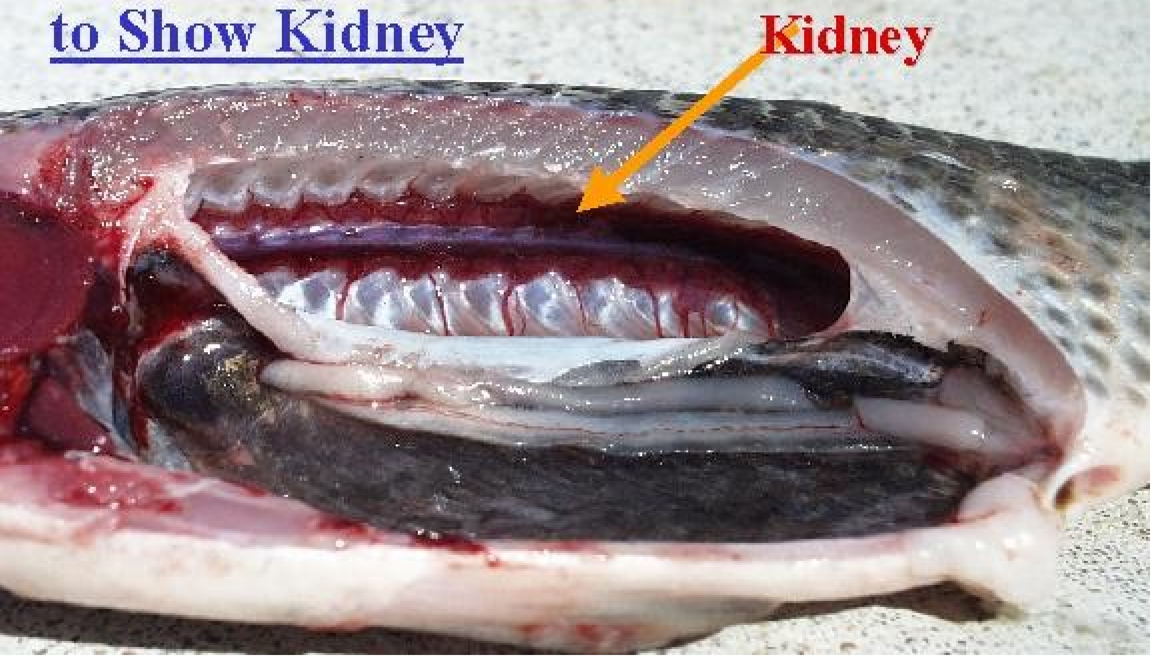
Osmoregulation & Excretion

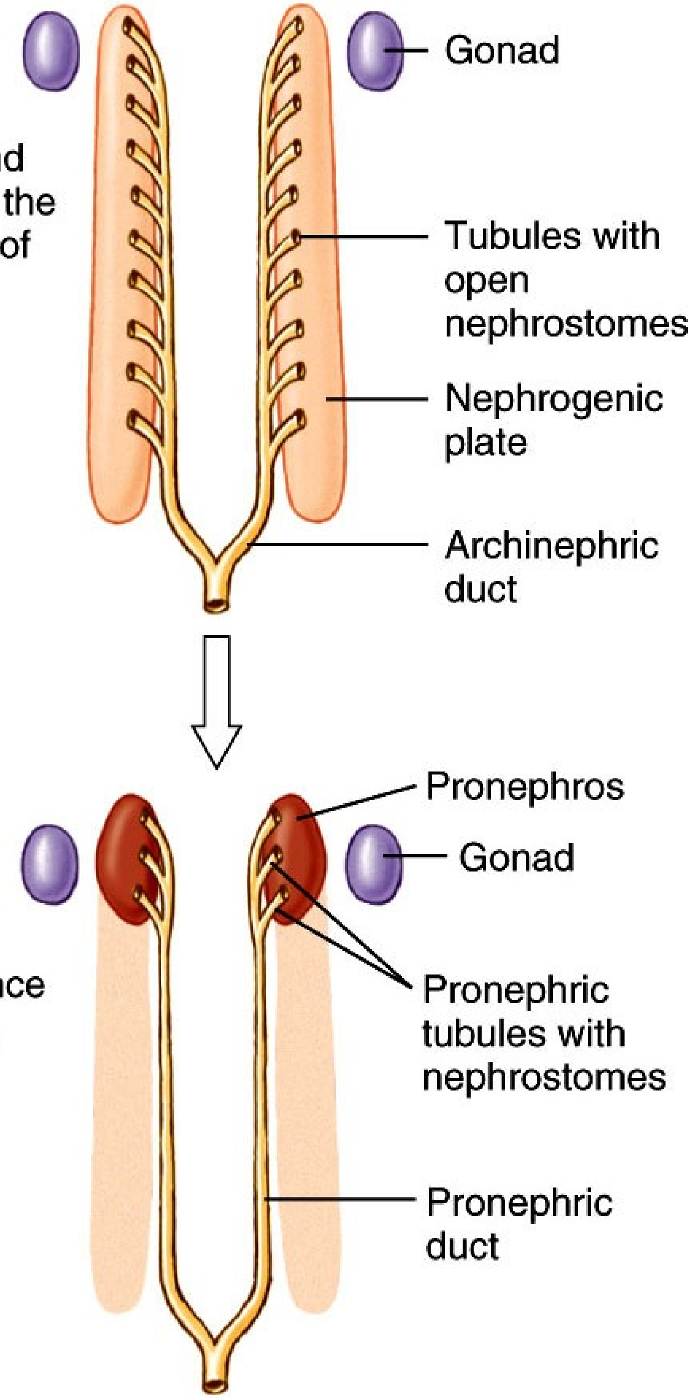


Kidney

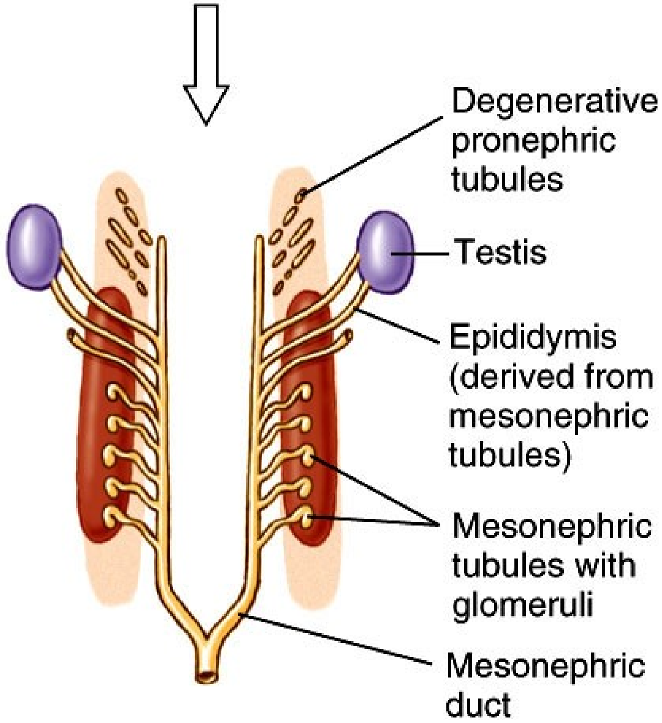
- Mesonephric, Paired, elongated, placed above the alimentary canal
- No sexual dimorphism
- Head kidney (lymphoid, hemopoietic, interrenal tissue)
- Trunk kidney (nephrons)

Archinephros: Kidney found in embryo of hagfish; this is the inferred ancestral condition of the vertebrate kidney.

