

Announcements

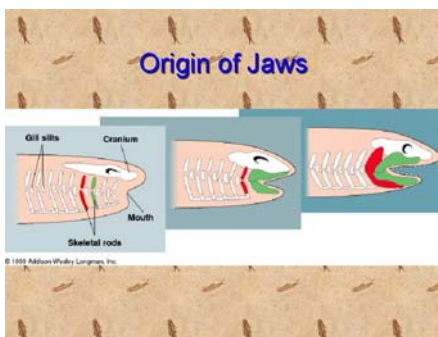
- Aravaipa Field Trip – leave Friday 10:50 – bring camping and breakfast, lunch – cool at night
- Who wants to hike?
- Mexico?
- No Lab Today

Function = feeding

- Elaboration of inertial suction feeding mechanisms.
- Remember - dealing with aquatic medium (800 times more dense and 80 times more viscous than air).
- Premium on effective suction and fluid propulsion mechanisms
- Also oxygen less, temperature stable, hydrate, buoyancy, viscosity (more drag).
- Food acquisition on land is a very different matter than that underwater.



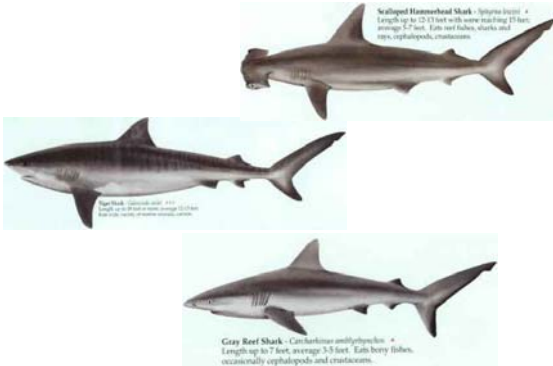
Where did jaws come from?



How to study feeding?

- High speed cinematography
- Electromyographic analyses
- Measurement of buccal cavity pressure differentials
- Strain gauge analyses
- = complex picture.

Chondrichthyes – Sharks, Skates, Rays



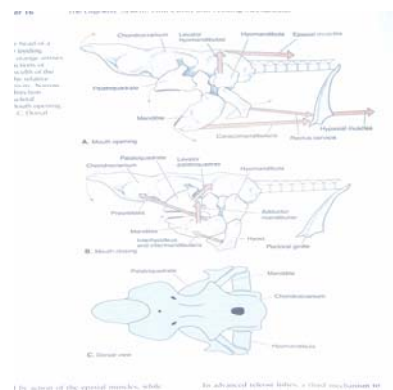
Chondrichthyes – Sharks, Skates, Rays

- MOUTH OPENING
- Lift head with epaxial muscles
- Mandible pulled down by ventral muscles between hyoid and pectoral girdle and between mandible and pectoral girdle.
- Enlargement of mouth/pharynx = suction
- BIG GAPE

Chondrichthyes – Sharks, Skates, Rays

- MOUTH CLOSING - ADDUCTION
- Formidable bite – Large adductor mandibulae (AM) and preorbitalis muscles
- AM insertion - optimized out-force at teeth
- Mouth volume restored by 3 muscles - levator palatoquadrati, interhyoideus and intermandibularis

Feeding in Chondrichthyes



Actinopterygian Feeding - Function

- Functionally Actinopterygian feeding in 3 categories:
 - 1) Ram feeding - fish overtakes food/prey by vigorous forward swimming with open mouth and opercula.
 - 2) Inertial suction - low pressure center in buccal cavity by rapid mouth opening and expansion of buccal floor. Pressure differential btw mouth and surrounding water results in flow of water into mouth. If velocity at prey is sufficiently great, prey carried into mouth.
 - 3) Manipulation - most complex - covers broad range of feeding behaviors involving use of buccal jaws (clipping, rasping, scraping and biting).

*****FISH USE ALL*****

Evolution of Feeding

- Evolution of Actinopterygian feeding mechanism shows increase in structural complexity. Cladistically derived lineages are considered structural complexity - defined as the number of connections in the structural network - increases.

