UNIVERSITY OF BASRAH
COLLEGE OF AGRICULTURE

DEPARTMENT OF FISHERIES & MARINE RESOURCES

FISH PHYSIOLOGY

A Postgraduate Course

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2016-2017

INTRODUCTION

Fish physiology is the scientific study of how the component parts of **fish function** together in the living fish. It can be contrasted with **fish anatomy**, which is the study of the form or **morphology** of fishes. In practice, fish anatomy and physiology complement each other, the former dealing with the structure of a fish, its organs or component parts and how they are put together, such as might be observed on the dissecting table or under the microscope, and the later dealing with how those components function together in the living fish.

https://en.wikipedia.org/wiki/Fish_physiology

Osmoregulation in Fish: Definitions

- **Homeostasis** = maintaining steady state equilibrium in the internal environment of an organisms
- **Solute homeostasis** = maintaining equilibrium with respect to solute (ionic and neutral solutes) concentrations
- **Water homeostasis** = maintaining equilibrium with respect to the amount of water retained in the body fluids and tissues

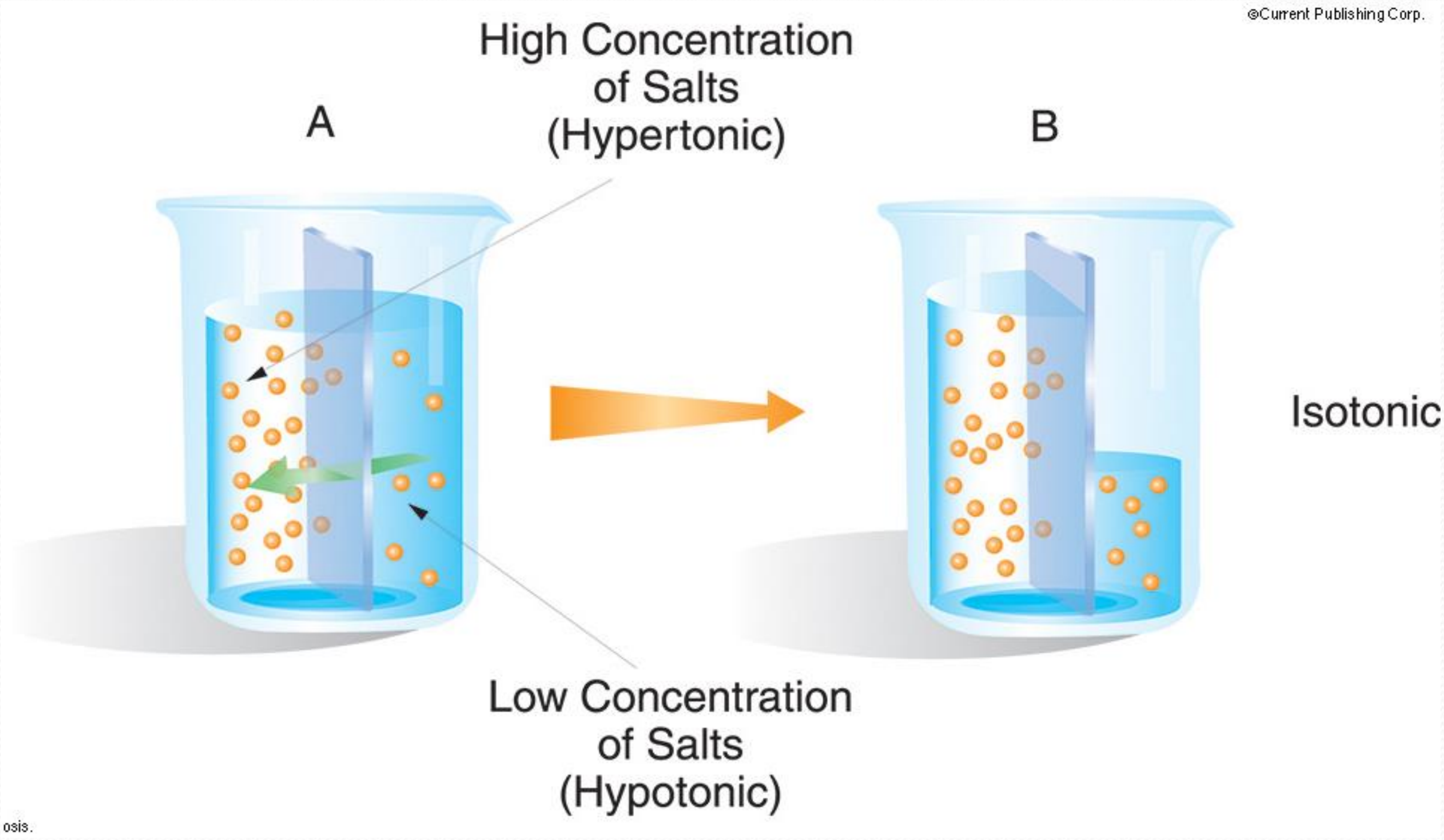
Definitions, continued

- Osmotic concentration
- Total concentration of all solutes in an aqueous solution
- measured in units of osmolal
- osmolals = 1 mole of solute/liter of water
  milliosmolals = 1/1000th of one osmolal

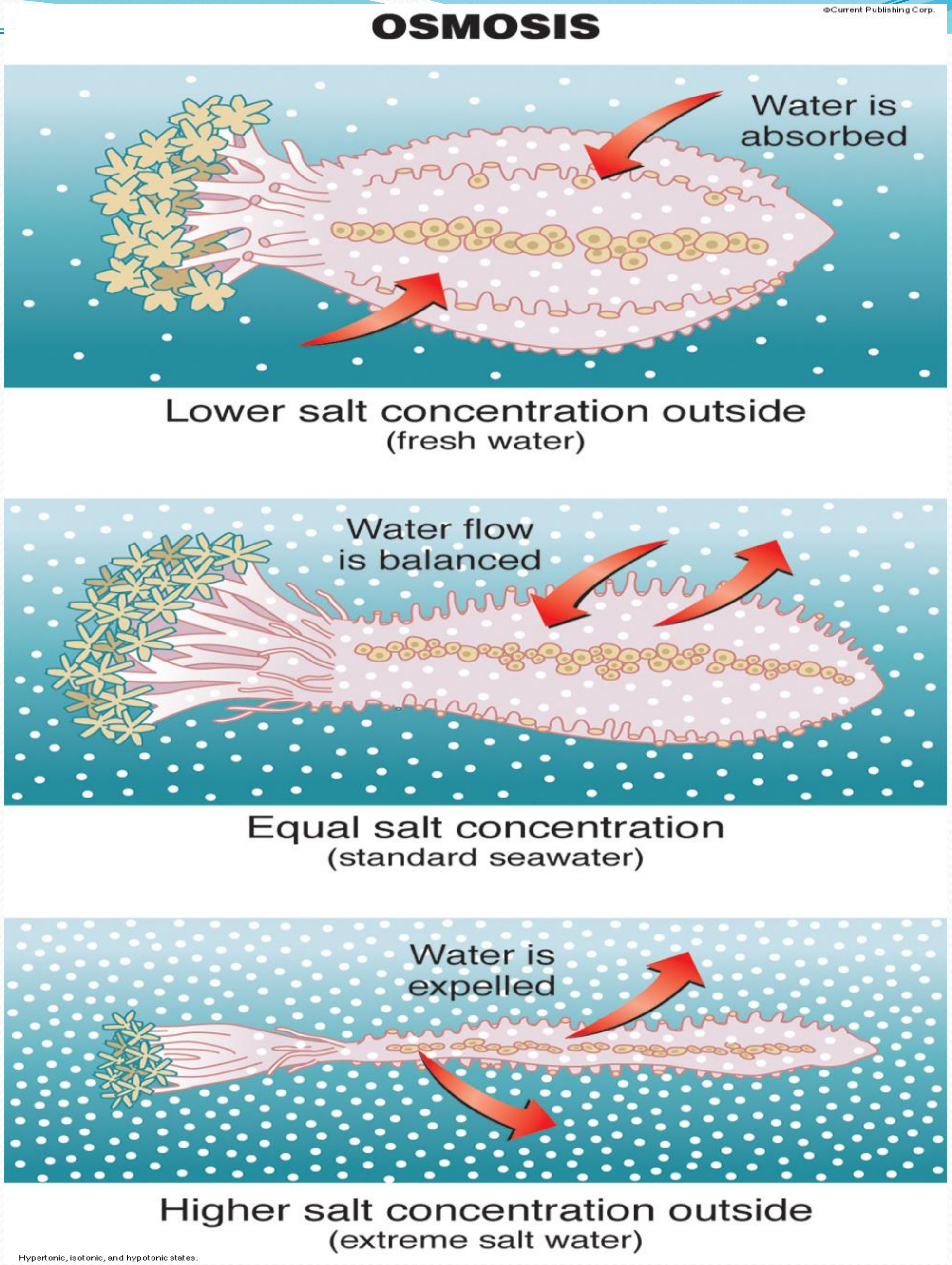
Osmoregulation in different environments

