Lecture 4. **Musculature**

As with osteology - head musculature will be covered later with the jaws

Muscles arranged in blocks called myotomes, comprised of myomeres and arranged in bundles. Separated by myosepta

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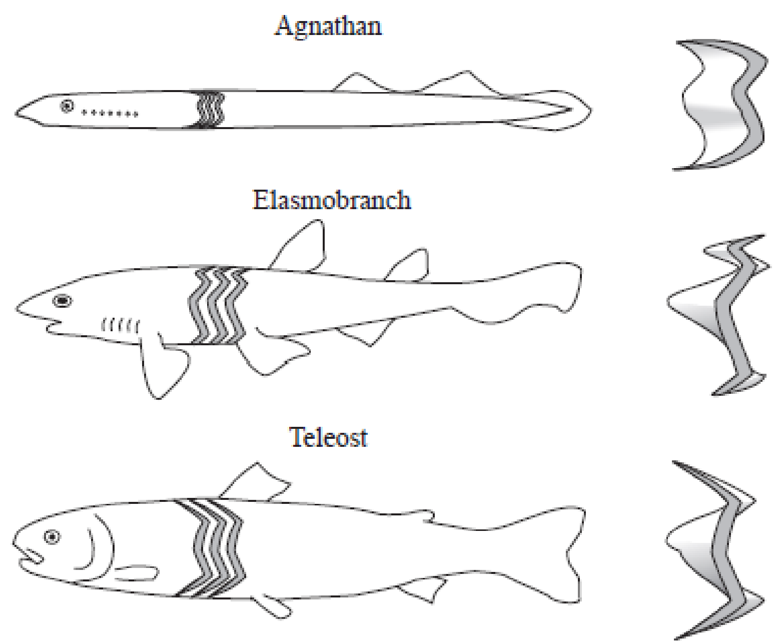


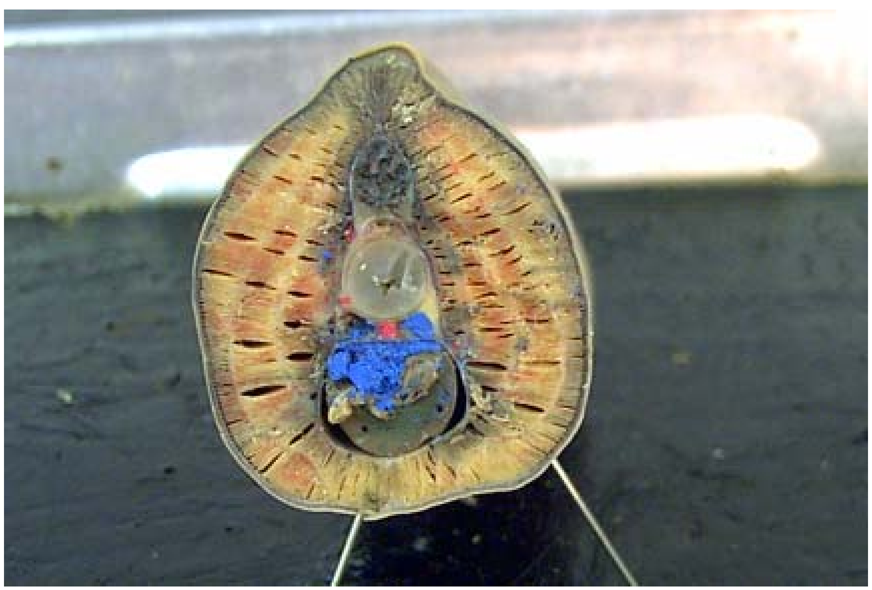
Fig. 1. Myotomal structure of the lateral muscle. Isolated myotomes are shown to the right of the fish.

