Convergent Evolution and Adaptations

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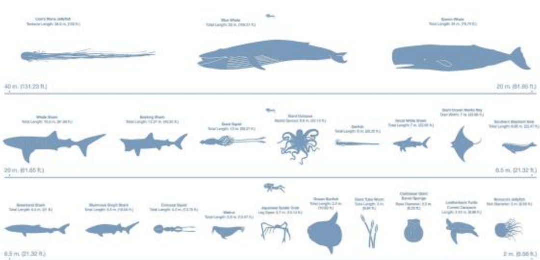
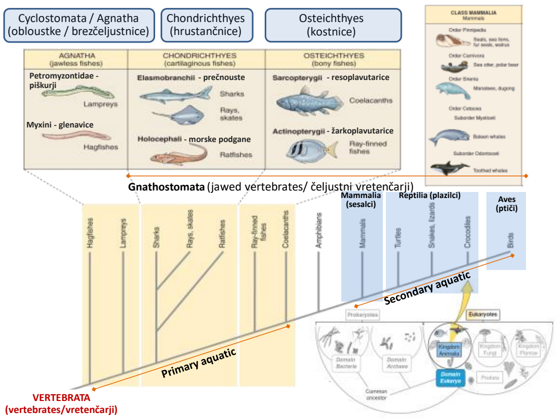
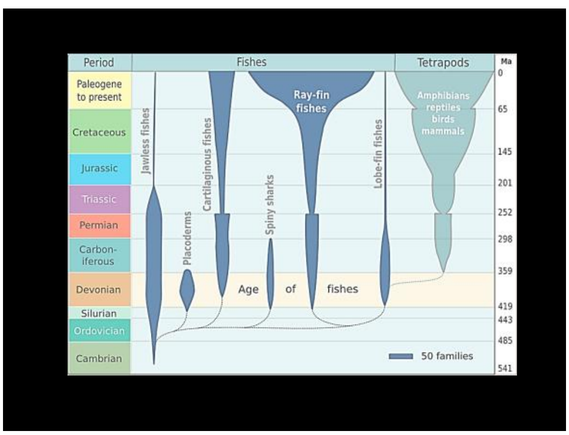
Large marine vertebrates

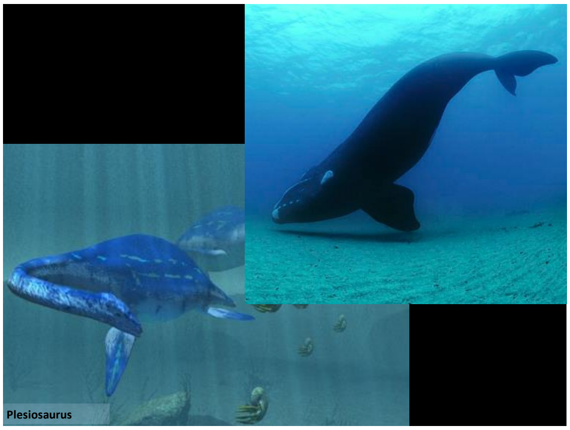






Convergent evolution

- independent evolution of similar features in species/taxonomic groups of different lineages
  - ⇒ analogous structures (organs): similar form or function but different evolutionary origin
  - homoplasy (Greek: *same form)*
- results of universal physical and physiological principles
  - ⇒ common biological (evolutionary) solutions in evolutionary distant taxonomic clades



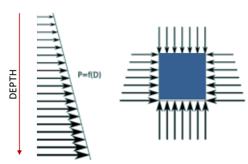
Life in water

- liquid, gas: fluids
  - fluid dynamics
- buoyancy, upthrust (uzgon): an upward force exerted by a fluid that opposes the weight of a partially or fully immersed object

Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object **Archimedes' principle**

Movement through the water:

- Energetically demanding
- *Drag* (upor sredstva)
  - *Friction drag* (trenje)
  - *Pressure drag* (pritisk)



