## Gill area

- Gill area an indicator of fish ability to withdraw oxygen from water
- Gills are expensive (osmoregulation, parasites etc.)
- Greater gill area in marine than freshwater (less oxygen available in saltwater)
- Greater for more metabolically active fish (e.g. tuna)
- Generally comparable to mammal lung surface area

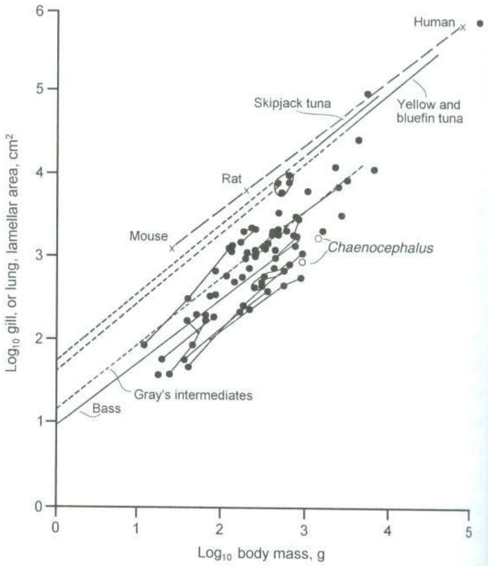
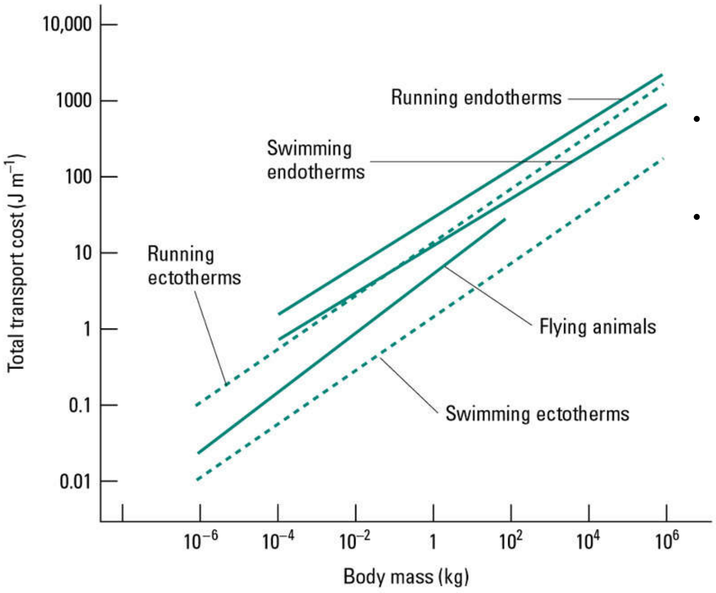


**Figure 8.5** Log$_{10}$ gill lamellar area in skipjack tuna (*Katsuomus pelamis*), yellowfin tuna (*Thunnus albacares*), bluefin tuna (*Th. thynnus*), and other fishes and log$_{10}$ lung area in mammals as a function of log$_{10}$ body mass. Sources: Modified from Muir (1969) and Hughes (1972a).

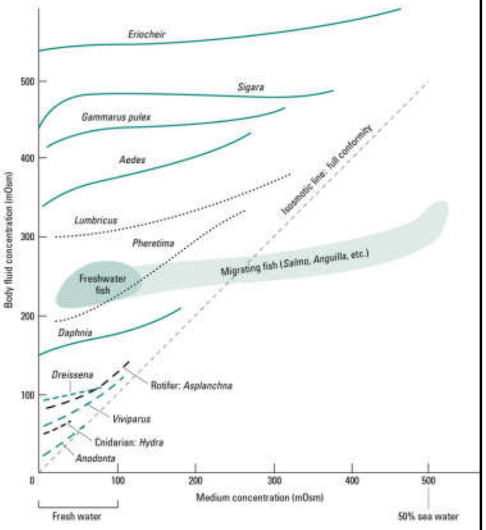
## Transport Cost: Swimming > flying > walking/running



- Swimming is fairly efficient.
- Lateral undulation is most efficient, slow acceleration and slow maximum speed.

