Retinas have rod & cone cells for **scotopic** & **photopic** vision; - Most bony fishes have **colour vision** but cartilaginous fishes have little or none. - Some sharks have a membrane that can be drawn across the eye to reduce brightness. - Some fish can see UV & others see **polarized** light.	

Unit 2: Funct. anat.: Nerv. & Sensory Syt.

- Fishes have specialized hearing-detecting apparatus called *lateral lines* consisting of a system of small canals lined with sound-sensitive sensory cells.

- It picks vibration from swimming of other animals & water displacement caused by sound waves.

- It allows fish to avoid obstacles, orient to currents, & keep their position in a school.

Unit 2: Funct. anat.: Nerv. & Sensory Syt.

- Fishes also perceive sound waves with their inner ears stones (*otoliths*) - paired hearing organs located to the sides of the brain just behind the eyes.

- Changes in the position of many fishes are detected by shifts in otoliths position.

- Some fishes also have the *Weberian organ* that transfer vibrations in the swim bladder to the inner ear.

Unit 2: Funct. anat.: Nerv. & Sensory Syt.

- Sharks may have a sharp sense of hearing & can possibly hear prey many miles away.

- Cartilaginous fishes have a sense organ, ***Ampullae of Lorenzini*** that can detect weak electrical currents.

- This system has been shown to help them detect prey – a kind of electrical sensing device.

Unit 2: Funct. anat.: Nerv. & Sensory Syt.

- It also assist in navigation, a sort of *electromagnetic compass* or *current detector* for sharks (with the greatest electrical sensitivity of any animal) to find prey.

- Ocean currents moving in the earth's magnetic field also generate electric fields that sharks can use for orientation & navigation.

- Electric fish can produce weak electric currents used in navigation & social communication.

Unit 2, 7: Hydromineral Balance in Fishes

Unit 2: Funct. anat.: Hydromineral Balance

- One of the key homeostatic functions in living organisms is the proper regulation of internal osmotic env't.

- Deviations from the normal range can adversely affect proper physiological functions through;
  - **water** loss or gain
  - the changing of internal **ionic concentrations**, &
  - shifts in the ionic & osmotic **gradients**

Unit 2: Funct. anat.: Hydromineral Balance

- Osmoregulation & osmoconformance in fishes
  - Definitions
  - Most fishes are osmoregulators
  - Difference between steno- & euryhaline fishes;
    - **Steno** – tolerate only small changes in the salinity of their external env't.
    - **Eury** – osmoregulate over a wide range of salinity levels in their external env't.
  - **Types & regulatory mechanisms**

Unit 2: Funct. anat.: Hydromineral Balance

- Type(s) of hydromineral balance in fishes
  - **Osmoconformers**
    - Hagfishes – exclusively marine
    - Marine elasmobranchs (cartilaginous fishes)
    - Sarcopterygians (bony fishes)
      - Marine
      - Freshwater…
  - **Osmoregulators**
    - Marine teleosts
    - Freshwater teleosts
    - Freshwater elasmobranchs
    - Diadromous species …

Unit 2: Funct. anat.: Hydromineral Balance

	MARINE		FRESHWATER	DIADROMOUS
	Osmoconformers	**Osmoregulators**	**Osmoregulators**	**Osmoregulators**
Examples	1. **Hagfishes** e.g. *Myxines glutinosa* 2. **Marine elasmobranchs** e.g. dog fish *(Squalus acanthias)* 3. **Marine Sarcopterygians** e.g. the coelacanth *Latimeria chalumnae* 4. **Freshwater Sarcopterygians** e.g. the Dipnoi (African & South American lungfishes)	**Marine teleosts** e.g. Poacher *(Agonus)*, sculpin *(Taurulus)*, etc	1. **Freshwater teleosts** e.g. Carp *(Cyprinus)*, Goldfish *(Carassius)*, etc 2. **Freshwater Elasmobranchs** e.g.*Potamotrygon*	1. Pacific lamprey *(Lamepetra tridentata)* 2. Pacific salmon *(Onchoryhnchus sp)* 3.American eel *(Anguilla rostrata)* 4. American shad *(Alosa sapidissma)*
Mechanisms				

Unit 2: Funct. anat.: Hydromineral Balance

- Mechanism (s) of hydromineral balance in fishes
  - **Osmoconformers**
    - Hagfishes - the overall osmotic concentration is about the same as that of sea water .i.e. there is no regulation at all. They are entirely marine & stenohaline.

