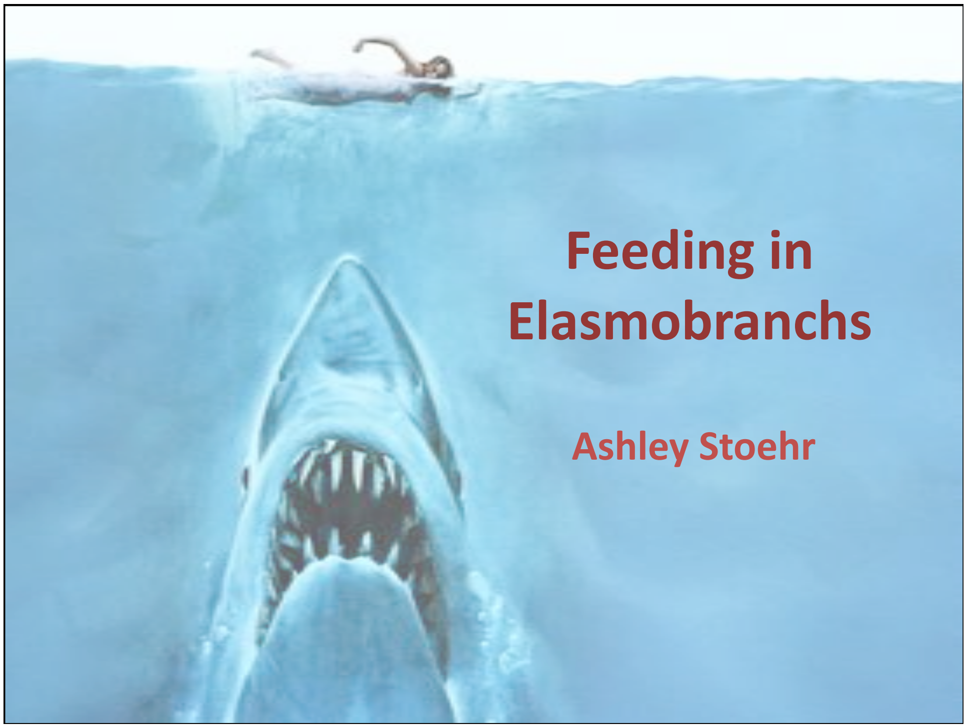
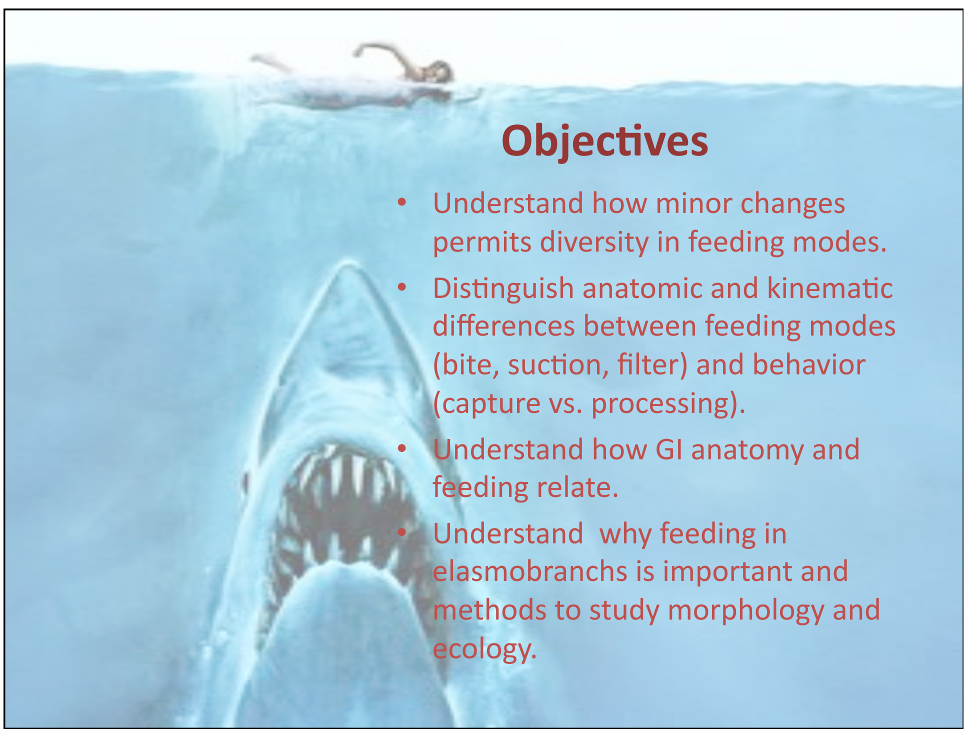


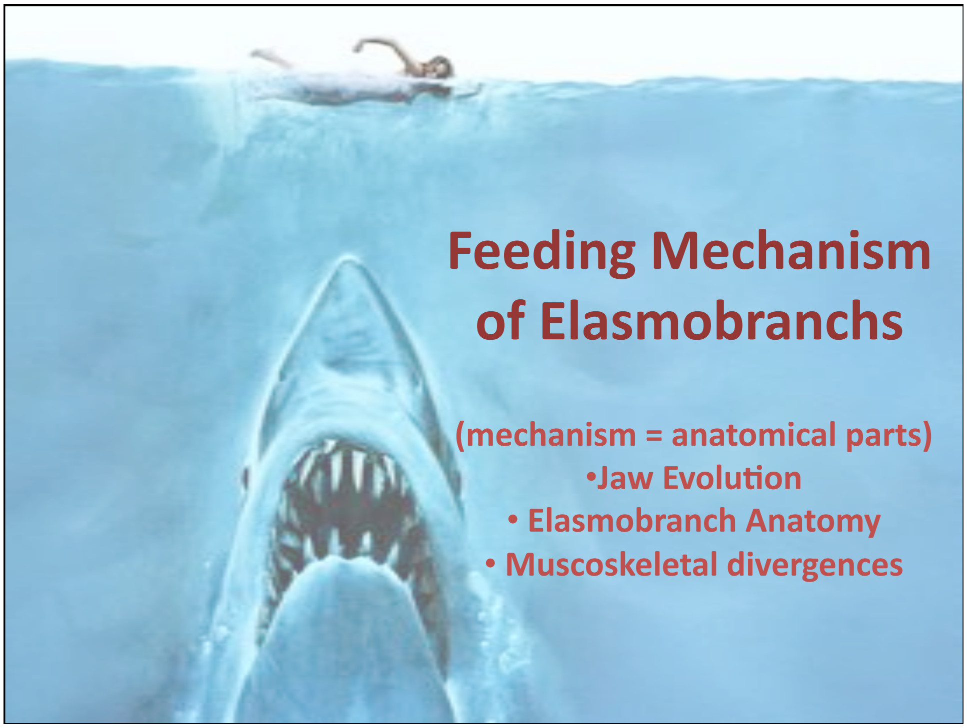
Feeding in Elasmobranchs

Ashley Stoehr



Objectives

- Understand how minor changes permits diversity in feeding modes.
- Distinguish anatomic and kinematic differences between feeding modes (bite, suction, filter) and behavior (capture vs. processing).
- Understand how GI anatomy and feeding relate.
- Understand why feeding in elasmobranchs is important and methods to study morphology and ecology.