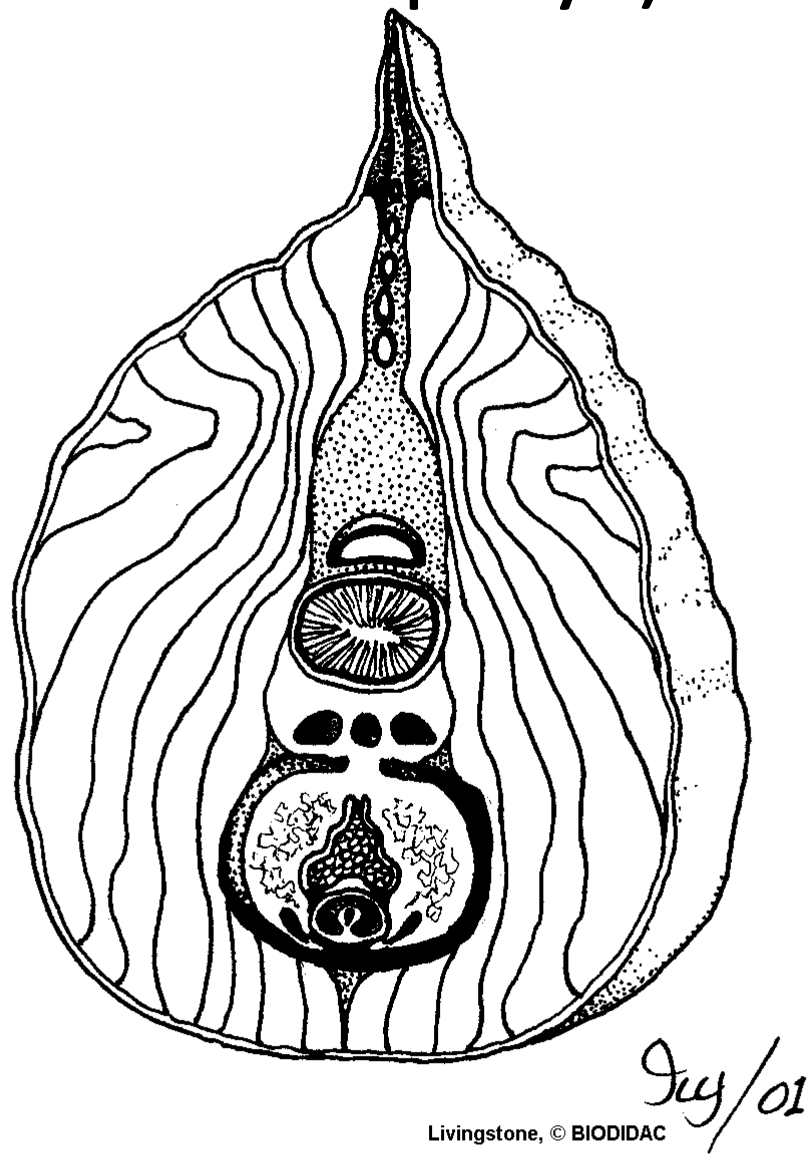
Differences between Groups
Agnathans (hagfish and Lampreys)

