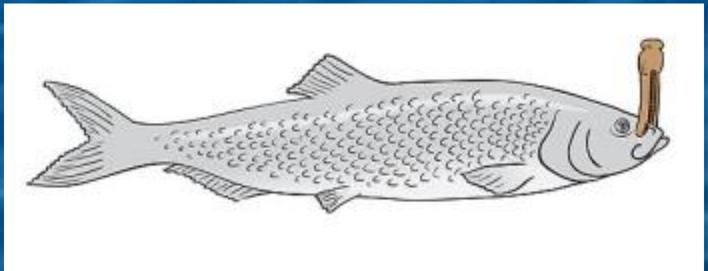


Sensory Perception, Behavior and Communication

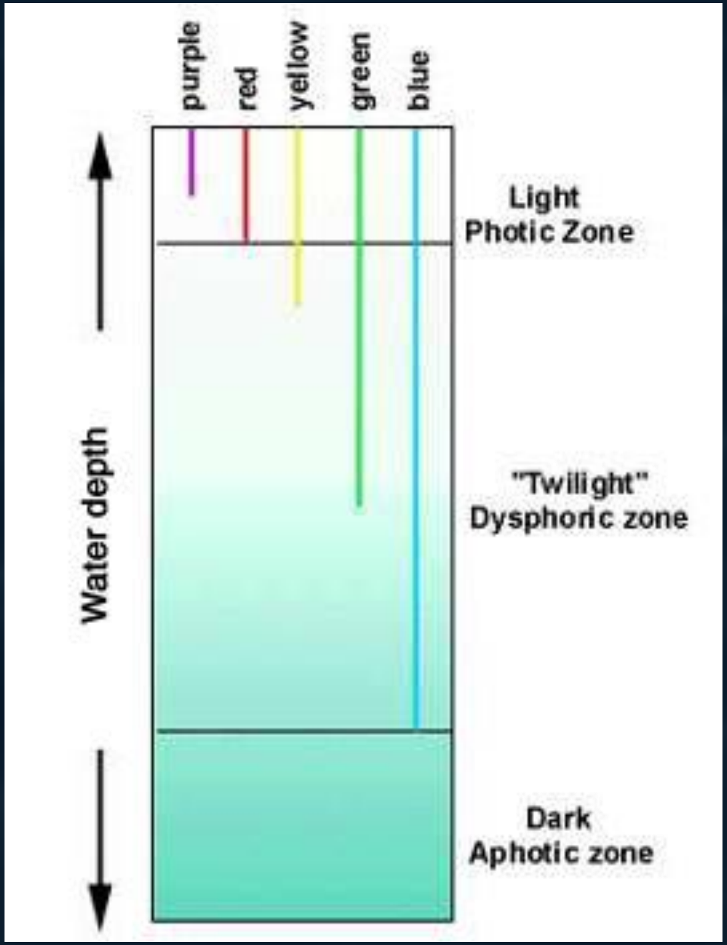
FT S273 - Fundamentals of Fisheries Biology

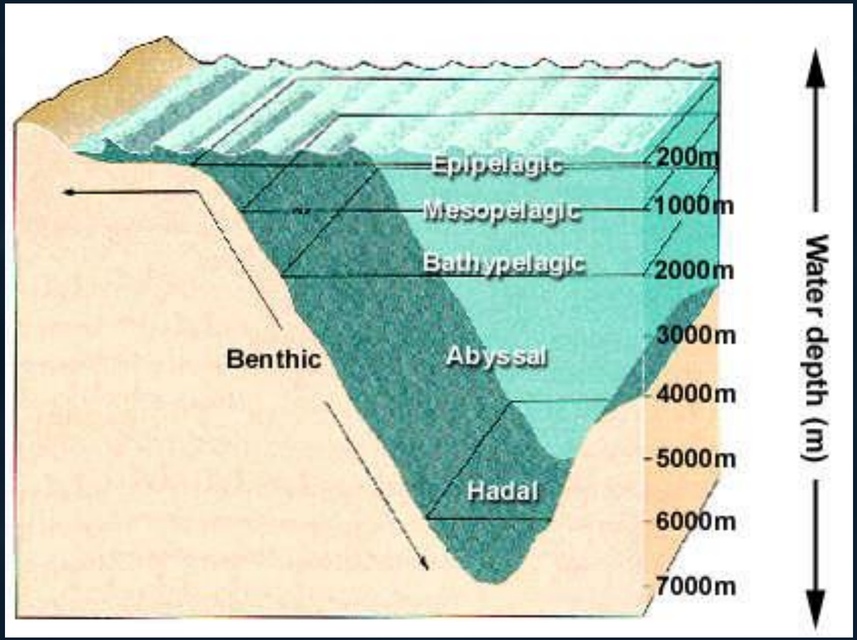
23 March 2015

Relevant characteristics of water

- Bad for light (penetrates to 100m)
- Good for sound (5x faster in water)
- Good and bad for odor

Light penetration in water





Also, the intensity of this light decreases rapidly with water depth, for example,

- only 73% of the surface light reaches a depth of 1 centimeter (less than a half inch)
- only 44.5% of the surface light reaches a depth of 1 meter (3.3 feet)
- 22.2% of the surface light reaches a depth of 10 meters (33 feet)
- 0.53% of the surface light reaches a depth of 100 meters (330 feet)
- 0.0062% of the surface light reaches a depth of 200 meters

- <u>Bottom line -- most of the light is absorbed or scattered within the top few meters of the ocean.</u>

Chemoreception

- Olfactory
- Gustatory

CrossMark
click for updates

Hydrodynamic aspects of fish olfaction

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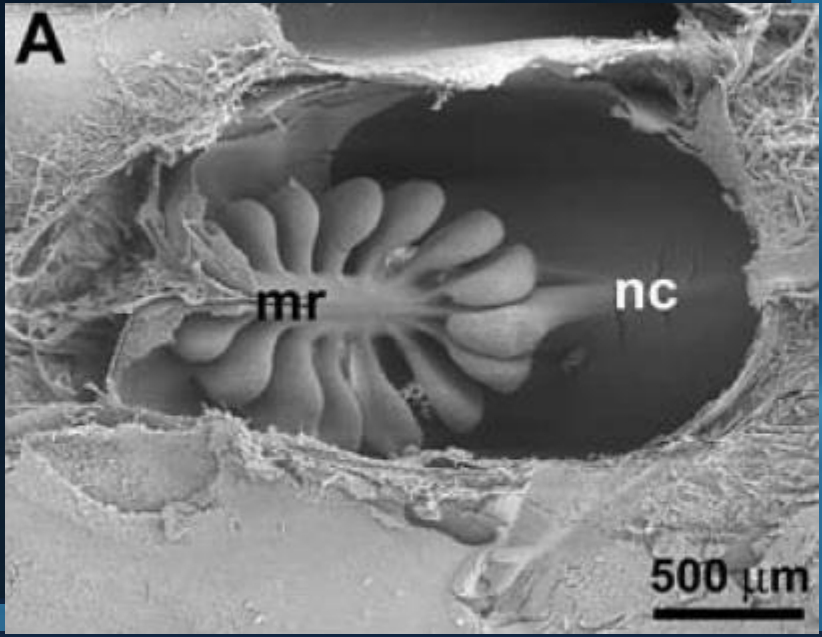
Abstract

Flow into and around the olfactory chamber of a fish determines how odorant from the fish's immediate environment is transported to the sensory surface (olfactory epithelium) lining the chamber. Diffusion times in water are long, even over comparatively short distances (millimetres). Therefore, transport from the external environment to the olfactory epithelium must be controlled by processes that rely on convection (i.e. the bulk flow of fluid). These include the beating of cilia lining the olfactory chamber and the relatively inexpensive pumping action of accessory sacs. Flow through the chamber may also be induced by an external flow. Flow over the olfactory epithelium appears to be laminar. Odorant transfer to the olfactory epithelium may be facilitated in several ways: if the olfactory organs are mounted on stalks that penetrate the boundary layer; by the steep velocity gradients generated by beating cilia; by devices that deflect flow into the olfactory chamber; by parallel arrays of olfactory lamellae; by mechanical agitation of the chamber (or olfactory stalks); and by vortices. Overall, however, our knowledge of the hydrodynamics of fish olfaction is far from complete. Several areas of future research are outlined.

OLFACTION

- Odor is sensed when dissolved chemical makes contact with olfactory rosette
- Fish who rely on smell cues have elongated rosettes
- Species relying on olfaction have more developed olfactory equipment
- On other end some fish have devolved olfaction mechanisms



Olfaction and Navigation

- http://www.seymoursalmon.com/lifecycle.php

Taste

- Gustatory chemoreception
- Taste bud sensory cells most commonly located on several exterior surfaces of the fish as well as in the mouth.

Klinotaxis

- http://sharkdivers.blogspot.com/2012/08/guadalupe-shark-week-best-ever.html

???

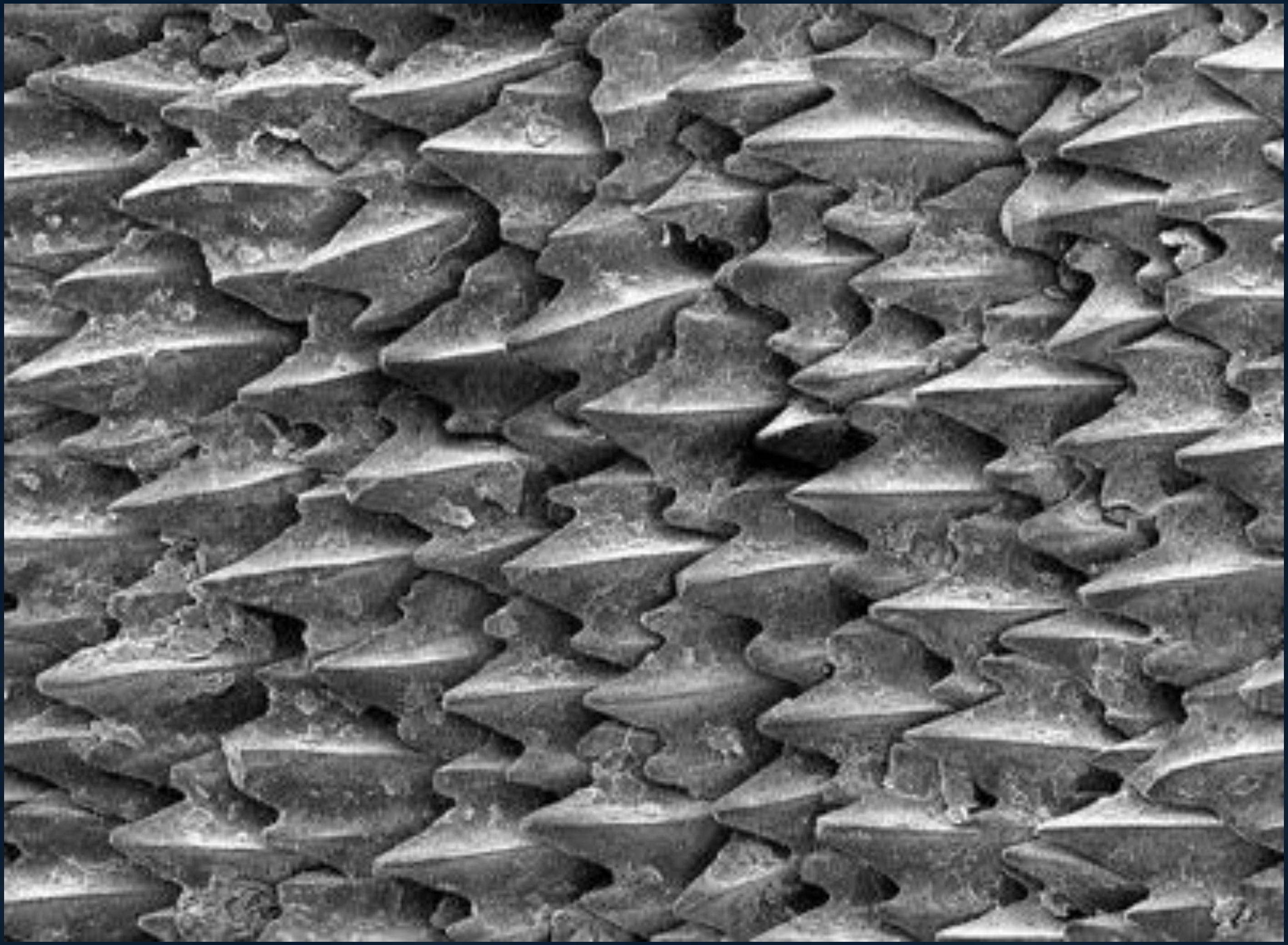
- http://thelife-animal.blogspot.com/2012_01_01_archive.html

