Convergent Evolution and Adaptations

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. \textit{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
   - Hydrodynamic body shape (streamlined body shape)
   - Reduced drag
   - Locomotor limbs with large surfaces (fins, flippers)
   - Changing in buoyancy (due to compression of air in lungs, swimming bladder, fur...)

2) Behaviour solutions
   - Intermittent locomotion
   - Selective use of sea currents
   - Travelling in a formation
Large Marine Vertebrates:
Streamlined Body Shape

Swimming:
thrust > drag
Large Marine Vertebrates

Body Shapes

- Fusiform
- Aft-rounded
- Compressed (flattened-side to side)
- Depressed (flattened-closely vertically)

Thermal biology

thermocomformer — thermoregulator
**Q₁₀ 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. **According 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. **According 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 different medias)
  - Body into the air or water
Large Marine Vertebrates

Regional endothermy

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

Red muscles / White muscles

- **Glycolytic, white muscles**: 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

Bluefin tuna

- **Rete mirabile**
- White swimming muscle
- Red swimming muscle
- Longitudinal vessels
- Longitudinal arteries

Temperature distribution in different regions of the body with varying temperatures.
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 heat exchange in sea turtles

- Leatherback turtle  - matrix form
- Loggerhead and green turtle  - radial form
Heat flow

Blood flow

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

John Dauveneau, T. Todd Jones, Timothy M. Wolff and George H. Balazs
Large Marine Vertebrates

Thermal Adaptations

Thermal energy storage, thermal insulation
- 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 \( \rightarrow \) reduced heat loss
- Increased insulation
  - Fatty tissue (blubber - marine mammals), fur, oil (leatherback turtle), feathers (marine birds)
- Heat exchange system: Regional endothermy
- Marine endotherms: increased metabolic heat production

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Homework

Kardong 2012:
- Chapter 4: Biological design