Simple striated muscles

W-shaped myomeres

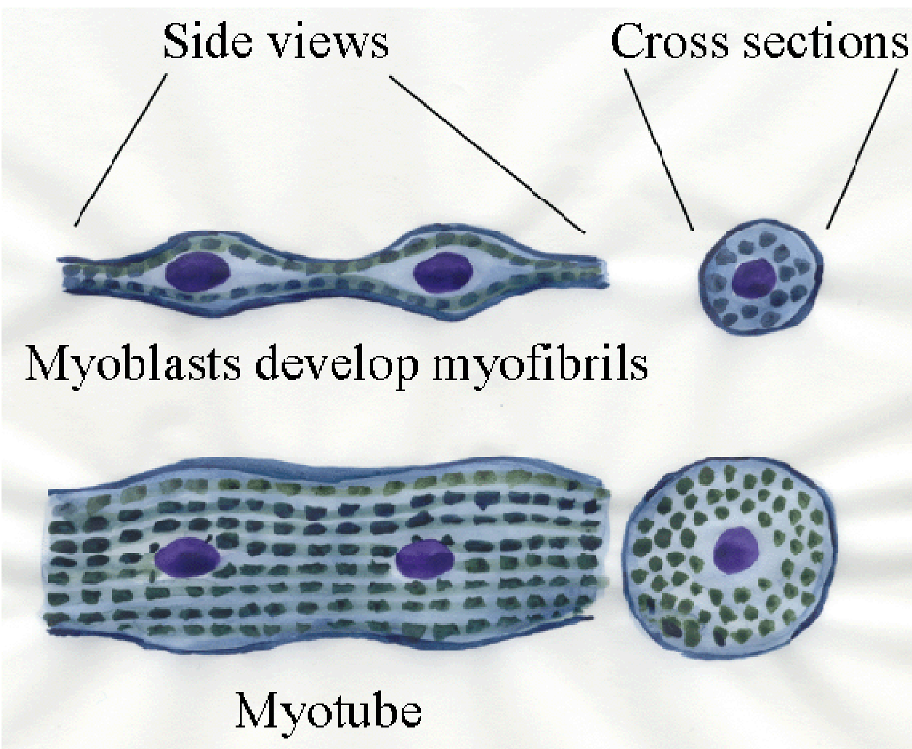
Uniformly segmental

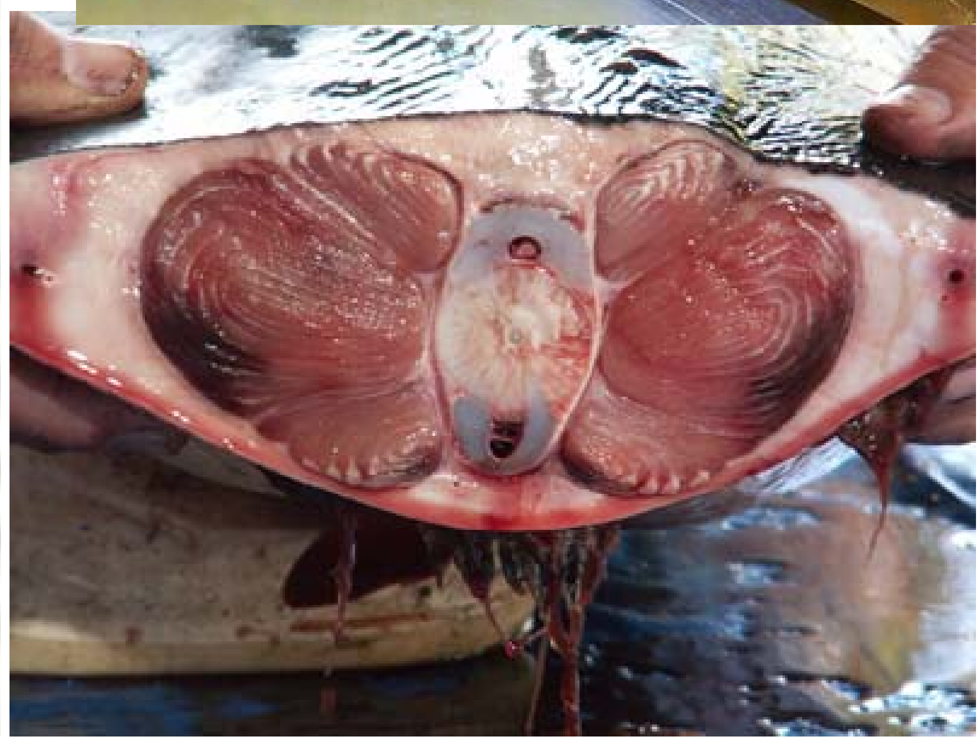




Chondricthyes

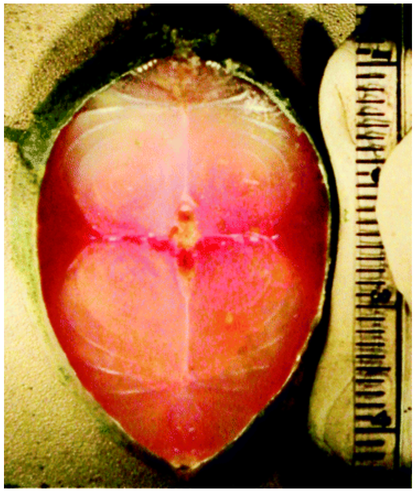
- Chondricthyes - number of myotubes fixed. Growth occurs in diameter and length. > 13 cm in basking sharks.