    - Marine elasmobranchs - (i) convert N-waste into *urea* & retain high levels in blood (ii) have high levels of *TMAO* (iii) rid themselves of Na^+ & Cl^- ions by active secretion via *rectal gland* (iv) have *glomerular kidneys* like FW fish since high levels of urea causes them to gain water (v) they move water by diffusion across their gills

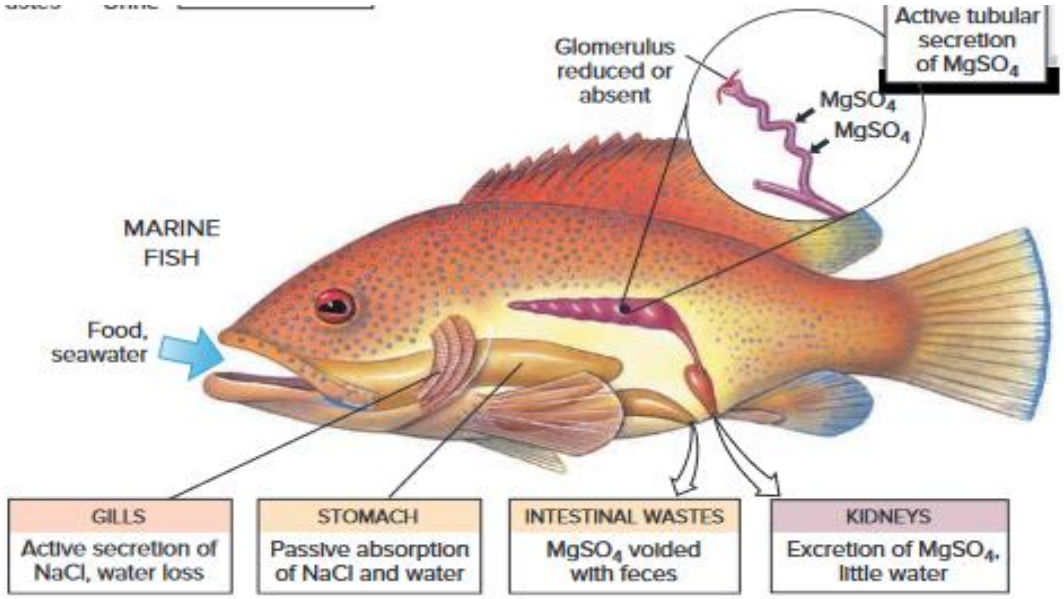
Unit 2: Funct. anat.: Hydromineral Balance

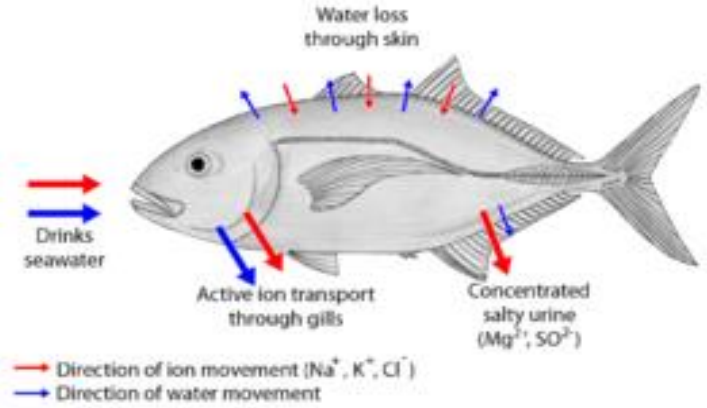
- Types of hydromineral balance in fishes
  - **Osmoconformers (cont)**
    - Sarcopterygians
      - **Marine** - The coelacanth *Latimeria* sp. also use the marine elasmobranch strategy i.e. high *urea* & *TMAO* in their blood.
      - **Freshwater** - e.g. African lungfish (Dipnoi) can survive long droughts by aestivating in mud burrows & produce & retain high *urea* levels which is less toxic but also help them to retain water.

