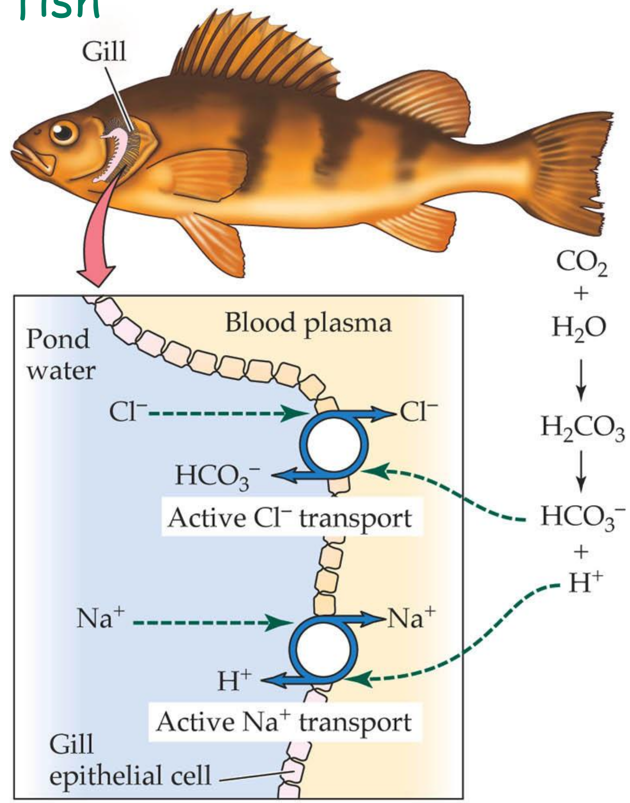
Water and Salt Physiology

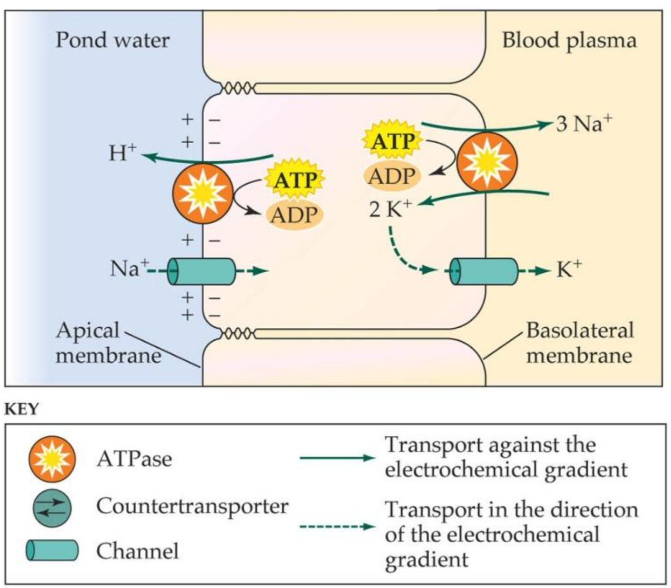
ADAPTATIONS: Active ion transport uptake across gill epithelium of a freshwater fish

Ions are **loss** in the **urine** and by **diffusion** in the gills

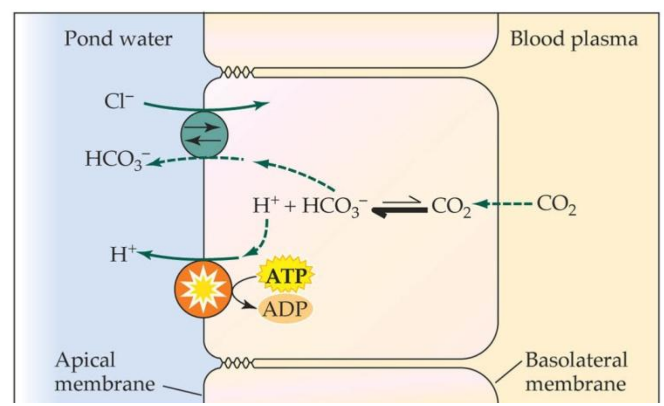
Na and CL are **gain** by two **independent** active transport in the gills



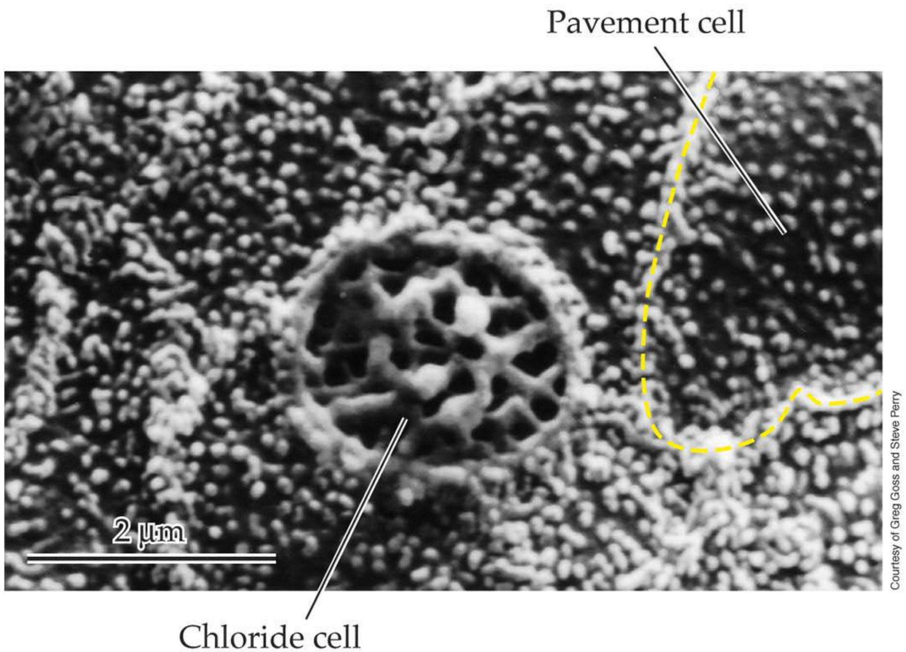
Electroneutral



Electroneutral



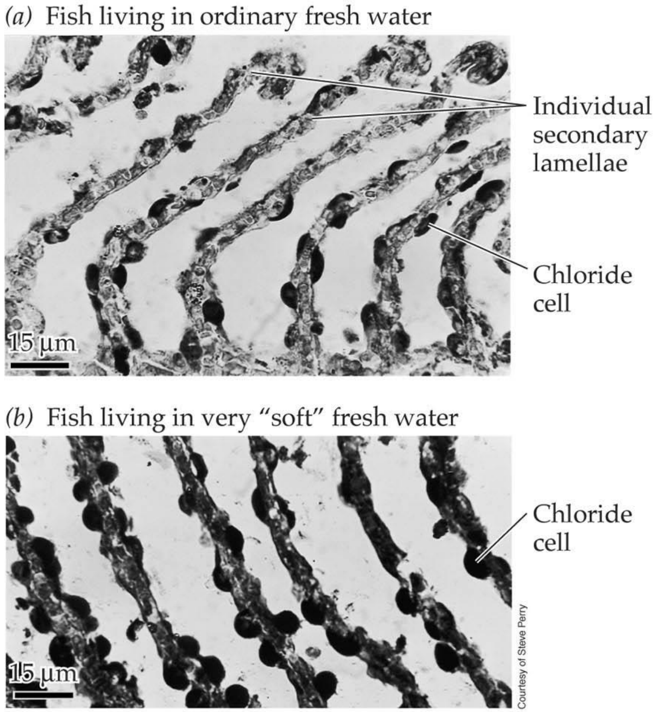
Chloride cell and pavement cells in gill epithelium of a freshwater teleost fish



Gill epithelium consists of two types of cells:

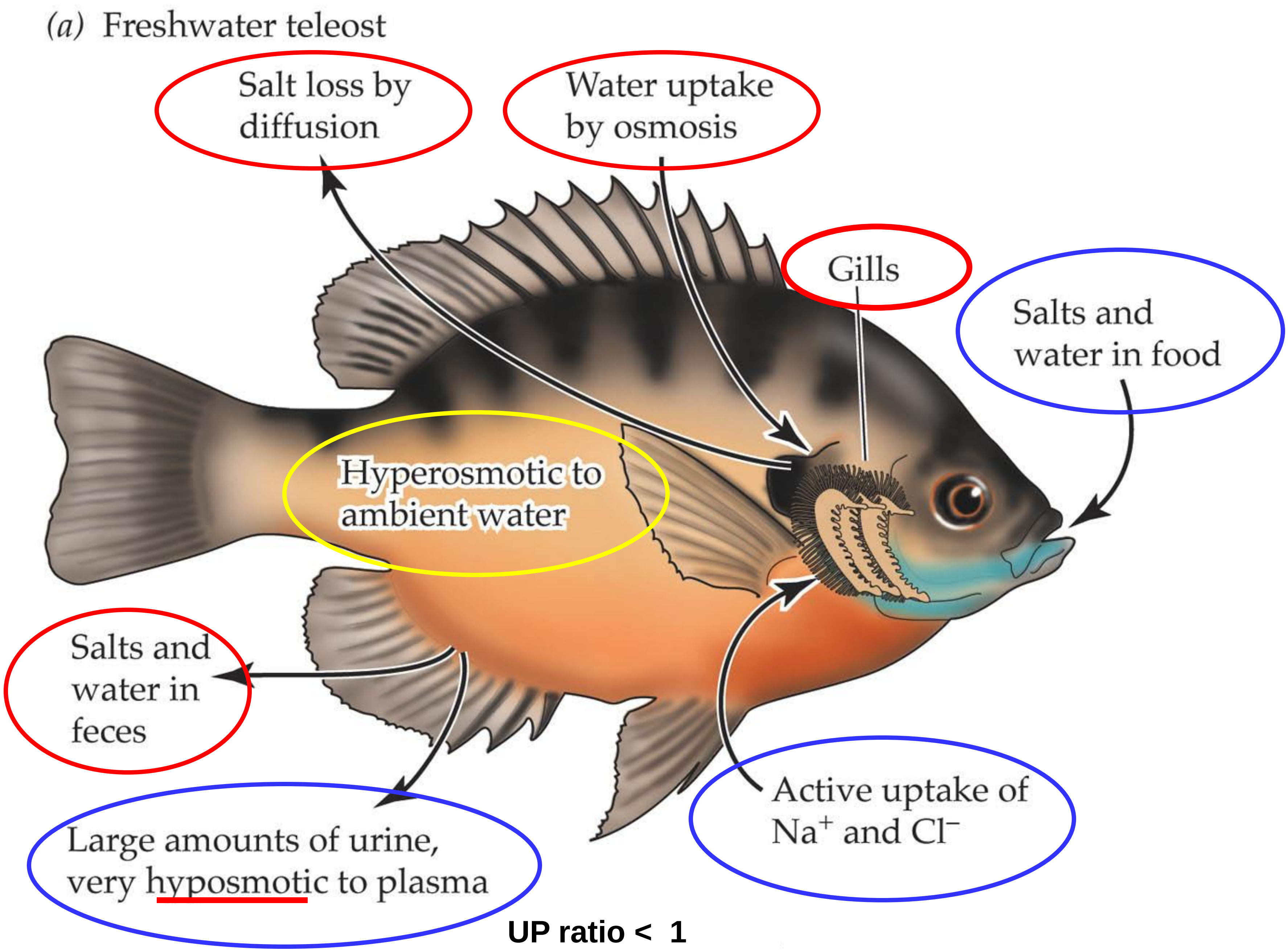
Chloride cells : (ion transport)