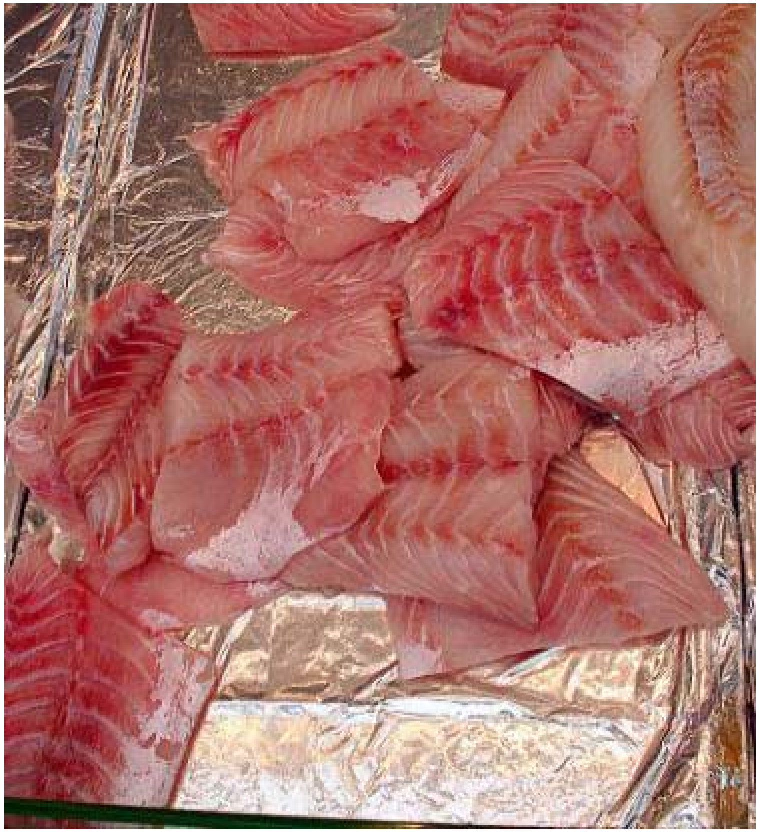




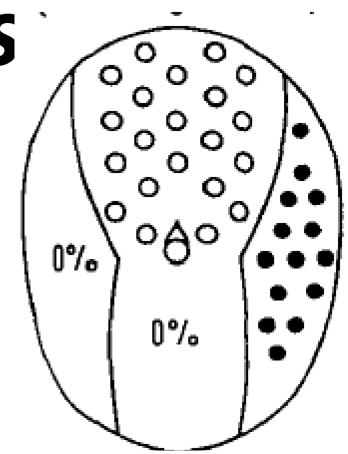
Bony fish

- Have a dual motor system
- V-shaped myomeres with new myomeres added posteriorly
- At hatching body has a sheath of red muscle surrounding white muscle
- Later concentrates on flank
- # increase throughout life