Taste

- Gustatory chemoreception
- Located on several surfaces to include:

- http://www.wildlife.state.nh.us/Fishing/Fishing_Reports/Fishing_Reports_2007/fishing_report_052407.htm

- http://fishingnoob.com/85/understanding-fish-senses/



- http://www.freerepublic.com/focus/f-chat/2717878/posts

- http://www.elasmodiver.com/shark_senses.htm

- http://wildlife.ohiodnr.gov/minnow

http://www.sportfishermen.com/board/f133/red-hake-big-eel-big-flounder-51143.html

Fishes based on sensory items

1. Feeding by sight and taste

2. Feeding in dimly lit environments (fish with barbels)

3. Sight feeders

Taste

Research is indicating that perhaps development and density of taste buds depends on variety of food and other organisms in environment

- http://www.flickr.com/photos/whitesharkecoventures/3198908133/

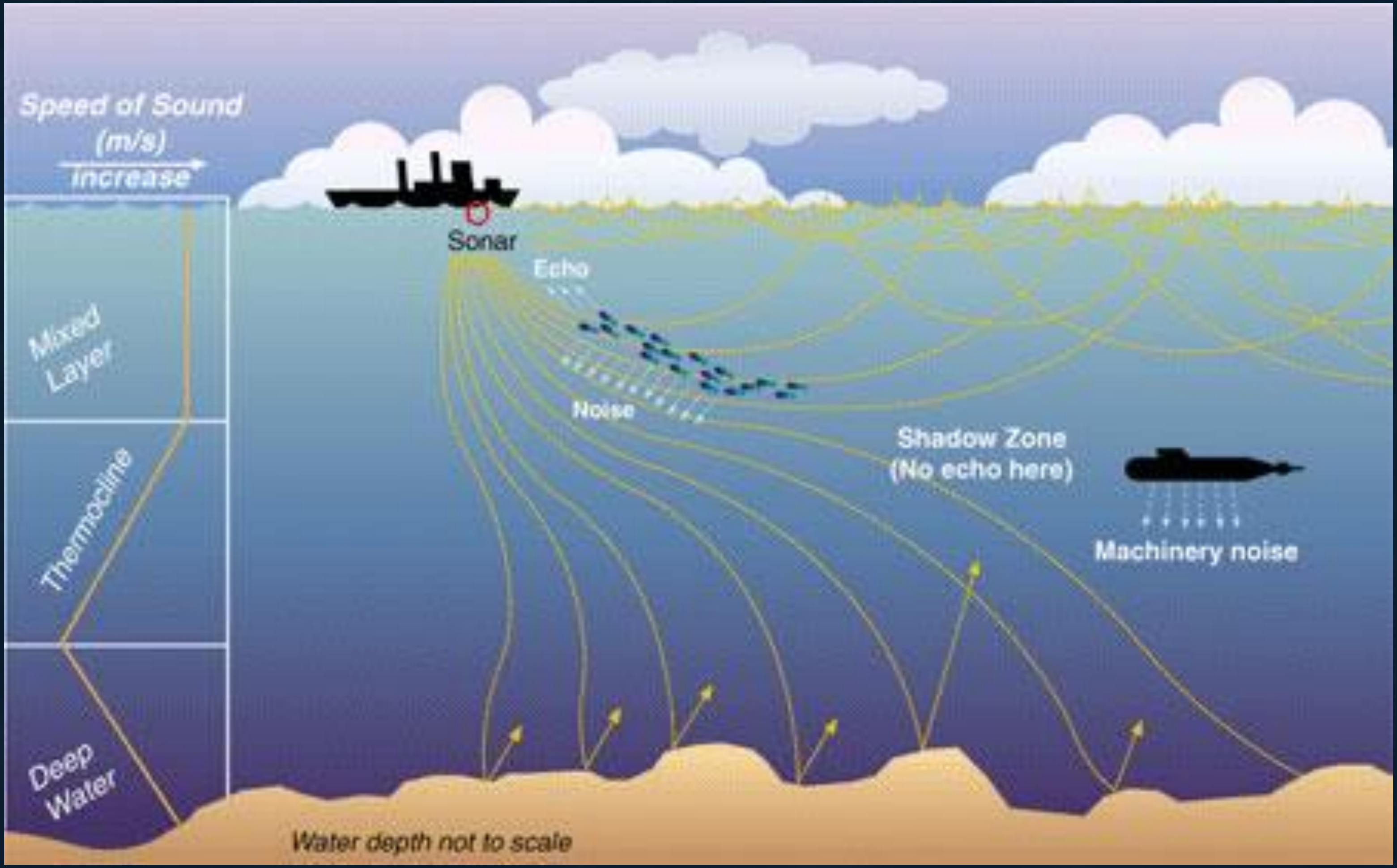
ACOUSTICOLATERALIS SYSTEM

This system senses sounds, vibrations and other displacements of water in the environment

Two main components:

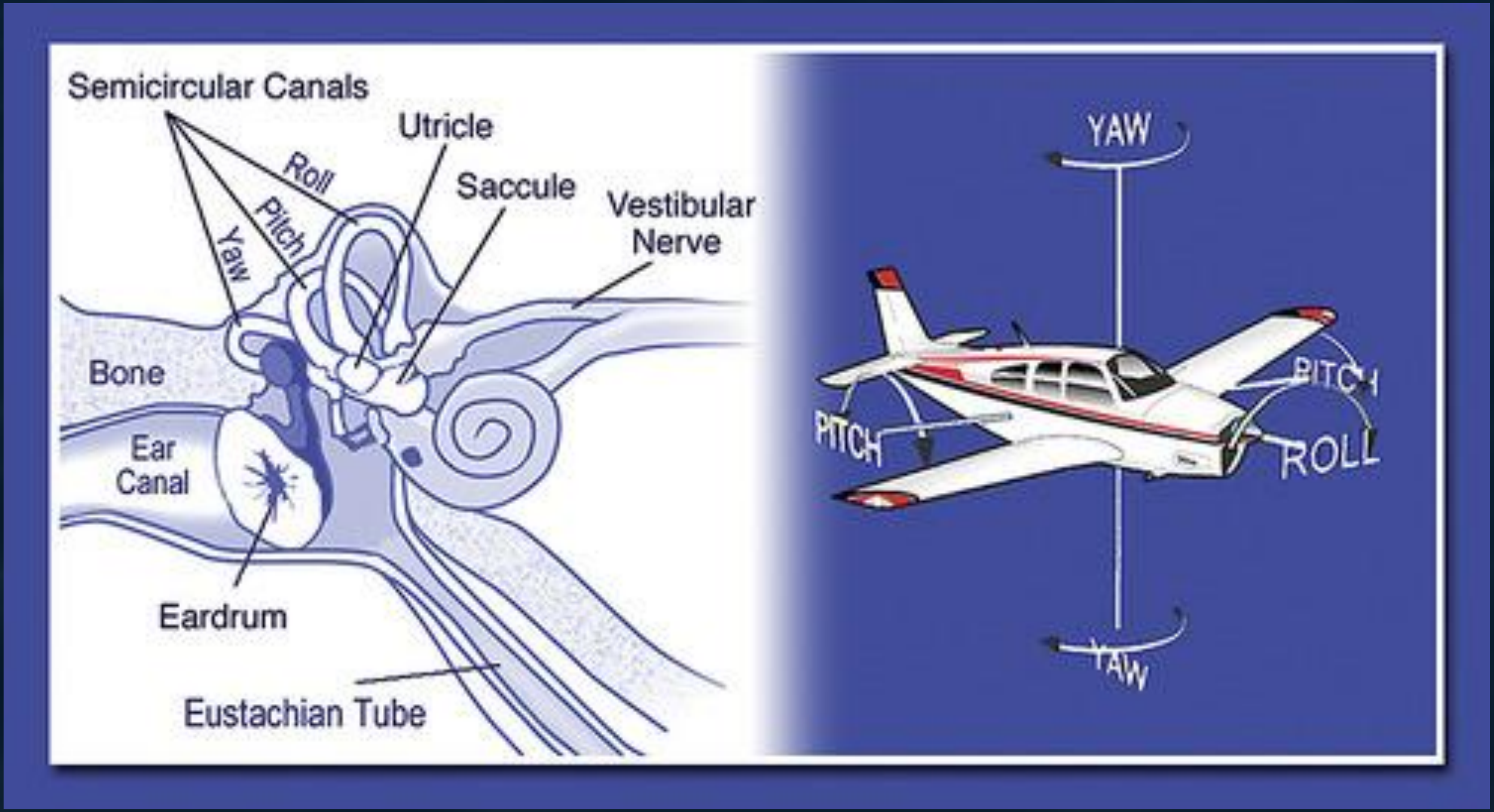
- *Inner ear*
- *neuromast/lateral line system*