- Challenge to homeostasis depends on
  - steady state concentration of solutes in the body fluids and tissues as well as
  - concentration of solutes in the external environment
    - marine systems: environment concentration = 34 - 36 parts per thousand salinity = 1000 mosm/l
    - freshwater systems: environment concentration < 3 ppt salinity = 1 - 10 mosm/l
    - Estuaries: vary with tides and precipitation

Hypertonic vs Hypotonic



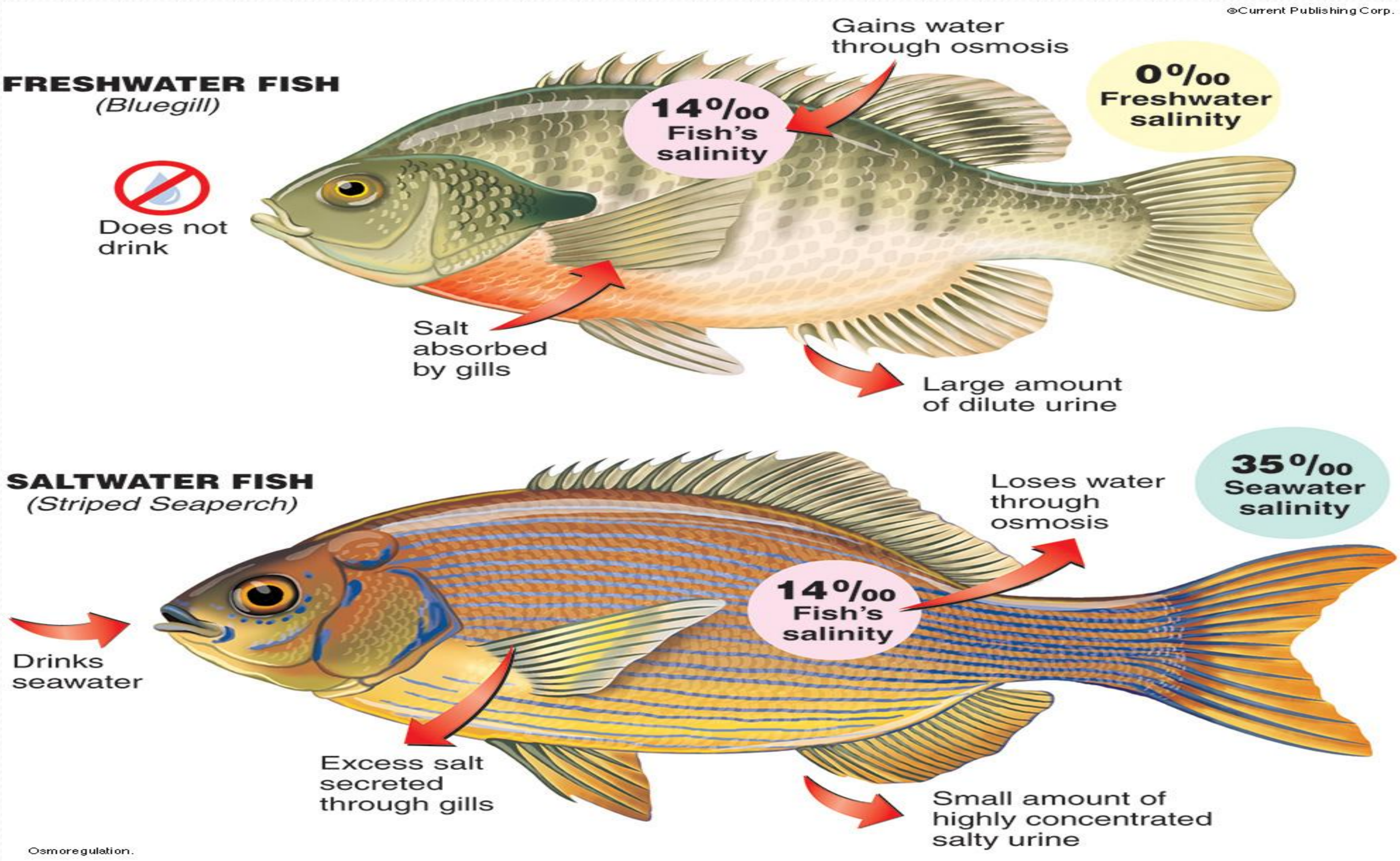
Cells swell or shrink



Osmoregulatory Strategies

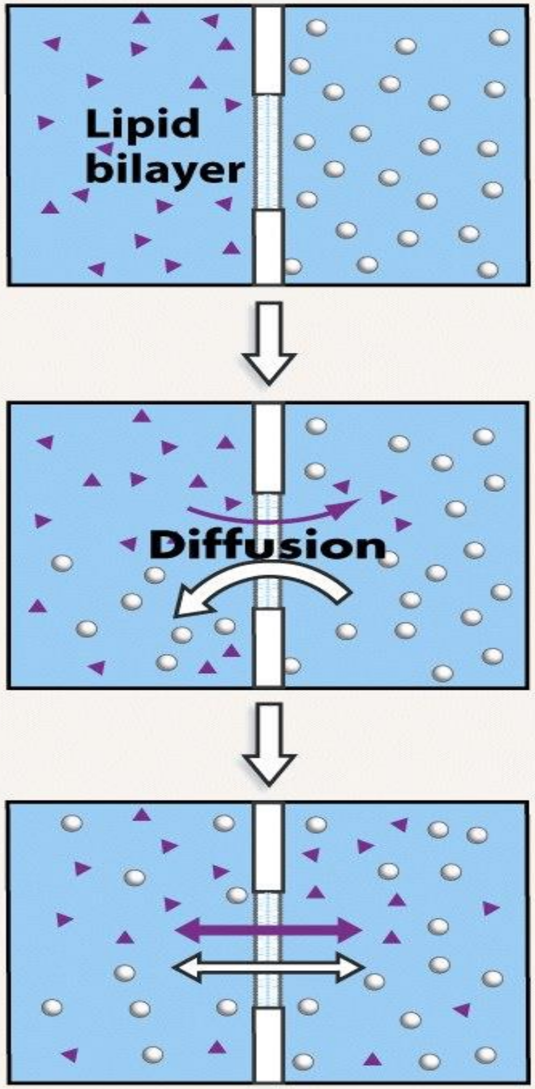
- Hypoosmotic – saltwater fish
- Hyperosmotic – freshwater fish
- Isosmotic: regulation of specific ions
- Isosmotic: nearly isotonic, osmoconformers

Freshwater vs Saltwater Fish



DIFFUSION

Solutes move from areas of higher concentration to areas of lower concentration.



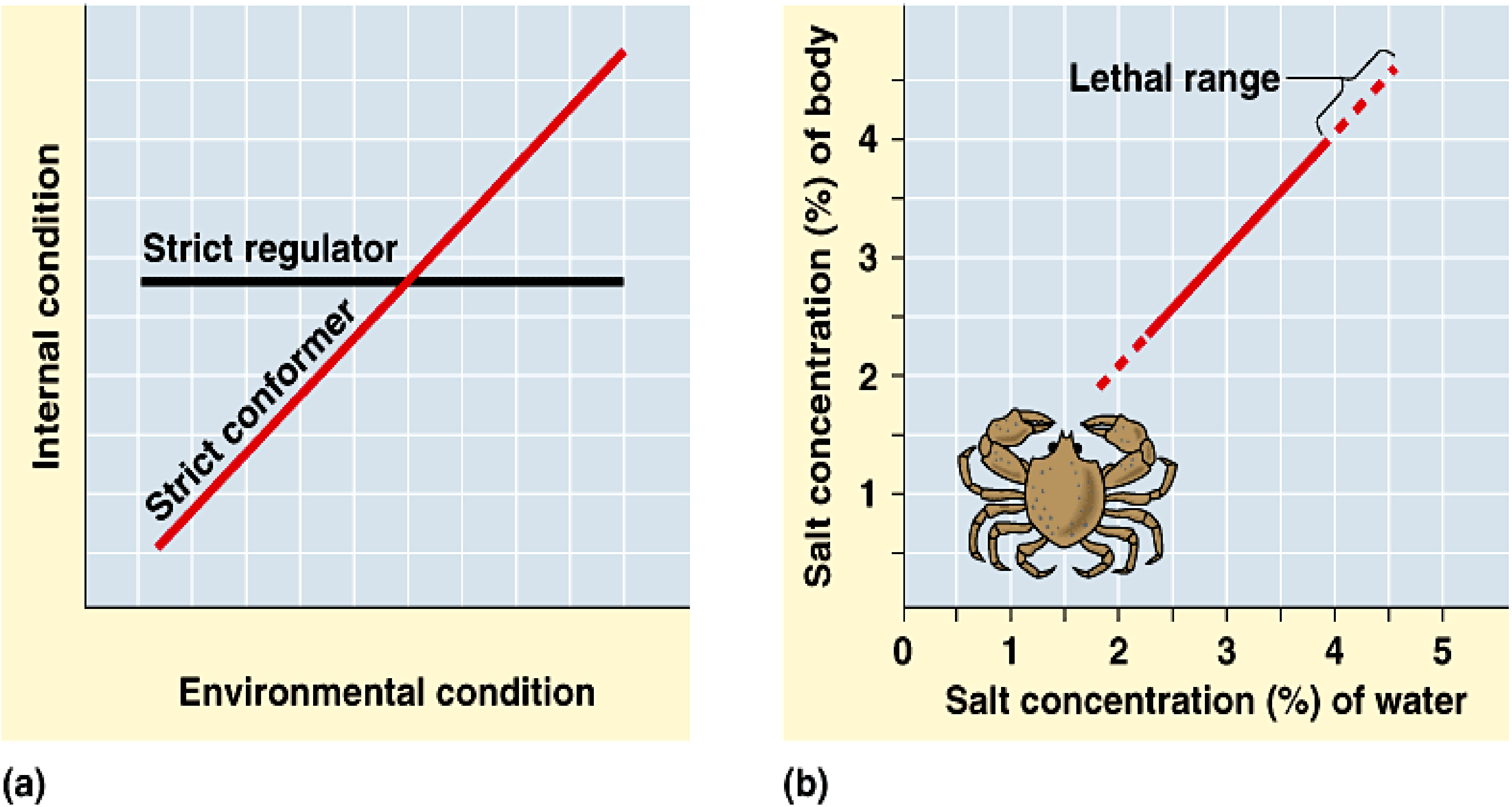
1. Start with two different molecules on opposite sides of a selectively permeable membrane (a phospholipid bilayer).