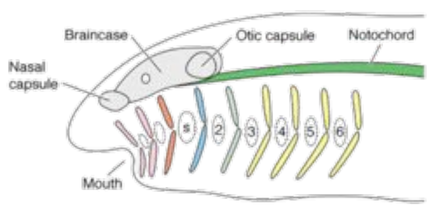


Feeding Mechanism of Elasmobranchs

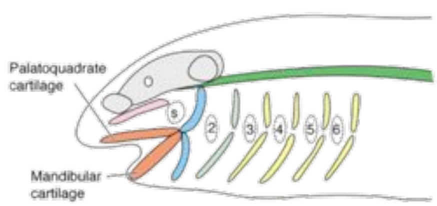
(mechanism = anatomical parts)

- **Jaw Evolution**
- **Elasmobranch Anatomy**
- **Muscoskeletal divergences**

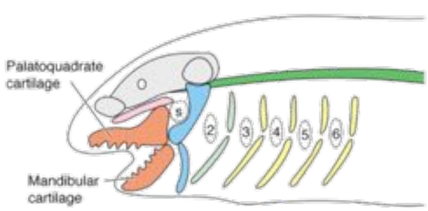
Jaw Evolution: Mandibular Hypothesis



A. Hypothetical jawless condition



B. Mandibular arch functions as jaws

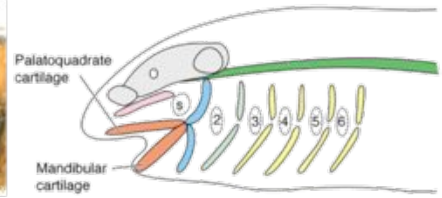


C. Jaws associated with braincase

- Opposable, articulated structure
- Serial homology based on morphological similarity
- Pharyngeal arches enlarged and moved anteriorly to become jaws

Jaw Evolution: Mandibular Hypothesis


A. Hypothetical jawless condition



B. Mandibular arch functions as jaws

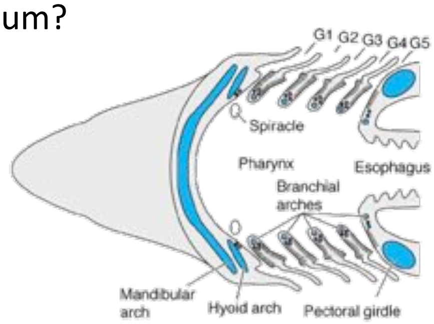

C. Jaws associated with braincase

- Position of gills previous problem for arch homology

Jaw Evolution: Velar Hypothesis

- Velar cartilage becomes the jaws
- Velum separates pharynx and respiratory tube in lampreys
- Do all agnathans have a velum?

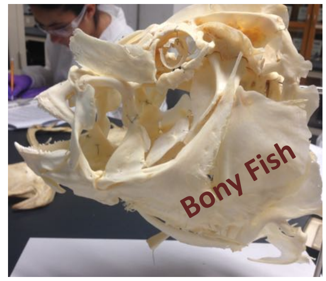
B. Petromyzon frontal section through pharynx



C. Squalus frontal section through pharynx

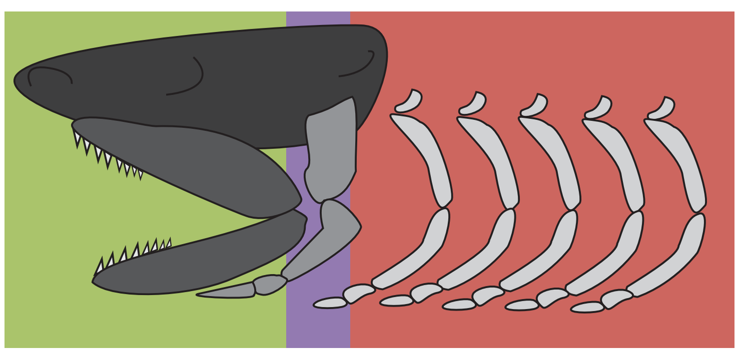
Why study elasmobranch feeding mechanism?

- Interface with environment
  - Jaws = Diversification
- Elasmobranchs are basal gnathostomes
  - "jaw-mouth"
- Sharks show functional diversity with morphological simplicity



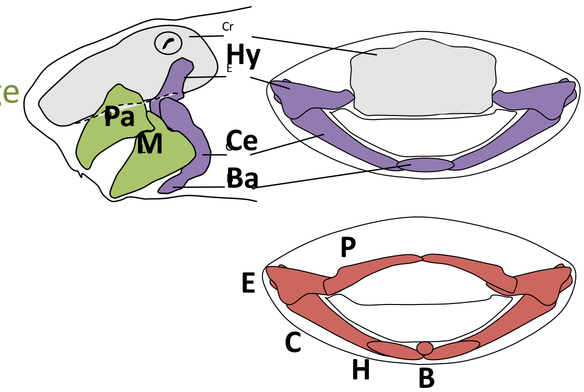
Feeding Mechanism of Elasmobranchs

- Buccal Cavity
  - Mandibular Arch
- Hyoid Cavity
  - Hyoid Arch
- Pharyngeal Cavity
  - Pharyngeal (Branchial) Arches



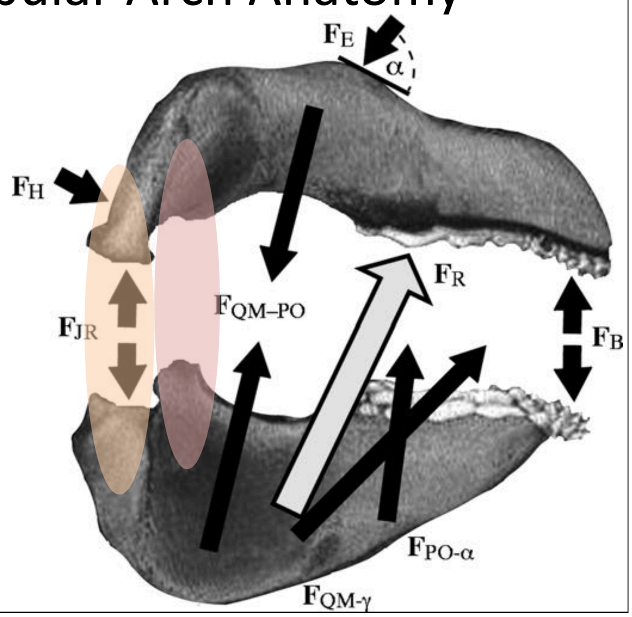
Arch Anatomy

- Mandibular Arch
  - Palatoquadrate
  - Meckel's cartilage
- Hyoid Arch
  - Hyomandibulae
  - Ceratohyal
  - Hypohyal
  - Basihyal
- Pharyngeal Arch (PECH-B)
  - Phargynobranchial, Epibranchial, Ceratobranchial, Hypobranchial, Basibranchial

