Osmoregulation

Osmoregulators: Animals living in a:

- Hypertonic Environment- Lose water to environment
- Hypotonic Environment- Uptake water from environment

Water movement:

- From low osmolarity to high osmolarity

Ion movement:

- From hight osmolarity to low osmolarity

Hypertonic solution- has higher concentration of solutes
Hypotonic solution- has lower concentration of solutes
Isotonic solution- have same concentration of solutes

Osmoregulation is energetically costly
~5% of resting metabolic rate of F.W. and S.W. (fish)

Stenohaline- Animals can tolerate narrow range of osmolar fluctuations
Euryhaline- Animals can tolerate wide range of osmolar fluctuations (either Osmoregulators or Conformers)

All freshwater and many marine = osmoregulators
Terrestrial = osmoregulators

Marine mammals = HYPOTONIC

- Invertebrates (most) = osmoconformers
- Vertebrates (most) = osmoregulators

HAGFISH-

- Jawless, vertebrate
- ISOTONIC with sea water (only exception- other vertebrates are osmoregulators)

SHARKS AND CARTILAGENOUS FISH

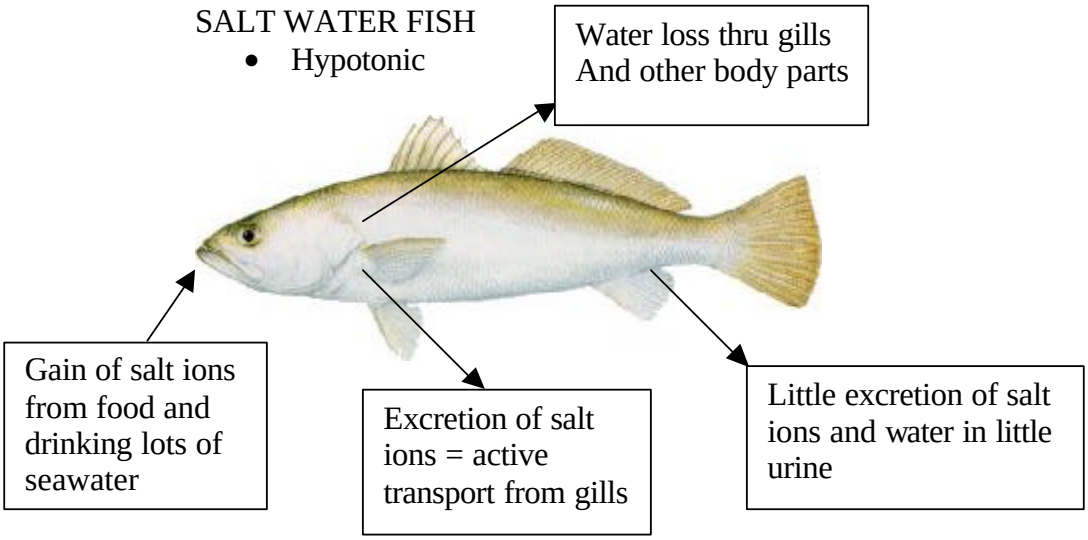
- Lower internal salt concentrations than sea water
- Kidneys excrete some salt
- Rectal gland excretes NaCl through anus
- Sharks are Isotonic/Hypertonic to sea water
- Do not drink water
- Water enters by osmosis and is excreted as urine
- Large amount of urea dissolved in body fluid makes shark slightly hypertonic
- Sharks also produce and retain compound TMAO that protects proteins from damage by urea

BONY FISH

- Evolved from fresh water then came to sea
- Similar to F.W. fish – osmolarity
- Constantly lose water (they are hypotonic) to their more concentrated medium
- Drink lots of water
- Pump out excess salts
- Little urine

SALT WATER FISH

- Hypotonic



FRESHWATER ANIMALS

- Hypertonic
- Constantly taking in water because body fluids are more concentrated than surroundings