2. Molecules diffuse across the membrane — each along its own concentration gradient.

3. Equilibrium is established. Molecules continue to move back and forth across the membrane but at equal rates.

Figure 42-1a Biological Science, 2/e

Body fluid osmotic concentrations



Osmoregulation in different environments

- Each species has a range of environmental osmotic conditions in which it can function:
  - stenohaline - tolerate a narrow range of salinities in external environment - either marine or freshwater ranges
  - euryhaline - tolerate a wide range of salinities in external environment - fresh to saline
    - short term changes: estuarine - 10 - 32 ppt
intertidal - 25 - 40
    - long term changes: diadromous fishes

Anadromous vs catadromous fish

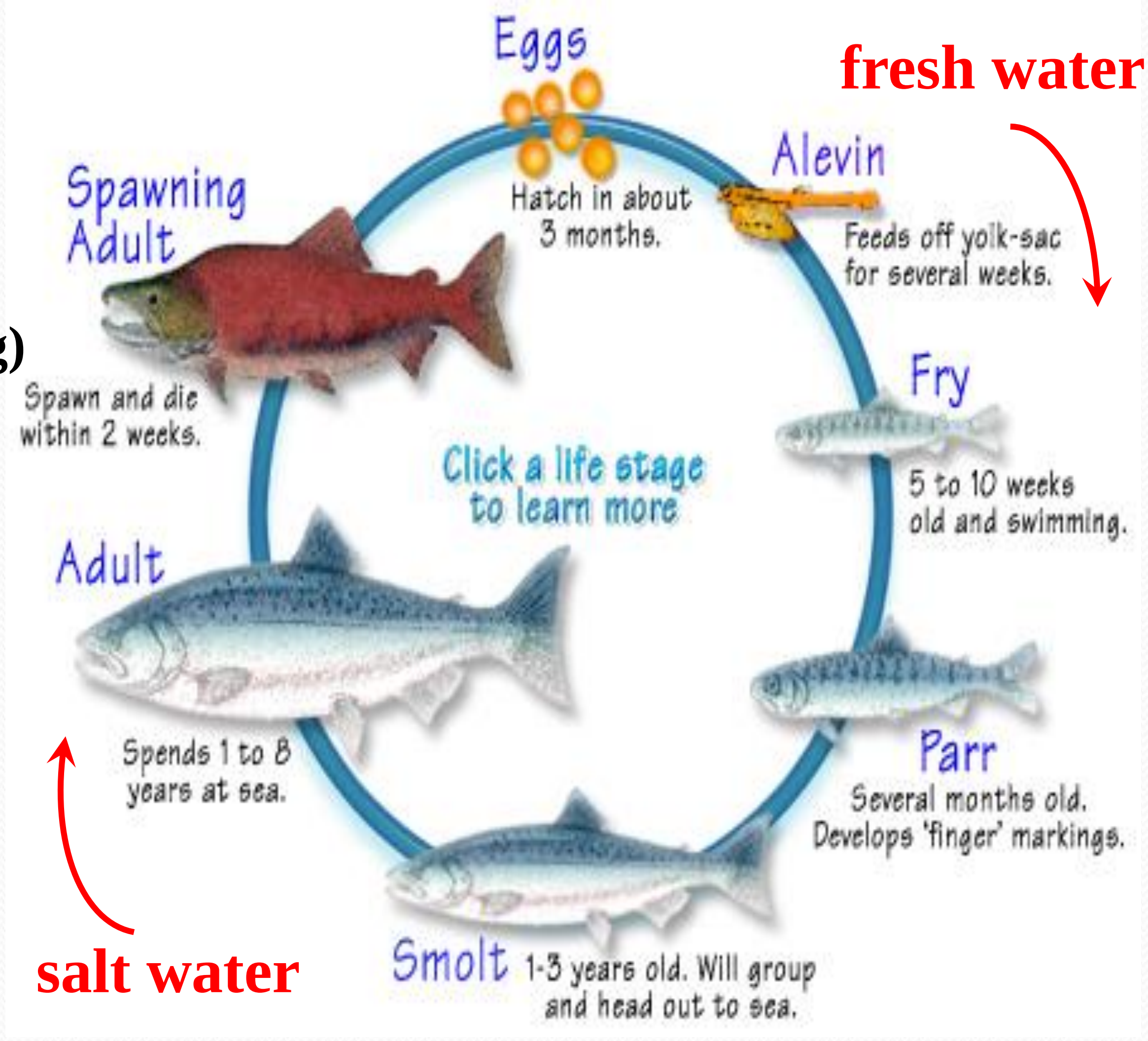
- **Diadromous** fishes - spend part of life in salt water, part in freshwater
- An **anadromous** fish, born in fresh water, spends most of its life in the sea and returns to fresh water to spawn (Greek: ἀνά *ana*, "up" and δρόμος *dromos*, "course") . Salmon, smelt, shad, striped bass, and sturgeon are common examples.
- A **catadromous** fish does the opposite - lives in fresh water and enters salt water to spawn (Greek: κατά *kata*, "down" and δρόμος *dromos*, "course") . Most of the *eels* are catadromous.

Diadromous fishes

[Anadromous](#) - Pacific salmon, lamprey, shad

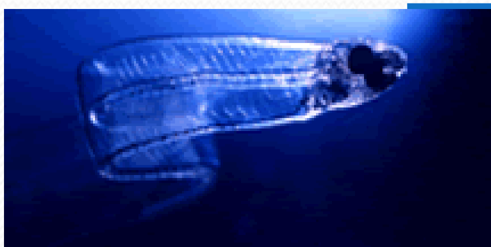
behavioral change (drinking)
changes in kidney function
[landlocked species](#) (Potamodromous) – reversion of salt-water tolerance