Unit 2: Funct. anat.: Hydromineral Balance

- Types of hydromineral balance in fishes
  - **Osmoregulators**
    - Marine teleosts - Are *hypoosmotic* to their env't & tend to *lose water* & *gain ions* (monovalent) across the thin ***gill membranes***
    - (i) they replace lost water by *ingesting seawater*;
    - (ii) major sea salts (Na, Cl-, K+) are eliminated by *chloride cells* of the gill filaments & opercular *skin* by active transport;
    - (iii) *kidneys* excrete divalent ions (Mg^{2+}, SO_4^{2-}, Ca^{2+});
    - (iv) the remaining divalent ions voided with *faeces*.

Unit 2: Funct. anat.: Hydromineral Balance

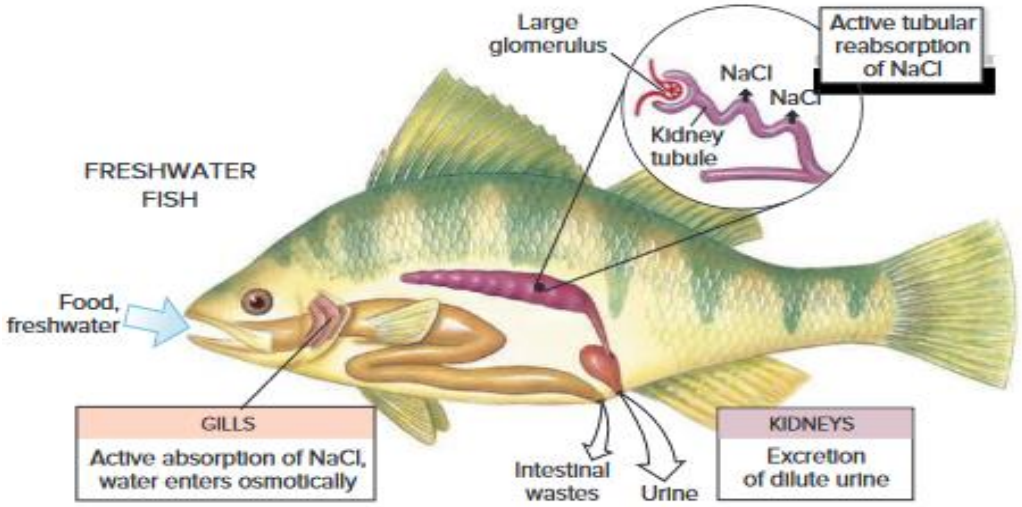


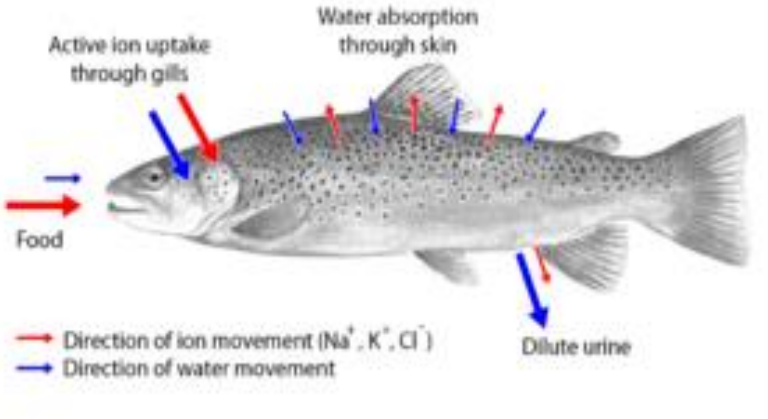


Unit 2: Funct. anat.: Hydromineral Balance

- Types of hydromineral balance in fishes
  - **Osmoregulators (cont)**
    - Freshwater teleosts - *hyperosmotic* to their env't & tend to *gain water* & *lose solutes* across the thin gill filaments, pharynx, & in urine
    - (i) they excrete large volumes of dilute urine through their *kidneys*;
    - (ii) *chloride cells* take up Na^+ & Cl^- ions by active transport from the surrounding into the blood;
    - (iii) this absorption together with salt present in the fish's *food* replaces diffusive salt loss

Unit 2: Funct. anat.: Hydromineral Balance





Unit 2: Funct. anat.: Hydromineral Balance

- Types of hydromineral balance in fishes
  - **Osmoregulators (cont)**
    - Freshwater Elasmobranchs – e.g. the Amazon stingrays *(Potamotrygon)* is a stenohaline sp. with internal env't similar to that of freshwater teleosts with essentially no urea.

    - Diadromous species – make appropriate adjustments in the mitochondria-rich cells of the gill epithelium to physiologically adapt to the dramatic changes in their osmoregulatory env't.

Unit 2, 8: Behavioural Adaptations in Fishes

Unit 2: Funct. anat.: Behav. Adaptations

- Fish have several *anatomical* & *physiological* adaptations which are best understood in relation to their *behaviour*.

- Behavioural adaptations in fishes include *aggressive behaviour* (e.g. territoriality, etc), *shoaling*, *migratory behaviour*, *communication* (e.g. biolumniscence, etc), *feeding*, *reproductive*, & *resting behaviours*, *interspecific interactions* (mimicry, symbiosis, predator-prey, etc),

Unit 2: Funct. anat.: *Territoriality*

- Some fishes are known to establish territories (home areas they aggressively defend against intruders).