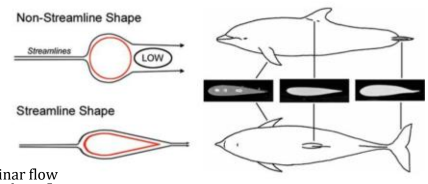
Large Marine Vertebrates:
Locomotion in marine environment

- energetically expensive

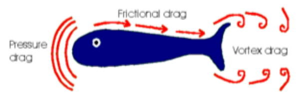
1) Morphological solutions
   - hydrodinamic body shape (streamlined body shape)
   - reduced drag
   - locomotory limbs with large surfaces (fins, flippers)
   - changing in bouyancy (due to compression of air in lungs, swiming bladder, fur...)
2) Behaviour solutions
   - intermittent locomotion
   - selective use of sea currents
   - trawelling in a formation

Large Marine Vertebrates:

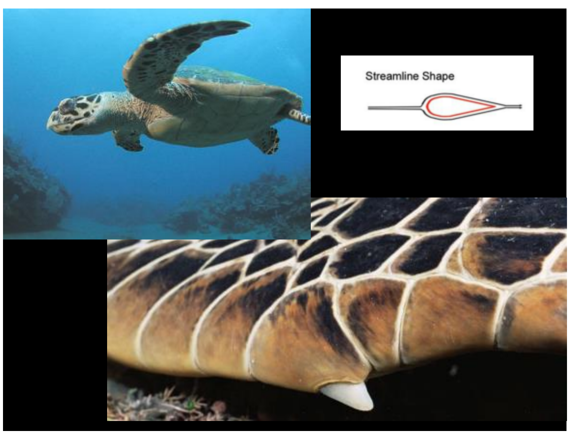
Streamlined body shape



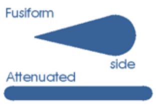
- laminar flow
- turbulemt flow

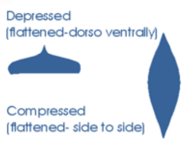


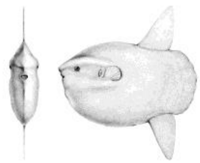
Swiming: thrust > drag

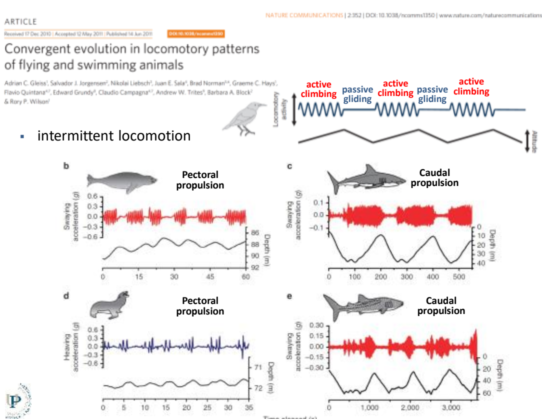


Marine Vertebrates:
Body shapes





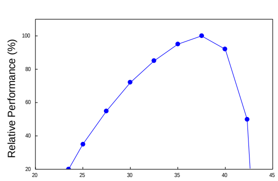




- intermittent locomotion

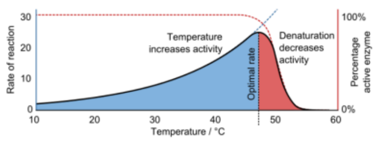
Thermal biology

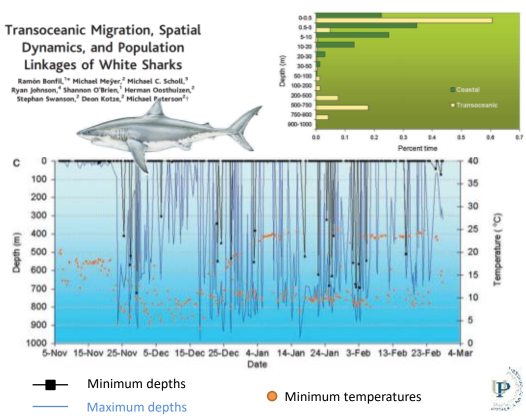
thermocomformer → thermoregulator



Q_{10} principle

- Biochemical principle
- Δ10°C: ~50% decrease in muscle activity
- Elevated body temperature:
  - Faster contraction of red muscles
  - Faster transfer of oxygen from blood to muscles (aerobic metabolism)
  - Faster decomposition of lactates (muscle relaxation)





Regulation of body temperature

1. Acording *steadiness of body temperature*

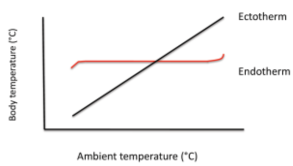