Basic structure of Actinopterygii (ray finned fishes) muscles



- Outer = red
- Inner = white

- Muscle fibres run parallel to mid-line
- Myotomes separated by myosepta

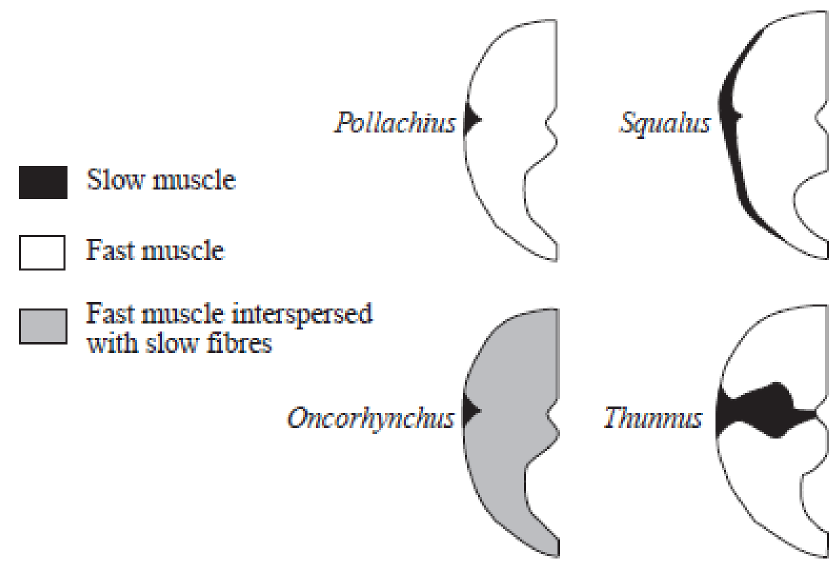


Fig. 2. Diagrammatic transverse sections to show the distribution of slow-twitch (red) and fast-twitch (white) muscle. Cross sections were taken at approximately 0.35 body lengths from the snout. Intermediate pink fibres are omitted because of their comparatively small cross-sectional area.

Overview of different muscle types and comparison of red and white muscles

	Red	White
Capillary bed	↑ - extensive	↓-sparse
Fibre density	↓	↑
Myoglobin	↑	↓
Glycogen	↓	↓
Muscle mass	↓	↑
Metabolic emphasis	Aerobic	Anaerobic
Rate of fatigue	Slow	Fast
Muscle performance	Efficiency	Power
Swimming type	Slow cruising	Fast bursts
Car analogue	High gear	Low gear

Body muscle arrangement (overhead)

The serial arrangement of muscle bundles -> Segmentation -> key to waves for swimming

<u>Terminology (overheads)</u>

- Epaxial (above), hypaxial (below) and carinalis muscles (on ridge between median fins)
- Lateralis superficialis – red, thin and mitochondria rich (overlies ventral portion of epaxalis and dorsal portion of hypaxalis)
- Epaxalis -> anteriorly connected to cranium and cleithrum
- Therefore epaxalis originates on vertebrae, centra and neural arches and spines and insert on lateral bases of fin rays
- Hypaxalis – circumvents coelom (body cavity)

Caudal fin musculature (overhead)

- Openers – abductors (to move away)
- Flexor dorsalis
- Flexor ventralis

- Two closers
- Adductor dorsalis
- Hypochordal longitudinalis

- Fin rays are opened through increase in muscle volume. (Analogy with fingers)
- Interradial muscles

Mechanisms for swimming

- Fish swim by passing a wave of contracting muscle from anterior to posterior. Muscles near the head of the fish contract first and contraction proceeds posteriorly down the length of the fish to the caudal fin.