Pronephros: Functional kidney in adult hagfish and embryonic fishes and amphibians; fleeting existence in embryonic reptiles, birds, and mammals



Mesonephros: Functional kidney of adult lampreys, fishes, and amphibians; transient function in embryonic reptiles, birds, and mammals



Nephron

- Renal corpuscle containing a vascularized glomerulus
- Ciliated neck connecting renal corpuscle with tubule
- Initial Proximal segment of tubule
- Second Proximal segment of tubule
- Intermediate segment
- Distal segment
- Collecting duct system

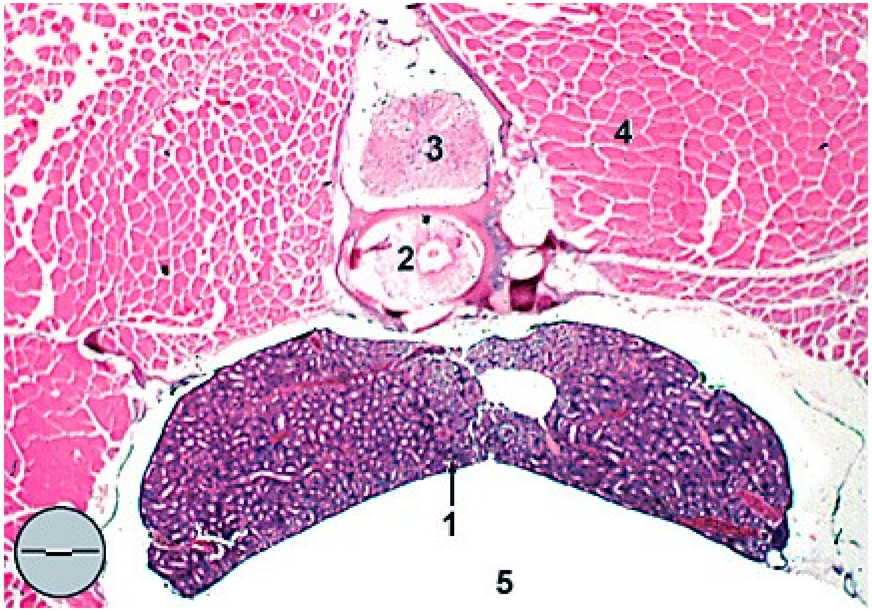
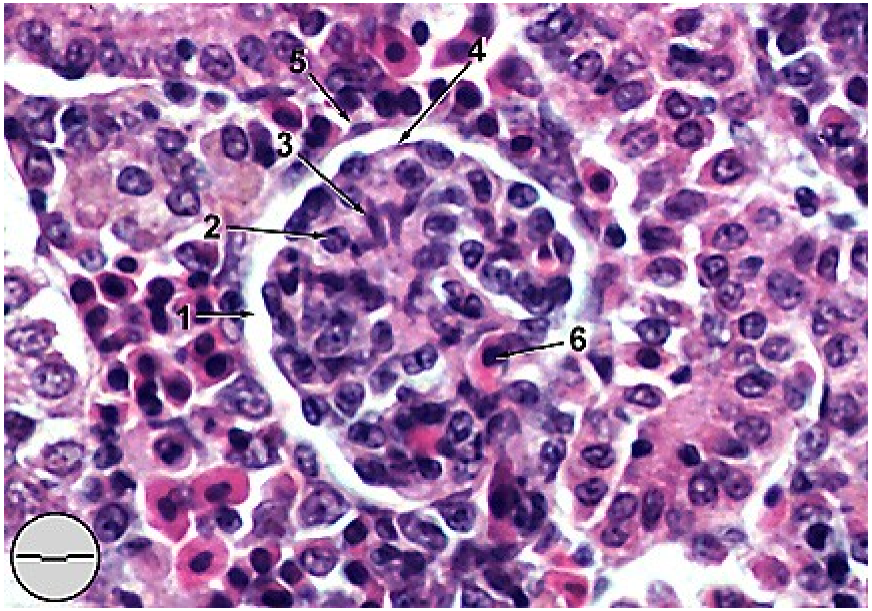


Figure 1. Trunk kidney, transverse section (Formalin, H&E, Bar = 325 µm).
1. kidney; 2. vertebrae; 3. spinal cord; 4. skeletal muscle; 5. abdominal cavity.



- **Figure 2. Glomerulus** (Formalin, H&E, Bar = 10.7 µm). 1. Bowman's space; 2. endothelial cell; 3. mesangial cell; 4. visceral epithelium of the renal capsule; 5. parietal epithelium of the renal capsule; 6. red blood cell in capillary.