Feeding in Primitive Actinopterygians - Anatomy

- 1. Dorsal epaxial muscles-neurocranial coupling; Elevates head
- 2. Ventral coupling - (hypaxial musculature, cleithrum, sternohyoideus and hyoid apparatus) = causes mandibular depression via insertion of mandibulohyoid ligament
- Mechanism for mandibular depression hypothesized to be primitive for fishes
- Found also in lungfish, coelacanth and Sharks

Primitive Actinopterygians

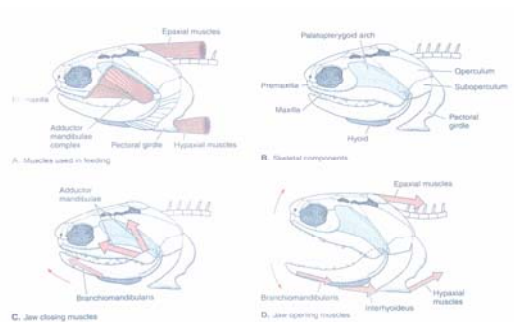


FIGURE 16-10
Lateral views of the head of a fossil primitive actinopterygian (a "paleoniscoid"), showing the feeding mechanism. A, The head with a reconstruction of the muscles used in feeding. B, The major skeletal components of the head. C, The lines of action of muscles (wide orange arrows) that close the jaw. D, The lines of action of muscles that open the jaw (wide orange arrows). (Modified from Lauder.)

Primitive Actinopterygians

- Primitive Actinopterygians (Paleoniscoids) - living Polypterids - jaw structure adapted to primarily "gripping" and "biting" habit.



Next Halecostomes Feeding Mechanism Amiidae



Halecostomes Feeding Mechanism

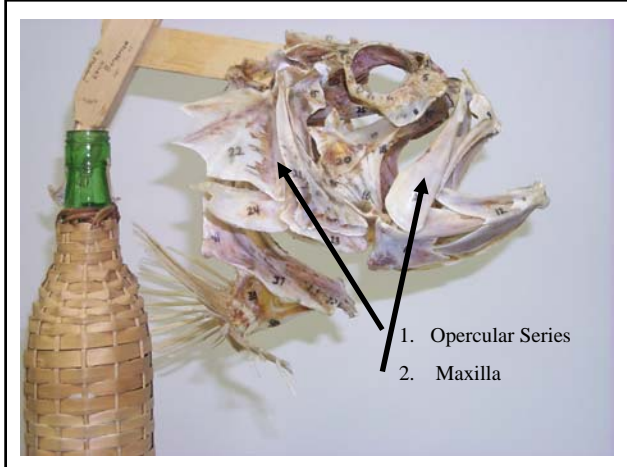
- 2 independent biomechanical pathways for mandibular depression:
- 1) Primitive ventral coupling retained.
- 2) New coupling = opercular series. Levitation of operculum by levator operculi muscle causes dorsal rotation of opercular series (operculum, suboperculum and interoperculum). Applied as force on mandible via interoperculo-mandibular ligament.
- Why have two biomechanically independent pathways of mandibular depression?
- Disassociation of primitive hyoid coupling from obligatory mouth opening functions allows changes in timing of hyoid depression in mouth opening. Increases versatility of control of fluid movement through buccal cavity.

Next Innovation - Halecostomes

1. Maxilla - primitively firmly attached to neurocranium is free and pivots on a medially directed process posterior to the vomer.
- High speed cinematography in *Amia* - maxilla swings anterior to its pivot as mouth opens = increase velocity of water from front of mouth into oral cavity



Amiidae



Halecostome feeding mechanism

- Water is dense viscous medium = places premium in effective suction and fluid propulsion mechanisms.
- Food capture first accomplished by highly effective suction mechanism. Theoretically any kind of prey or food floating or swimming in the water column - can effectively be collected by this basic feeding mechanism.
- ?Corollary? - no marked specializations or adaptations in trophic apparatus are necessary to collect wide variety of aquatic organisms - irrespective of position in water column or substrate.
- Fundamental dichotomy between this aquatic feeding model and basic terrestrial model

Teleosts

- Teleost feeding mechanism - distinguished from primitive halecostomes by division of premaxilla into a mobile, lateral toothed portion and a medial portion associated with ethmoid complex and change in opercle connections



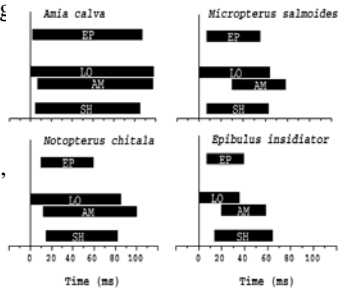
Teleosts

- 3 major changes occurred in structural network of head.
- 1) Insertion of mandibulohyoid ligament to interoperculum - effectively shifts action of hyoid and opercular couplings onto interoperculum. Only interoperculomandibular ligament transmits movement to mandible in Eurypteryii - Other teleosts retain primitive two-coupling system of Halecostomes.
 - 2) Development of elongate ascending process on premaxilla - principally associated with jaw protrusibility.
 - 3) Composition of adductor mandibulae muscle complex - again associated with evolution of jaw protrusion.