- *Poikilothermy* - temperature regulation characterized by wide variations in body temperature as a result of changing environmental conditions.
- *Homeothermy* - stable body temperature

2. Acording to the *energy source*

- *Ectothermy* – mode of thermoregulation in which body temperature primarily dependent on the absorption of heat energy from the environment.
- *Endothermy* - body temperature depends on the cell metabolism of the organism

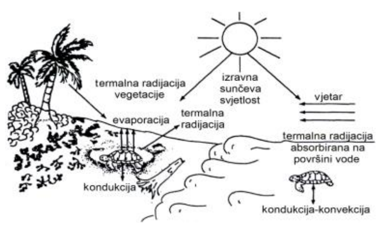
Regulation of T_b

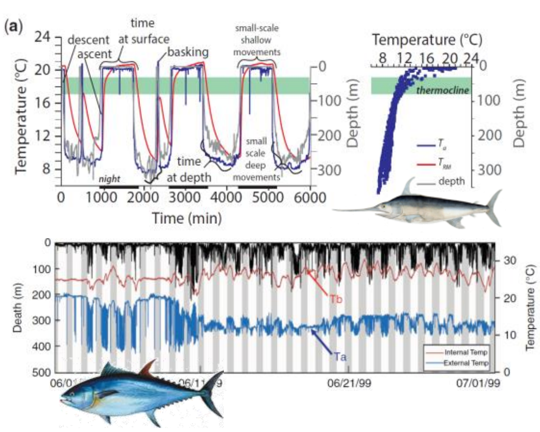
- high thermal capacity of water - fast and constant heat loss



Heat exchange

- radiation
- conduction (body-surface heat exchange)
- convection (heat exchange among diferent medias)
  - body into the air or water

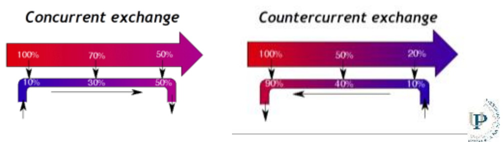




Large Marine Vertebrates

Regional endothermy

- Heterothermy
- Elevated temperatures in body regions importan for efficient performance, e.g. muscles
- *Countercurrent heat exchange*
- *Rete mirabile*: increased area for heat exchange



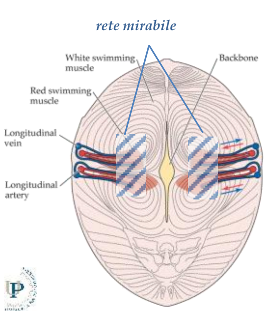
Red muscles / White muscles

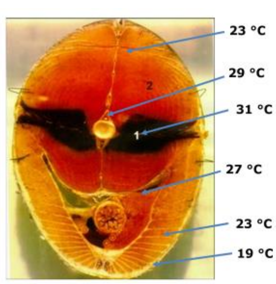
- **Glycolytic, white muscles:** for for high-intensity, short bursts of activity
  - White muscles are capable of working in both aerobic and anaerobic conditions
- **Oxidative, red muscles:** for long-duration, lower-intensity activities like swimming for long periods without fatigue
  - Mass of red muscle is moved centrally, along the mid-lateral line, and is independent of the rest of the muscle
  - In tunas, a proportion of red muscle is much greater than in other fish