# Osmoregulation

- Oceans: 1000-1150 m*Osm*
  - Inverts 1040-1200
  - Teleost – 300-350
  - Elasmobranch 1000-1200
- Freshwater: 0-100 mOsm
  - Teleost – 200-300
  - Elasmobranch – loss of compensatory osmolytes

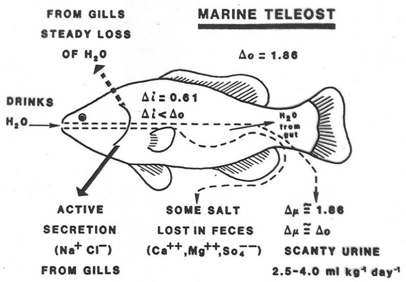


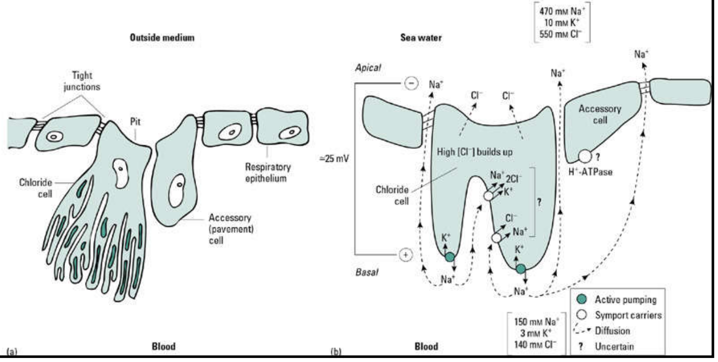
# Origin of marine teleosts

- Fossil record shows the first teleosts in freshwater ~150 mya
- First marine teleost fossil ~55 mya, followed by a rapid radiation

# Osmoregulation

- Skin with scales/mucus is generally a good barrier. Most water and ion flux is over gills.
- **Chloride cells** – active secretion of solutes over gills.





# Water flux rates

- Flux rates generally higher in freshwater fish
- Marine fish thought to have much lower permeabilities (skin and gills)

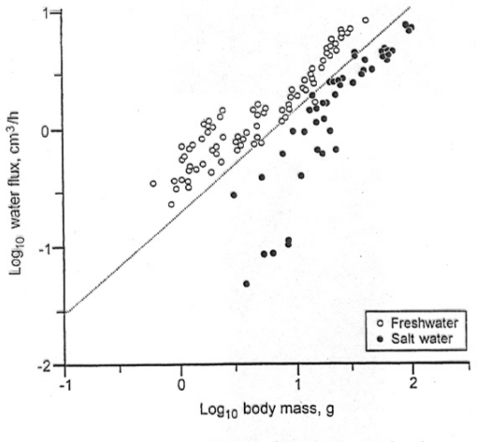


**Figure 6.7** $Log_{10}$ water flux in freshwater and saltwater fishes as a function of $log_{10}$ body mass. Source: Modified from Evans (1969).

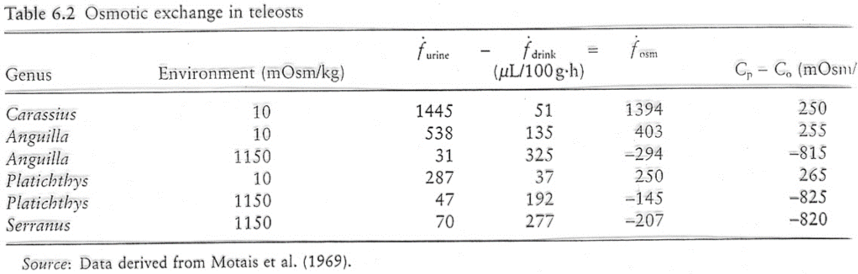


Table 6.2 Osmotic exchange in teleosts

| Genus | Environment (mOsm/kg) | $\dot{f}_{urine}$ − | $\dot{f}_{drink}$ = (μL/100 g·h) | $\dot{f}_{osm}$ | $C_p - C_o$ (mOsm/k |
|---|---|---|---|---|---|
| *Carassius* | 10 | 1445 | 51 | 1394 | 250 |
| *Anguilla* | 10 | 538 | 135 | 403 | 255 |
| *Anguilla* | 1150 | 31 | 325 | −294 | −815 |
| *Platichthys* | 10 | 287 | 37 | 250 | 265 |
| *Platichthys* | 1150 | 47 | 192 | −145 | −825 |
| *Serranus* | 1150 | 70 | 277 | −207 | −820 |

*Source*: Data derived from Motais et al. (1969).

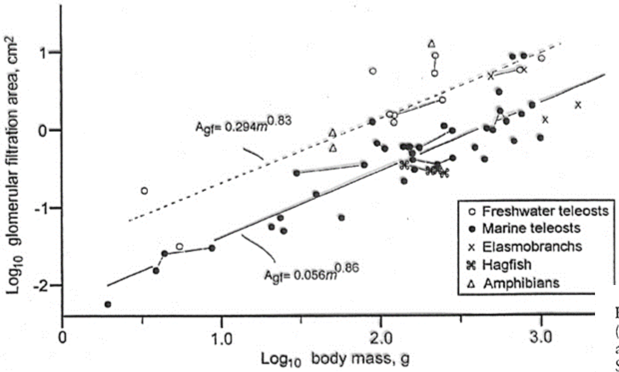


Figure 6.8 $\text{Log}_{10}$ glomerular filtration area ($A_{gf}$) in hagfish, elasmobranchs, teleosts, and amphibians as a function of $\log_{10}$ body mass. Source: Data derived from Nash (1931).