Teleosts – Modular Multiplicity

- Neuromuscular Firing in Different Species

- EP = epaxial, LO = levator operculi, AM abductor mandibulae,
- SH = sternohyoidius



Summarize aquatic feeding model

- Fish feeding apparatus = truncated cone or cylinder. Suction is generated when cone expands.
- Dense aquatic medium and expanding cone suction generating device = extremely versatile feeding model – taxonomic/ecological diversity of prey collected by suction in single teleost species unsurpassed by any feeding
- Versatility of expanding cone model = restricted not only to prey capture. Pressure differences in different areas within cone can be generated by modulating muscle actions. Captured prey moved or turned within cone - acts as a hydrodynamic tongue.
- Aquatic medium + suction + hydrodynamic tongue offer unparalleled array of prey capture opportunities for teleosts

Basic Terrestrial Feeding Model

- Feeding cycle = slow opening - hyolingual apparatus advances beneath prey - tongue fitted to prey. Second phase = fast opening - skull and mandible move apart.
- Prey transported by tongue. Fast closure - cranium descends while mandible is elevated - Tongue and hyoid move back.
- Final phase is slow close or power stroke during which prey is crushed.
- Pattern pervasive among terrestrial vertebrates. Very conserved muscle actions.
- Terrestrial feeding design characterized as being controlled by remarkably conserved neuromuscular outputs producing a constant pattern of jaw movements finely tuned with hyoid and tongue movements.

Basic Terrestrial Feeding Model

- Two major implications are:
- 1) prey capture must proceed actively by special adaptations and pursuit.
- 2) prey processing requires a precise design in the "hardware" of feeding apparatus to match nature of prey, as neuromuscular output (software) is constant.

Fundamental differences in aquatic and terrestrial feeding models

- Liem - major impact on nature of ecological performance of aquatic and terrestrial vertebrates. Generalizations from terrestrial systems applied to aquatic systems don't fit.
- Aquatic paradigms fundamentally different from terrestrial paradigms in vertebrate ecology?
- 1. Increased opportunism and food overlap prevail in aquatic systems - much empirical data support this.
- Fish have extensive diet switching, opportunism and reduced resource partitioning during normal food abundance. Resource partitioning in fishes = flexible partitions depending upon species present and prevailing resources.

Aquatic Example

- *Serrasalmus rhombeus*
- Piranha; Fish, crabs, birds, mammals, porcupine spines, lizards, beetles, fruits and seeds, tree resin, flowers and leaves.



Terrestrial

- More precise match of design w/ biological role. Less opportunistic feeding, increased resource partitioning and limited diet switching.
- Match bill design with preferred food & limited food overlap = Darwin's finches and Hawaiian Honeycreepers



Fundamental differences

- 2) Aquatic vertebrate feeding systems - convergent evolution uncommon. Versatility of expanding cone design does not require drastic changes in "hardware" for more specialized biological roles. Great diversity of forms can evolve to solve the same problem.
- Pursuit hunters - Design reflects underlying historical factors characteristic of lineages rather than functional convergence in response to common environmental challenges.

Ecological Convergence - African Great Lake Cichlids
Same phylogenetic history solving common problems



Fundamental differences

- Terrestrial carnivores and herbivores often exhibit a very precise matching in design and biological role
- Even across distant lineages. Marsupial v. Placental, Mongoose from Madagascar
- Common environmental challenges in feeding such as insectivory, carnivory, folivory etc. often solved by similar adaptations in "hardware" of terrestrial vertebrates.
- Convergence in feeding design reflects precise matching of form and function with specialized biological role rather than influence of historical factors (phylogeny).

Fundamental differences

- 3) Aquatic vertebrate feeding systems - relaxed competition and absence of character displacement.
- Teleosts diverse, abundant - few well-documented cases of character displacement.
- Competition rapidly reduced or avoided by extensive food switching? Not require major change in feeding structures.
- Terrestrial feeding systems precise matching of design and biological role; often very refined resource partitioning. Intense competitive interactions leads to character displacement

Summary

- Increased Structural Complexity with evolution of derived groups
- Agnathan Feeding – Evolution of jaws
- Chondrichthyes feeding
- Primitive Actinopterygian feeding
- Halacostome Feeding
- Teleost Feeding
- Modular Multiplicity
- Pharyngeal Jaws
- Aquatic vs Terrestrial Feeding
 - Morphological specialization
 - Jack of all trades vs Master of one
 - Convergent Evolution
 - Character Displacement