Pavement cells : (O_2 uptake)



Low in Calcium →

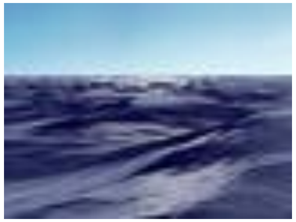
Water-salt relations in freshwater fish



UP ratio < 1

Marine environment

Water-Salt regulation in **Marine** Invertebrates



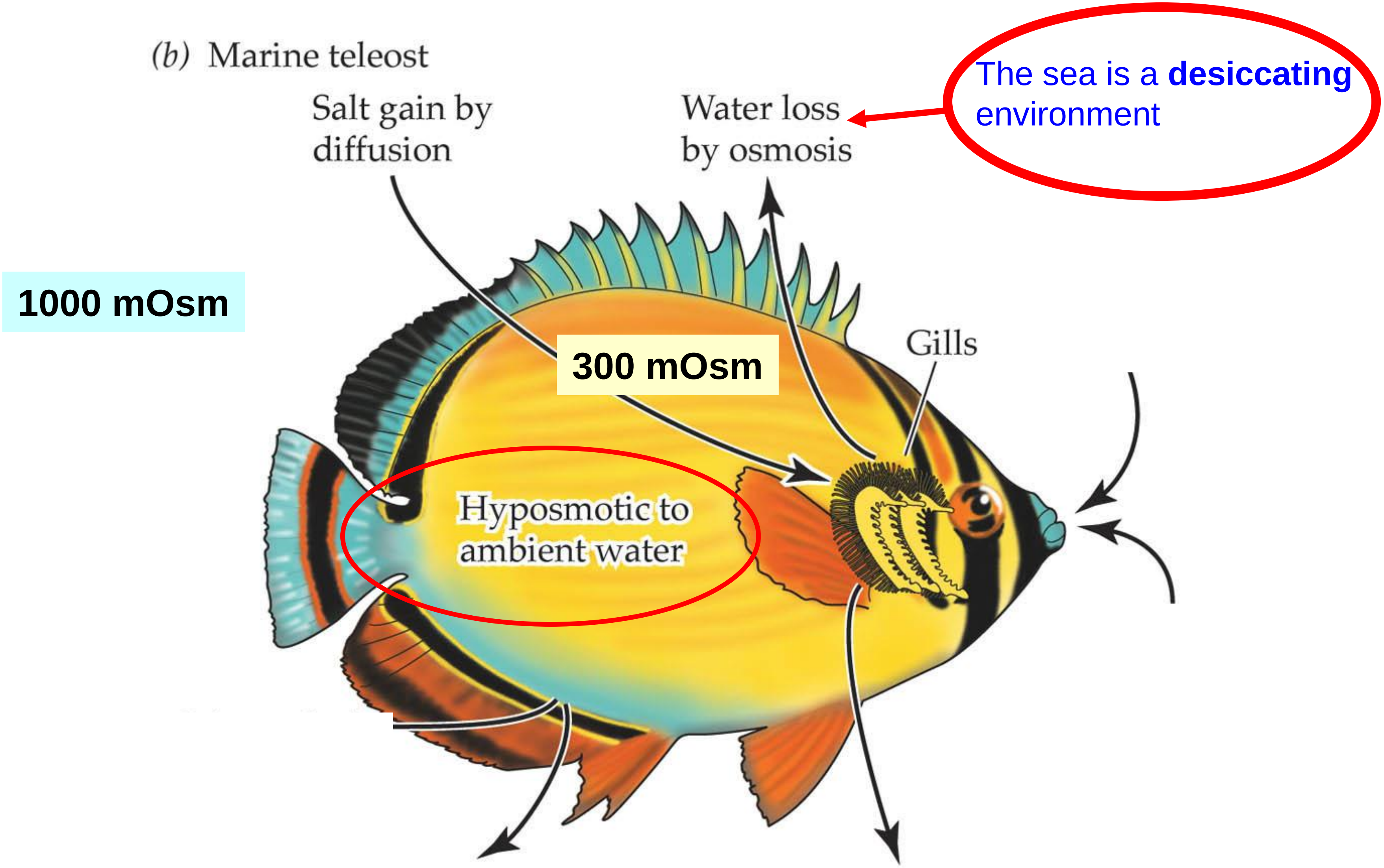
Most marine **invertebrates** are **ISOSMOTIC** to sea water

Solutes in the blood are mostly inorganic ions

Ion composition regulation by kidneys and gills

Water-salt relations in marine teleost fish

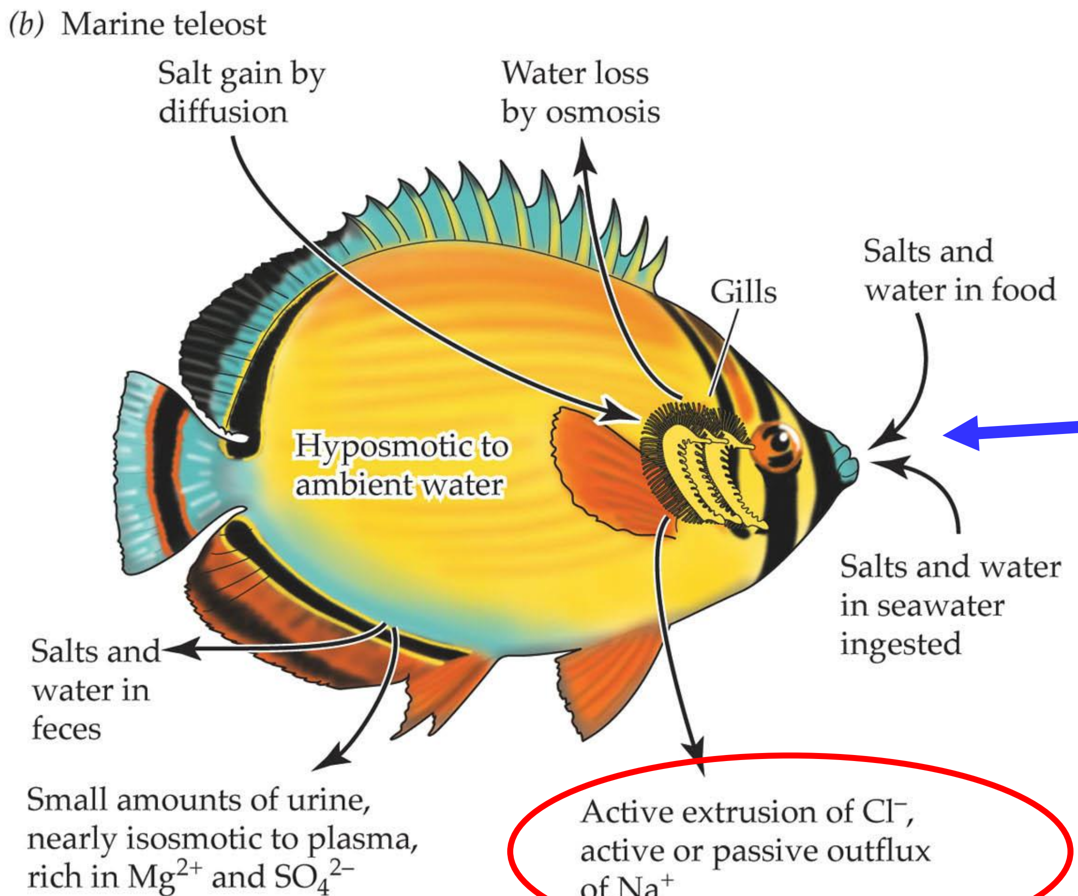
The marine teleost fish are Hyposmotic regulators



Water-Salt **regulation** in a Marine teleost fish

Loss of water by osmosis and urine production.
Water acquired by **drinking** and eating

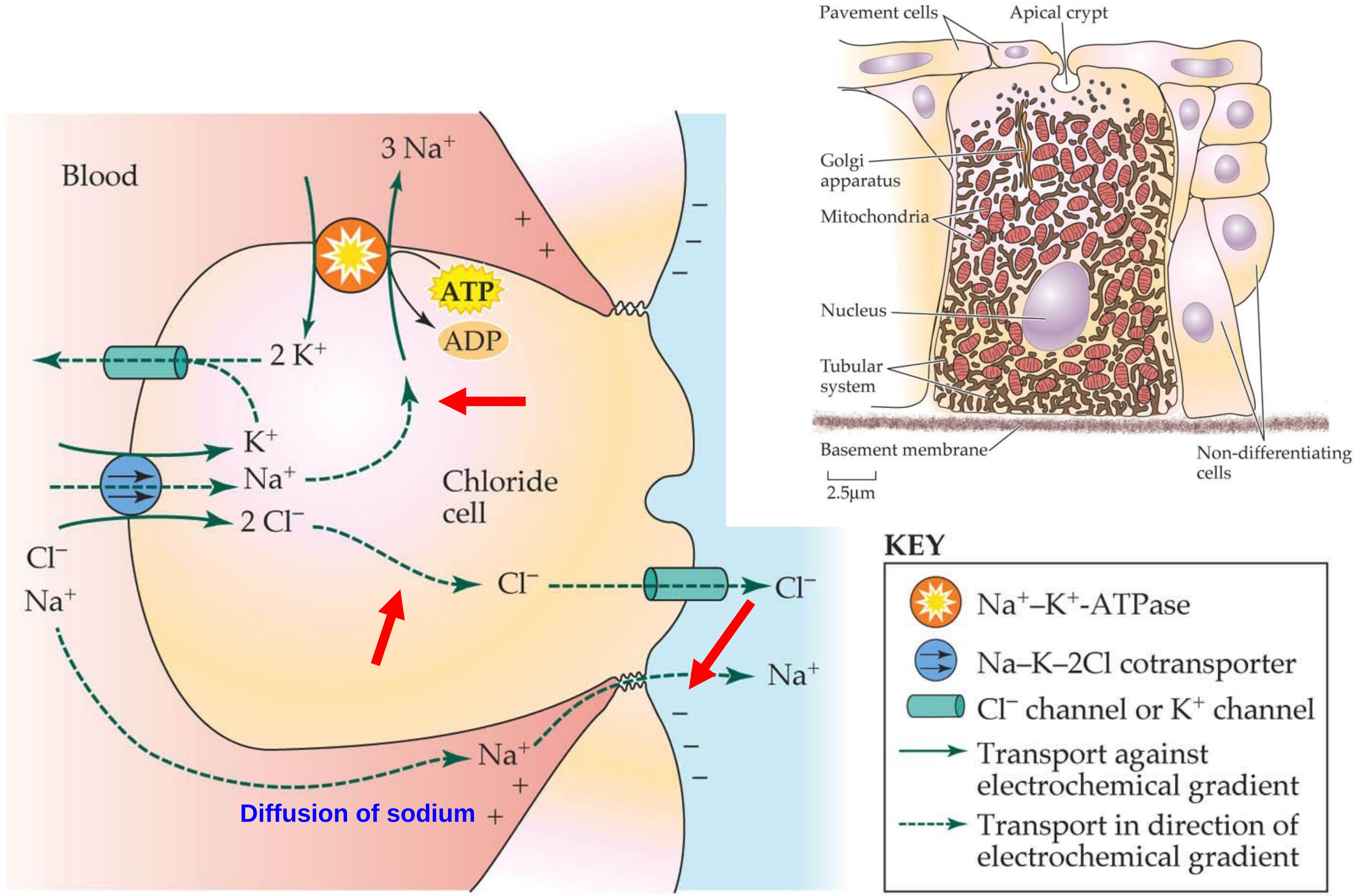
Eliminate divalent ions by urine.
Eliminate monovalent ions actively by the **gills** (extrarenal excretion)(principal osmotic regulator)