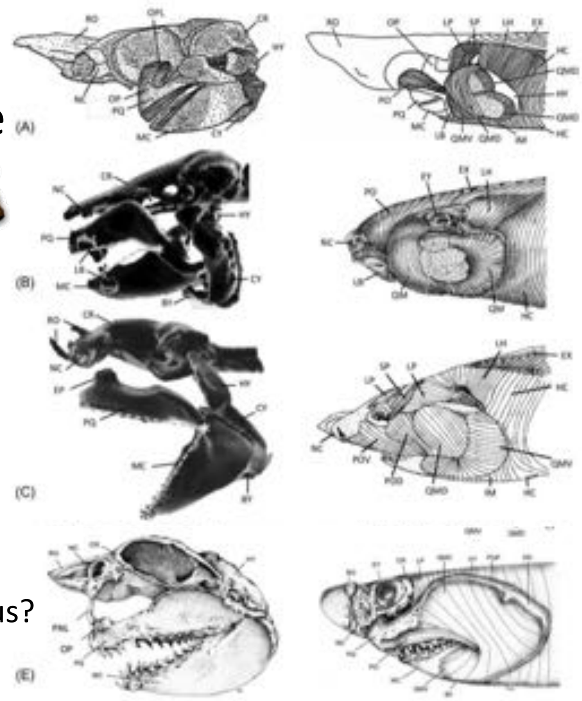


Mandibular Arch Anatomy

- Dual quadrato-mandibular joints

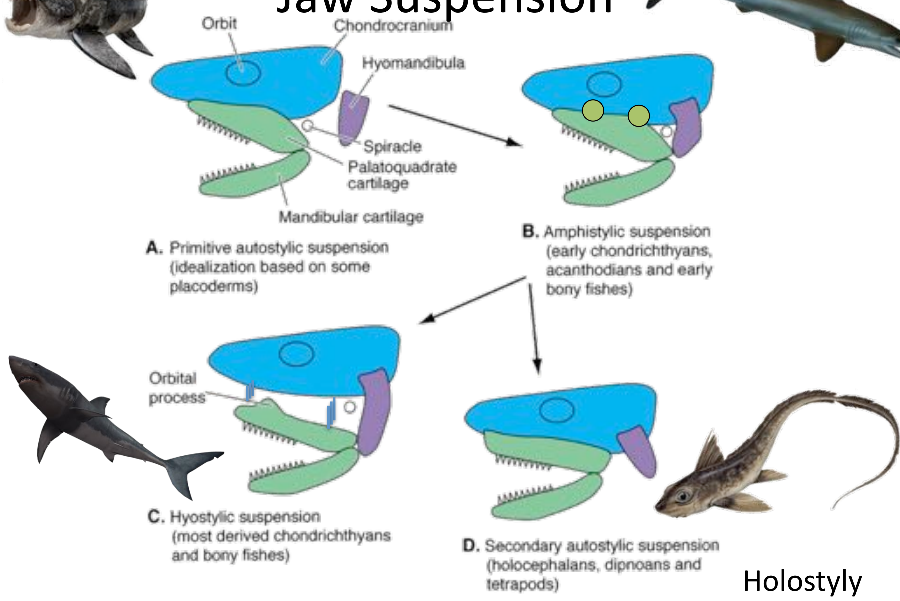


Changes to Skeletal Frame



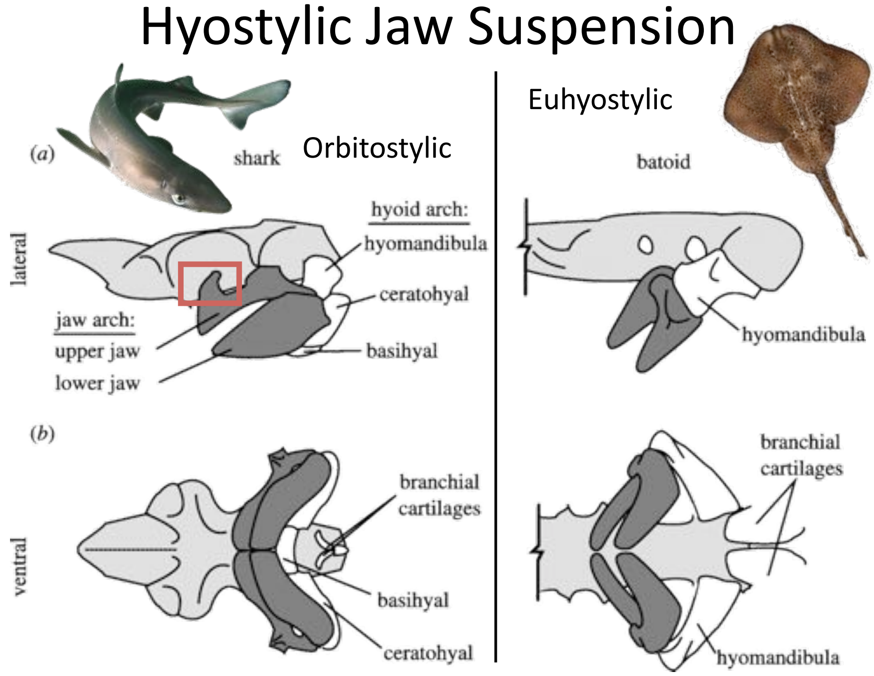
- Few skeletal changes (3 major)
- Which is durophagous?
  - **Grinds** hard prey