Hearing

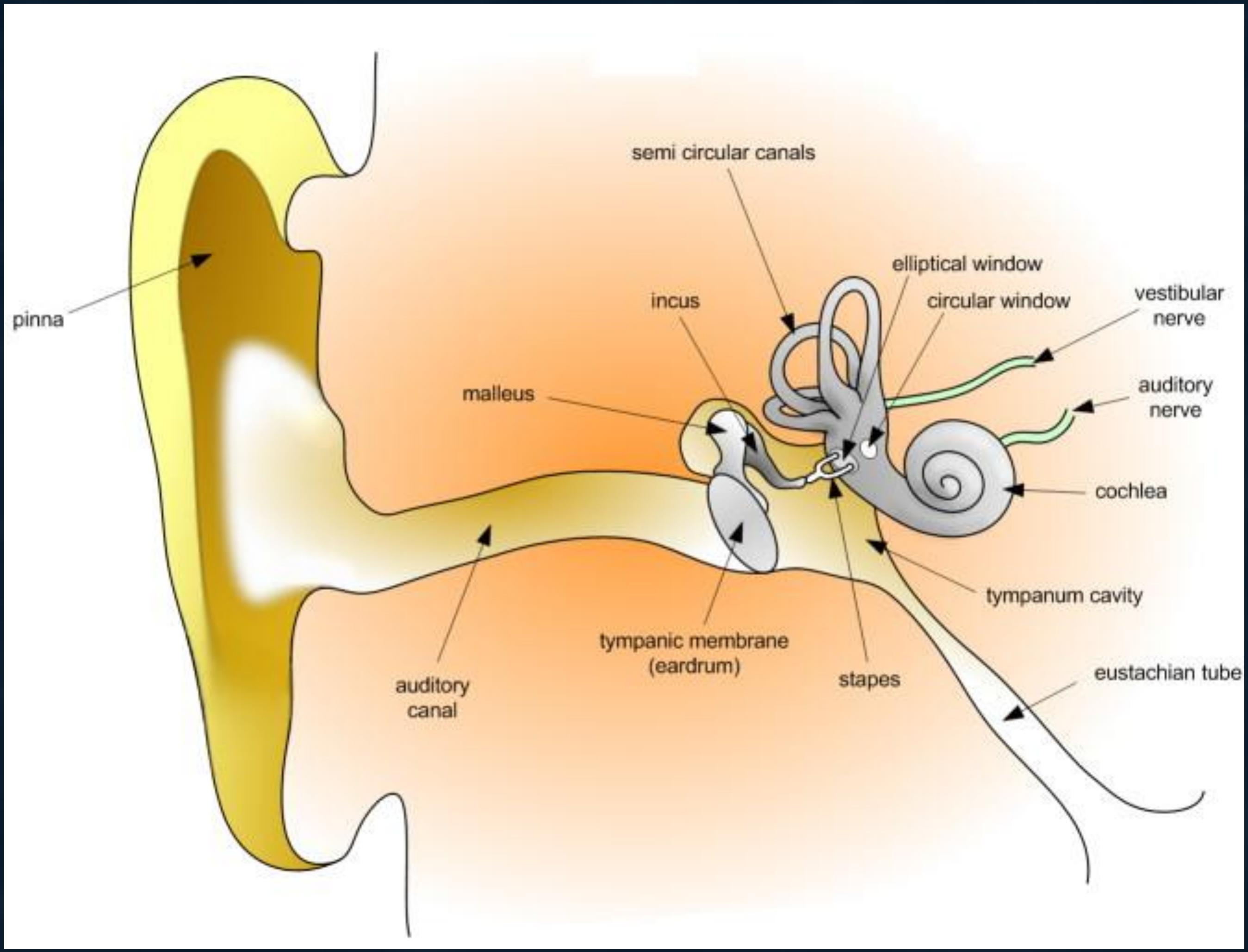


- http://www.timawa.net/forum/index.php?topic=30360.360

Structure of the Inner Ear

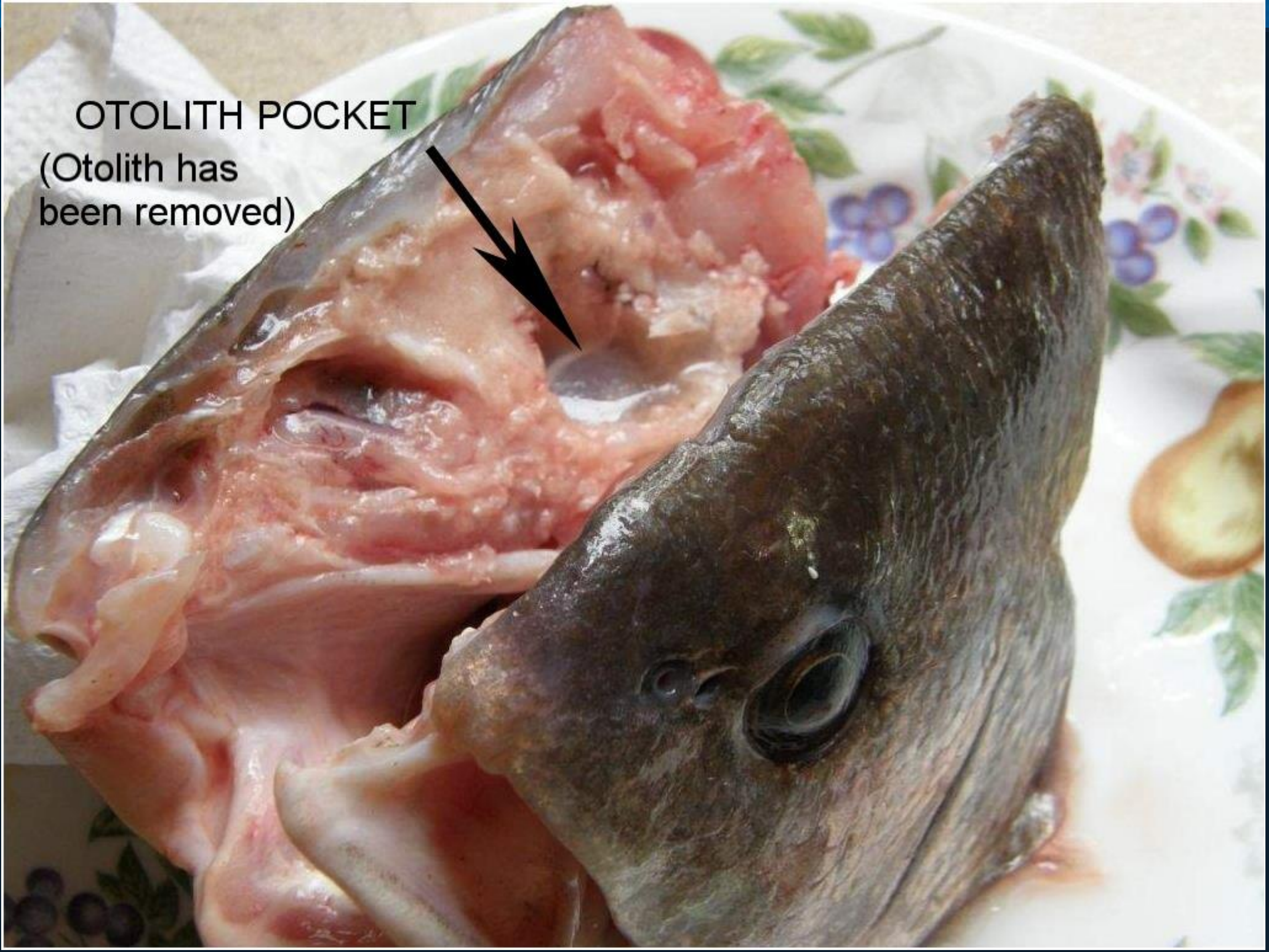


- http://www.geocities.jp/fishotoliths/index/otoliths-e.html



- http://pag.wikipedia.org/wiki/File:HumanEar.jpg

- http://www.gulffishing.com/BN_081_Otoliths.html

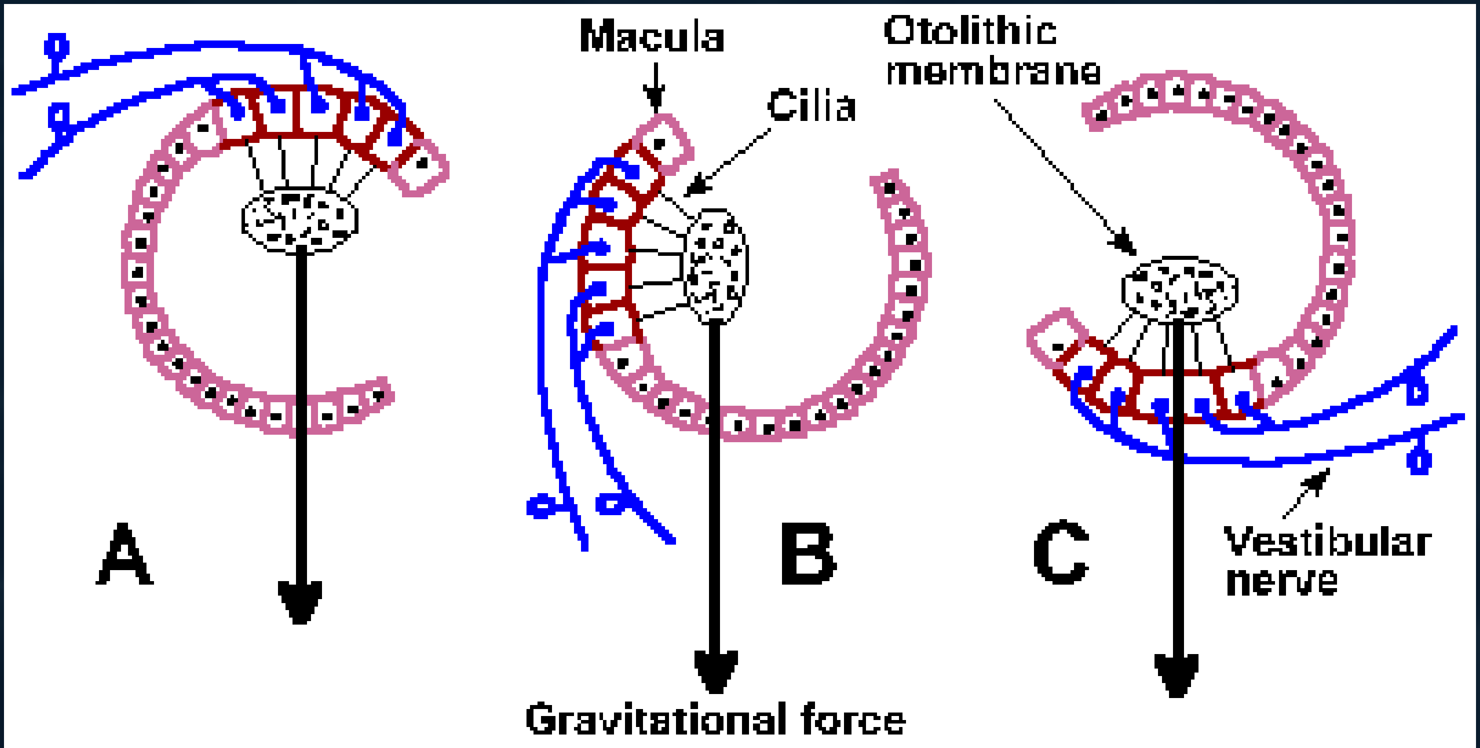


- http://ontariofishingcommunity.com/forums/index.php?showtopic=33003

- http://biologyoffishes.tumblr.com/post/46874689244/how-fish-hear

How a Fish Hears

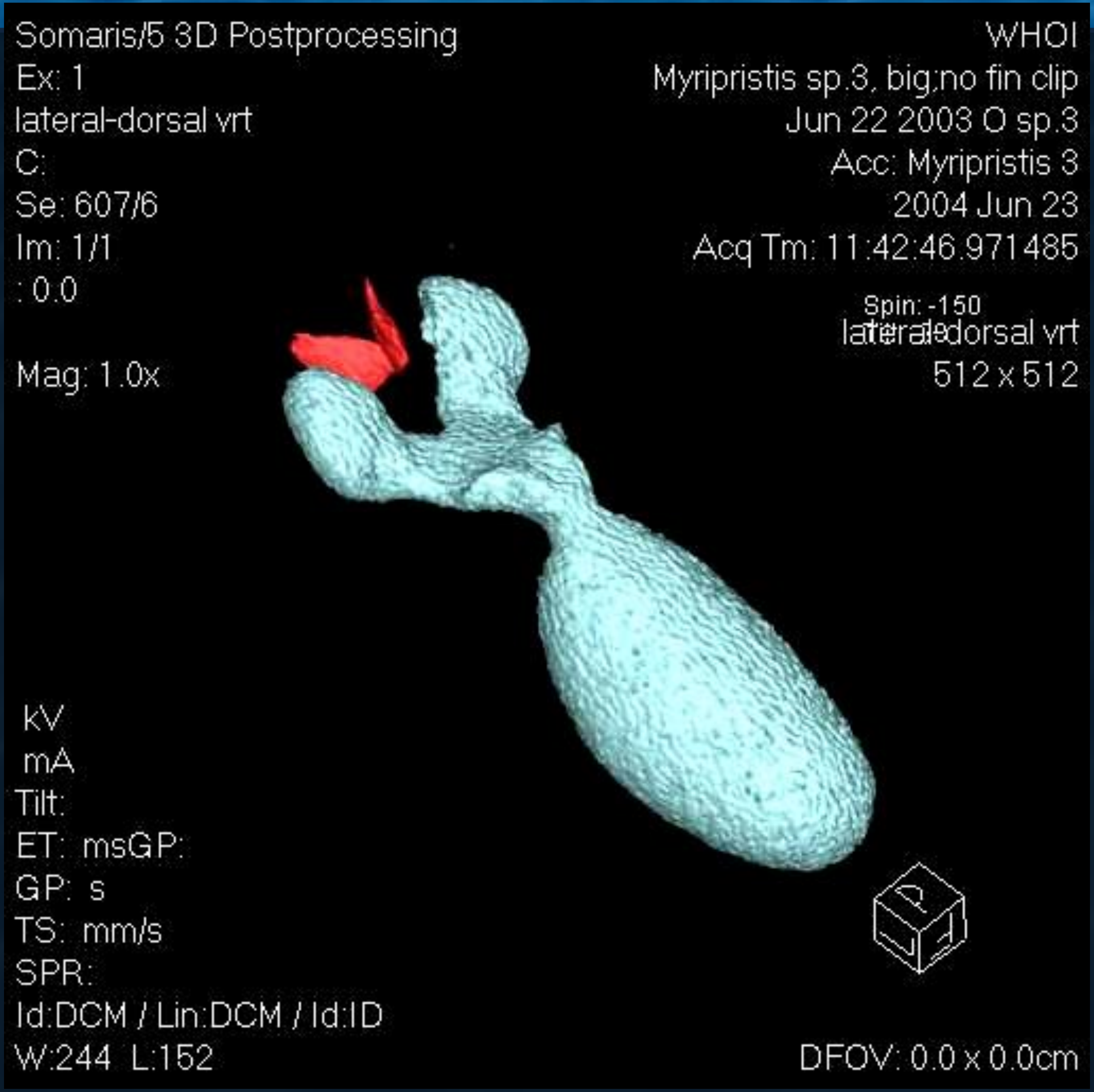
- As sound waves reach a fish, the whole fish moves with the waves, as water is non-compressible.
- The otoliths, being more dense than the rest of the fish vibrate at a different freq than fish
- The differential movement of the otoliths bends some of these cilia, which deforms the hair cells, which stimulates neural transmission to the auditory centers of the brain.