tuna

shark

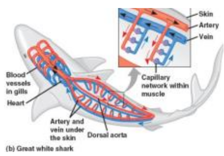
Bluefin tuna

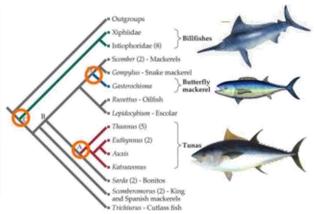


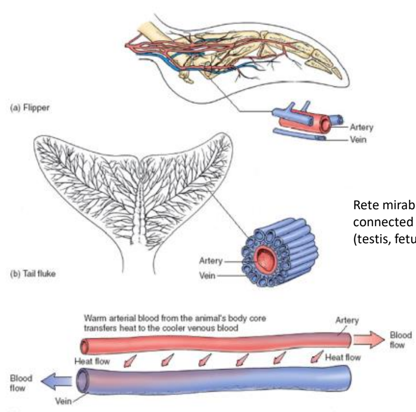


Regional endothermy

- Convergent evolution
- At least 3x just in evolution of bonny fishes
- Also in sharks: fam. Lamnidae (e.g. white, makos..)





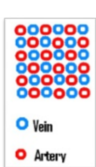


Rete mirabile are also connected to specific organs (testis, fetus, mouth)

Countercurrent exchange in sea turtles

Leatherback turtle

- matrix form



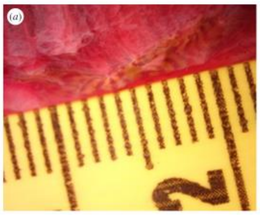
Loggerhead and green turtle

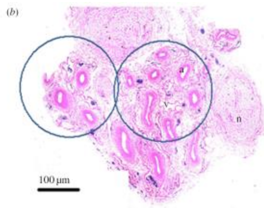
- radial form

BIOLOGY LETTERS

Topsy-turvy: turning the counter-current heat exchange of leatherback turtles upside down

John Davenport[1], T. Todd Jones[2], Thierry M. Work[3] and George H. Balazs[2]





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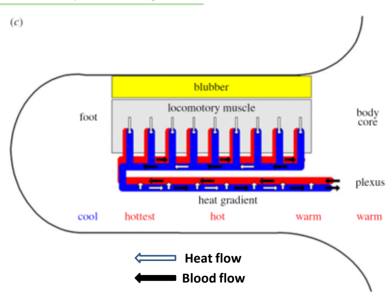
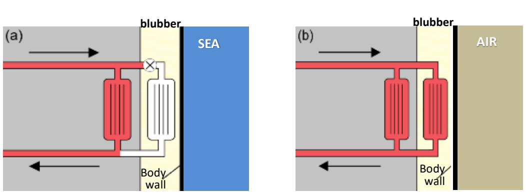


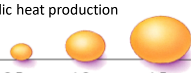


Secondary aquatic marine vertebrates

Thermal adaptations

Thermal insulation, thermal energy storage

- Increased insulation
  - fatty tissue (blubber – marine mammals), fur, oil (leatherback turtle)
- Decreased surface-to-volume ratio
  - low Surface area-to-Volume ratio decreases the relative area across which heat is lost
  - large marine vertebrates: small surface area to volume ratio -> reduced heat loss
- Marine endotherms: increased metabolic heat production
- Heat exchange system



diameter (cm):	0.5	1.0	1.5
surface area (cm^2):	0.79	3.14	7.07
volume (cm^3):	0.06	0.52	1.77
surface-to-volume ratio:	13.17:1	6.04:1	3.99:1

Readings

Kardong 2012:

- *Chapter 4*: Biological design