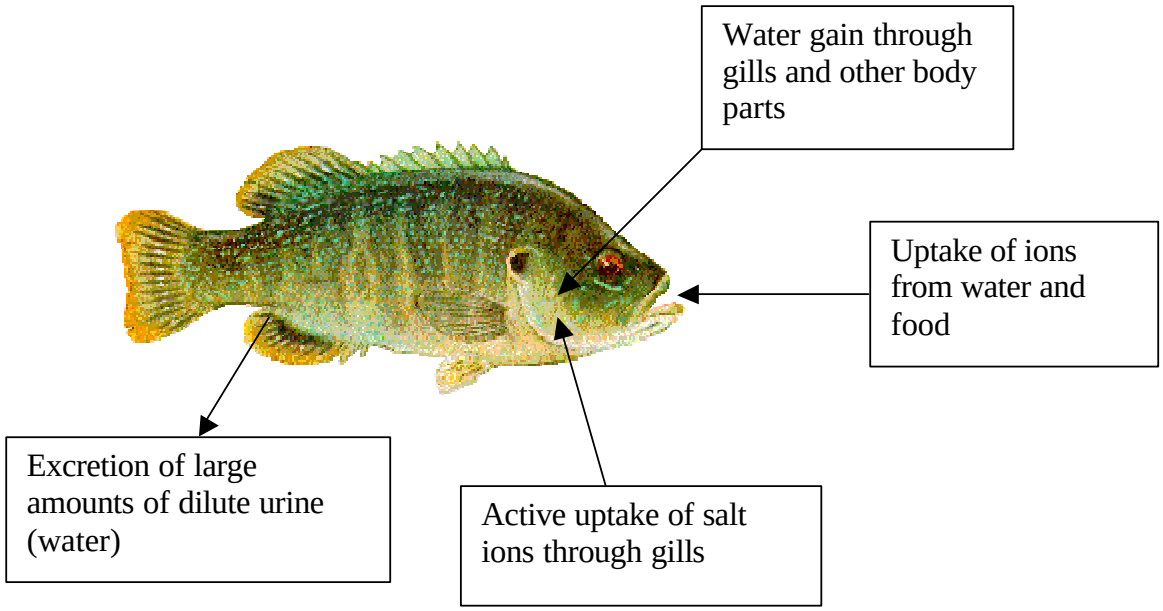
Water protozoa- have contractile vacuoles to pump out water

VERTEBRATES

- Ex) Fish excrete large amounts of dilute urine and regain lost salts in food and by active uptake from surrounding through gills
- Salmon and other migratory fish- between F.W. and S.W. are EURYHALINE and regulate like the fish that live in either FW or SW in each case

FRESH WATER FISH

- Hypertonic



Temporary waters- Aestivation during dry season

TERRESTRIAL ANIMALS

- Hypertonic
- Loss of water
- Humans die if they lose ~12% of their body water
- Waxy cuticle/keratinized skin
- Surfaces that prevent dehydration
- Drinking/eating = water
- Nervous and hormonal mechanisms to control thirst
- Behavioral adaptations = nocturnal & burrowing
- Kidneys that reabsorb most of the water and excrete very concentrated wastes.

	% Salt	Osmolar
Sea Water	3.45	1
Fresh Water	<0.05	<0.015
Brackish Water	<3.45	<1
Salt Lakes	5.0-25.0	1.5-7.0

SEA WATER= 3.5% salts (~ 35g salts/1 L water)
-Sodium, Chloride, Magnesium, Sulfate, Calcium

ISO-OSMOTIC- Body fluids have same osmotic pressure as the sea water
Ex) most marine invertebrates

OSMO CONFORMER- Osmotic concentration of body fluids fluctuates according to that of the environment

OSMO REGULATOR- Animal maintains or regulates within narrow limits the internal body osmolarity despite environmental changes

EURYHALINE- Animals= wide variations in salt concentration of water can be tolerated
-live in brackish water

STENOHALINE- Animals= narrow tolerance to environmental variation of salt concentration in water

UNITS:

M concentration = moles/liter= millimoles (10^-3)/liter

0.5 moles/ liter = 500 mmol/liter

OSMOLARITY of a solution depends on the number of dissolved particles (electrolytic solution)

Sea water= .47 mol Na & .55 mol Cl & some divalent ions (Mg, SO4)
Has osmotic concentration 1mol/L = 1 osmolar

ISOTONIC- a living cell is isotonic if when placed in a given solution the cell neither shrinks nor swells. (2 solns are equal in osmolarity)

HYPEROSMOTIC = body fluids are more concentrated than the medium

HYPO OSMOTIC= body fluids are less concentrated than the medium

Marine animals: vertebrates
- ex) osmoregulators

Fresh water and brackish
- osmoconformers= lower animals
- osmoregulators= higher animals (they remain hyperosmotic)

FRESH WATER ANIMALS

- Mechanisms of osmoregulation:
  - if animal is Hyperosmotic to environment,
  1) Water tends to flow into the animal (conc. Gradient)
  2) Solutes tend to be lost because water that enters must be excreted and carries solutes with it during excretion.
- Making all body surfaces highly impermeable
  - no completely impermeable animal
  - respiratory surfaces must be thin enough for gas exchange
  - respiratory surfaces = site of solute loss
- Active Transport of solutes, ions
  - food

- uptake from medium
- uptake from medium against concentration= active transport (requires E)

MARINE ANIMALS

Hypo osmotic

- Active transport for osmoregulation
- Animal looses water to the more concentrated environment
- Solution- increase drinking of water
- " " " with drinking, there is also an uptake of ions from medium
- ions must be evacuated against concentration gradient – active transport
- site of active transport: gills, respiratory surfaces, malpighian tubules

Agnathostomes- jawless vertebrates

Hagfish- strictly marine and stenohaline

- body fluids have same concentrations as sea (the only vertebrate to do so)
- iso osmotic