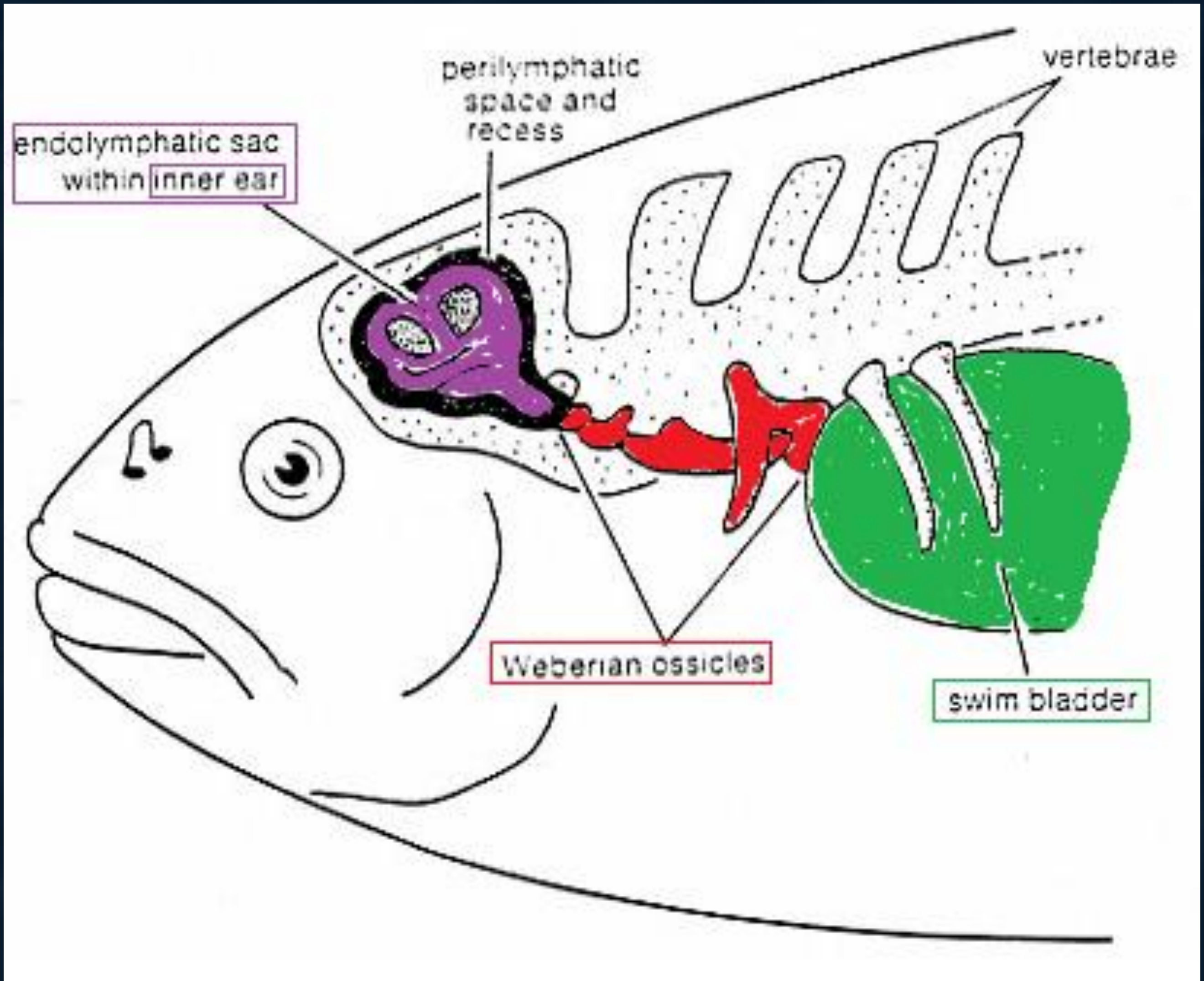
- http://michaeldmann.net/mann9.html

High Frequency Sound

- Some fishes have adaptations to increase the sensitivity of their hearing.
  - The gas bubble of the swimbladder of some bony fishes can serve as a sort of amplifier
  - Some fishes (cod, squirrelfish) have forked extensions of the swim bladder that lie close to the ear.
  - Weberian ossicles



- http://csi.whoi.edu/fish/indo-pacific-squirrelfish-0002jpg



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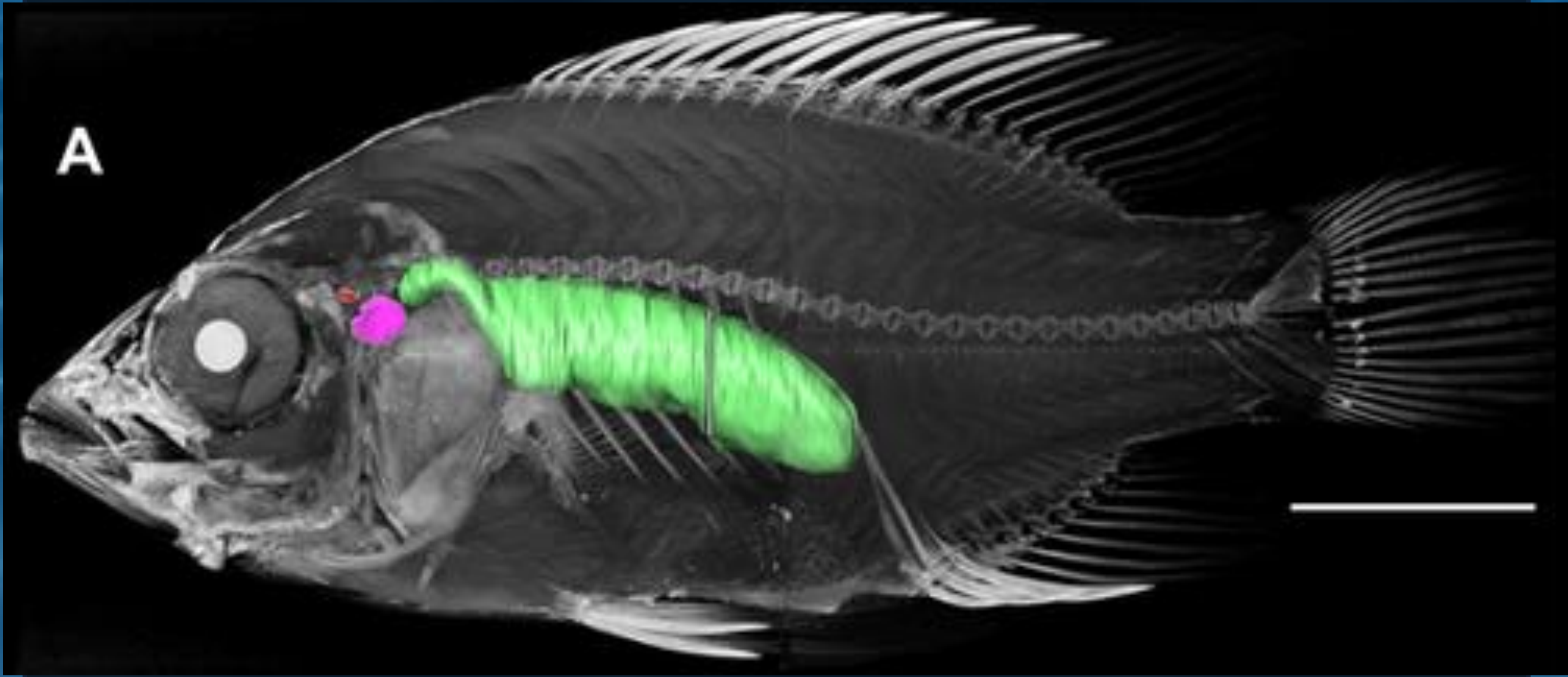


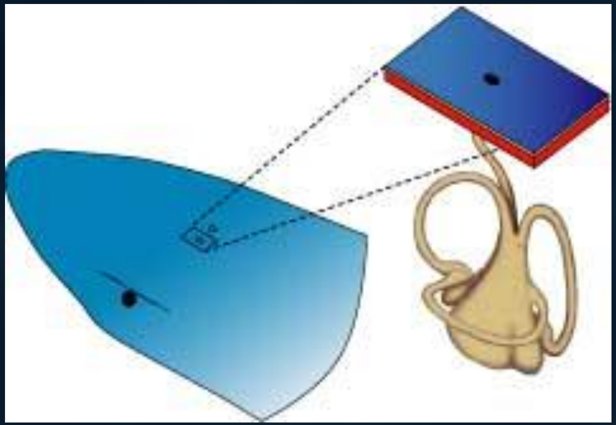
http://biologyoffishes.tumblr.com/post/46874689244/how-fish-hear

Hearing in Elasmobranchs

- Sharks and Rays show evidence of hearing ability, especially at low frequencies (Why?)
- Sharks are very attracted to irregularly pulsed sounds such as those made by struggling prey.

Hearing mechanisms in elasmobranchs

- Cartilaginous fishes generally have ducts connecting the inner ear to the outer environment
- Although these fishes cannot produce otoliths, some substitute exogenous materials to serve similar function of otoliths



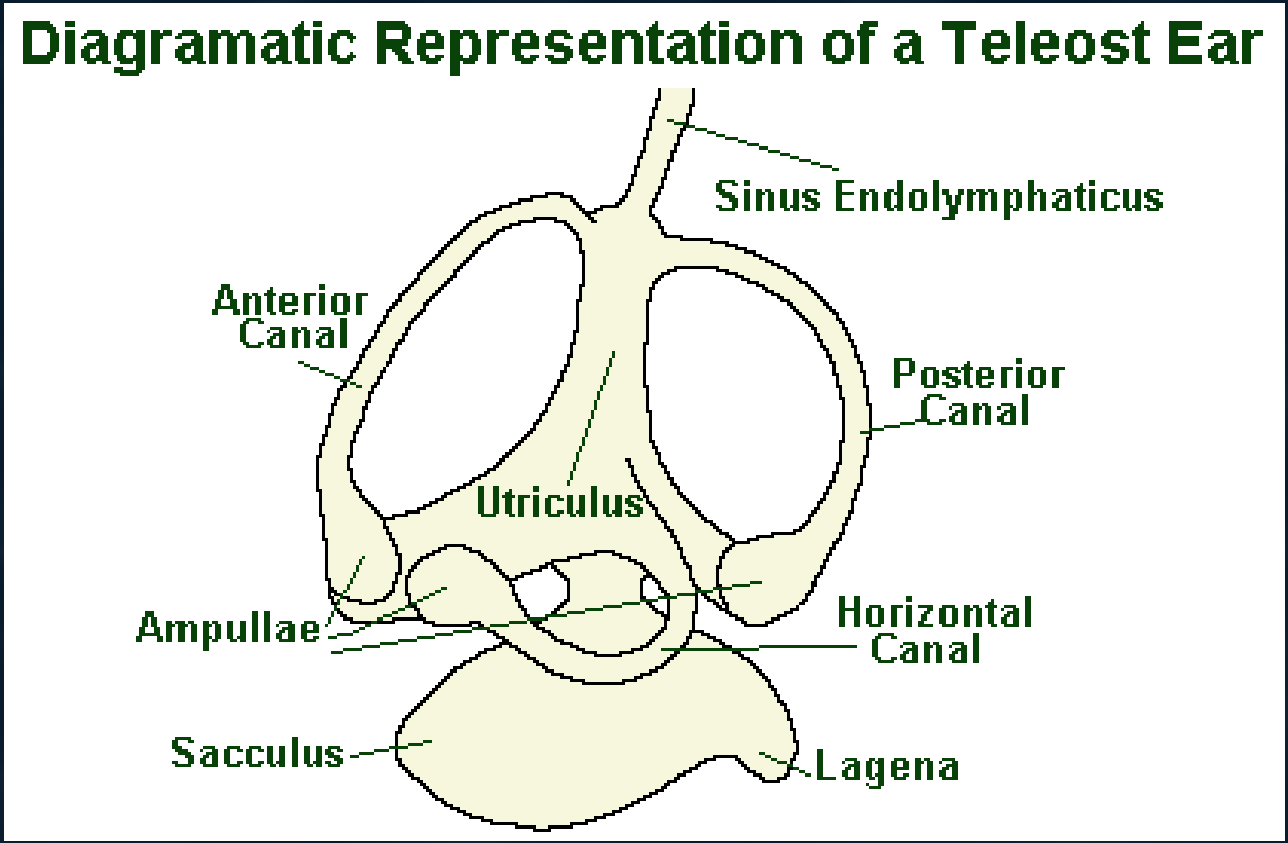
http://www.sharkinfo.ch/SI4_02e/lfas.html