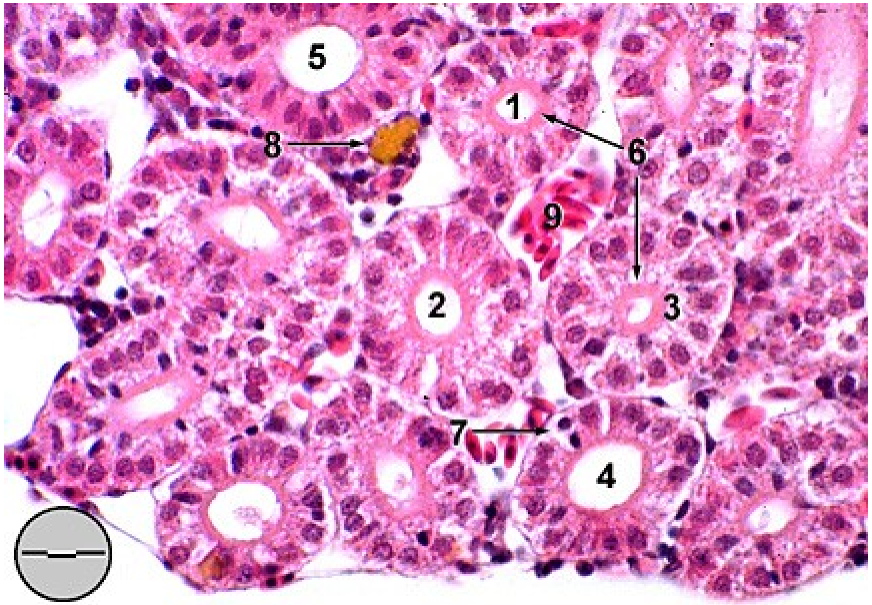
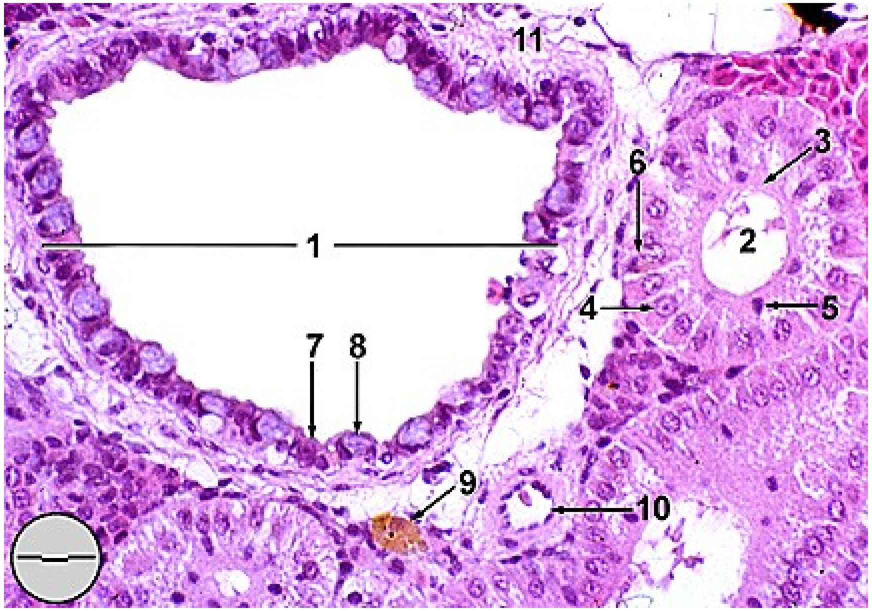