Skeletal Changes Jaw Suspension



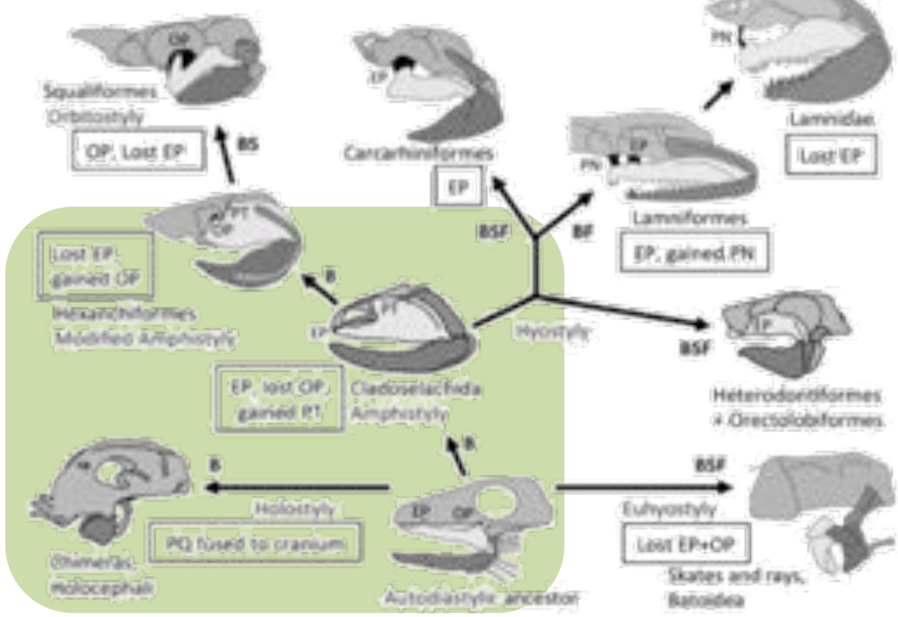
Holostyly

Hyostylic Jaw Suspension



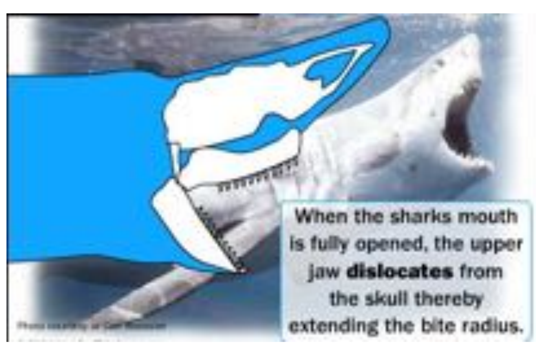
PQ = palatoquadrate; EP = ethmoid process;
OP = orbital process; PN = post-orbital process

B = bite; S = suction; F = filter



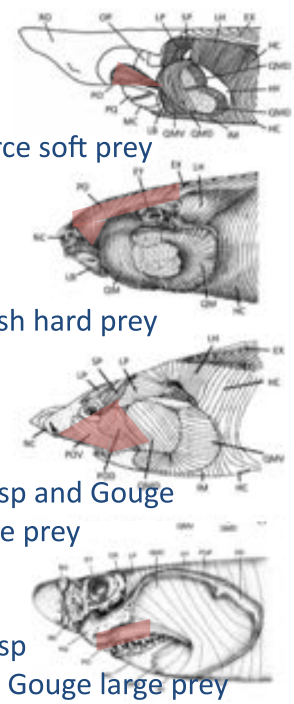
Why Protrude the Upper Jaw?

- General feeding
  - Close distance to prey
  - Hydrodynamic
- Bite feeding
  - Exposes teeth
  - Facilitate precision and cutting action
- Suction feeding
  - contributes to small gape



Preorbitalis: Feeding Musculature

A. Squaliformes: basal preorbitalis (PO) extends from jaw joint to nasal capsule, protracts upper jaw
B. Orectolobiformes: preorbitalis divides and extends to chondrocranium, protracts upper jaw
CD. Carcharhiniformes and Lamniformes: preorbitalis divides and extends further onto upper jaw; levator palatoquadrati (LP) protracts rather than retracts upper jaw.
E. Batoids: soooo many muscles.



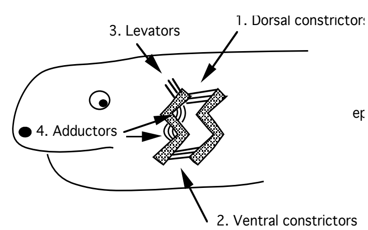
A
Pierce soft prey

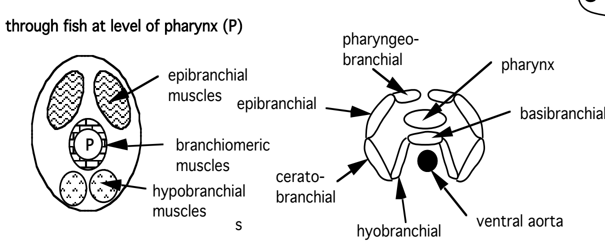
B
Crush hard prey

C
Grasp and Gouge large prey

D
Grasp and Gouge large prey

Feeding Musculature





- Adductors compress arches and adduct jaws
  - adductor mandibulae complex (quadrato + preorbitalis)
- Constrictors elevate or compress arches
- Hypobranchial muscles depress jaw and hyoid
  - Coracomanidbularis, coracoarcualis-coracohyiodeus