Water

UP ratio = 1

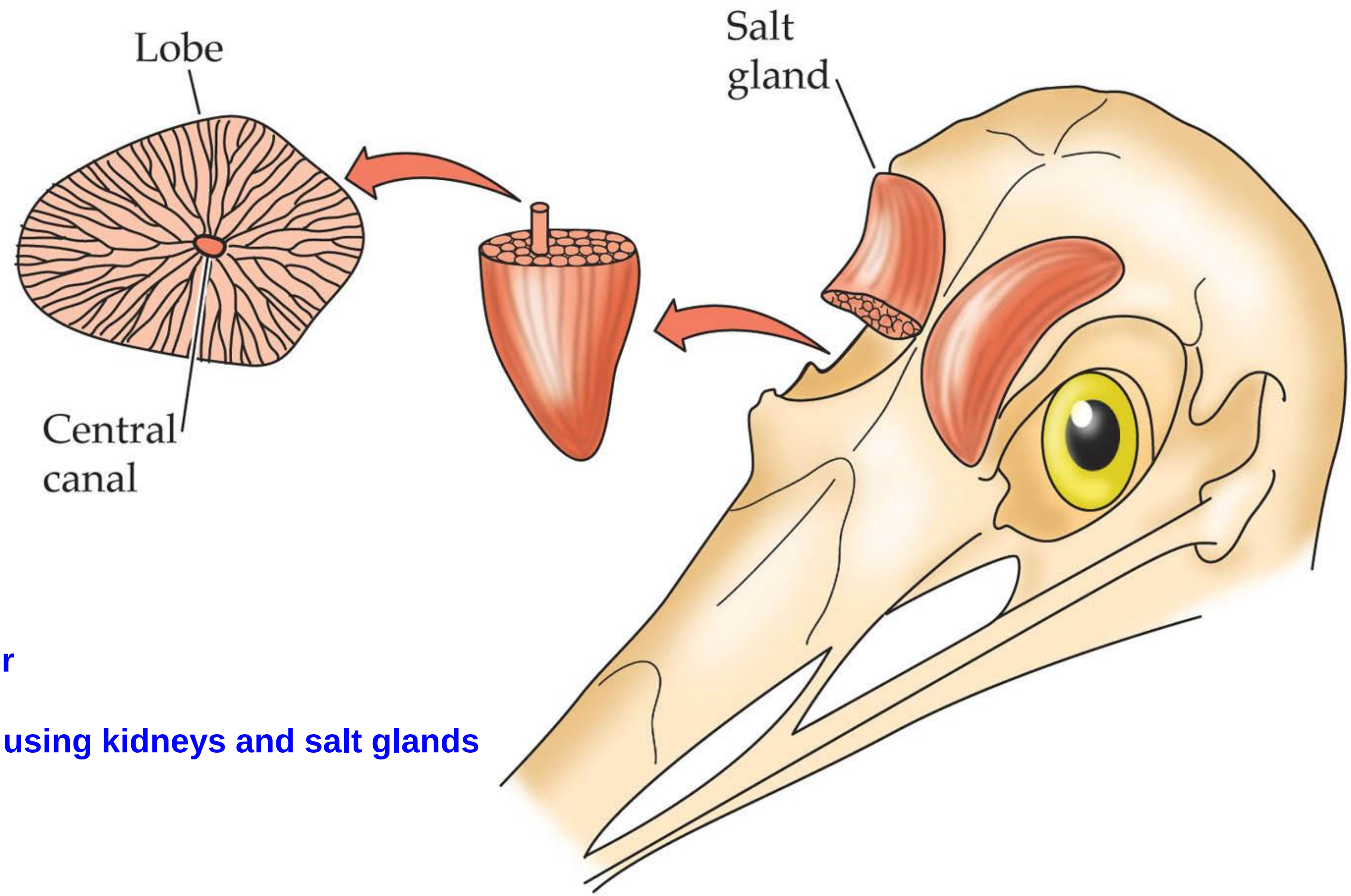
NaCl secretion by a chloride cell of a marine teleost fish



Cl^- transport is **secondary active transport**, Na-K- 2 Cl^- cotransporter.
ELECTROGENIC -----Strong electrochemical gradient for Na.