- Some defend such territories during *reproduction* & *breeding* but others have almost permanent territories that they use for *feeding* & resting or as *shelter*.

- Thus, territoriality is common is crowded env'ts where resources are most likely to be in short supply.

Unit 2: Funct. anat.: *Territoriality*

- For e.g. coral reef damselfishes are famous for fiercely defending their territories, often attacking fishes many times their size or even divers.

- 3 factors are key in deciding which fish wins a fight;
  - previous residency
  - size
  - results of previous encounters

Unit 2: Funct. anat.: *Territoriality*

- The most frequently observed form of defence is the "*nip*" in which a defending fish attacks an intruder & attempts to bite its caudal tail or side.

- But often, *aggressive behaviour* is in the form of *bluffing* instead of actual fights e.g.
  - raised fins,
  - an open mouth,
  - rapid darting,
  - sound production, etc.

Unit 2: Funct. anat.: *Shoaling*

- A *shoal* describes all social groups of fish including schools & aggregations of fish with random orientation & varying nearest neighbour distances (NND).

- A *school* describes a group of fish swimming at about the same speed in roughly parallel orientation & maintaining a constant NND.

Unit 2: Funct. anat.: *Shoaling*

- A shoal can go from classic, polarized organization to an amorphous mass in seconds, depending on whether they are *traveling*, *feeding*, *resting*, or *avoiding predators*.

- Some e.g. herrings, sardines, & some mackerels, school throughout their lives but others are part-time schoolers especially as *juveniles* or during *feeding*.

- Most Chondricthyes are solitary but some e.g. hammerhead sharks, mantas, & rays sometimes school

Unit 2: Funct. anat.: *Shoaling*

- It is estimated that over 4000 species of *marine* & *freshwater* species school as adults.

- Members of schools are typically all about the same size.

- Stationary schools common around coral reefs, kelp beds, rocks, & shipwrecks, however, may include members of different sizes or even different species.

Unit 2: Funct. anat.: *Shoaling*

- Several reasons have been suggested for schooling in fishes & include;
  - increased *swimming efficiency*
  - Increased *food finding efficiency*
  - increased *reproductive success*
  - reduced *risk of predation*

- The combined benefits of these factors provide strong selective incentives for fish to join shoals & become part of a highly cooperative group.