Teeth

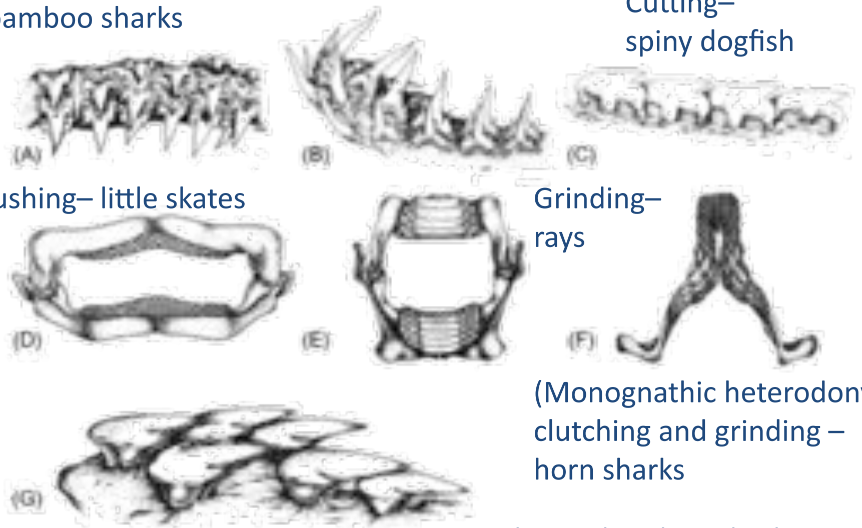
Clutching – bamboo sharks

(Dignathic heterodonty) Lower jaw tearing– sand tiger sharks

Cutting– spiny dogfish

Crushing– little skates

Grinding– rays



(Monognathic heterodony) clutching and grinding – horn sharks

Crushing - bamboo sharks

Teeth

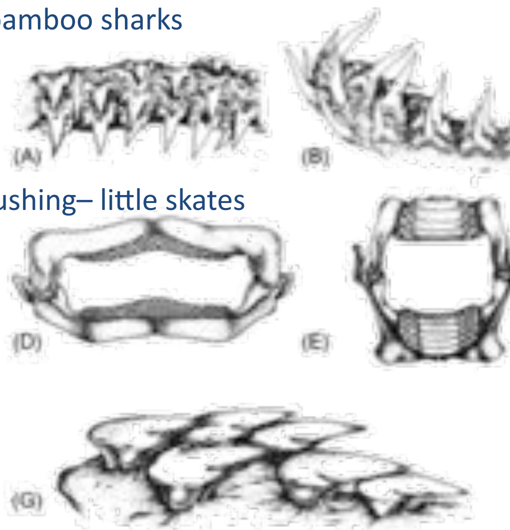
Clutching – bamboo sharks

(Dignathic heterod

Lower jaw tearing-

sand tiger sharks

Crushing– little skates

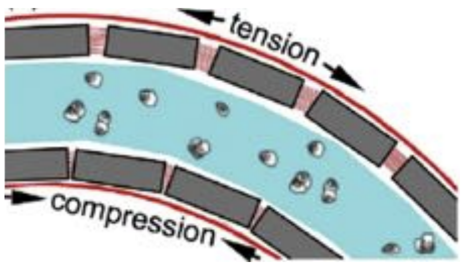


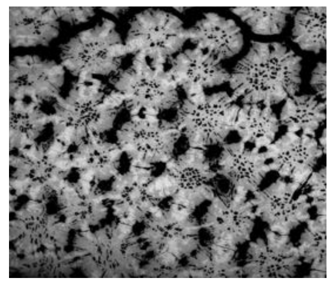
ny)

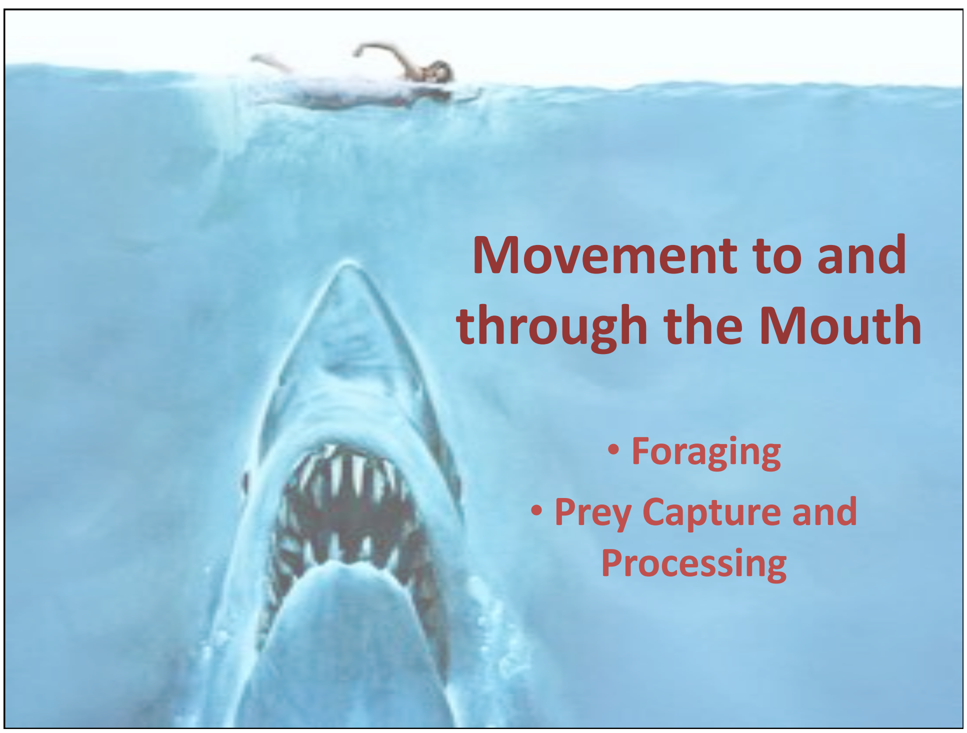
Crus

Consider Cartilage

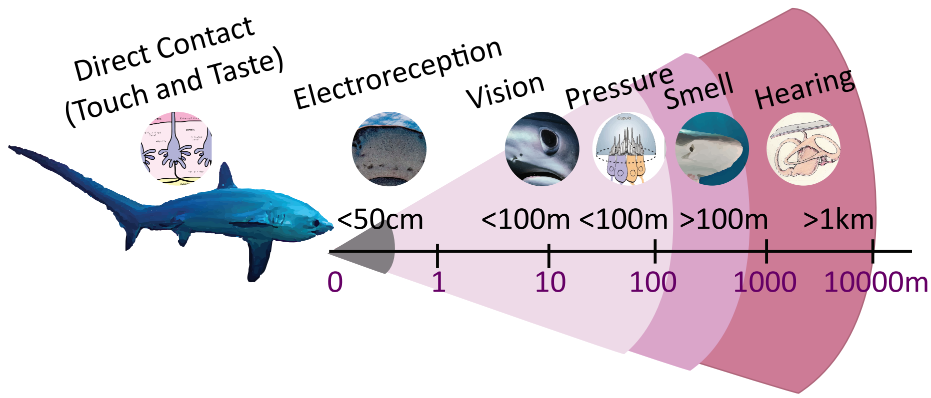
- Tessellated in areas of stress
  - Single shape repeated without gaps or overlap
- Ligaments or fibrous outer layer above tesserae above softer, cartilaginous core
- Stiffness, flexibility, and energy dissipation
  - Resist loads but deforms to dissipate energy