Birds in ocean environments: salt glands of a herring gull

Hyposmotic regulators

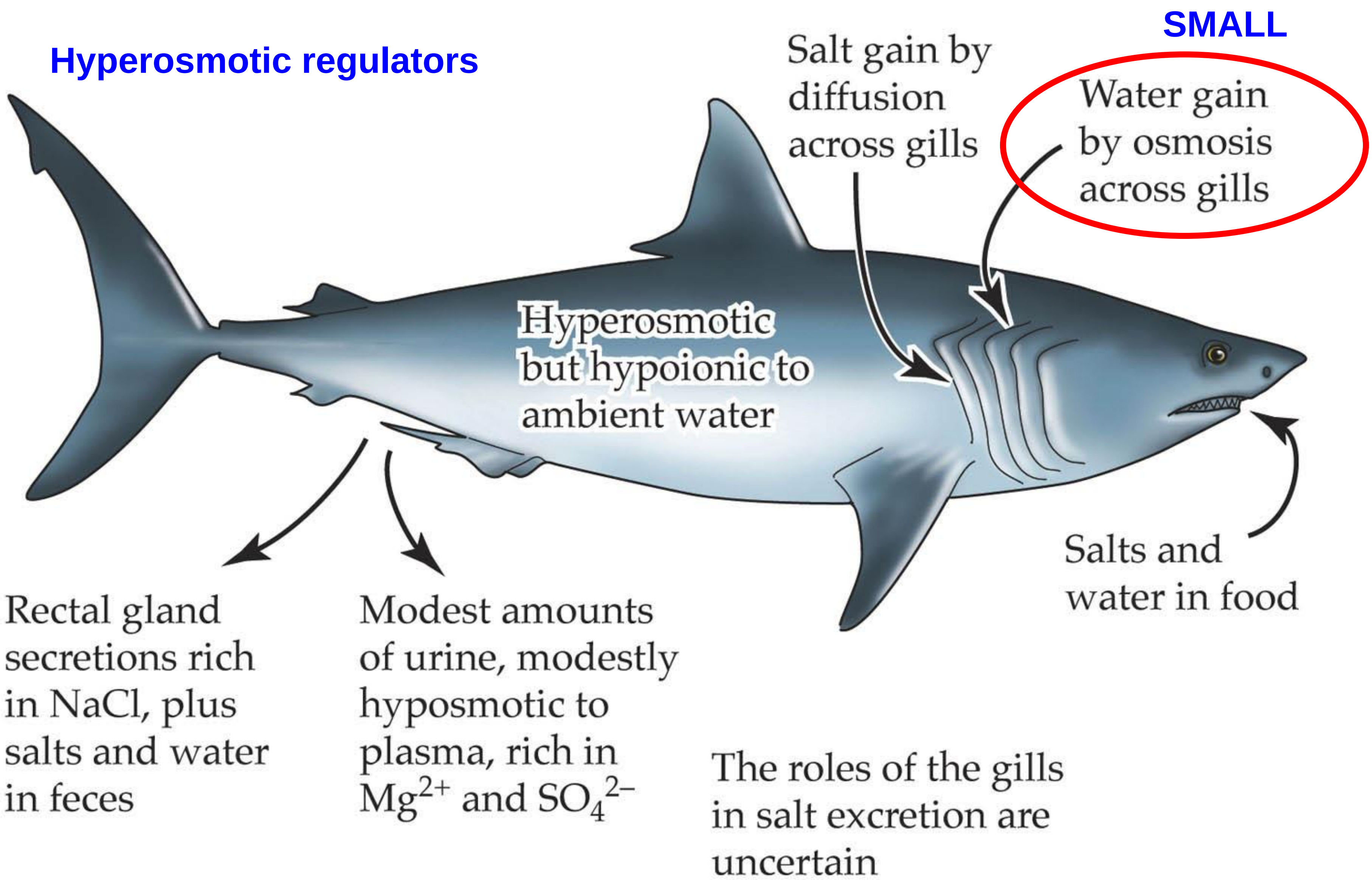


Drink sea water

Eliminate ions using kidneys and salt glands

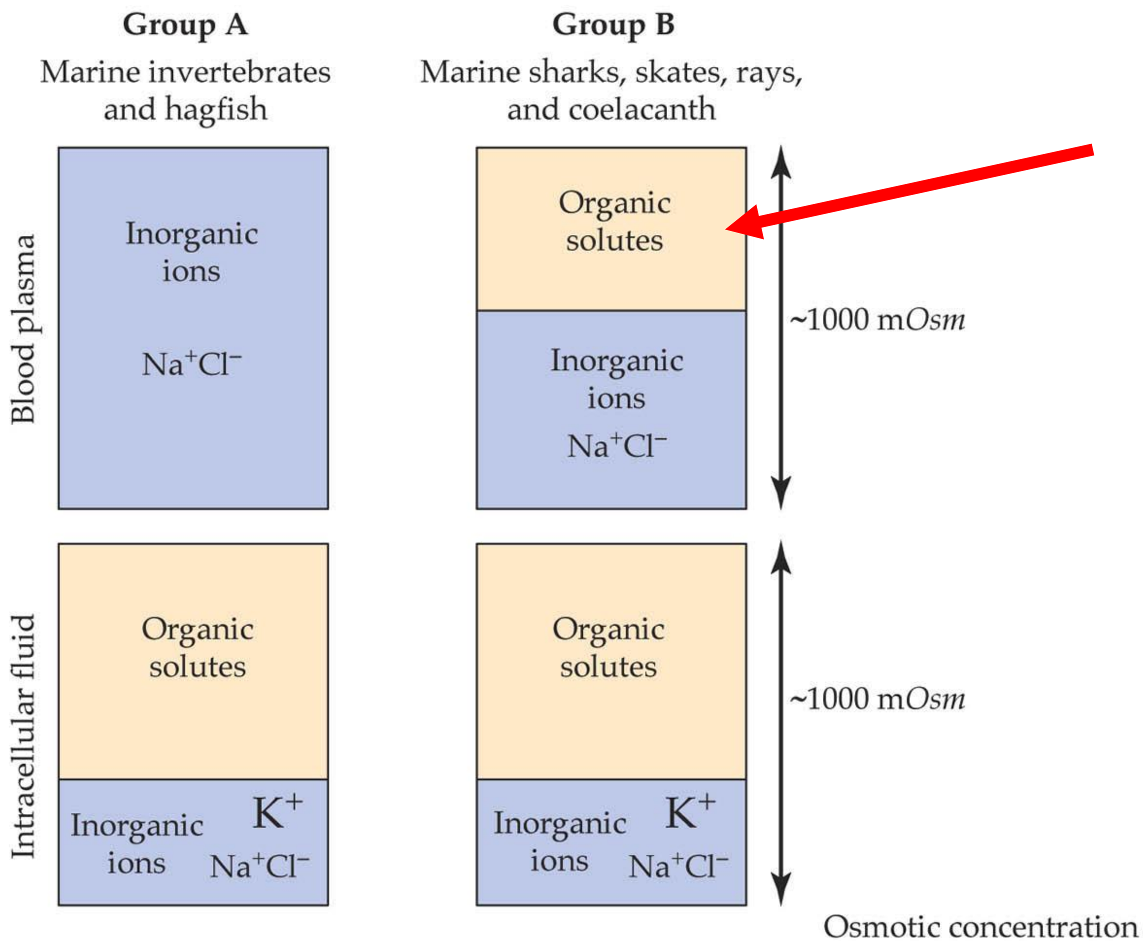
Water-salt relations in a marine shark

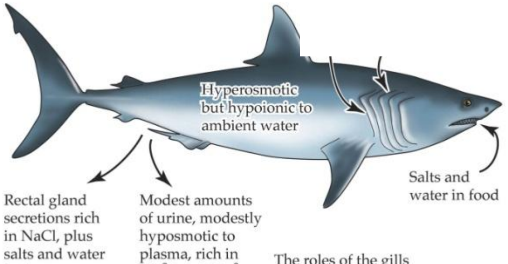
Hyperosmotic regulators



Urea and trimethylamine oxide (TMAO) are counteracting organic solutes

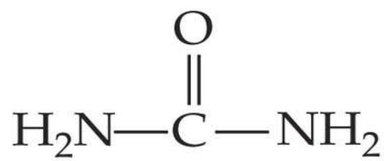
Water–salt relations in a marine shark



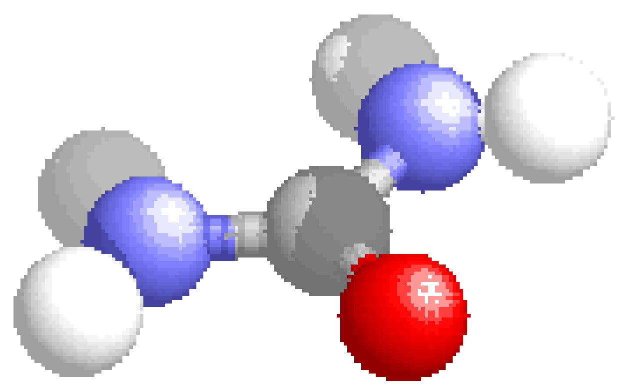


UREA and Trimethylamine oxide (TMAO)

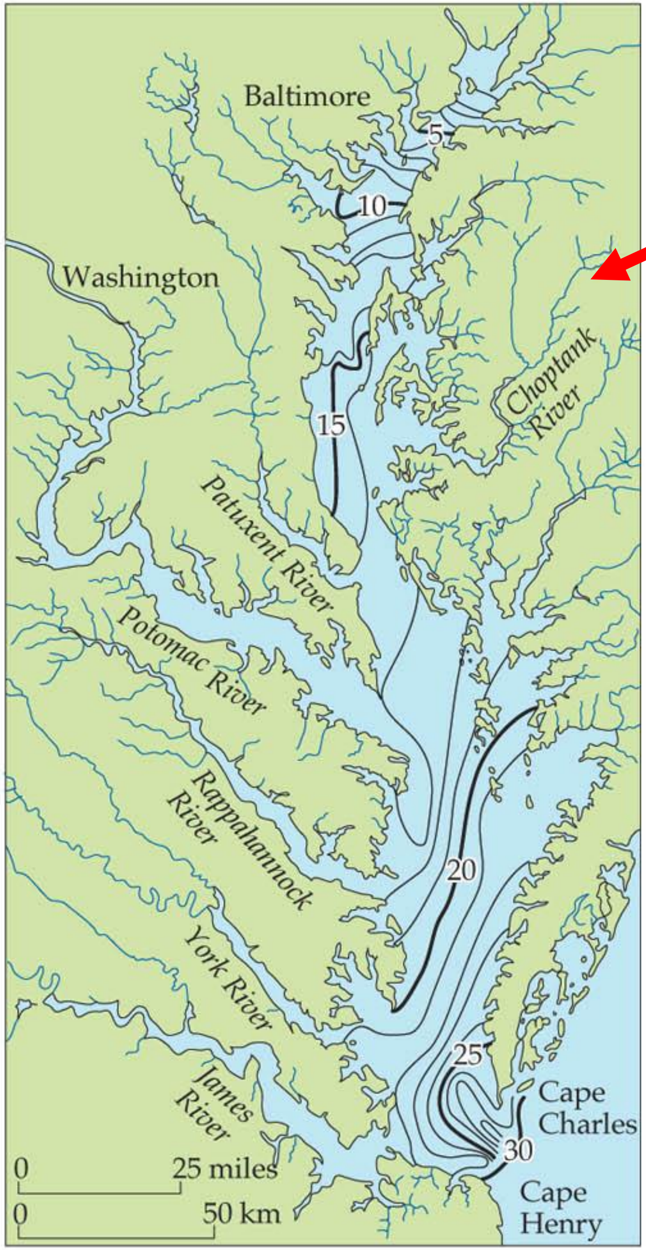
Tri methylamine oxide
CH3
\
CH3–N–O
/
CH3



Urea



Animals from brackish water



Brackish water **Salinity:** from 0.5 -30

Brackish water **Osmotic pressure**: 15- 850

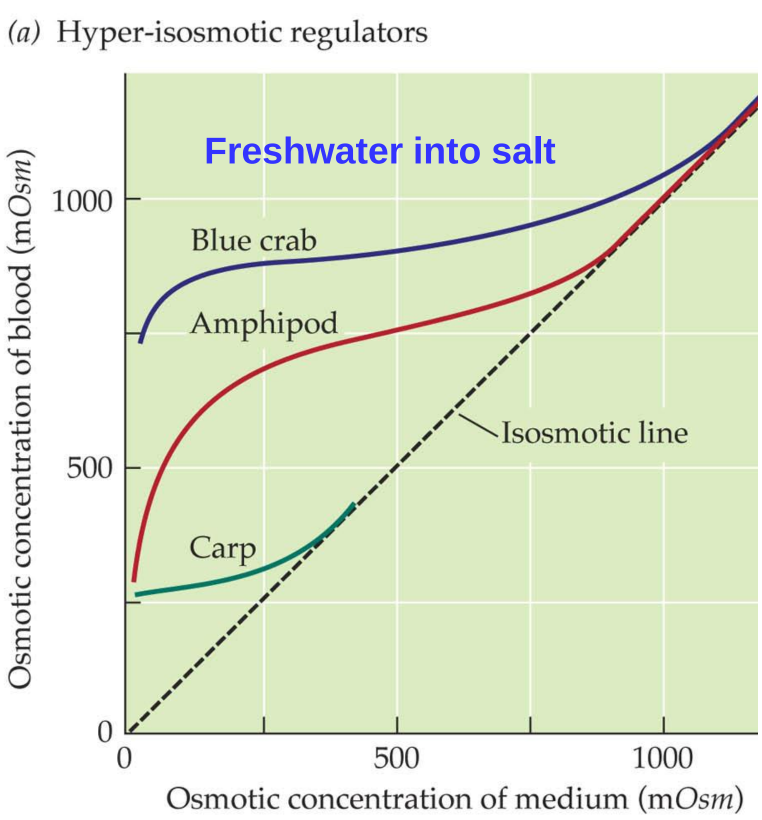
A typical shoreline of the Chesapeake Bay

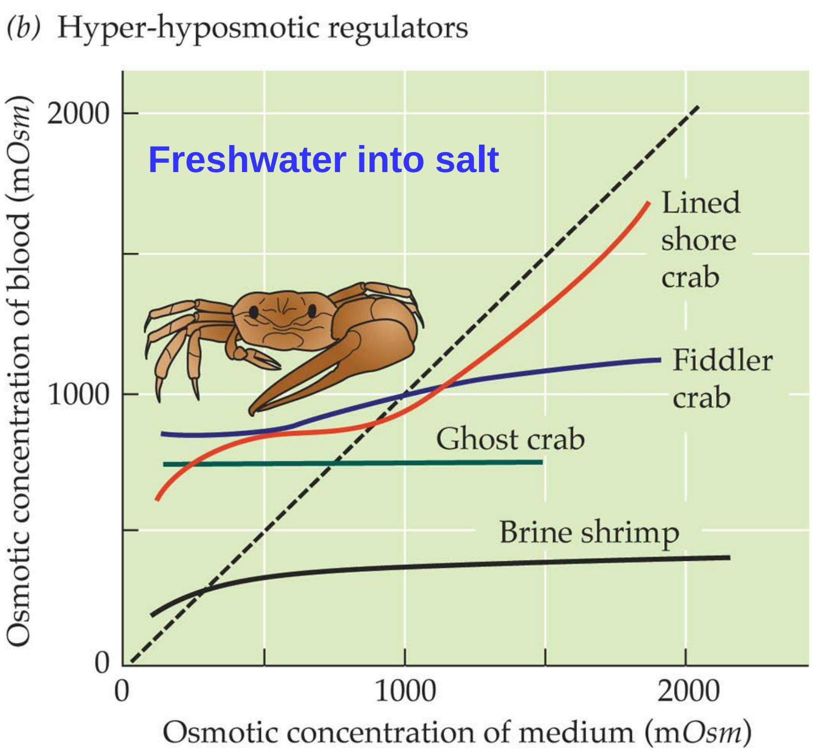
Animals from brackish water

Stenohaline: narrow range of salinity

Euryhaline: broad range of salinity

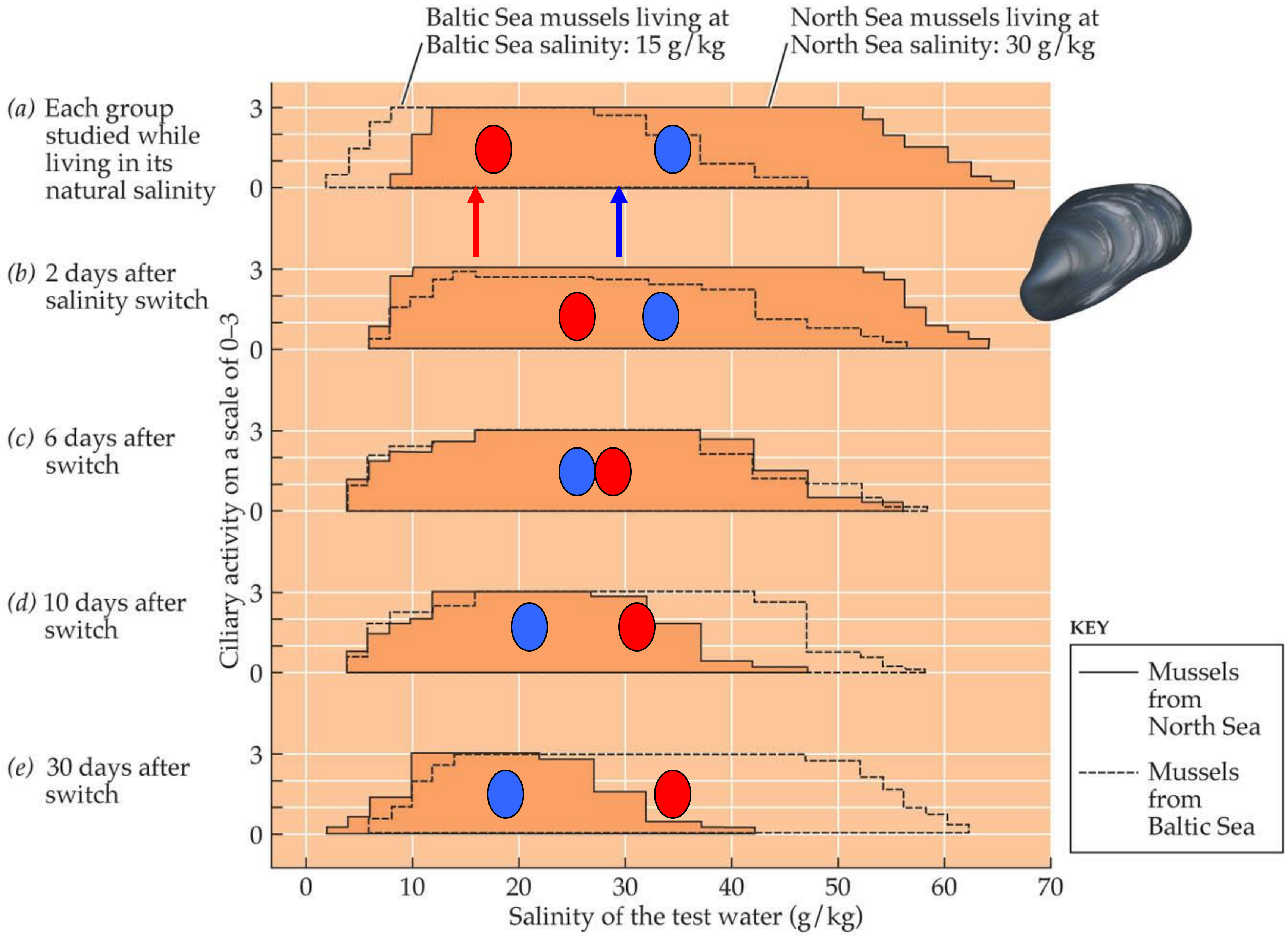
Most invertebrates in the ocean are **stenohaline osmoconformers**