Metamorphosis – cued to photoperiod,
lunar cycle

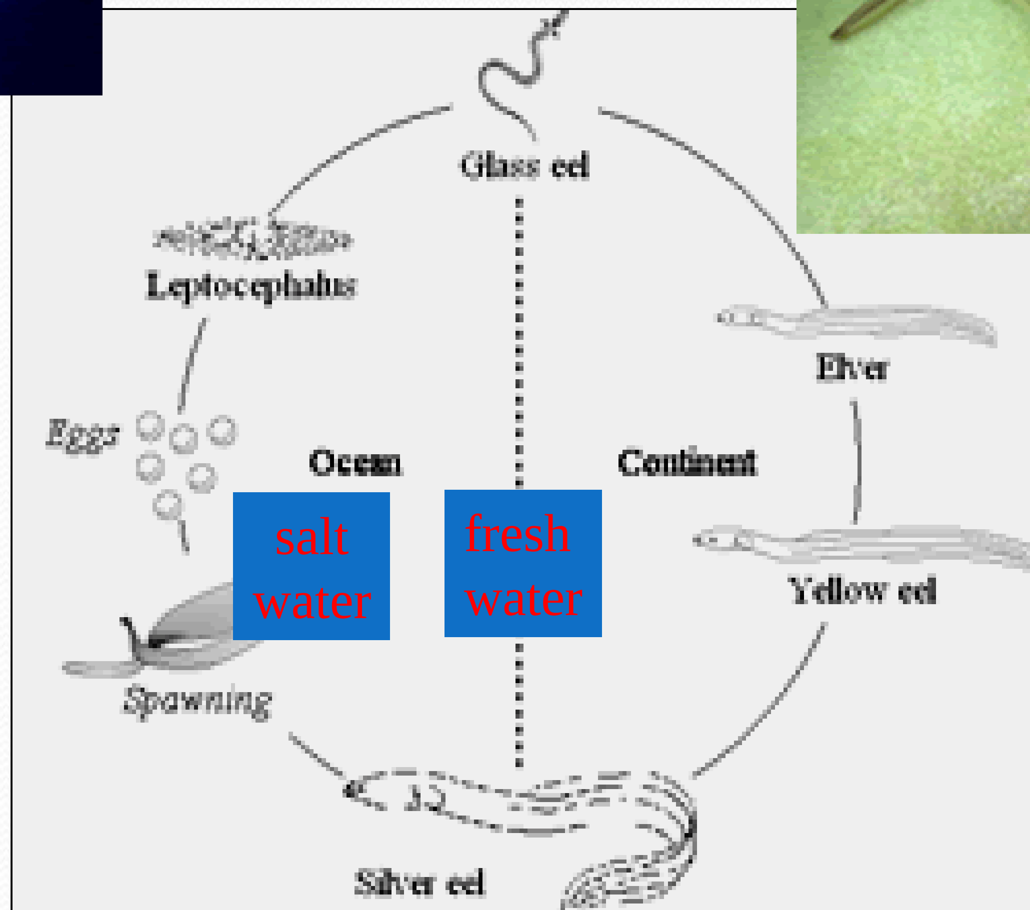


Diadromous fishes

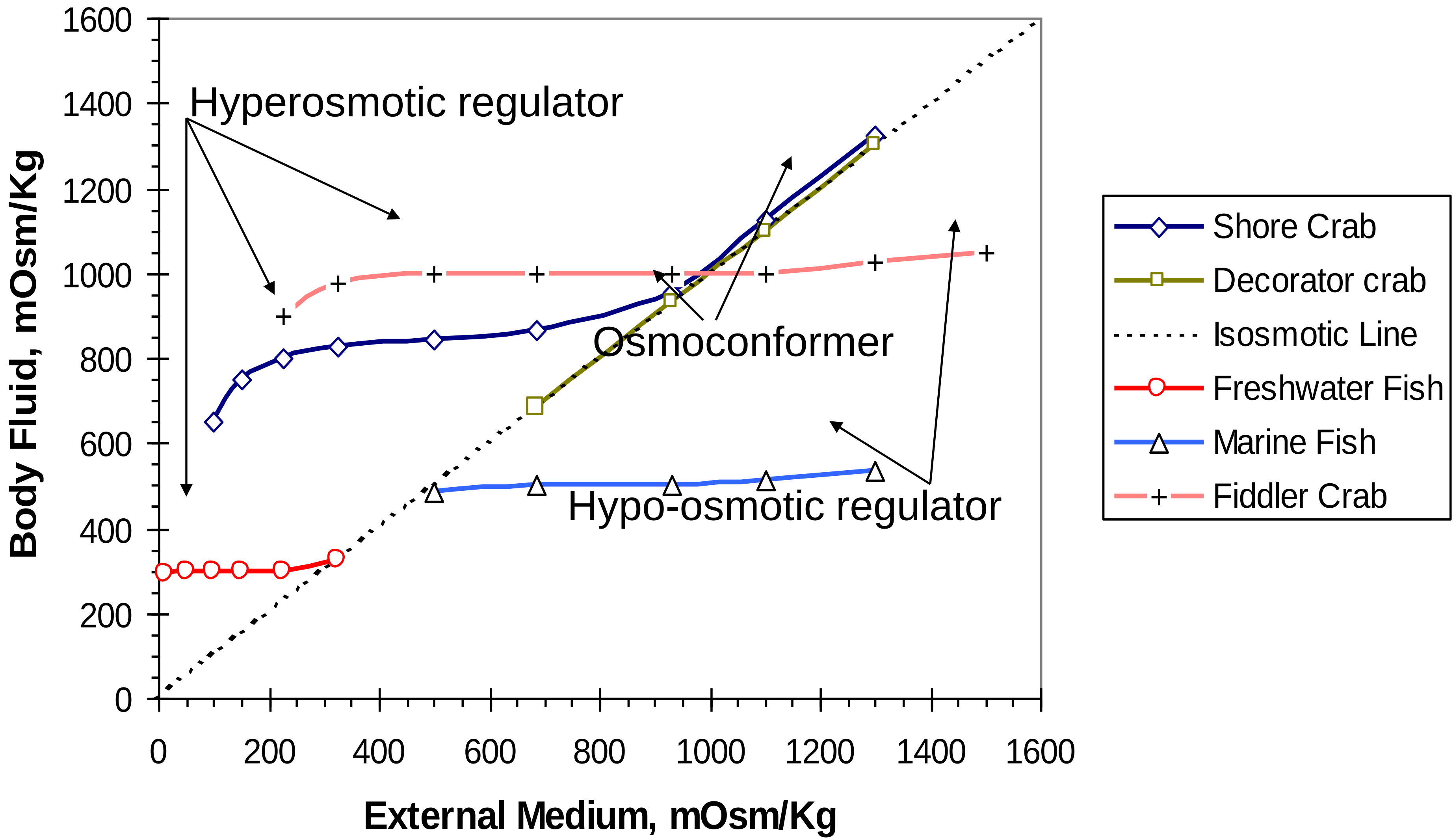
Catadromous - eels



Hormone-mediated changes associated with metamorphosis . Convert from FW adaptations to SW or vice versa, depending on direction of migration