Foraging: Finding Food

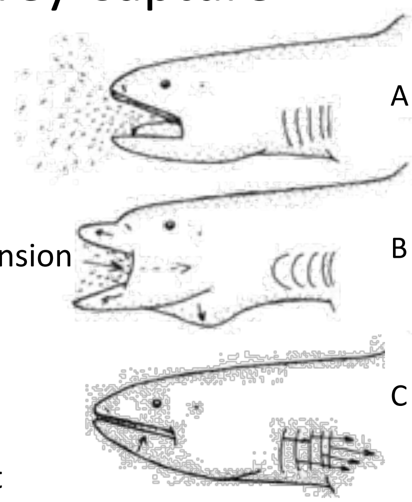


Prey Capture Modes

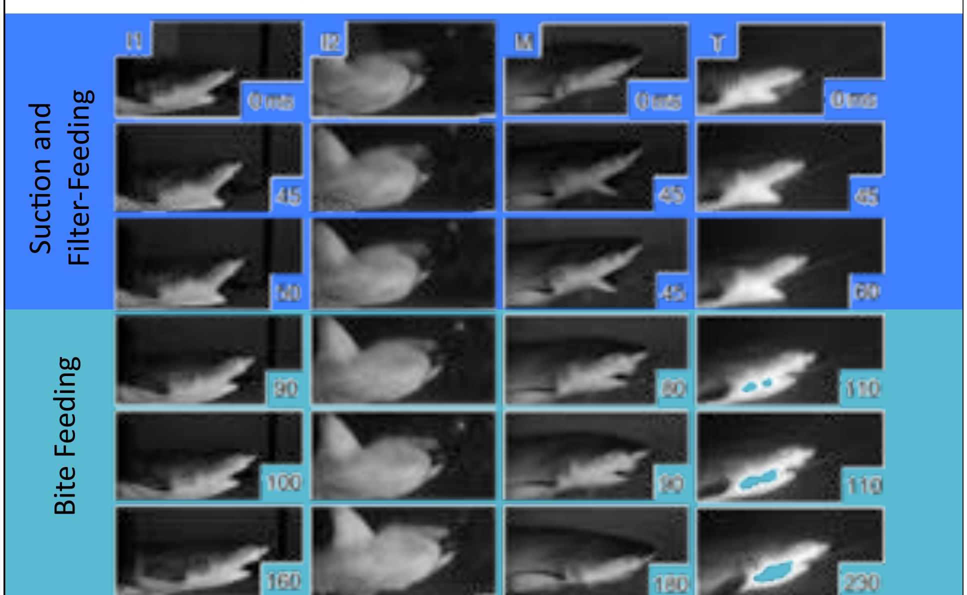
- Suction: sequential expansion
  - Intermittent, inertial suction feeding
    - <u>High velocity, low volume</u>
  - Continuous, ram suction feeding (swim agape)
    - <u>Low velocity, high volume</u>
  - Filter feeding: straining food by passing particles through specialized "filter" structure
- Bite: approach, cease, bite
- Functional Continuum

Stages of Prey Capture

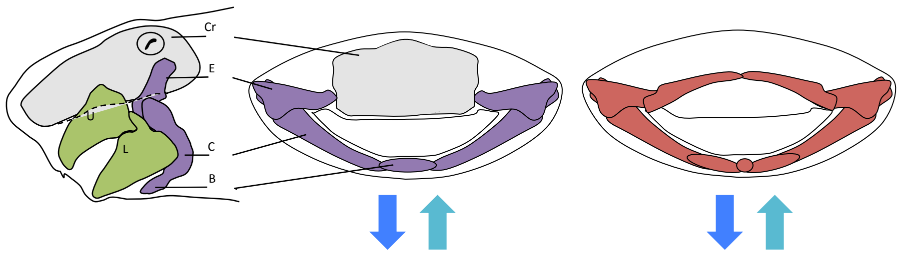
A. Preparatory
   - Cranial elevation
B. Expansive
   - Lower jaw depression
   - Sequential cavity expansion
C. Compressive
   - Lower jaw elevation
   - Upper jaw protrusion
D. Recovery
   - Jaws and arches revert

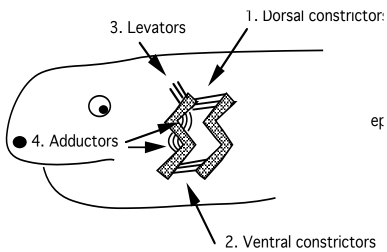


Stages of Prey Capture



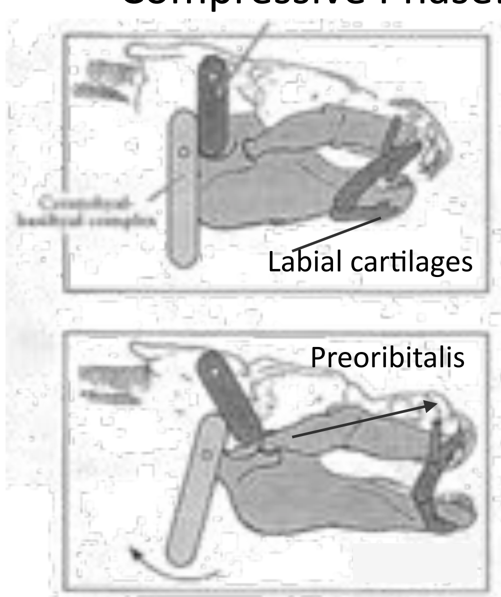
Expansive and Compressive Phases

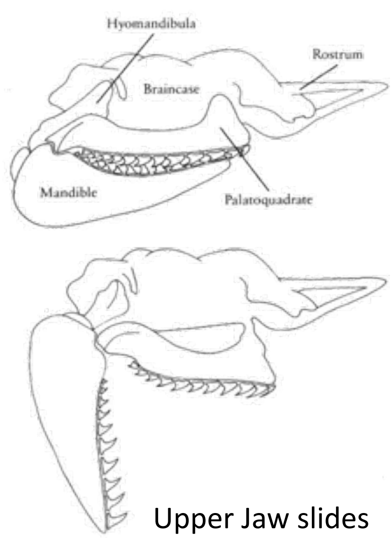




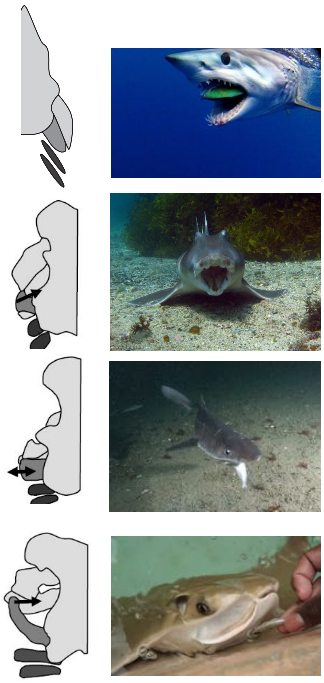
- Coracomandibularis depresses lower jaw
- Coracoarcualis and coracohyoideus depress basihyal
- Preorbitalis protrudes upper jaw
- Adductor mandibulae elevates lower jaw