Unit 2: Funct. anat.: *Migratory behaviour*

- *Migration* is the regular long-range mass mov't of fish from one place to another.

- Fishes in all aquatic env'ts may migrate phenomenal distances & use various homing mechanisms.

- It can be once a day, once a year, or once in a life time & some are between on & offshore areas or up & down the vertical column of the open water.

Unit 2: Funct. anat.: *Migratory behaviour*

- The general patterns are made up into 3 basic forms:
  - *Oceanodromy* – migrate entirely within salt water
  - *Potamodromy* – migrate entirely within freshwater
  - *Diadromy* – migrate between salt & fresh waters

- Most fish migrations relate to *reproduction* (spawning) & separation of *life history stages* (growth) but, many are also in response to *changing env'tal conditions* e.g. temperature & mov't & abundance of food (feeding).

Unit 2: Funct. anat.: *Migratory behaviour*

- Diadromy is broken into 3 basic types;
  - *catadromy* – freshwater sp. that migrate to sea to spawn e.g. anguillid eels, etc.
  - Most feeding & growth occurs in freshwater prior to the migration of fully grown adult fish to sea to reproduce.
  - There is either no subsequent feeding at sea or any feeding result in little somatic growth e.g. European & American eels, scorpion fishes, sculpins, flounders, etc

Unit 2: Funct. anat.: *Migratory behaviour*

- *anadromy* – salt water sp. that migrate to freshwaters to spawn e.g. salmons, trouts, sturgeons, etc

- Most feeding & growth takes place at sea, prior to the migration of fully grown adult fish into freshwater to reproduce.

- There is either no subsequent feeding in freshwater or any feeding result in little or no somatic growth e.g. salmon, shad, herrings, trouts, anchovies, sturgeons, lampreys, etc.

Unit 2: Funct. anat.: *Migratory behaviour*

- *amphidromy* – move between salt & fresh waters for purposes other than spawning

- Unlike catadromy & anadromy, where there is a difference between the feeding & growing biome & the reproductive biome, here, the principal feeding biome is the same as the reproductive biome (freshwater)

- e.g. members of the Gobiidae, Eleotrdae, & Galaxidae

Unit 2: Funct. anat.: *Migratory behaviour*

- About ½ of all diadromous fishes are anadromous, while catadromous & amphidromous types constitute 25% each.

- Catadromy is favoured in cooler regions where biological productivity is greater in the sea than in freshwater.

- The sea is hence a better feeding & growing biome where growth is rapid, survival is higher, size at maturity is higher, & fecundity is greater.

Unit 2: Funct. anat.: *Migratory behaviour*

- Anadromy is favoured in warmer regions where biological productivity is greater in freshwaters than in sea.

- Hence, the main trophic life stage occurs in freshwaters for the same reasons that catadromous fish spend their life main trophic life stage at sea.

- Amphidromy is favoured on oceanic islands & provides a way for fish to colonize habitable island freshwaters or favours recolonization of these waters after a disturbance.

Unit 2: Funct. anat.: *Migratory behaviour*

- These patterns place early life history stages in habitats most favourable for growth & devt.

- Before the migration, anticipatory changes in *serum ion content*, *body colour*, & *visual pigments*, etc are made.

- Mechanisms of such migrations have been severally hypothesized & include orientation to cues of:
  - *currents*, *temperature*, *polarized light*, *sun*, *earth's magnetic field*, *odours*, *salinity*, etc

Unit 2: Funct. anat.: *Migratory behaviour*

- E.g. salmons are known to find their home streams with remarkable accuracy, the result of a king of chemical memory.

- The ability of an animal to find its way back to a home area is known as *homing behaviour* using the various cues previously listed.

Unit 2: Funct. anat.: *Colouration*

- *Colouration*: Different colours are found in fishes & can be used as **camouflage**.