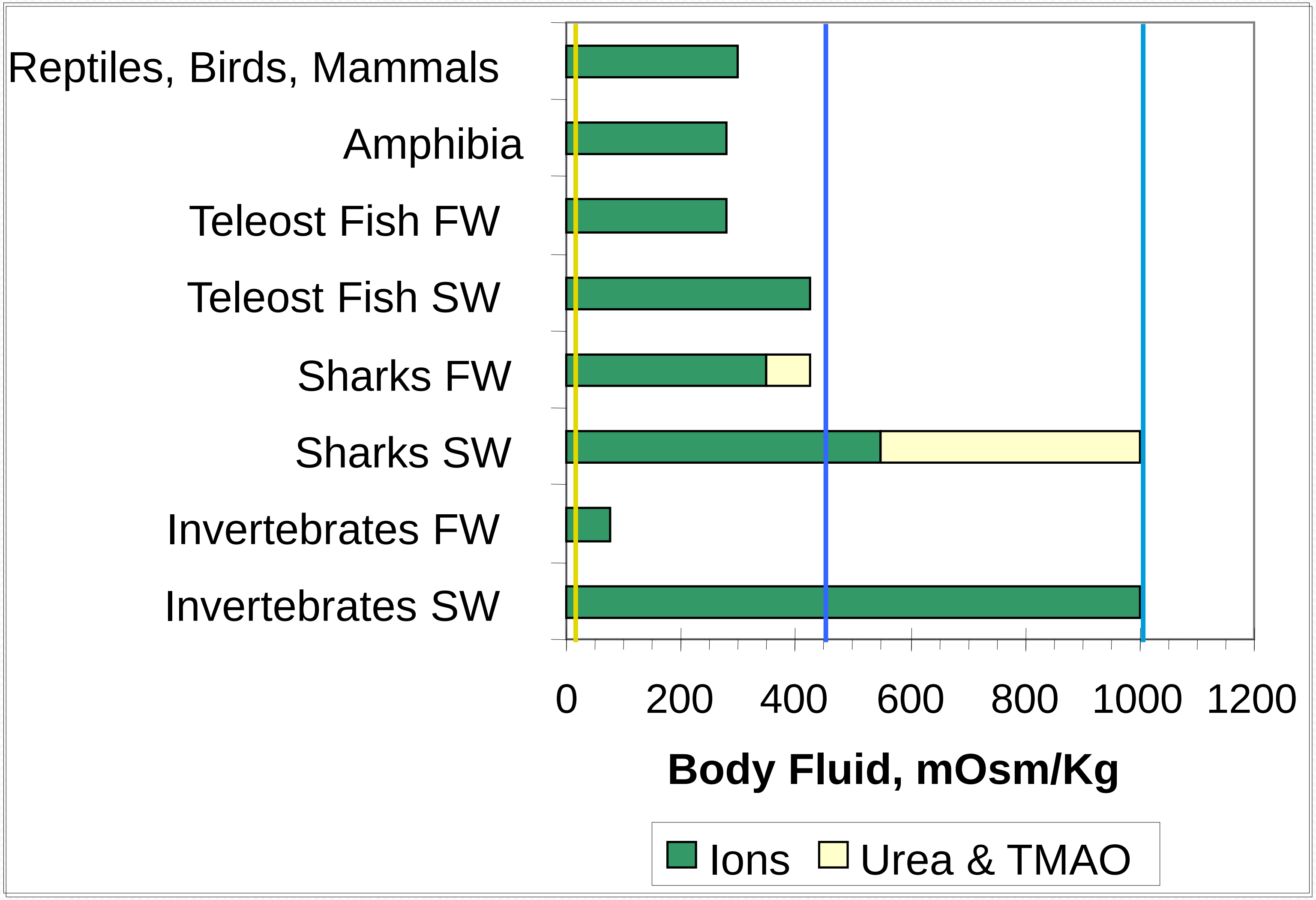


Types of Osmoregulators

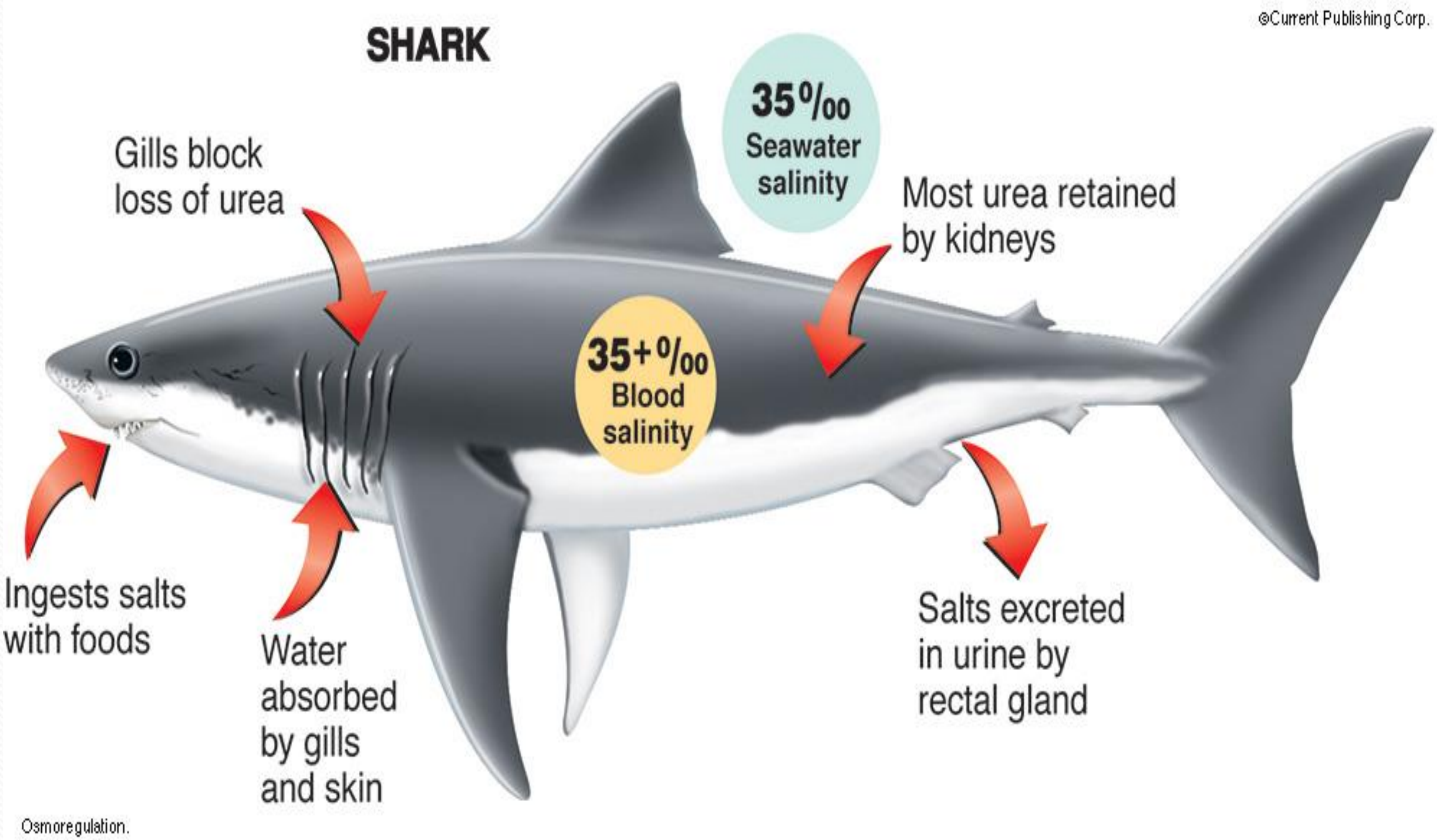


Osmoregulators and osmoconformers

Fresh water Brackish water Seawater

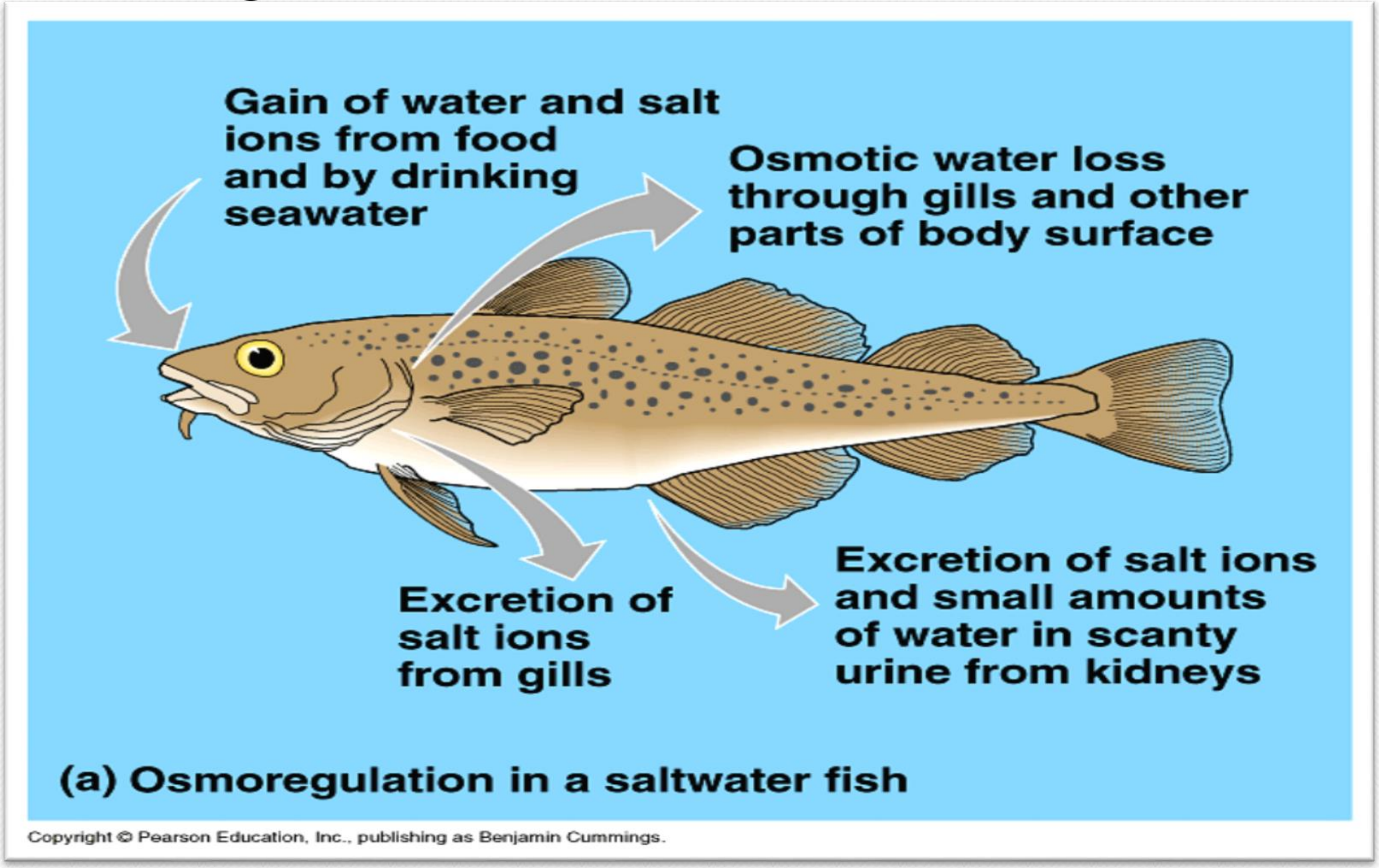


Osmoregulation in Elasmobranchs



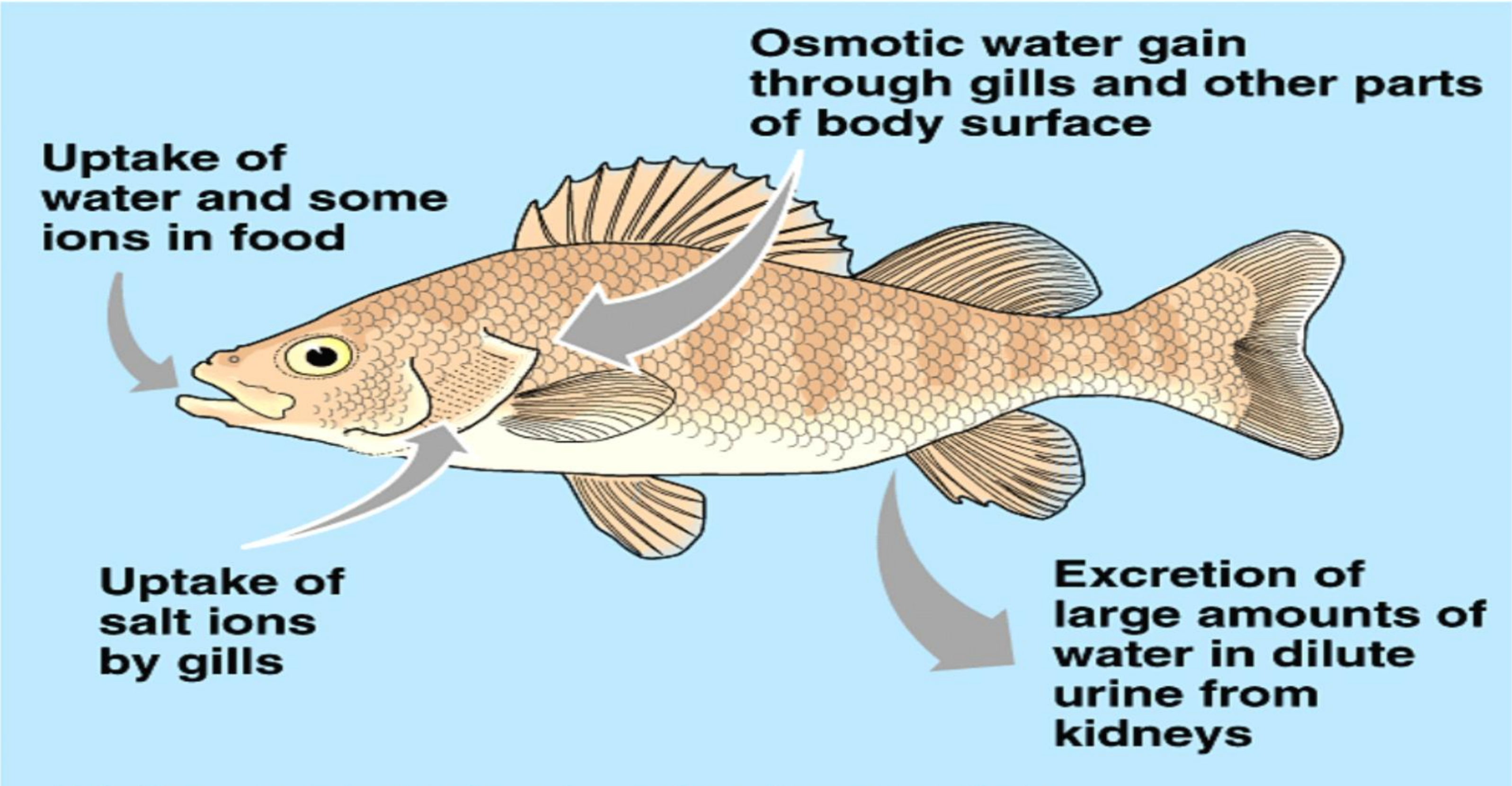
Osmoregulation in Saltwater Fish

Marine fish face two problems: they tend to lose water and gain ions.



Osmoregulation in Freshwater Fish

Freshwater fish face two problems: they tend to lose ions and gain water.



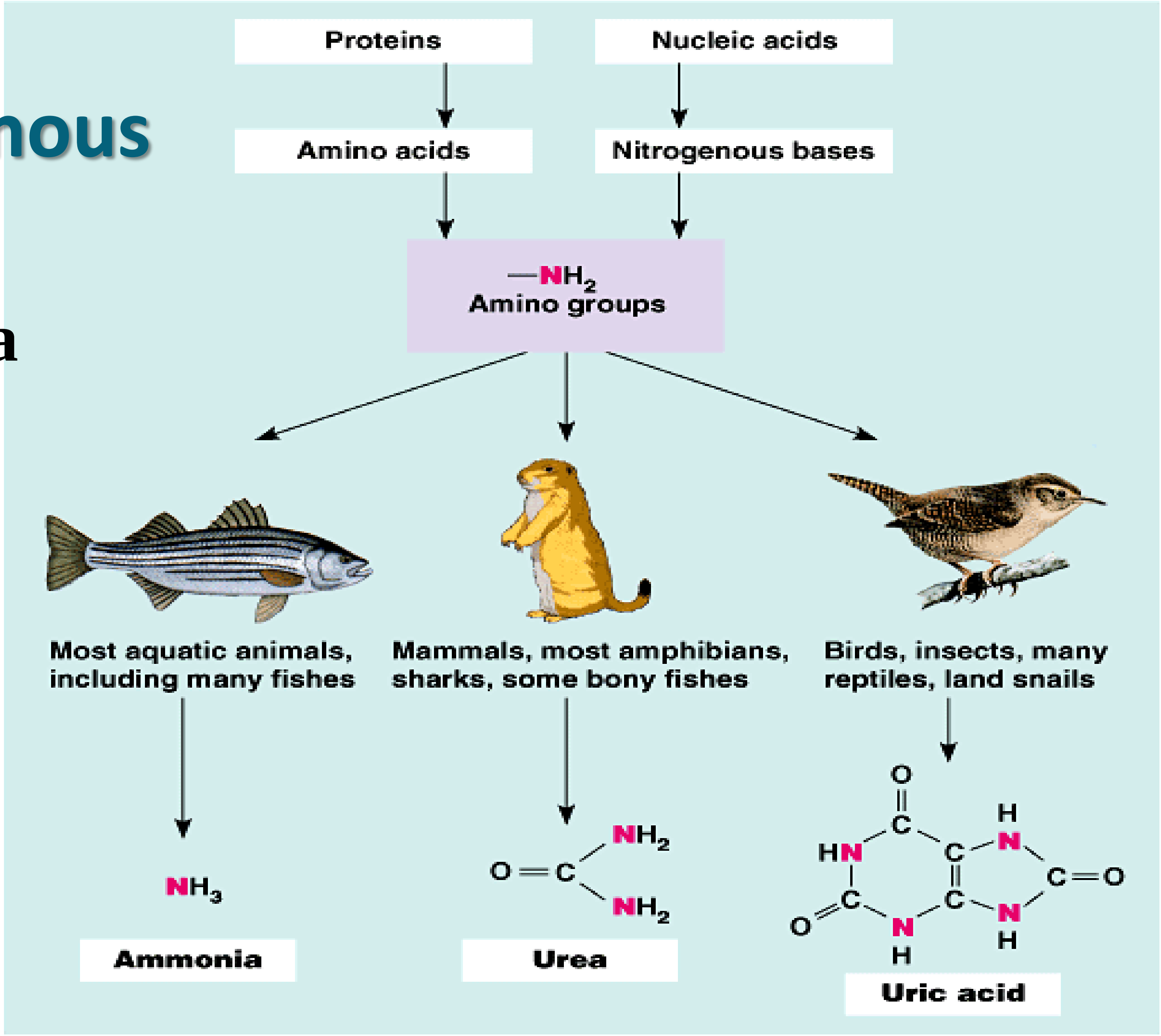
(b) Osmoregulation in a freshwater fish

Nitrogenous Wastes

Ammonia

Urea

Uric acid



What about rapid ion flux?

Euryhaline

- Short-term fluctuations in osmotic state of environment, e.g. in intertidal zone or in estuaries
- salinity can range from 10 to 34 ppt with daily tides
  - these fish have both kinds of chloride cells
    - when salinity is low, operate more like FW fishes
    - when salinity is high, operate like marine fishes
    - kidneys function only under low salinity conditions

Euryhalinity & Adaptation

- **Euryhaline organisms are able to adapt to a wide range of salinities.** An example of a euryhaline fish is the molly (*Poecilia sphenops*) which can live in fresh, brackish, or salt water. The European shore crab (*Carcinus maenas*) is an example of a euryhaline invertebrate that can live in salt and brackish water. Euryhaline organisms are commonly found in habitats such as estuaries and tide pools where the salinity changes regularly. However, some organisms are euryhaline because their life cycle involves migration between freshwater and marine environments, as is the case with salmon and eels.

How to reduce stress in stressed fish?

- Minimize the osmotic challenge by placing fish in conditions that are ***isosmotic***
  - add salt to freshwater, e.g. in transporting fish or when exposing them to some other short-term challenge
  - dilute saltwater for same situation with marine species

Challenging Osmotic Stress

- Stressors (handling, sustained exercise such as escape from predator pursuit) cause release of adrenaline (epinephrine)
- Adrenaline causes diffusivity of gill epithelium to increase (become “leaky” of water & ions)
- This accentuates the normal osmoregulatory challenge for FW or marine fishes

Osmoregulation Strategies

Osmoconforming (no strategy) Hagfish internal salt concentration = seawater. However, since they live IN the ocean….no regulation required!

Osmoregulation Strategies

Elasmobranchs (sharks, skates, rays, chimeras)

- Maintain internal salt concentration ~ 1/3 seawater, make up the rest of internal salts by retaining high concentrations of urea & trimethylamine oxide (TMAO).

- Bottom line…total internal osmotic concentration equal to seawater!