Compressive Phase: Jaw Protrusion





Upper Jaw slides out and down

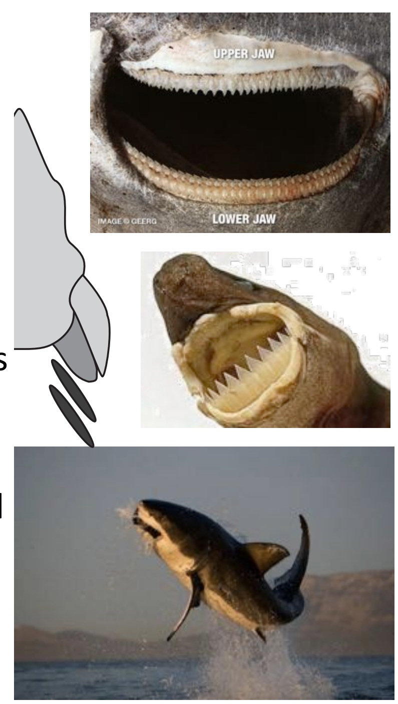


Skeletal Change: Hyomandibula

- Carchariniformes and Lamniformes: long posterior hyomandibulae and long jaws (bite)
- Orectolobiformes and Heterodontiformes: Short lateral hyomandibulae and short jaws (suction)
- Squaliformes: longish posterolateral hyomandibulae and short jaws (general)
- Batoids: long anterior hyomandibulae and short jaws (general)

Bite Feeders

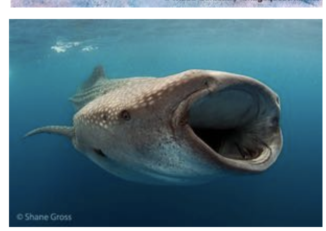
- Long jaws
- Long posteriorly orientated hyomandibulae
- Large gape
- Tall, wide heads
- Hypertrophied adductor muscles
- Large teeth
- Bite kinematics more variable
  - Large species less constrained



Bite Feeding

Suction Feeders

- Short jaws
- Short, lateral hyomandibulae
- Labial cartilages
- Small gape
- Small teeth
- Hypertrophied abductor muscles
  - Rapid buccal expansion
- Suction kinematics stereotyped
- Orectolobiformes specialized (mostly inertial)

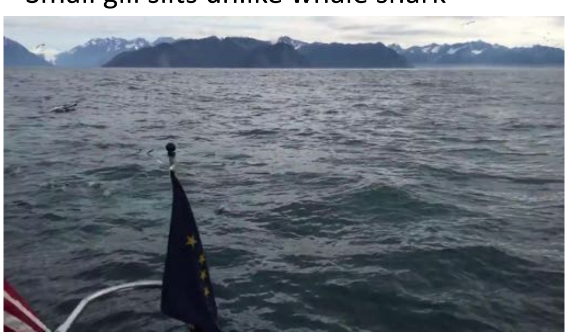


Whale Shark Feeding (Orectolobiformes)

- Intermittent Inertial Suction Filter-Feeding
  - Stationary, Vertical
- Ram Filter-Feeding
  - Continuous, Passive

Megamouth Feeding (Lamniformes)

- Intermittent, **Inertial/Ram** Suction
- Large terminal mouth, buccal cavity
- Upper jaw protrusion and basihyal depression
- Elastic skin
- Small gill slits unlike whale shark

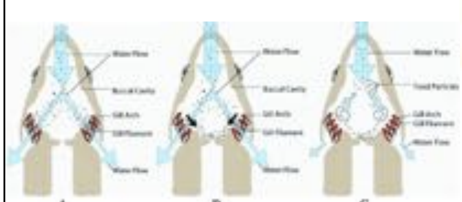


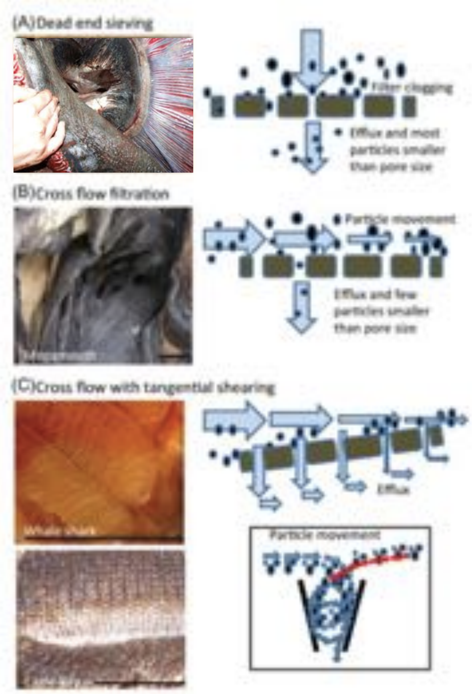
Basking Shark Feeding (Lamniformes)

- Continuous ram filter-feeding
- Large, subterminal mouth
- Large gills
- Little jaw protrusion, lateral jaw rotation

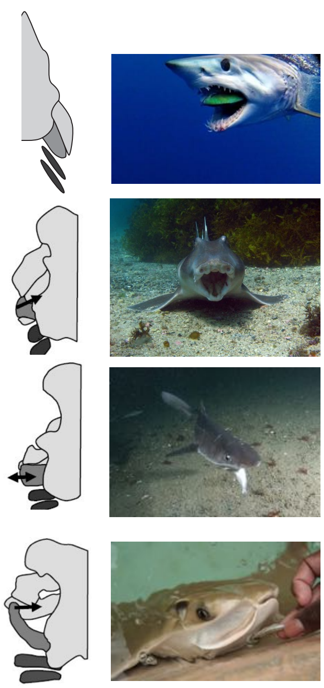
Filter Feeding

- Basking (A) and Megamouth (B) Sharks
  - Gill rakers
- Whale sharks (C)
  - Gill seive
  - Shed in winter





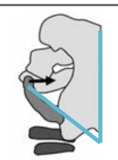
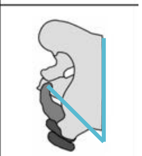
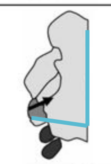
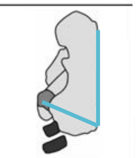
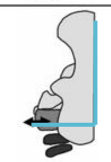
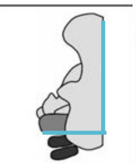
Combination Feeding: Functional Continuum



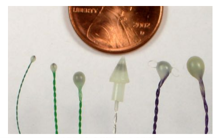
Ecomorphology

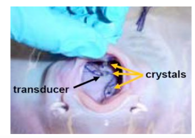
- Carchariniformes and Lamniformes: long posterior hyomandibulae and long jaws (bite)
- Orectolobiformes and Heterodontiformes: Short lateral hyomandibulae and short jaws (suction)
- Squaliformes: longish posterolateral hyomandibulae and short jaws (general)
- Batoids: long anterior hyomandibulae and short jaws (general)

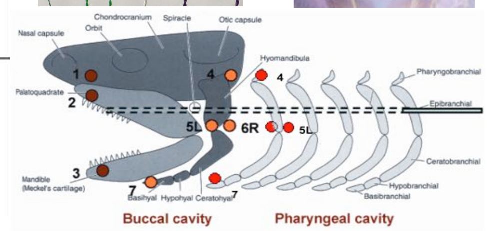
Prey Capture Kinematic Measurements

Species	Resting Position	Feeding Position
Little Skate Ant HY: 48 (43-55)		
Bamboo Shark Lat HY: 70 (61-78)		
Spiny Dogfish Lat HY: 100 (95-107)		

- The jaws and hyoid potentially evolved from pharyngeal arches. Are movements stereotyped during ventilation and feeding?