Hyper and Hyposmotic regulators

Acclimation of mussels to changed salinity



Terrestrial environments

Terrestrial environments: air is a fluid that **dehydrates** organisms.


A typical shoreline of the Chesapeake Bay

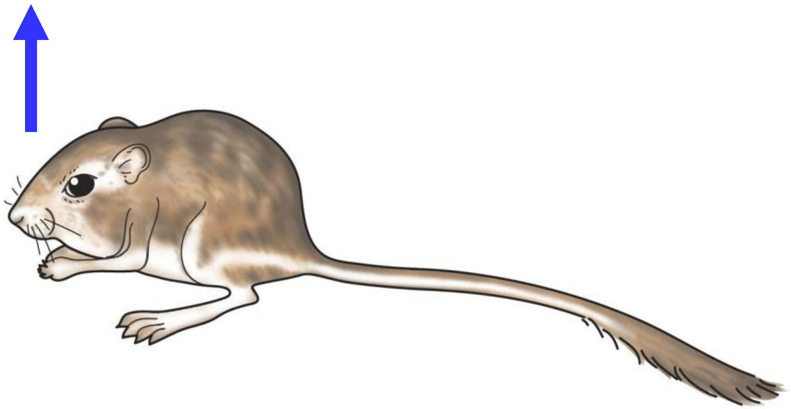
Evaporation: is a gas diffusion mechanism. Water (as vapor) moves from an area of higher partial pressure to one of lower partial pressure.

Humidity: is the water content of air.

Saturation water vapor pressure: maximum water pressure before condensation in the form of liquid.

Evaporation

Terrestrial organisms lose water by evaporation



1. **Air humidity**: lower water vapor pressure of air--- higher evaporation
2. **Temperature of body fluid:** warmer more evaporation.
3. **Rate of air movement:** windy more evaporation.
4. **Permeability of integument to water:** High ---- higher evaporation.

Humidic and Xeric animals

Humidic: restricted to humid microenvironments

Earthworms, slugs, centipedes, amphibians

Xeric: capable of living in dry environments

Mammals, birds, reptiles, insects, arachnids

How rapidly they desiccate!

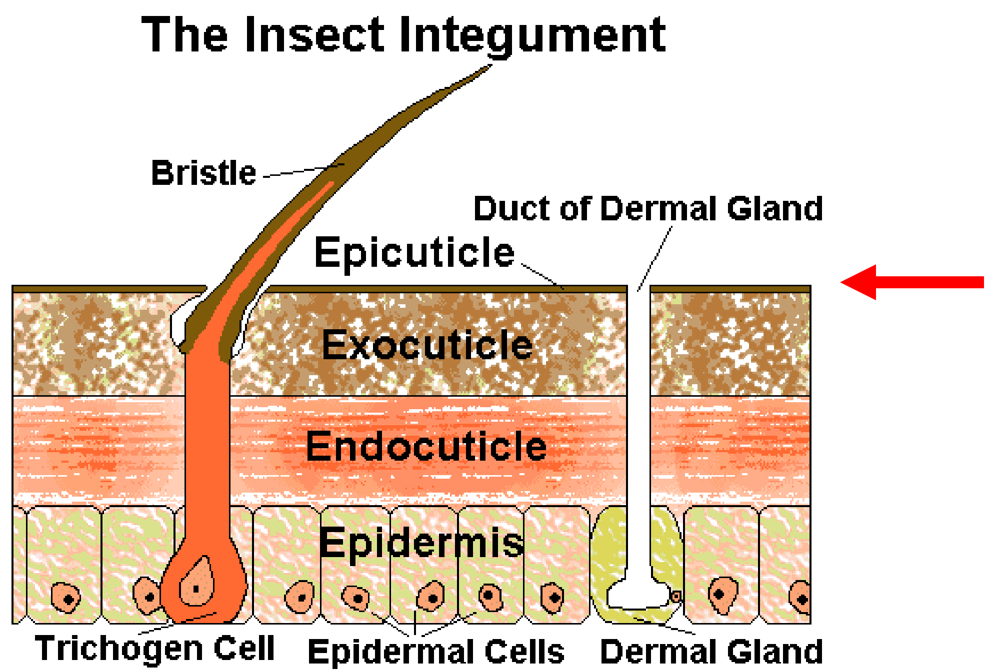
Low integumentary permeability to water reduces evaporative water loss

The evolution of a **low permeability of integument to water** is one of the most important adaptation to a xeric life

Very thin layer of **lipids** are responsible of low **integumentary permeability**

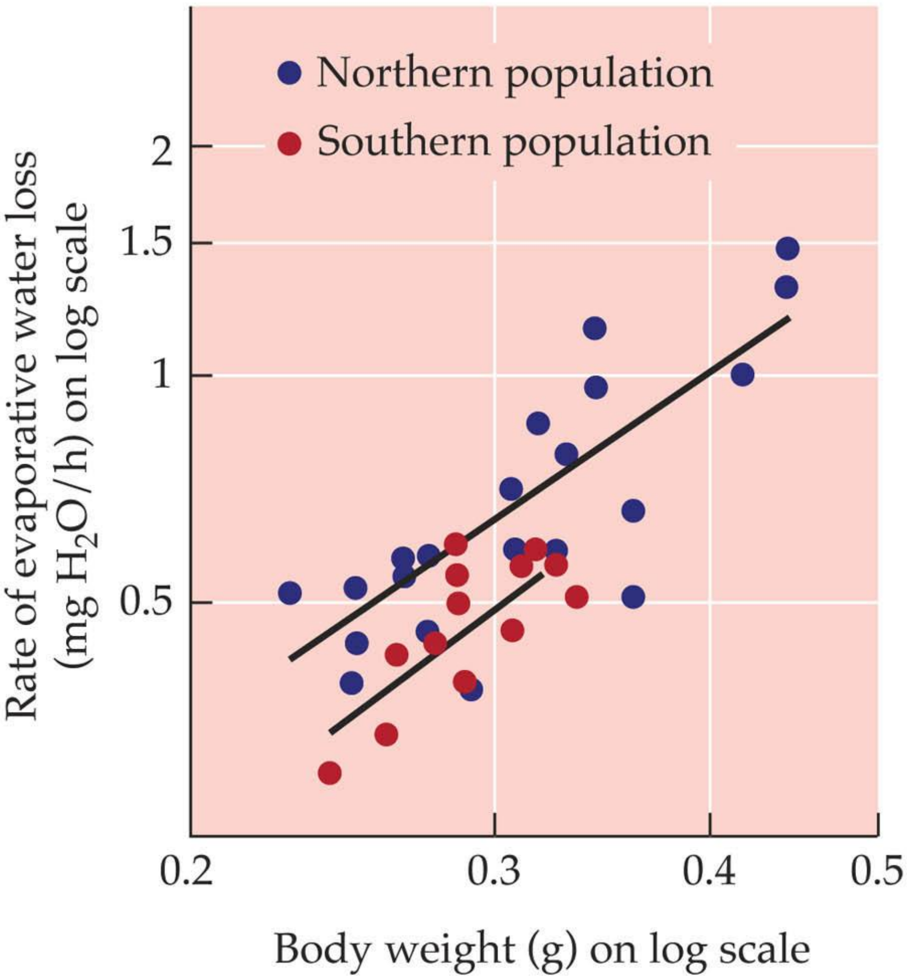
Mammals: glycolipids in the skin

Insects: long-chain carbohydrates and waxes in the epicuticle

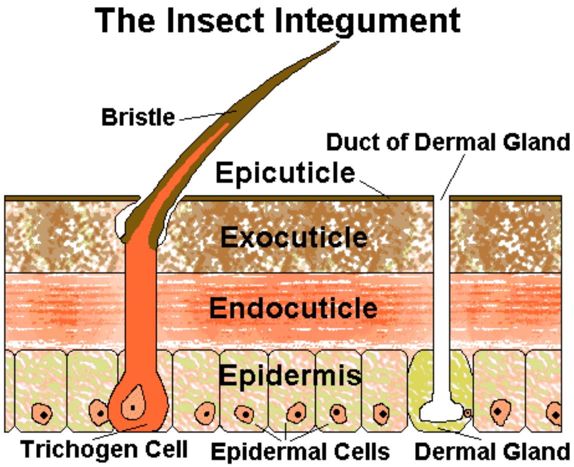


Differentiation in protection against evaporative water loss in grasshoppers populations