Elasmobranchs

- Many sharks can detect directionally pulsed sounds from long distances
- Apparently difference in amplitude or time of sounds received on either side of the shark denotes direction

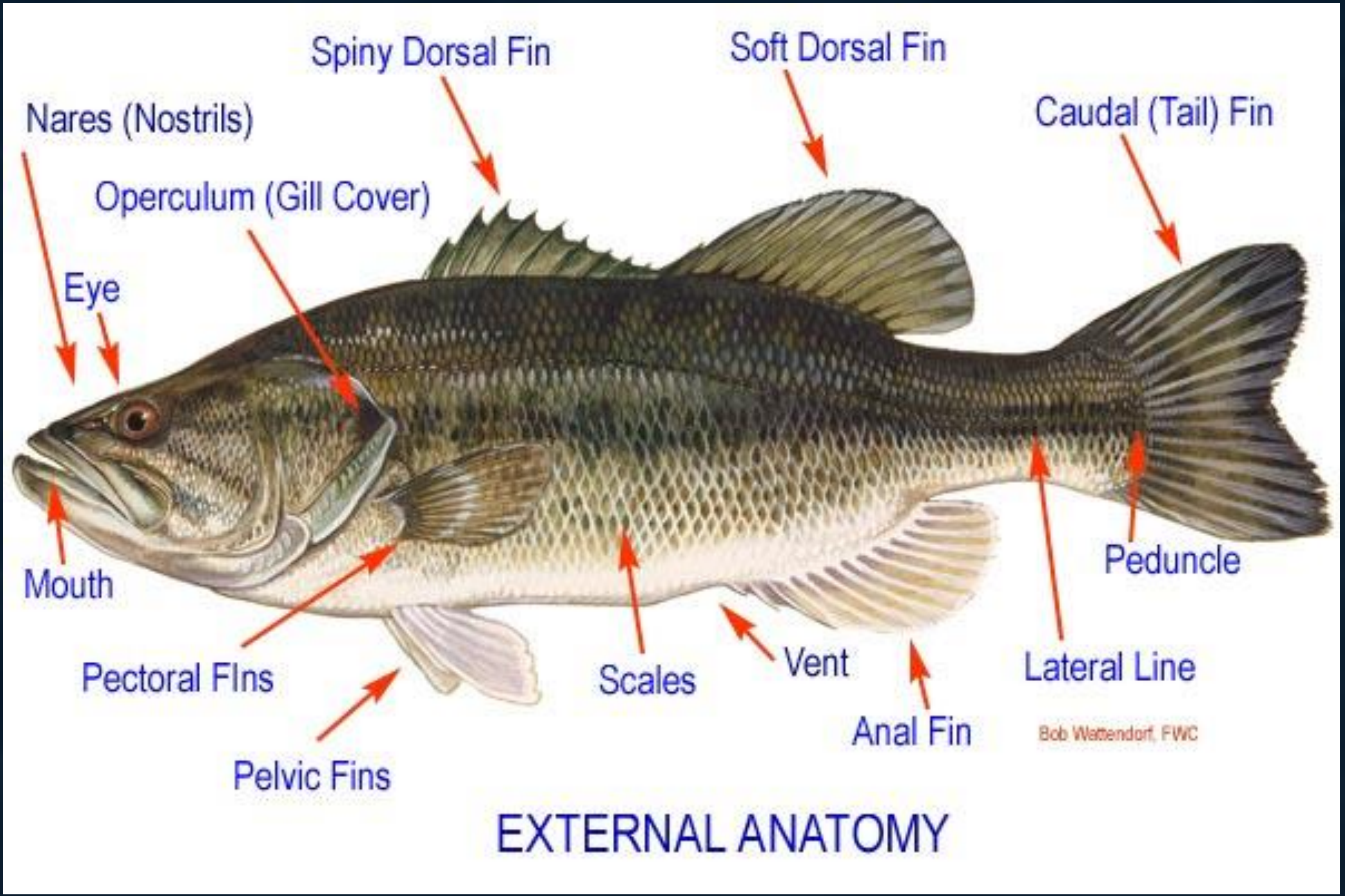
- http://natural-wild-life.blogspot.com/2011/09/hammerhead-shark.html

EQUILIBRIUM AND BALANCE



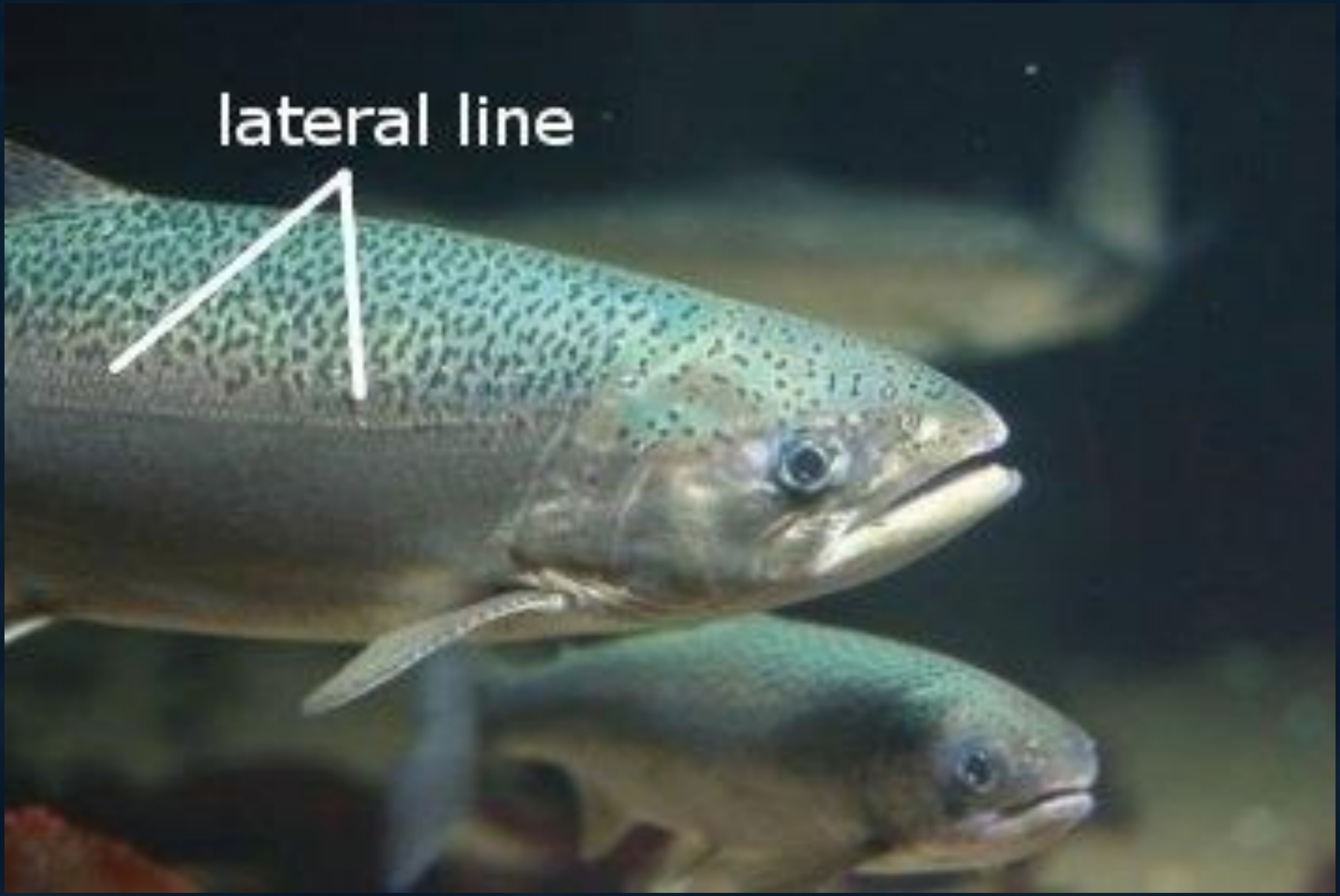
- http://www.earthlife.net/fish/hearing.html

Break 1

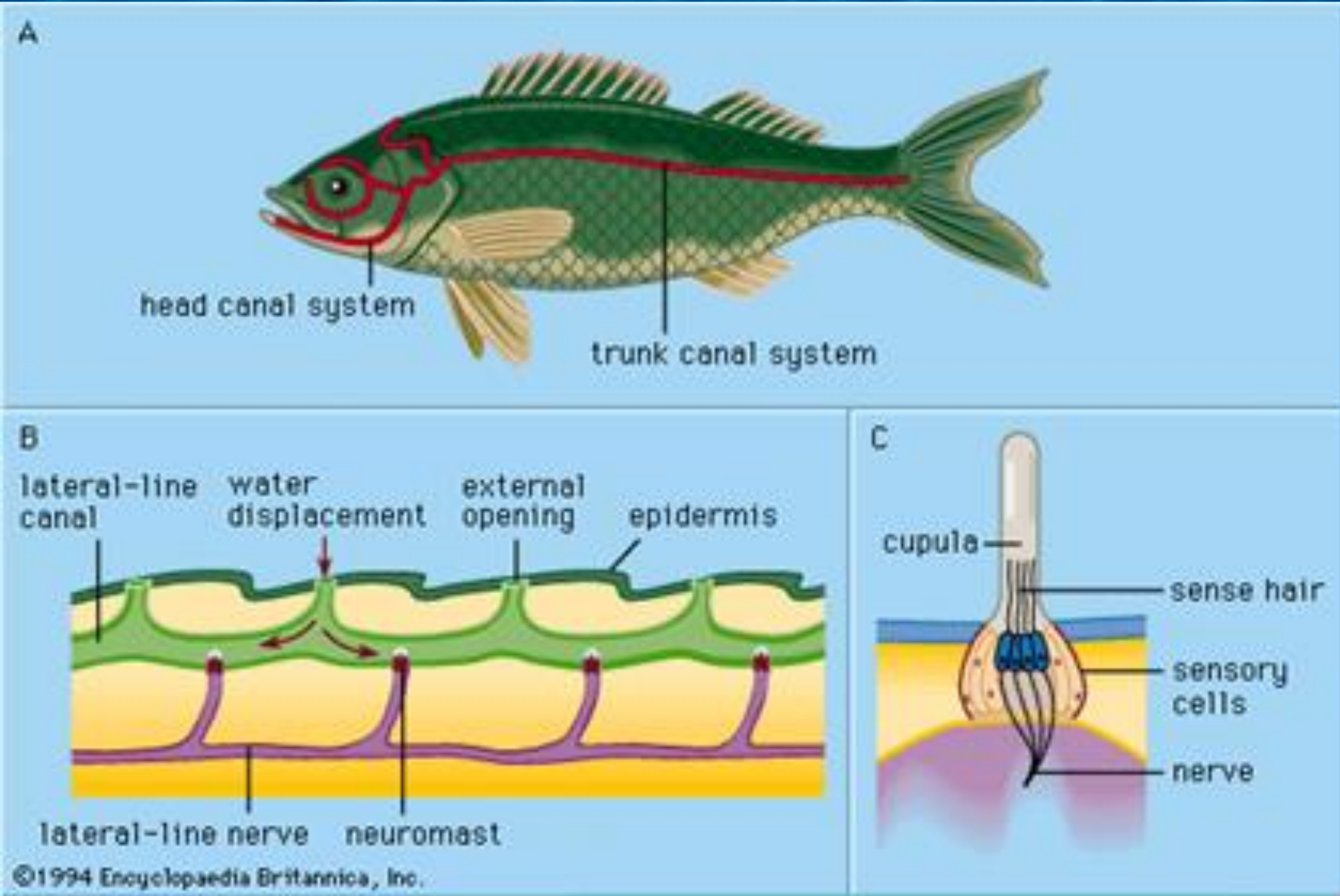

Spiny Dorsal Fin
Soft Dorsal Fin
Caudal (Tail) Fin
Nares (Nostrils)
Operculum (Gill Cover)
Eye
Mouth
Peduncle
Pectoral FIns
Scales
Vent
Lateral Line
Anal Fin
Bob Wattendorf, FWC
Pelvic Fins
EXTERNAL ANATOMY