- Some fishes are very brightly coloured especially those living in the tropics.

- The coloured pigments in fishes are found in special cells called **chromatophores**.

Unit 2: Funct. anat.: *Colouration*

- Fishes also have *structural colours* that result when a special surface reflects only certain colours of light.

- Most structural colours of fish are the results of crystals contained in special chromatophores called *iridophores* that act like tiny mirrors.

- The iridescent shiny quality of many fishes is produced by structural colours & chromatophores.

Unit 2: Funct. anat.: *Colouration*

- Colours can tell a lot about fishes e.g. some change colour with their mood or reproductive condition.

- They may also use colour to advertise themselves in what is known as *warning colouration*.

- E.g. the colourful bar-tailed lionfish advertises spines that contain a powerful venom capable of killing a human.

Unit 2: Funct. anat.: *Colouration*

- *Cryptic colouration* (camouflage), i.e. blending with the env't to deceive predators or prey is a common adaptation e.g. the stonefish (*Syananceia verrucosa*)…

- Others such us some flatfishes, blennies, sculpins, & rockfishes can change colour to match their surroundings.

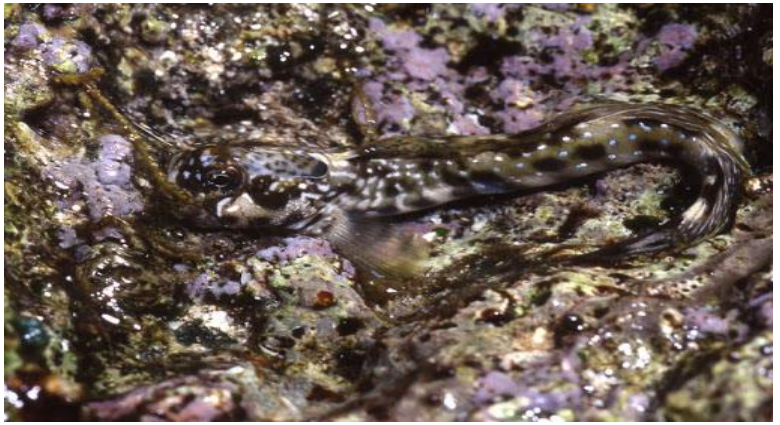
Unit 2: Funct. anat.: *Colouration*

Stonefish (*Syananceia verrucosa*)

Unit 2: Funct. anat.: *Colouration*

Flatfish

Blennies



Rock fish

Unit 2: Funct. anat.: *Colouration*

- Fish also use *disruptive colouration* – presence of stripes, bars, or spots that break up the outline of a fish to prevent detection by potential predators or prey e.g. butterfly fish (*Chaetodon trifasciatus*)

- But, open water fishes & many shallow-water predators are rarely colourful.

- Most of them have silver/white bellies & dark backs.