Differences in the lipid composition in the epicuticle

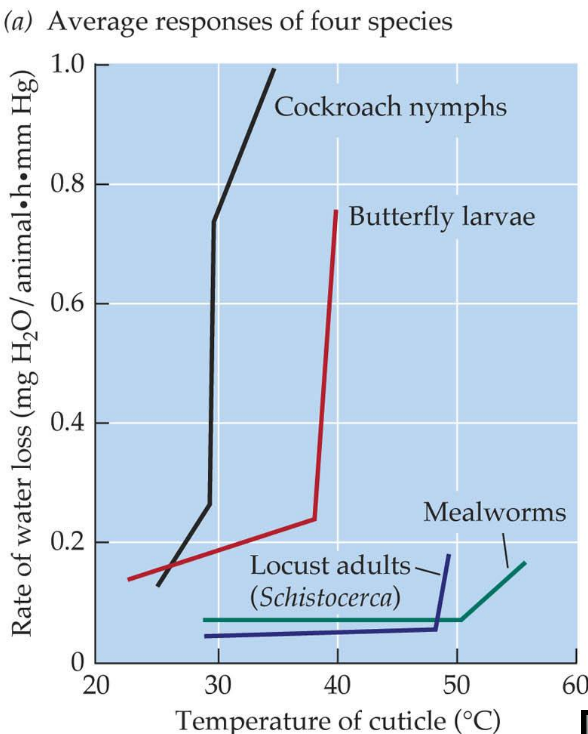


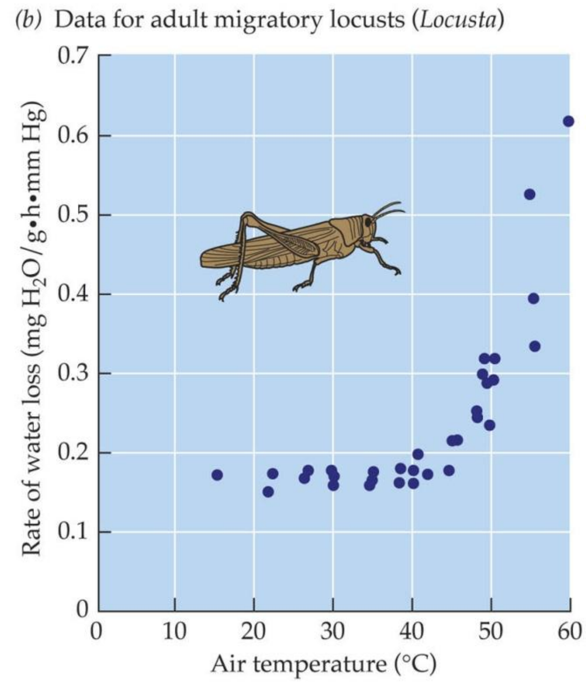
25 C

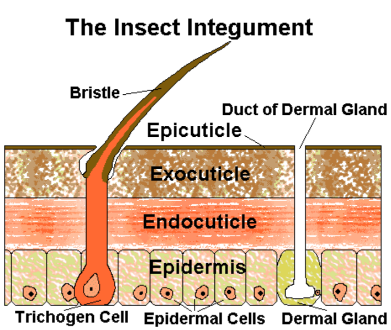


The rate of evaporative water loss of insects increases at a transition temperature

The increase in permeability at a **transition temperature** is a consequence of **lipid melting**

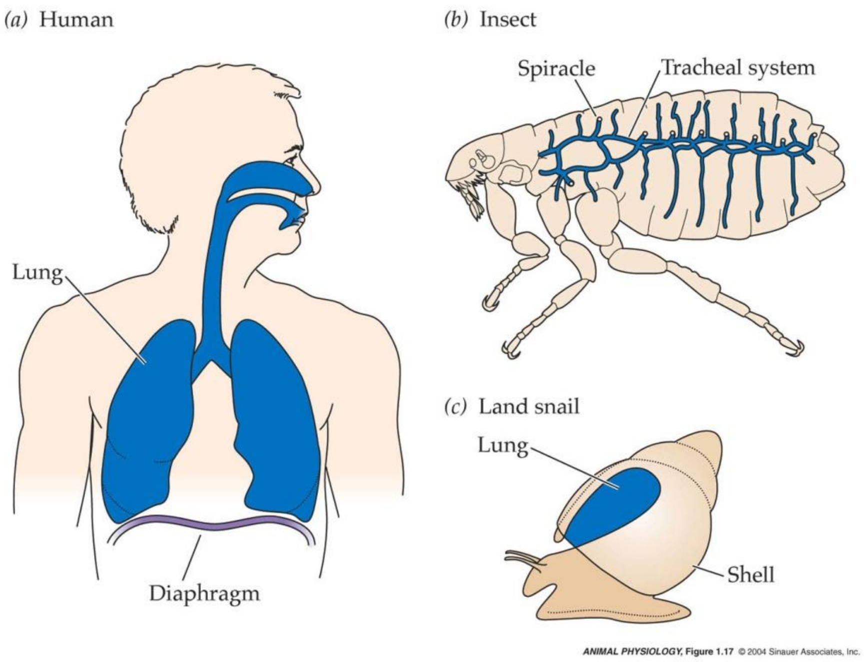






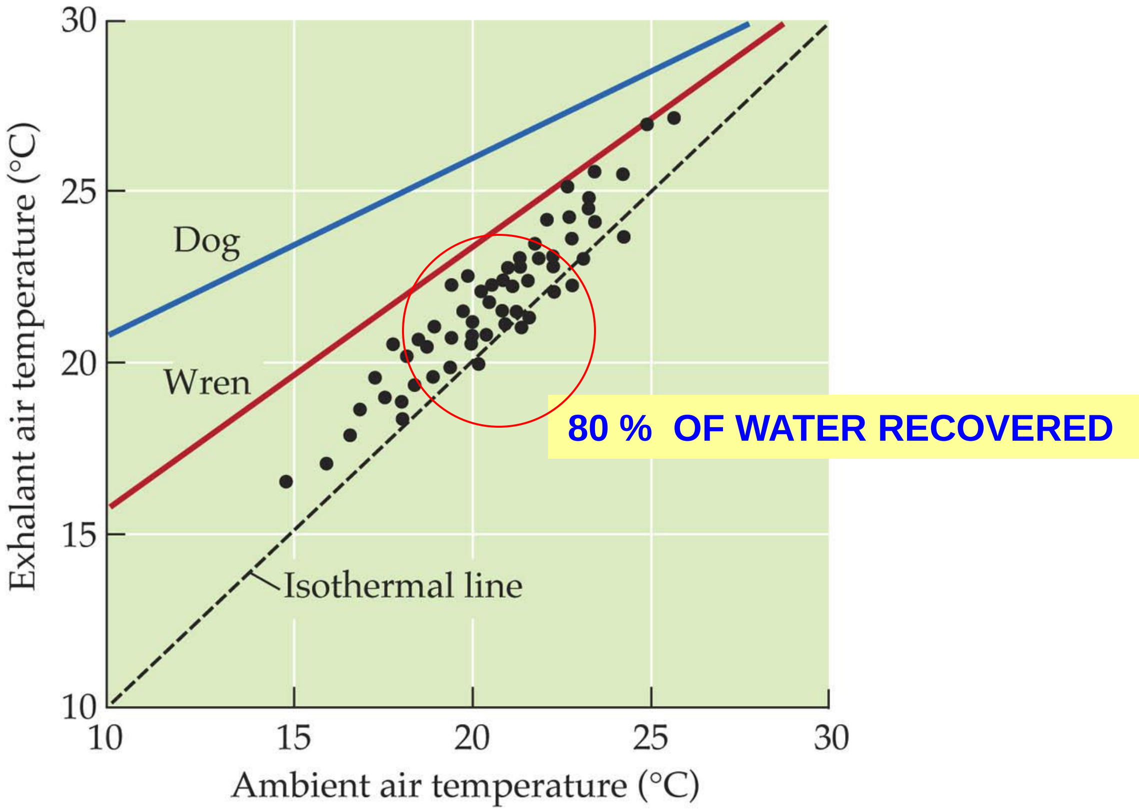
Respiratory evaporative loss depends on the function of the breathing organs

Humidic animals have respiratory surfaces directly exposed to the air

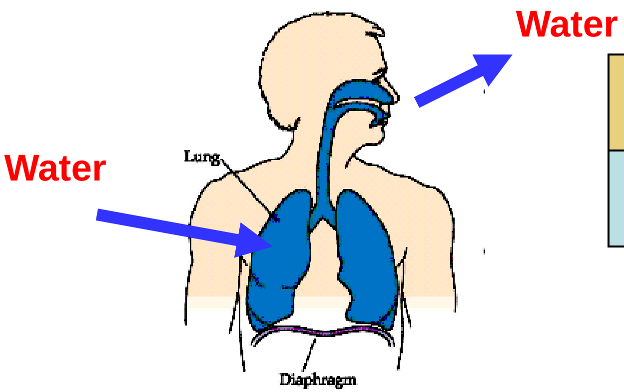


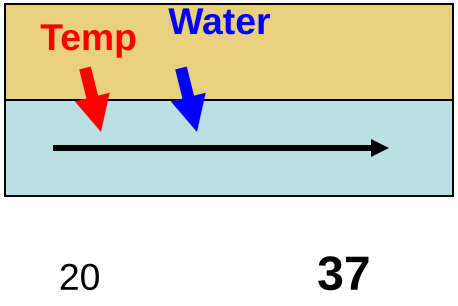
Xeric animals have **invaginated** respiratory structures

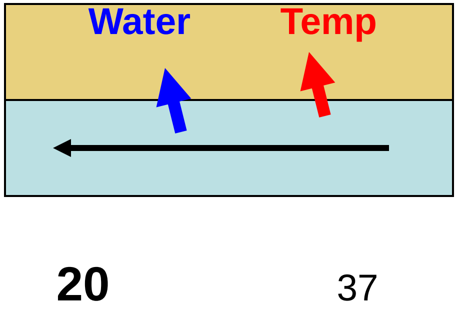
The temperature of air exhaled from the nostrils



The rate of metabolism is important

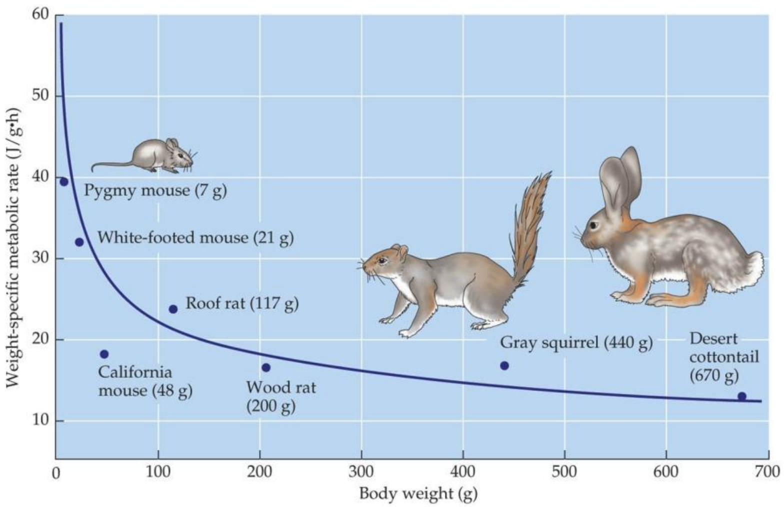




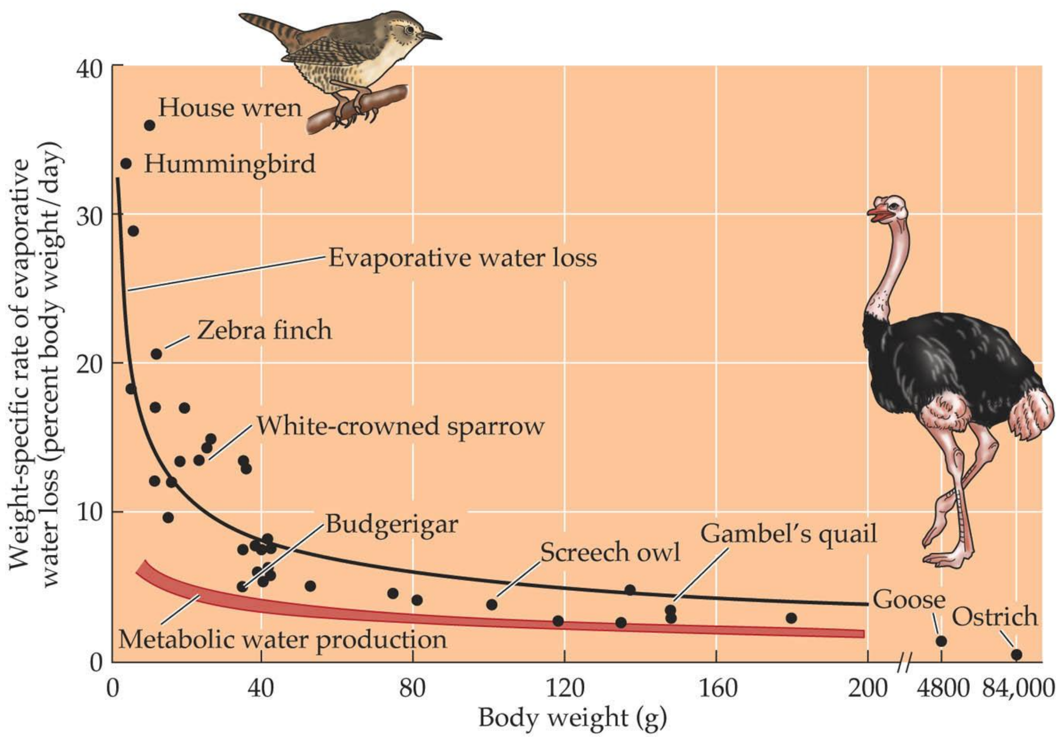


Within a group, total rate of evaporative water loss is an allometric function of size