LATERAL LINE SYSTEM

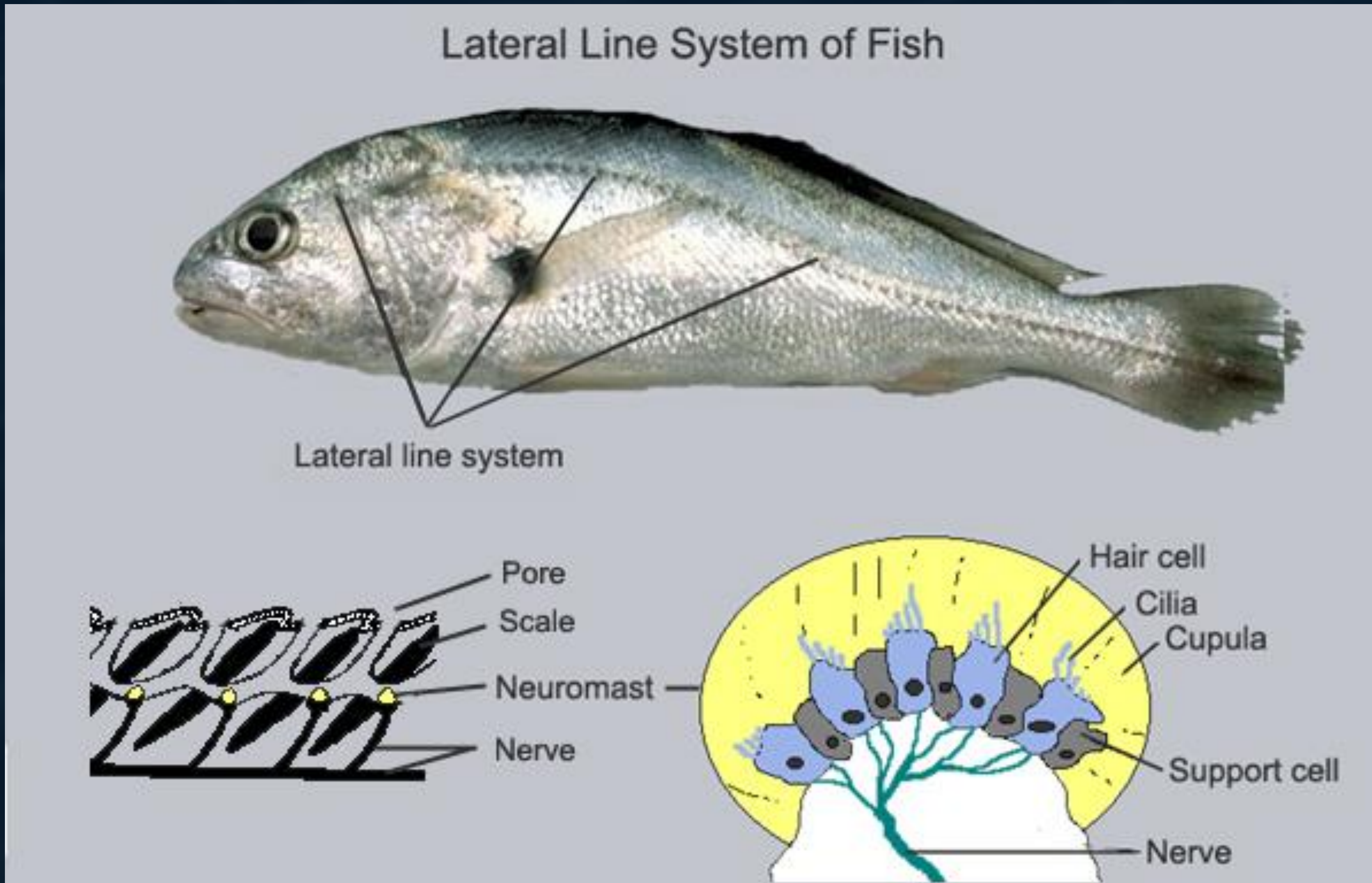
- Distant touch sense
- Using mechanoreceptors similar to those in auditory and equilibrium systems, water movements around fish can be detected
- The lateral line receptors, or neuromasts (Fig. 10.5) consist of individual hair cells and an attached cupula, similar to those of the inner ear.
- Water movements bend the protruding cupula, stimulating the hair cell by bending the attached cilia.



- http://fishingnoob.com/85/understanding-fish-senses/



- http://www.marinebuzz.com/2008/01/08/marine-robots-use-intelligence-of-fish-to-navigate-at-sea/



- http://agora-dialogue.com/fish-farming-silent-screams/

LLS continued

- depends heavily upon feeding habits and habitat.
  - Moving water = have more canal than free neuromasts.
- canals probably protect the neuromasts from constant stimulation in fast water.
- The lateral line is often displaced from the midline of the body in fishes whose pectoral fins would constantly stimulate the neuromasts (Fig. 10.7)

Atlantic Halibut

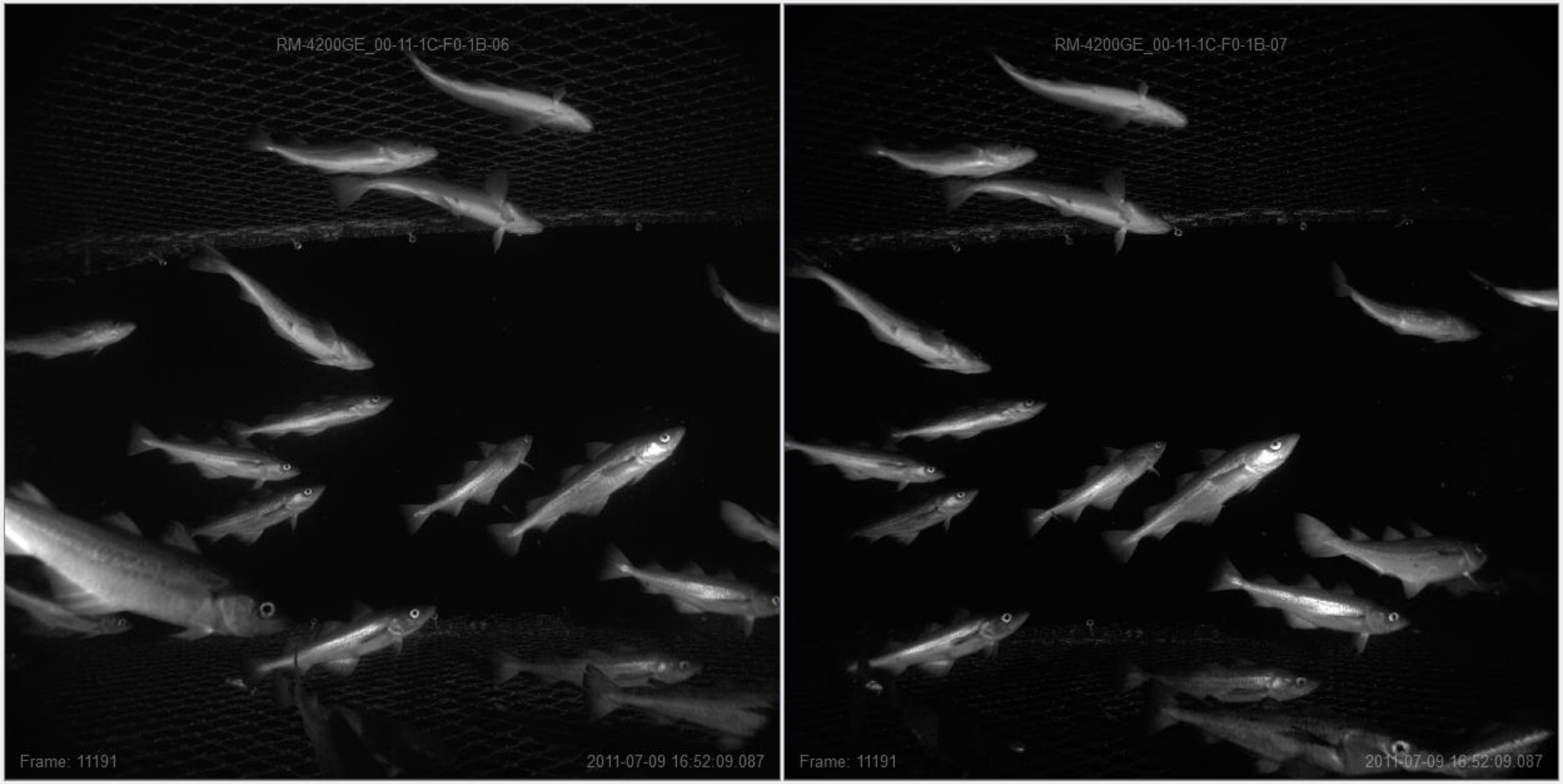
- http://www.fish-fishes.com/salt_water_fish/halibut_atlantic.html

- http://wildlife-archipelago.gr/wordpress/fish/stargazer-uranoscopus-scaber/

Skipjack Tuna

- http://dpipwe.tas.gov.au/sea-fishing-aquaculture/recreational-fishing/scalefish/tuna-fishing/tuna-species-identification-size-and-possession-

Rheotaxis



- http://www.afsc.noaa.gov/Education/Internships/2011/intern_leeuw.htm

Electroreception

- Adaptations for electroreception are widespread among fishes
- In elasmobranchs, the ampullae of Lorenzini detect minute electrical currents in water;
- In teleosts the external pit organs fulfill the same function (Fig. 10.8).