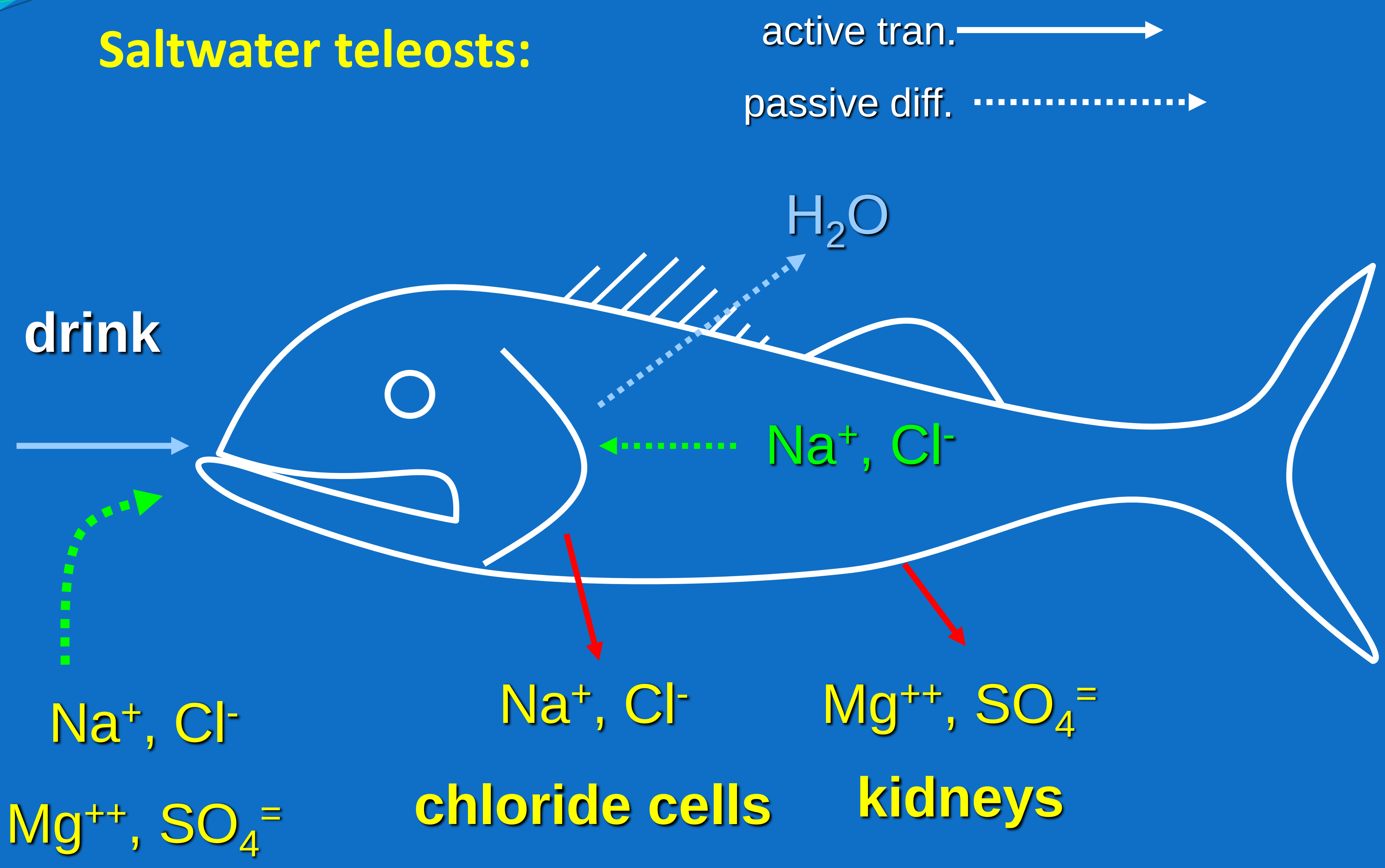
- How is urea retained?
  - Gill membrane has low permeability to urea so it is retained within the fish. Because internal inorganic and organic salt concentrations mimic that of their environment, passive water influx or efflux is minimized.

Osmotic regulation by marine teleosts...

- ionic conc. Approx. 1/3 of seawater
- drink copiously to <u>gain</u> water
- Chloride cells eliminate Na^{+} and Cl^{-}
- kidneys eliminate Mg^{++} and $SO_4^{=}$

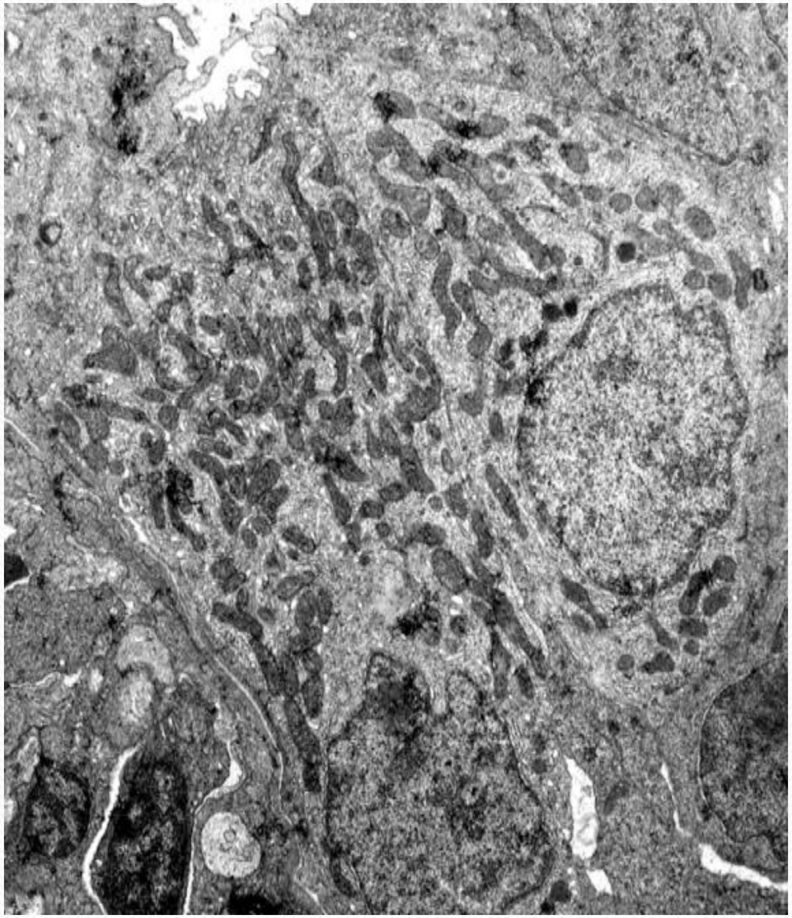
advantages and disadvantages?

Saltwater teleosts:



CHLORIDE CELLS

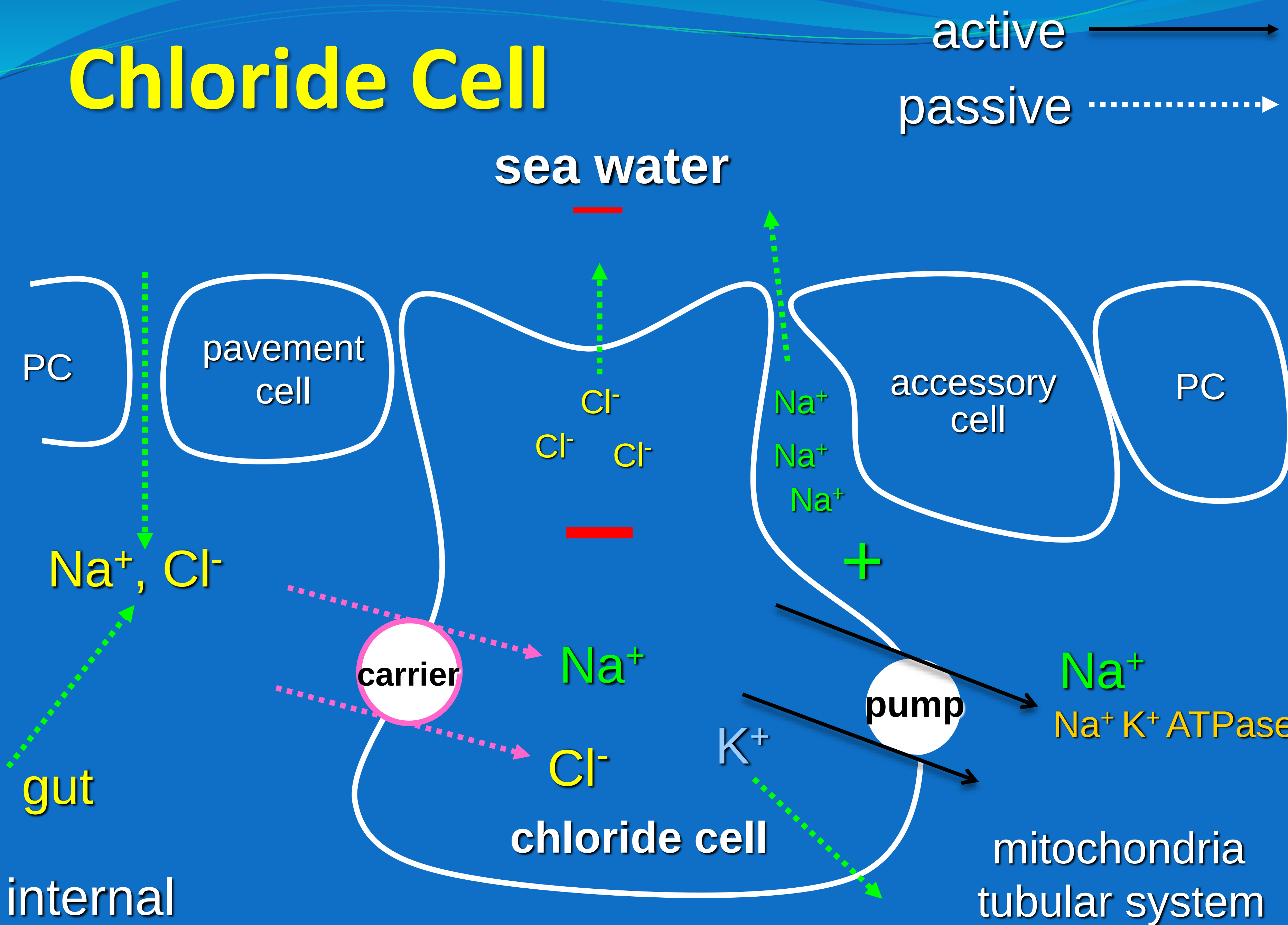
- **Chloride cells are cells in the gills of teleost fishes which pump excessive sodium and chloride ions out into the sea against a concentration gradient (Active transport). Energy cost ?**



Mechanism of action

Teleost fishes consume large quantities of seawater to reduce osmotic dehydration. The excess of ions absorbed from seawater is pumped out of the teleost fishes via the chloride cells. These cells use active transport on the basolateral (internal) surface to accumulate chloride, which then diffuses out of the apical (external) surface and into the surrounding environment. Such mitochondria-rich cells (?) are found in both the gill lamellae and filaments of teleost fish.