## Osmoregulatory Costs

Mullet metabolic rates increase dramatically (double) at higher salinity.

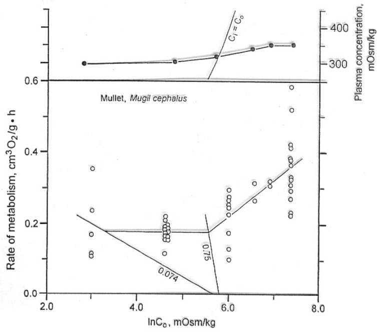


Figure 6.9 Plasma concentration and rate of metabolism in juvenile mullet (*Mugil cephalus*) as a function of ln external concentration. Source: Data derived from Nordlie and Leffler (1975).

Pupfish metabolic rates increase dramatically (double) at lower salinity.

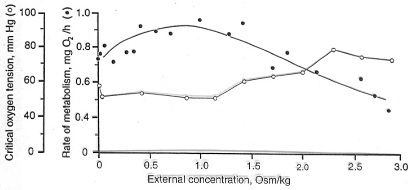
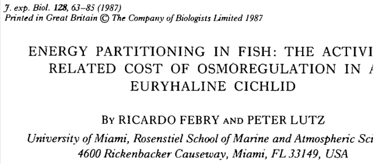


Figure 6.10 Rate of metabolism and critical oxygen tension in the teleost *Cyprinodon variegatus* as a function of the external concentration. Sources: From Nordlie et al. (1991) and Haney and Nordlie (1997).

# Osmoregulatory Costs



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ENERGY PARTITIONING IN FISH: THE ACTIVI
RELATED COST OF OSMOREGULATION IN
EURYHALINE CICHLID

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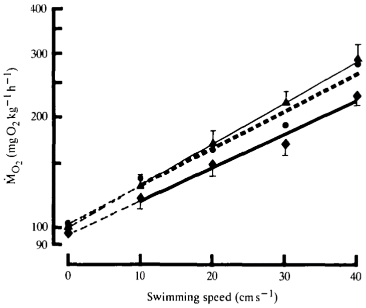

Fig. 3. Means and lines of best fit for oxygen consumption rates *versus* swimming speed at each salinity. Bars indicate ±S.E., $N = 16$ in fresh water, $N = 10$ in isosmotic sea water and $N = 10$ in sea water. ▲, fresh water; ●, sea water; ◆, isosmotic sea water.

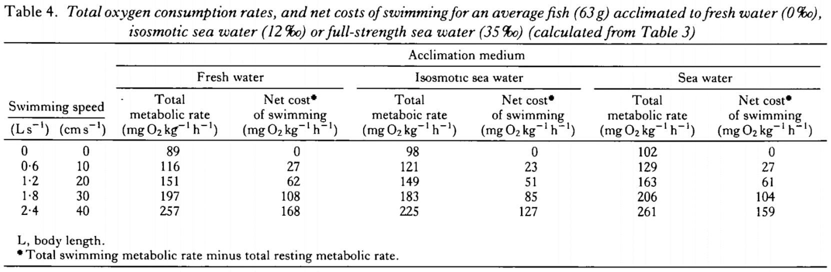

Table 4. *Total oxygen consumption rates, and net costs of swimming for an average fish (63 g) acclimated to fresh water (0 ‰), isosmotic sea water (12 ‰) or full-strength sea water (35 ‰) (calculated from Table 3)*

| Swimming speed | | Acclimation medium | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fresh water | | Isosmotic sea water | | Sea water | |
| (L s$^{-1}$) | (cm s$^{-1}$) | Total metabolic rate (mg $O_2$ kg$^{-1}$ h$^{-1}$) | Net cost* of swimming (mg $O_2$ kg$^{-1}$ h$^{-1}$) | Total metaboic rate (mg $O_2$ kg$^{-1}$ h$^{-1}$) | Net cost* of swimming (mg $O_2$ kg$^{-1}$ h$^{-1}$) | Total metabolic rate (mg $O_2$ kg$^{-1}$ h$^{-1}$) | Net cost* of swimming (mg $O_2$ kg$^{-1}$ h$^{-1}$) |
| 0 | 0 | 89 | 0 | 98 | 0 | 102 | 0 |
| 0·6 | 10 | 116 | 27 | 121 | 23 | 129 | 27 |
| 1·2 | 20 | 151 | 62 | 149 | 51 | 163 | 61 |
| 1·8 | 30 | 197 | 108 | 183 | 85 | 206 | 104 |
| 2·4 | 40 | 257 | 168 | 225 | 127 | 261 | 159 |

L, body length.
* Total swimming metabolic rate minus total resting metabolic rate.