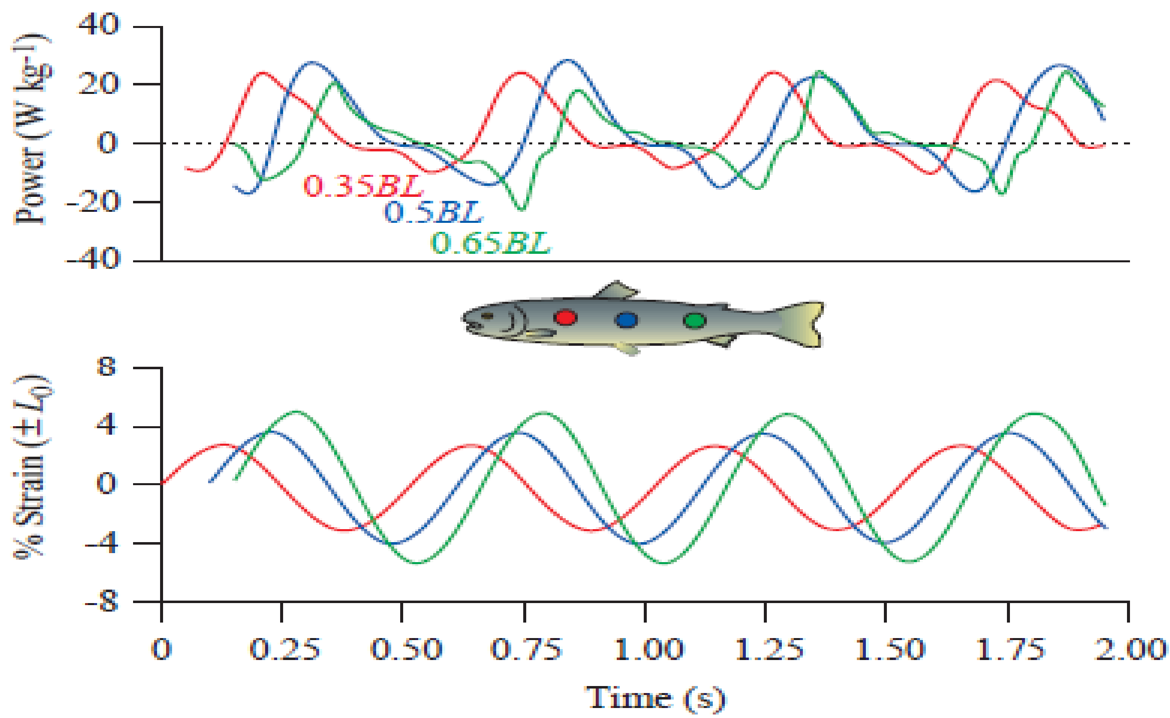


Fig. 6. Instantaneous power output of slow muscle and corresponding strain recordings over three oscillatory cycles at a tailbeat frequency of 2 Hz. Recordings are from preparations of *Oncorhynchus mykiss* at three body positions 0.35, 0.5 and 0.65 body lengths (*BL*) from the snout. L_0 is muscle length when the body of the fish is straight (Hammond et al., 1998).

- Undulatory swimming in fish is powered by the segmental body musculature of the myotomes.
- Myotome and myosepta orient more perpendicular to midline to push aside. Therefore bend (flex) laterally.
- At rest in a rhomboidal shape in a frontal/horizontal cross section
- With contraction muscle fibres will shorten by half their length while maintaining volume. Becomes rectangular
- Power generated by this muscle and the interactions between the fish and the water generate a backward-travelling wave of lateral displacement of the body and caudal fin.

Why do they need myosepta?

- If there were no myosepta, but simply a series of interconnected muscle fibers, then the wave would be very dampened. That is, as anterior fibers contract they would pull on posterior fibers and stretch them so the shortening of the whole side would be much less than if the anterior fibers contracted without the posterior fibers lengthening. Myosepta effectively transmit the contractile force to the backbone and skin, which keeps the posterior fibers from lengthening.