Smaller animals -------higher metabolism



Higher metabolism--------higher respiratory water loss

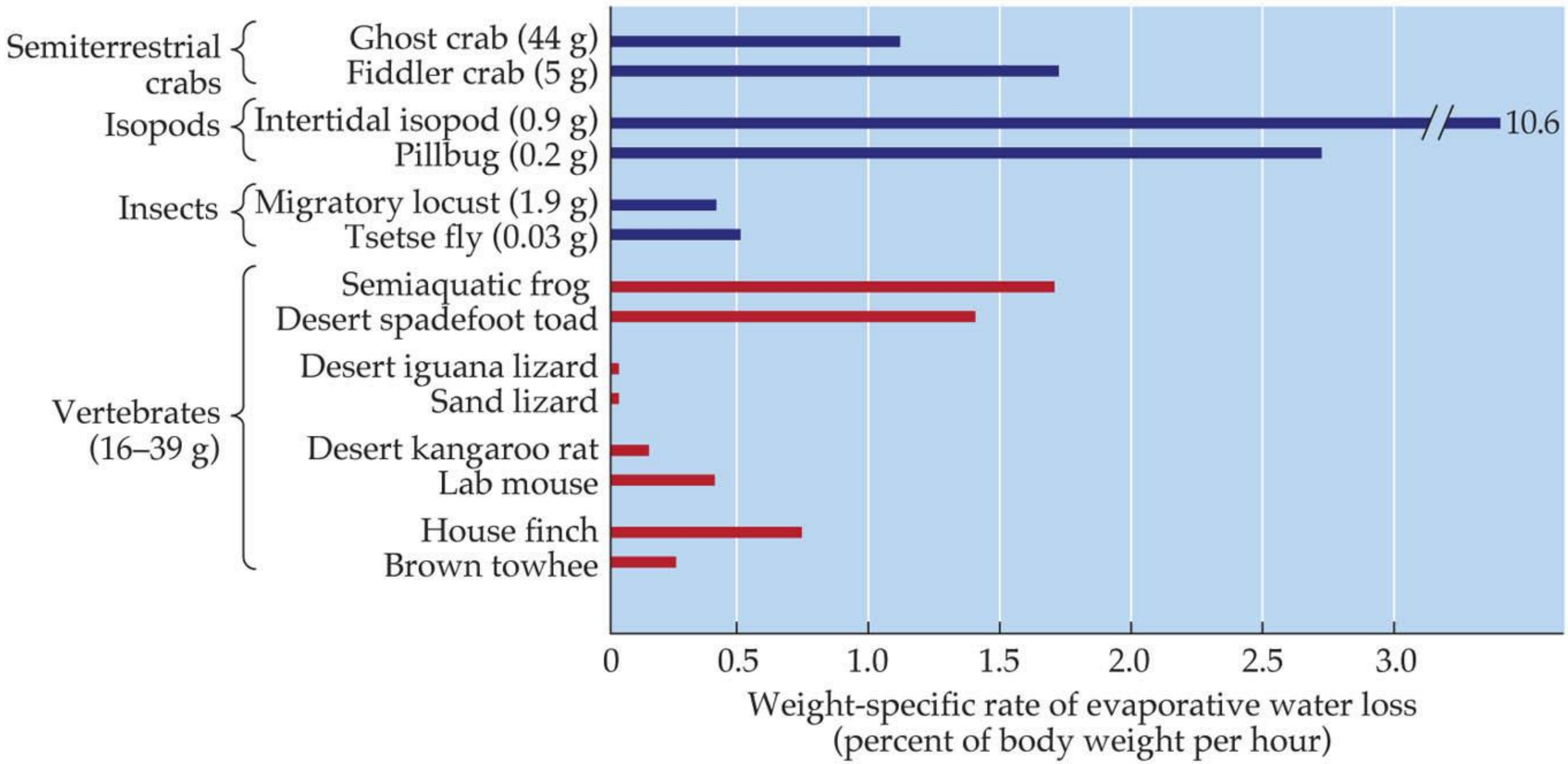


Adaptations: better extraction of oxygen, cooling of exhaled air.

Total rate of evaporative water loss depends on body size and phylogenetic group

Small bodies------- higher weight-specific rates of evaporative water loss (EWL)

Small bodies------- higher surface/volume ratio
------- Higher metabolism



Permeability integuments, metabolic rate

Excretory water loss depends on the concentrating ability of excretory organs

Terrestrial animals modulate concentration, composition and volume of urine

Two ways to minimize loses:

1. **Concentrate** the urine
2. **Reduce the amount of solute** excreted in the urine

Low U/P ratios

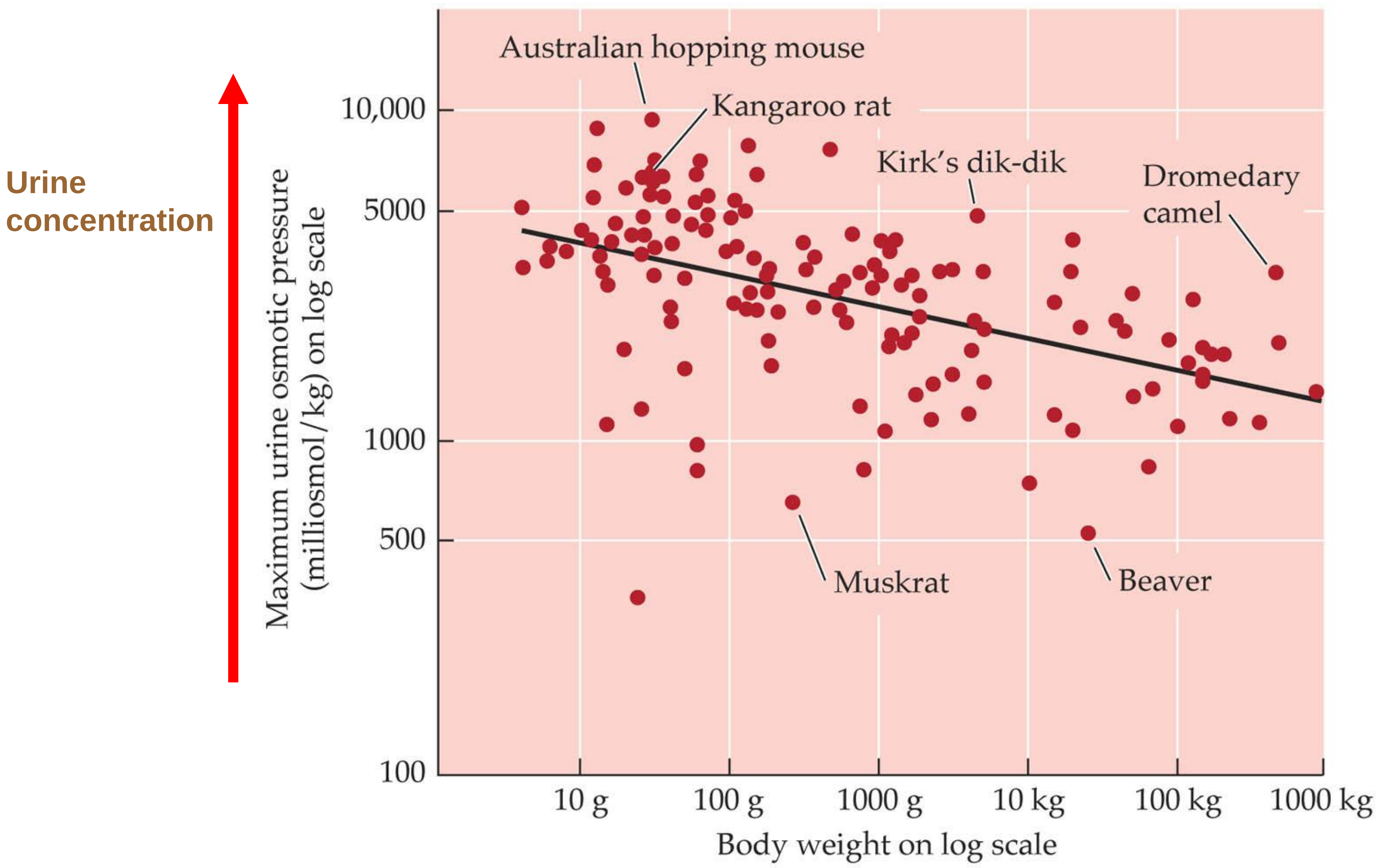
High U/P ratios

Hyperosmotic urine

Salt glands help to decrease water required for excretion (birds, lizards)

Excretory water loss depends on the **concentrating ability** of excretory organs

The **Maximum concentration of urine** mammals can produce is in part a function of size and part related with the habitat