Lamprey- both sea and freshwater

- Hypo osmotic (lower internal salt conc than sea)

Cartilaginous fish- total body osmolarity ~1 osmolar

- urea= 0.5
- salt= 0.5

Sharks and Rays-

- marine
- hypo osmotic
- add to body fluids Urea in order to maintain osmolarity in equilibrium with sea
- urea is highly toxic to tissues but a compound (TMAO) detoxifies it
- salts are ingested with food, water, etc.
- salts are excreted by kidney, gills but also specialized by rectal gland
- sharks that live in fresh water have less urea in their tissues and osmoregulate

TELEOST FISH

- marine= hypo osmotic
- fresh water= hyperosmotic
- salmon- lives at sea but reproduces in fresh water
- Eel- lives in fresh water but reproduces in sea water

Marine teleosts-

- May lost body water to the more concentrated sea water through respiratory surfaces= gills
- Solution is to drink water

- But, drinking water also brings salts into the body
- Salts must be excreted
    - Kidney
    - Specialized chloride cells which are found in gills and which implement the active transport of chloride ions out of body: Na ions follow passively
    - Kidney plays important role in excreting excess water and of the divalent ions (Mg and sulfate)
    - Only a small part of total salts come from drinking. There is some passive influx in the gills and the fish must work against concentration gradient to excrete them by active transport

Fresh water teleosts-

- Hyperosmotic to environment
- Major problem: osmotic water inflow through 1) gills 2) skin to some degree
- Excess water excreted as dilute urine (there is ion loss w/ urine)
- Ion loss w/ urine is replaced by ion uptake through gills, in food
- Excess salts are excreted through urine and diffusion across gills (insignificant)

Migratory fish

- Probably reverse the function of gills

Amphibians

- Aquatic / semiaquatic
- Larvae= gills
- Adults= lungs

Fresh water amphibians

- Similar to teleost fish
- Skin- main organ of osmoregulation
- When animal is in water- inflow of water and animal excretes highly dilute urine
- Loss of solutes/ions in water and through skin
- Loss of solutes must be balanced through active transport of salt from medium into body through skin
- Na active uptake
- Cl diffusion

Salt water amphibians

- Crab eating frog (SE Asia)
- Strategy: same used by sharks
- Adding large amounts of urea to body fluids (amphibian skin is permeable so there would be water loss)
- Adding urea to body fluids makes the frog iso-osmotic even slightly hyper-osmotic then sea water
- Like sharks, there is a small influx of water which helps formation of urine

- Urea is retained through reduction of urinary volume (also needed for muscle contractions)
- Tadpoles of this frog adopt the teleost method then switch

Earthworm
- Skin permeable to water in both directions
- Hypertonic
- Fresh water animal adaptations

Amphibians
- Those that live near water, see above
- Those that live in deserts
    - Aestivation during dry season
    - Urinary bladders filled w/ dilutes urine= water reserve
    - Waxy substances that make skin waterproof in both directions (secreted by skin glands)
    - Uric acid excreted to conserve water

Snails
- Live in microhabitats
- Aestivation – withdraws in shell and covers entrance w/ mucus (barrier to water loss)

ARTHROPODS
Crustaceans
- Most depend on water either to reproduce or to keep the body surface moist. When out of water most seek hide-outs, burrows, and pools
- Some more terrestrial can combat water loss of evaporation by drinking or feeding on moist food. Their cuticle is water permeable. They live in micro-habitats which are humid. Still breathe through gills.

BIRDS AND MAMMALS
- Use water for evaporative cooling (sweating, panting)
- In deserts, water is obtained by animals exclusively from food
- Evaporation from respiratory tract
- Significant reduction in respiratory water loss occurs from exhalation of air at lower temperatures than the body core
- Ex) during inhalation- walls of passages lose heat to air flowing inside even to a temperature below that of the inhaled air
- Ex) during exhalation- the warm air from lungs passes over the cool surfaces and air is cooled and condenses on the walls. This water is absorbed.

Marine vertebrates
- Have lungs
- Drink sea water eat salty foods

- Salts must be excreted in a concentrated manner
- Reptilian and bird kidneys do not have the capability of concentrating urine so another mechanism for salt excretion is needed

Reptiles

- Salt excreting glands
- Lizards- nasal gland
- Turtles- orbital gland
- Snakes- sublingual gland
- Crocodiles- glands on the surface of tongue and kidney

Birds

- Nasal glands (above the orbit of each eye)
- They become active only when exposed to stress
- Nasal glands have a rather constant output of extremely concentrated salty liquid
- Only select ions (Na and Cl) are eliminated

Mammals

- The food ingested varies in salt content
- Kidneys of whales and seals can produce very concentrated urine – more concentrated than sea water
- Females need water for milk production. To reduce water loss, more concentrated milk is produced.
- Usually they refrain from drinking sea water