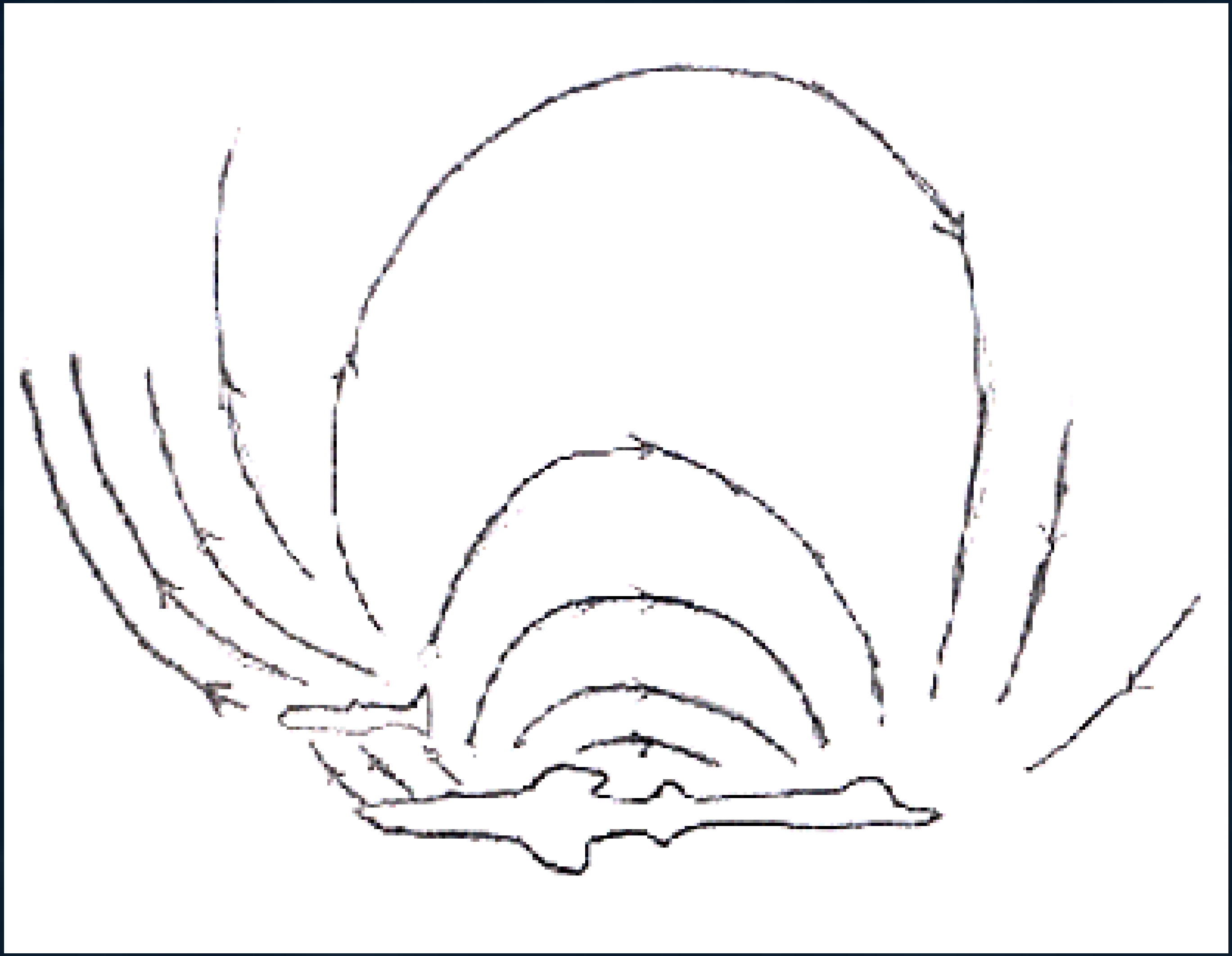
Electroreception

External pit organs – detect electrical currents

Contain electrically conductive gel

Rare in Teleosts

In Elasmobranch – ampullae of Lorenzini

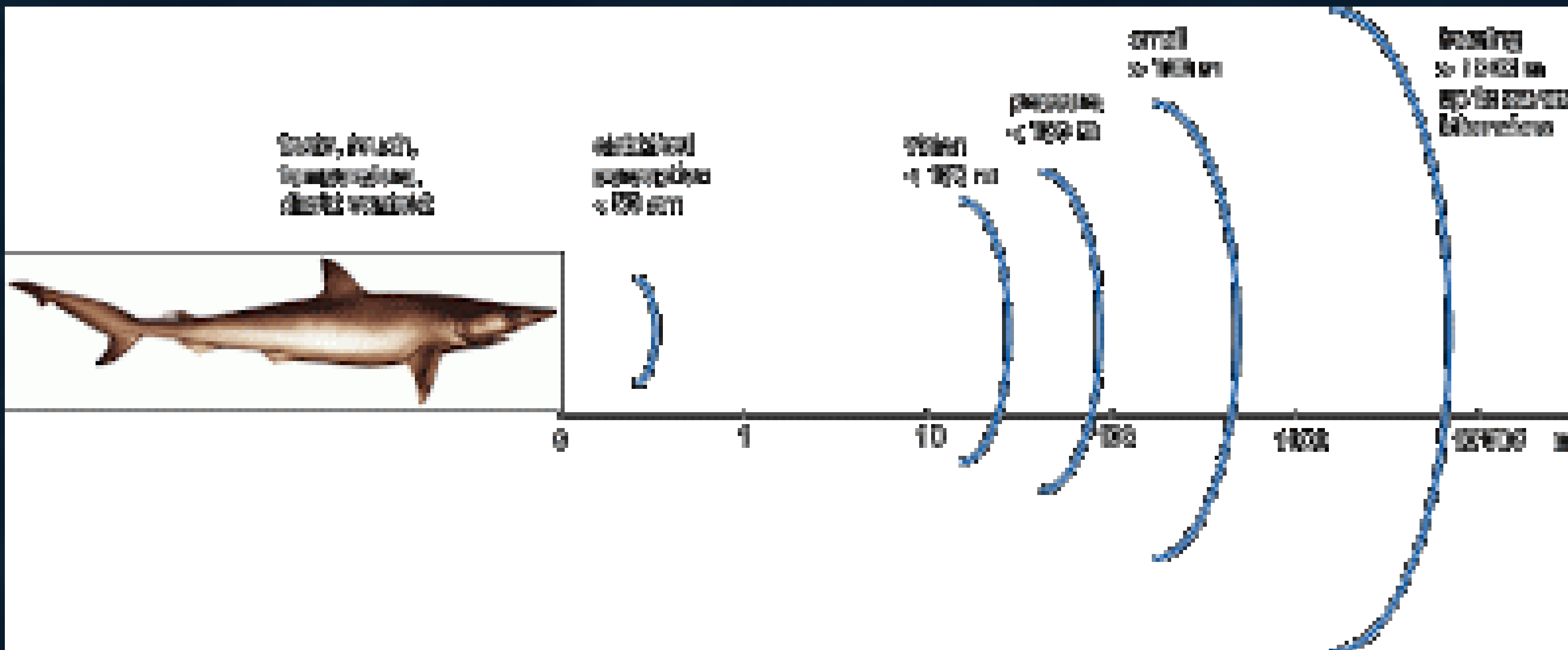


- http://hoopermuseum.earthsci.carleton.ca/sharks/P4-1.htm

- http://www.elasmodiver.com/shark_senses.htm

Electroreception

- Different from other sense organs, electroreceptors both send and receive
- Light is received by eyes but transmitted via bioluminescent cells;
- Sounds received via acousticolateralis system but transmitted via swim bladder muscle contraction
- dissolved chemicals received by gustatory and olfactory sensory epithelia but transmitted via secretions from broken skin

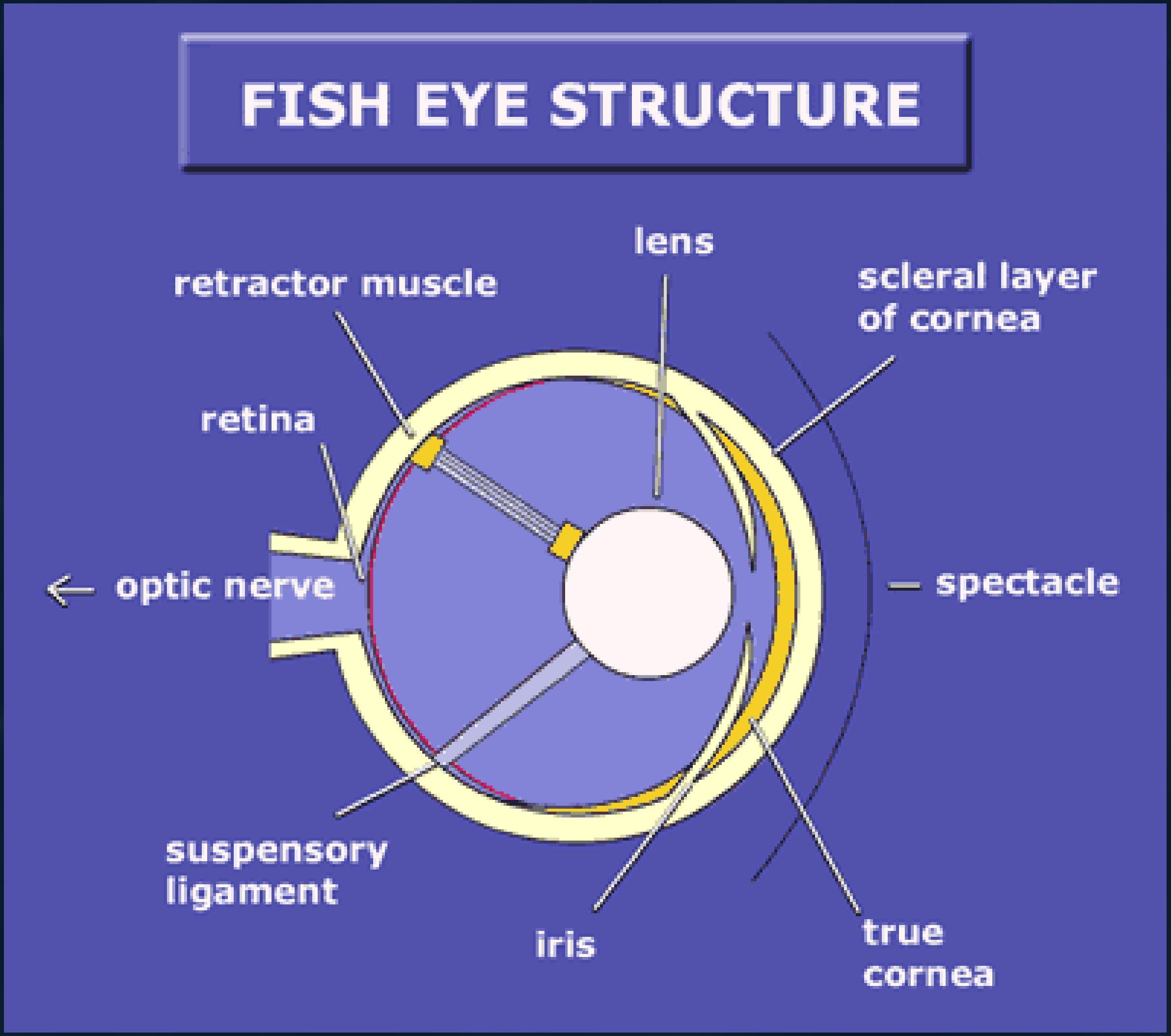


- http://sharksblogman.blogspot.com/2010/10/senses.html

Magnetoreception

- An electrical conductor (such as a fish) moving through a magnetic field induces an electrical field through that conductor
- A fish that has dorsal and ventral electroreceptors swimming through (perpendicular to) a magnetic field should be able to detect the resulting induced electrical currents. If the fish places itself in a north-south orientation, the induced current will cease. Therefore, a fish can detect direction using the earths magnetic field

VISION/PHOTORECEPTION



Vision - Elasmobranchs

- The lens of elasmobranchs is not spherical but slightly flattened
- Some elasmobranchs also have operculum pupillae that can descend over the pupil to protect it from excess light.
- However, the nictitating membrane of some predatory sharks is an adaptation to protect the eye from damage while feeding

- http://www.discovery.com/tv-shows/shark-week/photos/hammerhead-sharks-pictures.htm

Visual Acuity

- The retina is made of a dense layer of rod and cone cells.
  - The closer the rods are packed in the retina, the more acute a fishes distinction of light/dark, as well as the ability to see in dim light
- In change from larval to juvenile stages, fishes may change the rod cone densitites