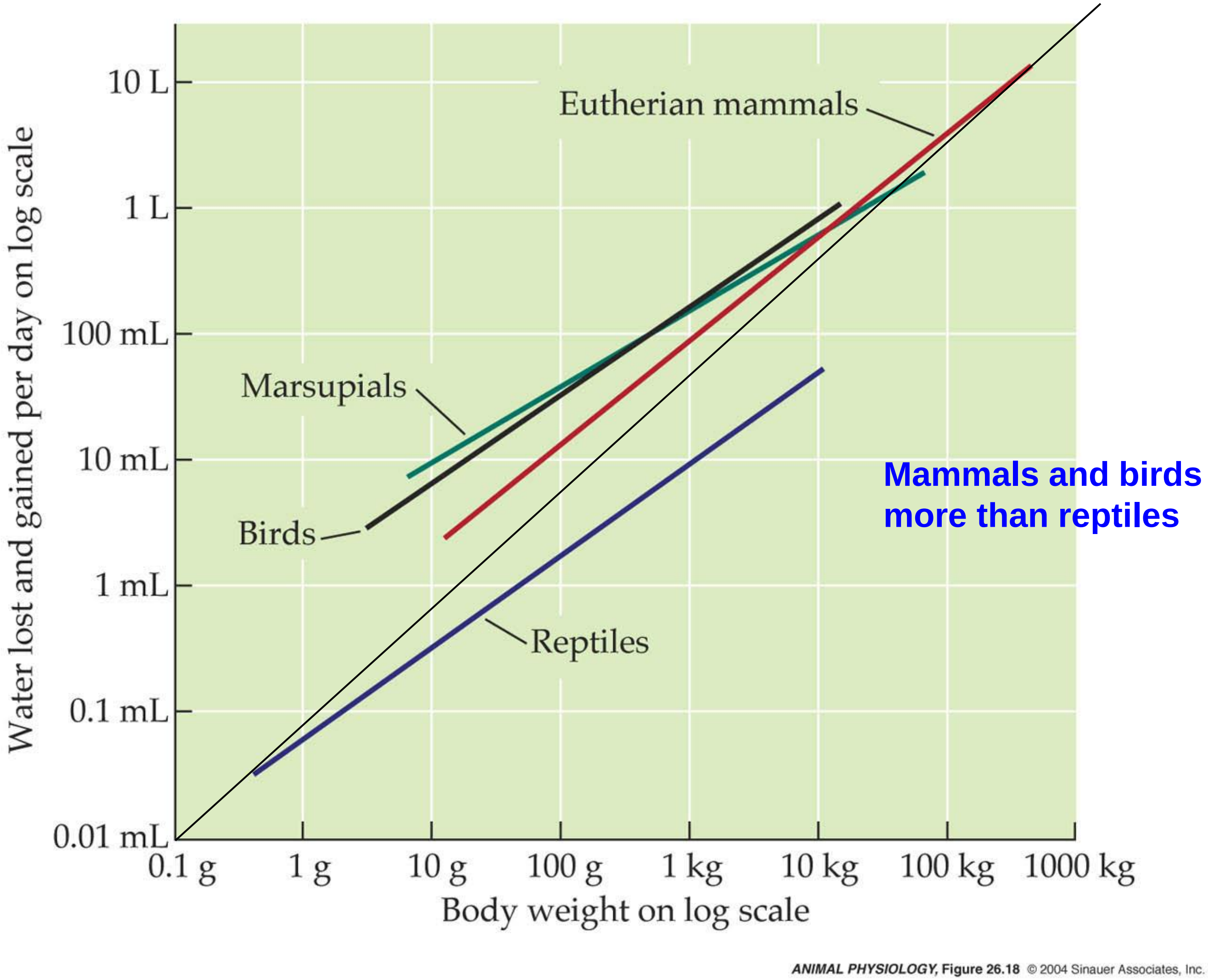


Water-turnover rates of free-living terrestrial vertebrates as a function of body size

Water turnover: is the water lost and gain per day

Animals with **high water turnover** are more expose to dehydration

The water-turnover rates of a particular group is a function of body size



Mammals and birds turn over more than reptiles

Amphibians occupy xeric habitats despite their humidic nature

- Amphibians are able to invade dry habitats thanks to**:**

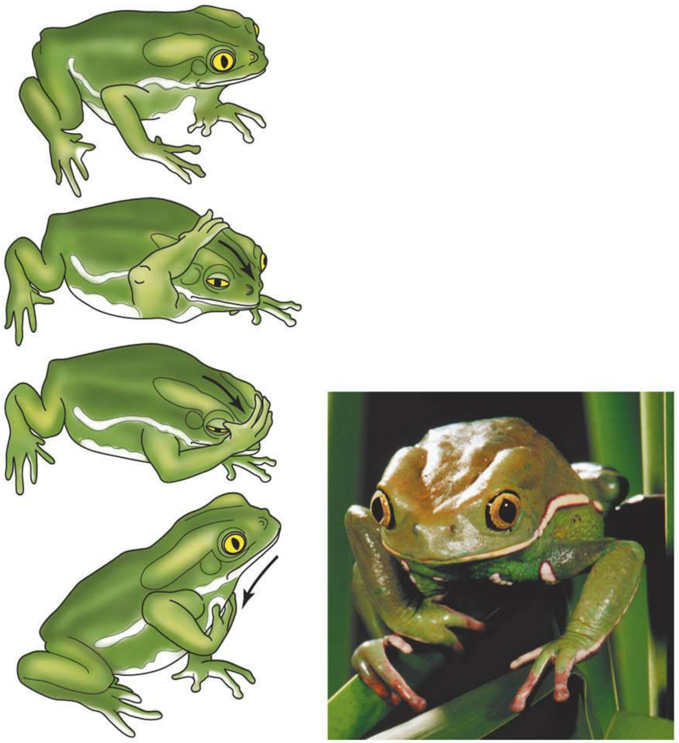
  Protective behavior
  Advantageous patterns of seasonality
  Particular physiological adaptations

- **Problems:**

  High integumental water permeability
  Low ability to concentrate urine
  Carnivores: high urea

- **Solutions:**

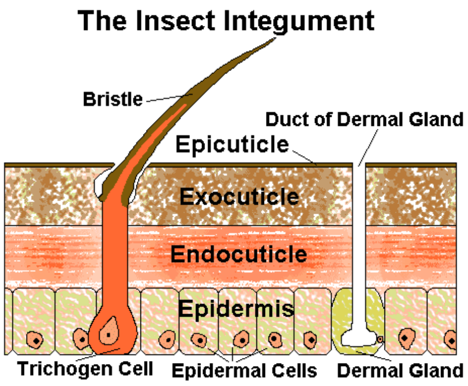
  Absorb water across their skins (also drink)
  Behavioral and seasonal dormancy
  Decrease integumental water permeability.
  Reduce urinary water losses (uric acid)



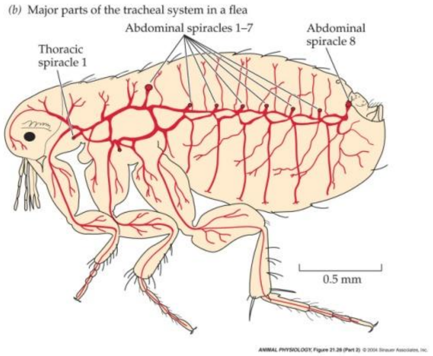
ANIMAL PHYSIOLOGY, Figure 26.19

Arboreal frogs (*Phyllomedusa)* spread protective lipids over their skin surface

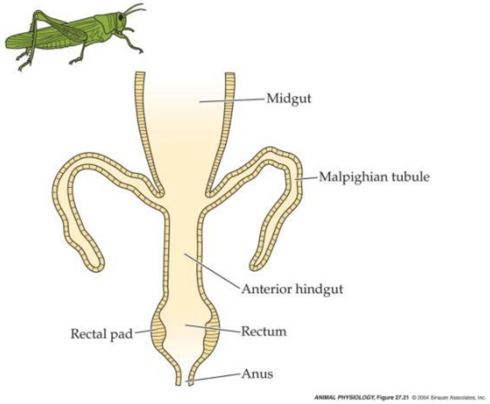
Insects are excellent water managers



Low integumentary permeability



Low respiratory water losses



Ability to concentrate the urine

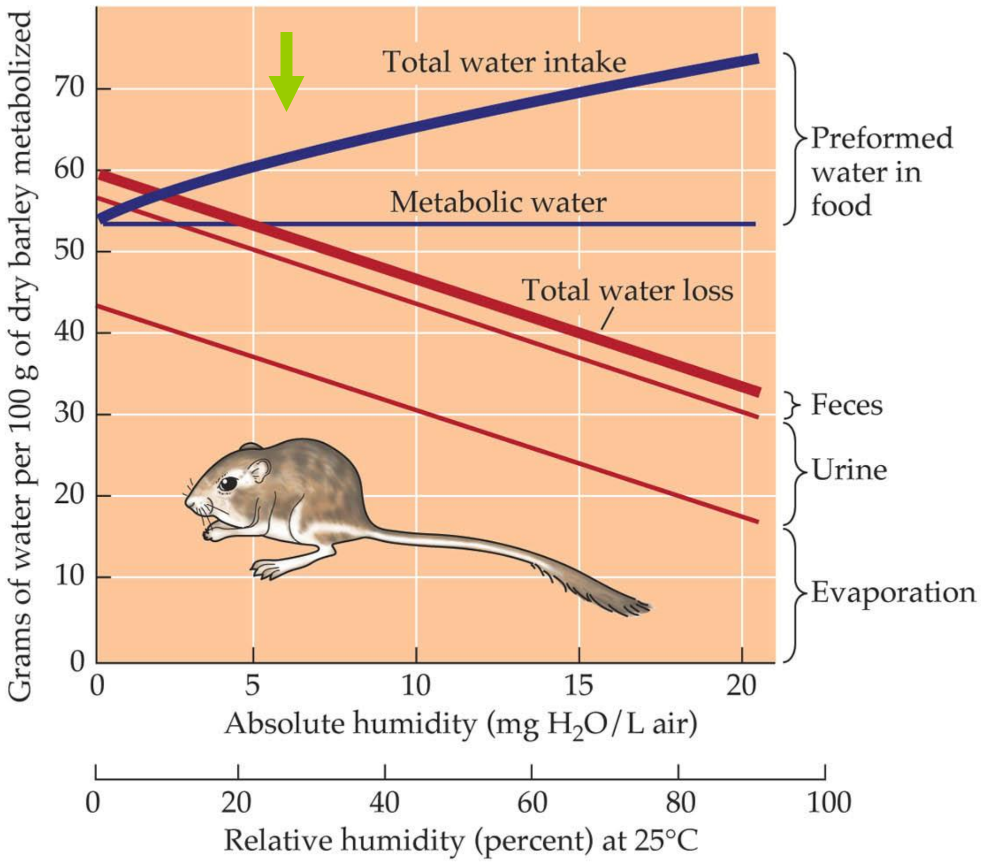
Water losses are low and organisms survive on metabolic water for long periods

Xeric vertebrates are well adapted to prevent water losses.

- **Problems:**
  High metabolic rates
  Carnivores: high urea
  Limited access to water

- **Solutions:**
  Low integumental water permeability.
  Reduce urinary water losses (uric acid)
  Behavior to avoid water stress

A kangaroo rat water budget

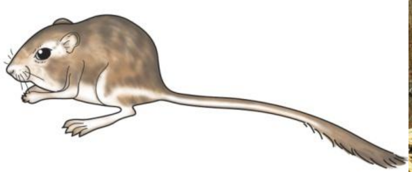


- **Very low cutaneous water permeability.**
  Very concentrated urine
  Very low fecal water looses

Metabolic water

Approximate catabolic gains and losses of water in caged kangaroo rats (*Dipodomys*) and laboratory rats (*Rattus*) when eating air-dried barley and denied drinking water at 25°C and 33% relative humidity The values given are grams of H_2O per gram (dry weight) of barley ingested. Those for the kangaroo rats are from Box 25.1.

Category of water gain or loss	Kangaroo rats	Laboratory rats
Gross metabolic water produced	**0.54 g/g**	**0.54 g/g**
Obligatory water losses		
Respiratory	0.33	0.33
Urinary	0.14	0.24
Fecal	0.00	0.03
Total obligatory water losses	**0.47**	**0.60**
Net gain of metabolic water	**+ 0.07**	**– 0.06**



Important to **CONSERVE** water

Summary

Terrestrial organisms lose water by evaporation .

Evaporation:

1. Air humidity: lower water vapor pressure of air--- higher evaporation
2. Temperature of body fluid: warmer more evaporation.
3. Rate of air movement: windy more evaporation.
4. Permeability of integument to water: High ---- higher evaporation.

Terrestrial organisms **gain water** by

1. Drinking preformed water.
2. Eating preformed water.
3. Metabolic water: water produced by catabolic reaction

Obligatory water losses: respiratory, urinary and fecal obligatory water losses..

Humidic: restricted to humid microenvironments

Xeric: capable of living in dry environments

The evolution of a **low permeability of integument to water** i
s one of the most important adaptation to a xeric life