Unit 2: Funct. anat.: *Colouration*

Butterfly fish

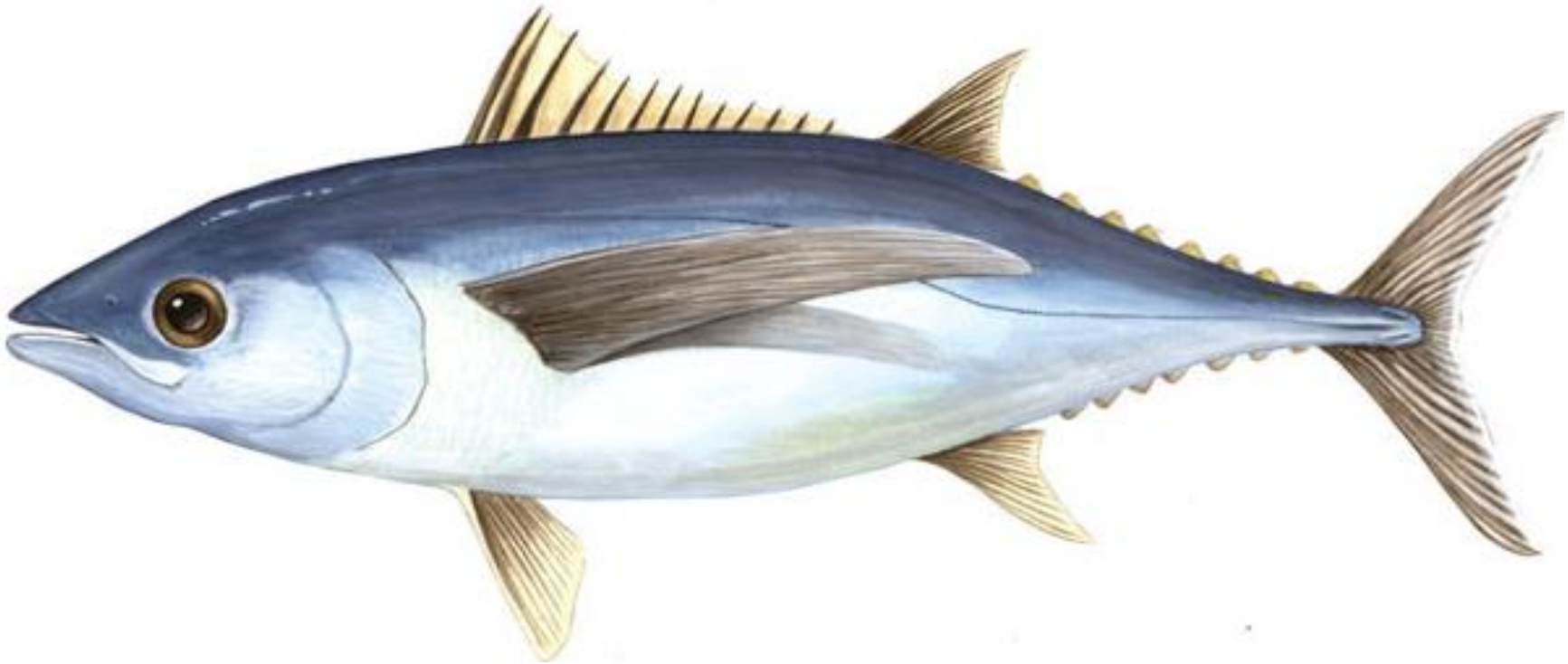
Unit 2: Funct. anat.: *Colouration*

- This distinctive colour pattern, known as *countershading*, is a form of disguise in open water.

- When viewed from below, the white belly blends with the bright light coming from the surface.

- The dark back blends into the water's colour as seen from above.

Unit 2: Funct. anat.: *Colouration*



Open water fish

Unit 2: Funct. anat.: *Colouration*

- Deep-water fishes also use colour for concealment & they tend to be black or red – colours which are hard to see in deeper waters.

Unit 2: Funct. anat.: *Biolumniscence*

- Deep sea fishes exhibit this phenomenon e.g. *Blepherodon*, etc.

- It is the process by which energy from a chemical reaction is transformed into light energy.

- In deeper parts of the ocean, light is absent & vision is not useful for locating prey.

Unit 2: Funct. anat.: *Biolumniscence*

- There is however, a major exception to this rule.

- Many marine animals e.g. some fish species emit light as a product of a chemical reaction taking place in specialized cells (*photocytes*) or organs (*photophores*).

- When a substance known as **luciferin** reacts with O2 in the presence of the enzyme **luciferase**, the chemical product gives off blue-green light.

Unit 2: Funct. anat.: *Biolumniscence*

- Bioluminescence is widespread in marine organisms.

- It is produced either by specialized structures (*intracellular luminescence*) or by symbiotic bacteria (*intercellular luminescence*).

- It is different from *phosphorescence* or *fluorescence* in which light involves energy received from other sources causing emission.

Unit 2: Funct. anat.: *Biolumniscence*

- Bioluminescence is mainly a marine phenomenon.

- Reasons attributed to bioluminescence include:
  - **confusing predators**
  - **finding mates**
  - **camouflage**