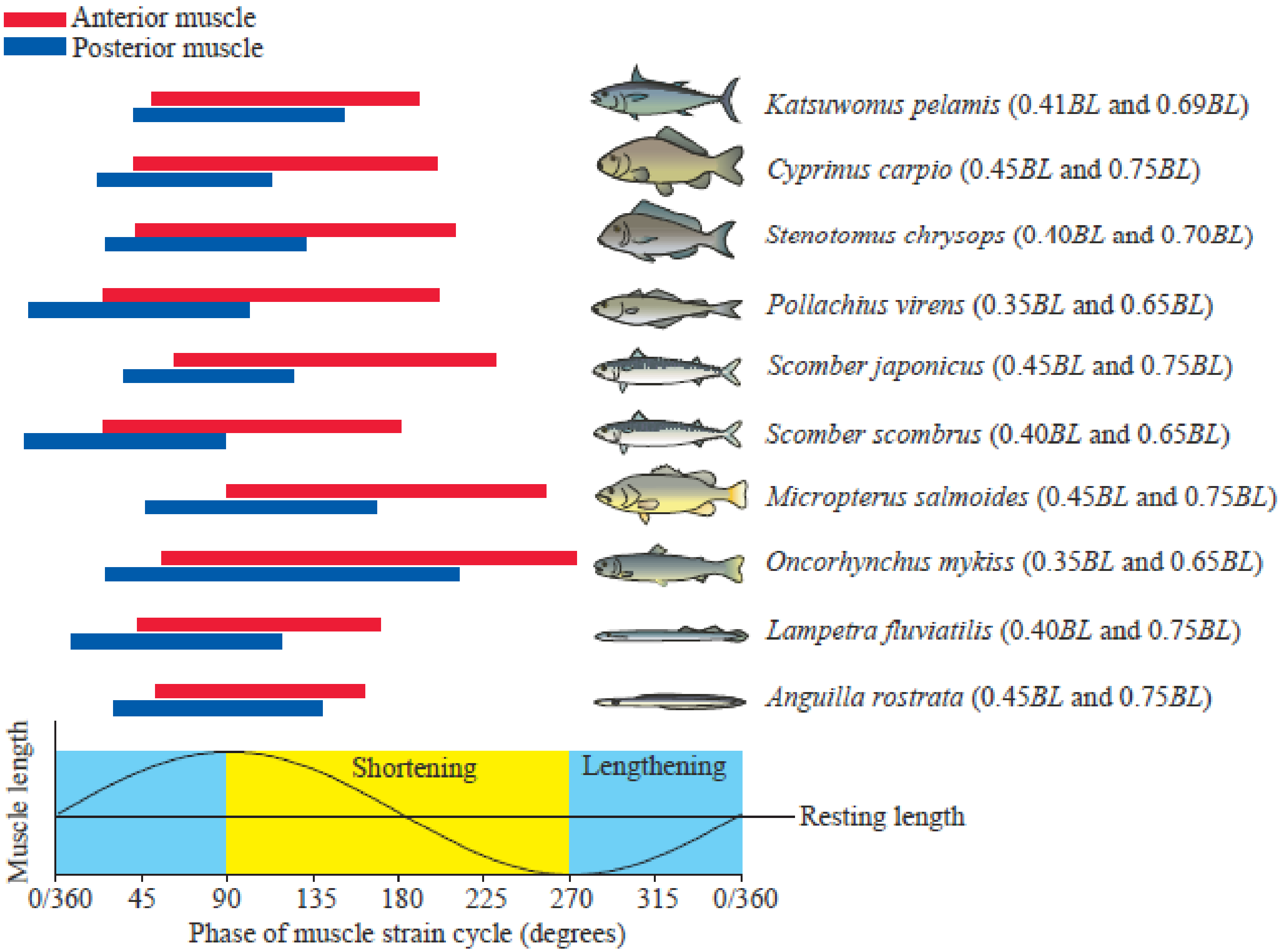


Fig. 4. Activation of anterior and posterior slow muscle in a range of fish taxa. Activation is shown relative to the muscle strain cycle. The position on each species from which data were recorded is expressed as a proportion of the body length (*BL*) from the snout. There is a general decrease in propulsive wavelength down the list of species. Electromyographic timing data are derived from Knower et al. (1999) (*Katsuwonus pelamis*), van Leeuwen et al. (1990) (*Cyprinus carpio*), Rome et al. (1993) (*Stenotomus chrysops*), Hammond (1996) (*Pollachius virens*), Shadwick et al. (1998) (*Scomber japonicus*), Wardle and Videler (1993) (*Scomber scombrus*), Jayne and Lauder (1995) (*Micropterus salmoides*), Hammond et al. (1998) (*Oncorhychus mykiss*), Williams et al. (1989) (*Lampetra fluviatilis*) and Gillis (1998) (*Anguilla rostrata*).

- It is still unclear how the muscle force is transmitted to the tail.
- If contraction occurs away from bending, the muscle force must be transmitted down the body by structures other than by direct connection of the muscles to the vertebrae.
- Several structures have been suggested to transmit muscle force including tendons, myosepta, and skin.