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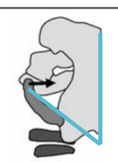
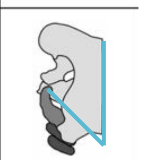
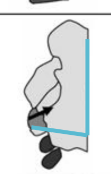
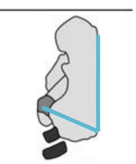
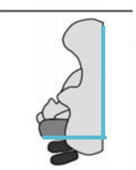
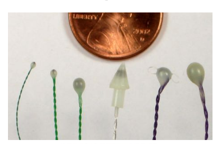
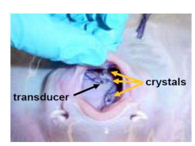
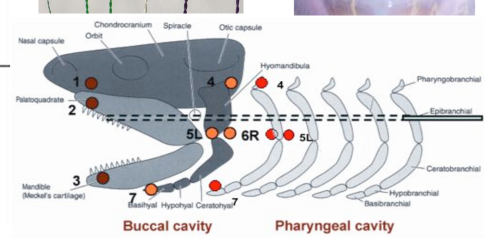
Little Skate Ant HY: 48 (43-55)		
Bamboo Shark Lat HY: 70 (61-78)		
Spiny Dogfish Lat HY: 100 (95-107)		

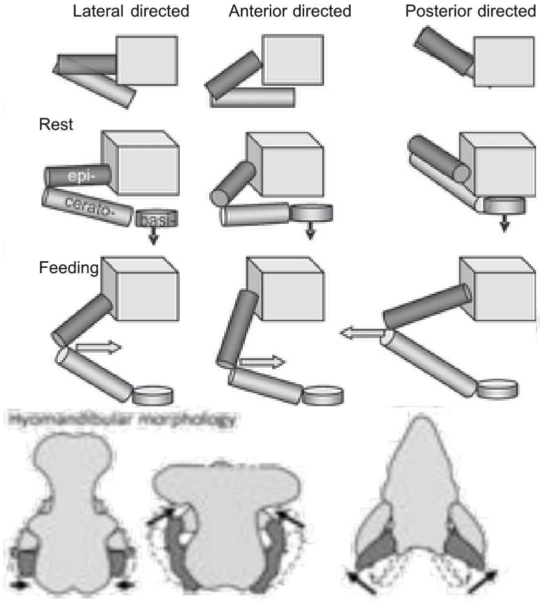
- Hyoid and pharyngeal arches move similarly during ventilation.
- Pharyngeal arches move similarly during ventilation and feeding.
- Hyoid arch plays key role in feeding.







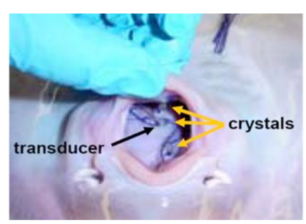
Differences in Expansive Phase



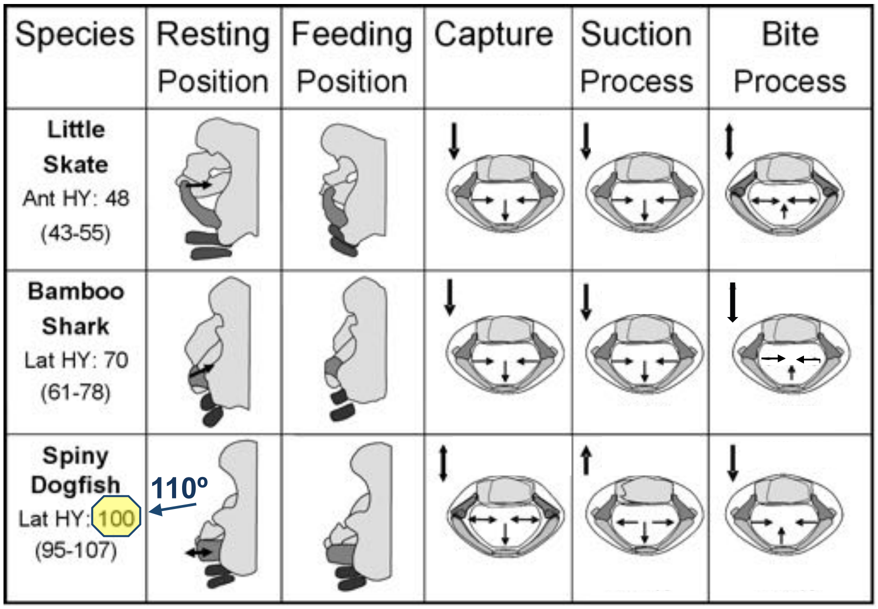
- How does the hyoid arch expand during feeding?
  - Basihyal depresses during expansion
- Suction feeders (lateral, < 110°) decrease hyoid width. Bite feeders (> 110°) expand cavity in all directions.
  - Orientation relates to changes in gape size?

Prey Processing – "Chewing?"

- External and Internal
  - Head shaking, spitting
  - Expansion and compression to break down prey
- Does arch morphology (hyoid and pharyngeal) affect kinematics and prey processing, does it differ from capture?
- Does the mechanism differ between suction and bite processing?



Hyoid Arch During Prey Processing



Added Slide: Results Overview

- Little skates (anterior hyomandibulae) decrease hyoid width during suction capture and suction processing, but variably change width during bite processing. May relate to loss of skeletal basihyal and muscle diversification to create diversity in feeding behaviors.
- Bamboo sharks decrease hyoid width during suction capture and suction processing. They decrease width during bite processing. They are specialized for suction, so during bite the hyoid arch simply moves the opposite way.
- Spiny dogfish increase or decrease hyoid width during suction capture. This could depend on the degree of suction (rapidity of cavity expansion) or the gape size necessary for prey item (increase hyoid width → greater gape?). This variability likely stems from the lateral-posterior (rather than truly posterior like a mako) hyomandibular position. During suction processing they increase hyoid width (like a bite feeder) and during bite processing they decrease hyoid width.