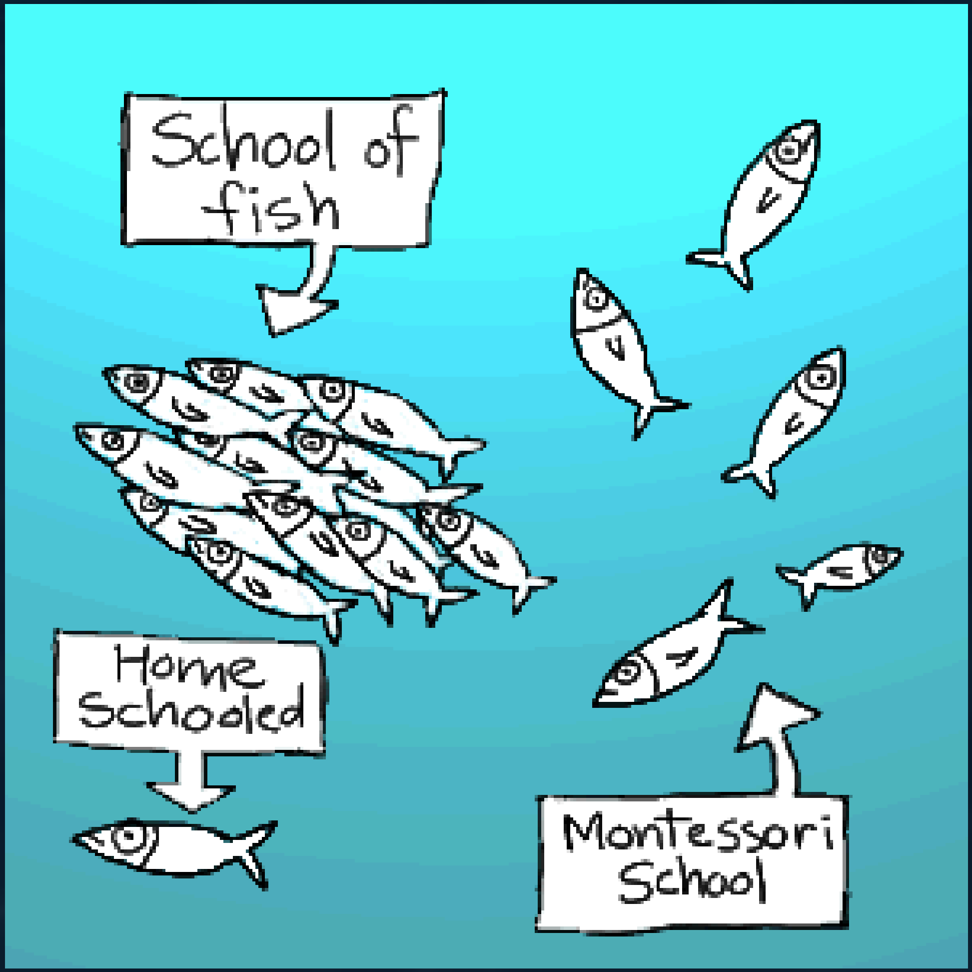
Visual Pigments

- As light strikes either the rods or cones, it is absorbed by a light sensitive pigment s which are located in the photoreception area of the retina.
- Absorption of light by these pigments stimulates the retinal cells to send impulses to the optic lobe via the optic nerve.

More adaptations

- UV Vision
- Polarized Light
- Other light receptive organs

- http://www.livescience.com/animals/



- http://paulwilkinson.wordpress.com/2011/05/08/homeschool-parents-wont-teach-or-allow-others-to-teach-sunday-school/

Break 2

Seven categories of behavior

- Migratory behavior
- Shoaling behavior
- Feeding behavior
- Aggressive behavior
- Resting behavior
- Reproductive behavior
- Interspecific interactions

MIGRATORY BEHAVIOR

oceanodromy –fish that migrate entirely within salt water

potamodromy – species that migrate entirely in fresh water

diadromy – migration between fresh and salt water as part of regular life cycle:

anadromy – Fresh -> Salt -> Fresh

catadromy – Salt -> Fresh -> Salt

amphidromy – Salt -> Fresh -> Salt -> Fresh

Disadvantages

- Not always advantageous to migrate
- Resident fish indicate energetics not always worth it
- Many fish migrate and have done so for long time – indicates it serves significant function

Why do fish migrate

- Energetic cost is high – is it worth it?

Advantages

- Increases probability that larval stages will find way to suitable habitats
- Reduces likelihood of intraspecific competition for food among different age classes – mostly likely to affect plankton feeding fishes such as herring
- Puts life stages in habitats where feeding and growth can be maximized
- Reduces probability of cannibalism

Migration…

- While most migrations have to do with reproduction and/or separation of life history stages, many are also in response to changing environmental conditions – primarily temperature and the movement and abundance of food organisms

Honing

- Ability of fish to return to place where spawned/hatched
- Many intertidal fish can hone to their tide pool after being displaced by several hundred meters during flood tide
- An Atlantic coast fish returns to same estuary it was hatched – not known how or why
- Pacific salmon most studied – odor of home water implanted during smoltification – this enables them to return to stream
- Evidence is also suggesting that adult salmon can detect pheromones given off by juveniles in the fresh water systems

Most likely proposed so far include:

1.Orientation to gradients of temp., salinity and chemicals

2. Sun orientation

3. Orientation to geomagnetic and geoelectric fields

SHOALING BEHAVIOR

- Shoal: any group of fish that remains together for social reasons
- School: is a polarized, synchronized shoal
- Schooling is an extreme form of shoaling – fish move into and out of schools all the time

Source: BBC; JP Trenque

- http://www.okeanosgroup.com/blog/aquariums/behold-the-fish-tornado-creating-a-schooling-fish-aquarium/

- http://deepbluehome.blogspot.com/2011/02/shoal.html

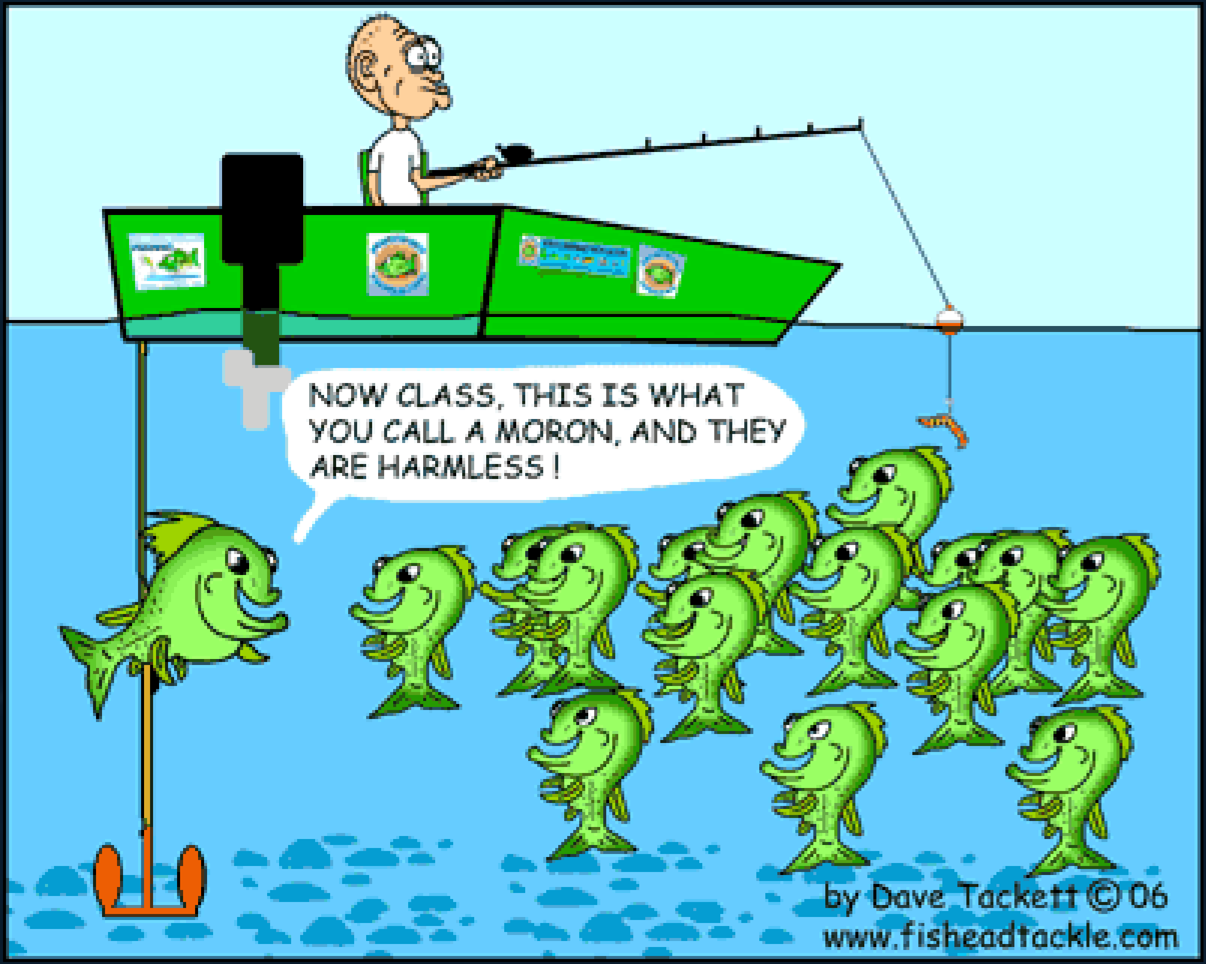
Shoaling and commercial fish

- Many commercially important fish shoal and this behavior makes them more vulnerable to fishing pressure and capture in large numbers
- In many commercial species the largest shoaling occurs during migrations, when smaller shoals join together.
- Some North Atlantic herring shoals have been measured to be 279 million to 4,580 million m3 with densities of .5-1.0 fish per/m3
- Migrating mullet shoals in the Caspian Sea have been documented 100 km long

Why do fish shoal?

1. increased hydrodynamic efficiency
2. increased efficiency finding food
3. increased reproductive success
4. reduced risk of predation
   - Dilution and confusion effect

How do fish school?



Shoals and Predators

- One strategy is to attack at low light levels
- Another strategy is to swim along shoal and pick off fish that are sick, don't stay in form, or make an error in responding
- More effective is the to attack in schools – schooling fish cannot avoid another school as effectively as they can a lone predator

FEEDING BEHAVIOR

- Diet at any given time is reflective of typical and atypical food types present as well as competing fishes – also by characteristics of environment, predators and prey

Break 3

Optimal foraging theory

- natural selections favors predators that maximize efficiency of prey capture

Food abundance/scarcity

- When food is scarce – fish capture any food source likely to produce a net energy gain

- When food is abundant, fish selects prey most likely to produce the most energy with least amount of effort

Several factors influence choice of prey

- Competition
- Availability
- Environment
- Reducing risk of predation
  - Risk sensitive foraging

AGGRESSIVE BEHAVIOR

- Frequently observed in fish
- Most common in mating and protection of breeding territories
- Also associated with defense of space and food

Factors contributing to outcome of encounter

- previous residency
- size
- results of previous encounters

COMMUNICATION

- "the action on the part of one organism that alters the probability pattern of behavior in the other organism in a fashion that is adaptive to one or both of the participants."
- Includes signals given and mechanisms used to receive
- Signals used include
  - Visual
  - Auditory
  - Chemical
  - Electrical

Visual/Color

- Colors in fish are two basic types: pigments (biochromes) and structural colors
- Pigments are colored compounds located primarily in chromatophores – cells located mostly in dermis of skin – but also in epidermis, peritoneum, eyes and other organs
- Hues change through combined action of chromatophores containing pigments of different colors overlying one another or by internal changes of chromatophores containing more than one pigment

Visual/Non-visual cues

- Visual cues are carried to chromatophores by sympathetic nerves, special hormones secreted by the pituitary gland or a combo of the two.
- Nonvisual cues can also cause color change – the nerves associated with chromatophores are very sensitive to adrenaline – and acetylcholine.

Fish have many different kinds of pigments

- Caretenoid pigments are responsible for bright reds and yellows and greens (when yellow caretenoids overly a blue structural color).
- Melanins are mainly dark red, brown, black and form the background coloration of most fish
- Purines (mostly guanine in fish) are crystalline substances that are difficult to classify as pigments

What is adaptive significance of complex color patterns of fish?

- Purposed 3 main purposes:
  - Thermoregulation
  - Intraspecific communication
  - Evasion of predators

Common color patterns in fish and their multipurpose nature:

- red coloration
- poster colors
- disruptive coloration
- countershading
- eye ornamentation
- eye spots
- lateral stripes
- polychromatism

red coloration

Poster colors

Disruptive coloration

Disruptive coloration

Countershading:

Eye ornamentation

Eye spots

Lateral stripes

Polychromatism

Auditory signals

- Some species use sound others do not
- Some use continuous sound that is central to how they function
- Some fish sing during courtship
- Sound is produced by:
  - stridulation – rubbing hard structures together
  - vibration of swimbladder
  - incidental to other activities

Sound

- produced by fish can be varied by:
  - changes in loudness (amplitude),
  - duration,
  - rate of repetition,
  - number of pulses within a signal