Chloride Cell

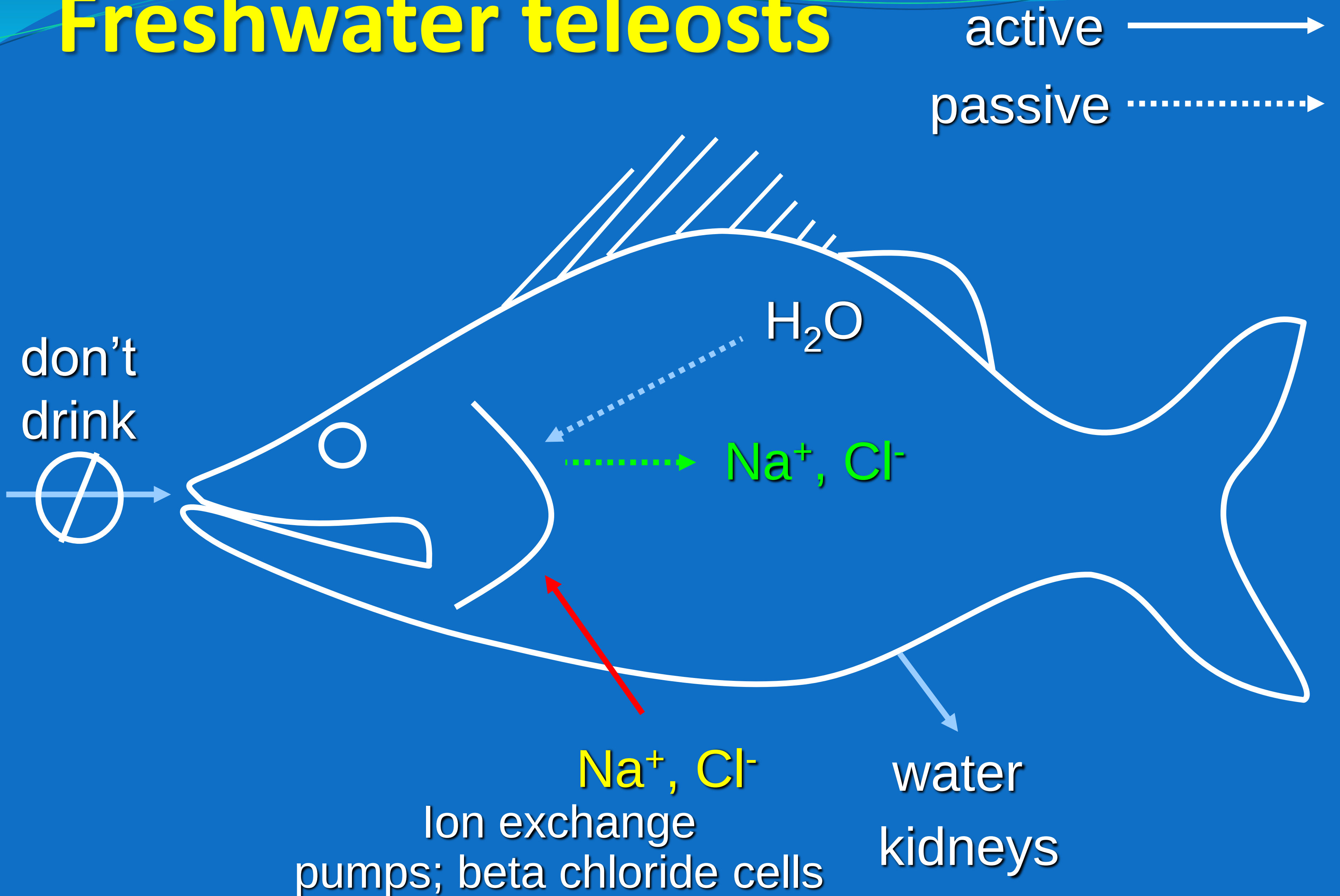


Osmotic regulation by FW teleosts

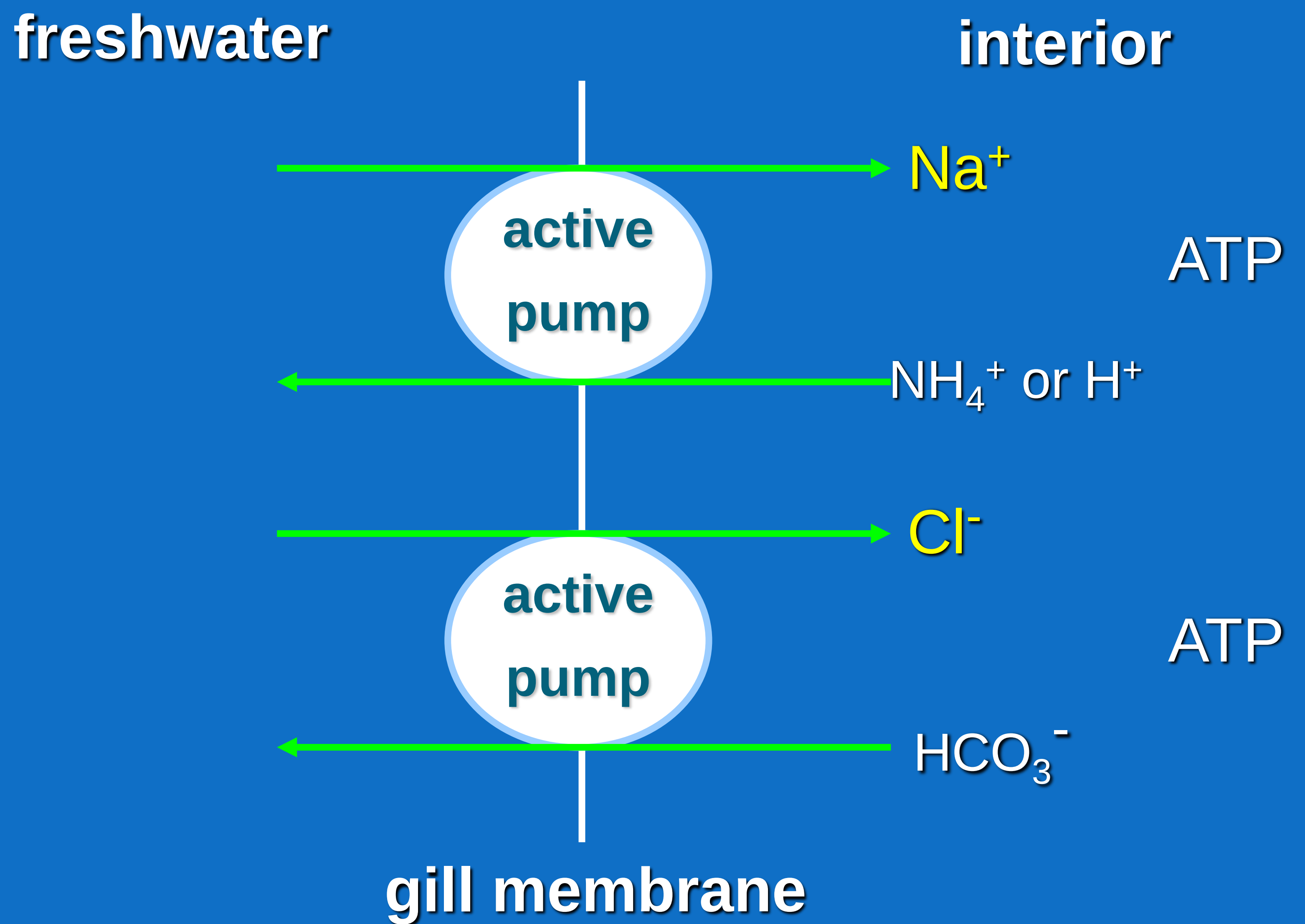
- Ionic conc. Approx. 1/3 of seawater
- Don't drink
- **Chloride cells** fewer, work in reverse
- Kidneys eliminate excess water; ion loss
- Ammonia & bicarbonate ion exchange mechanisms

advantages and disadvantages?

Freshwater teleosts



Ion Exchange Mechanisms



Conclusive discussion

- Energy cost of osmoregulation in marine, brackish water and freshwater fishes.
- Endocrine (hormone) control of osmoregulation.
- The role of kidney and rectal gland in salt balance in elasmobranchs.
- Diet and osmoregulation.
- Interactions of immune and osmoregulatory systems.