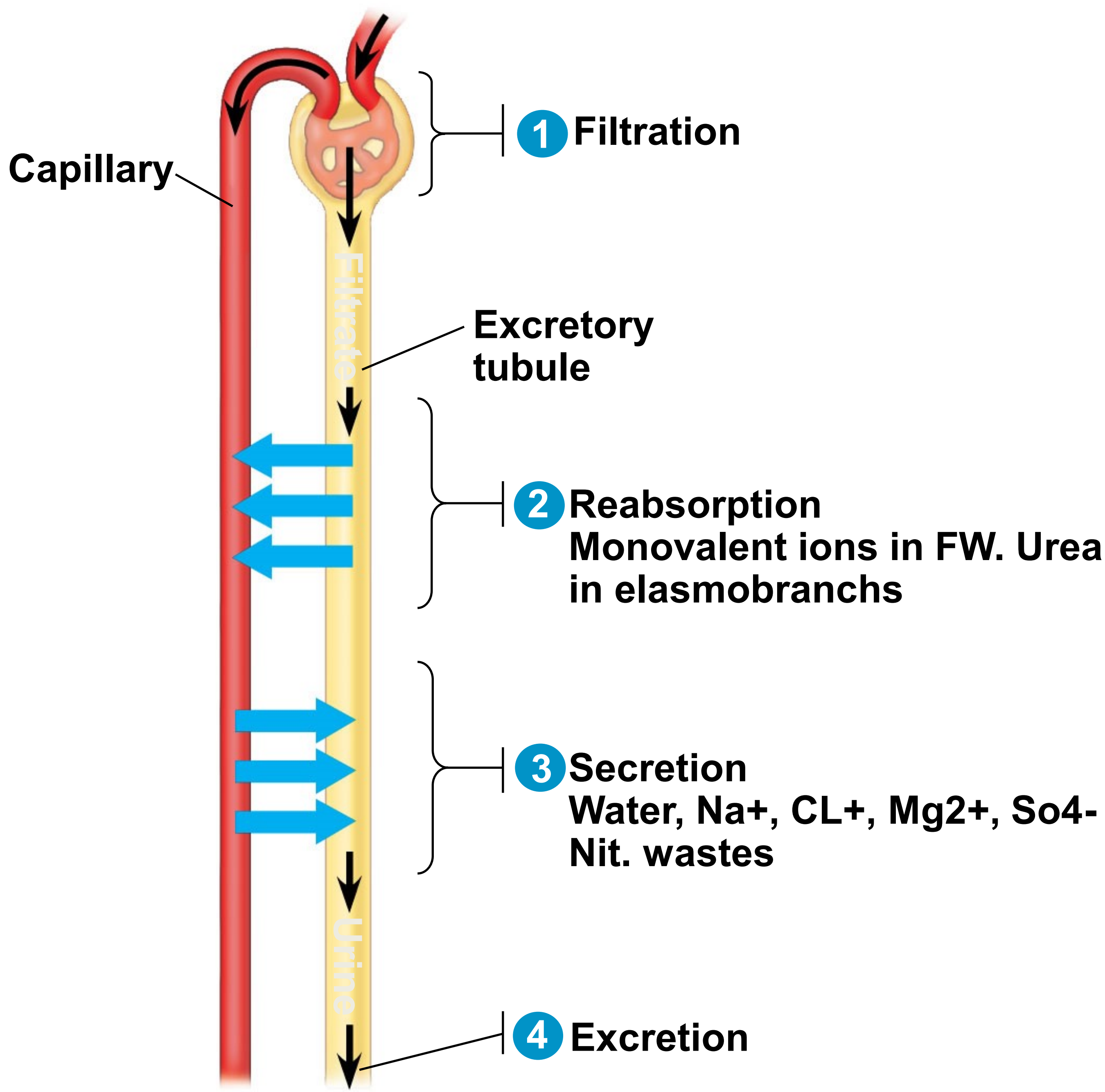
Figure 3. Kidney tubules, transverse section (2) (Formalin, H&E, Bar = 16.7 μm). 1. first proximal tubule; 2. second proximal tubule; 3. intermediate tubule segment; 4. distal tubule; 5. collecting duct; 6. brush border; 7. mitotic epithelial cell; 8. melanomacrophage; 9. red blood cells.



- **Figure 4. Large collecting duct, transverse section** (Formalin, H&E, Bar = 18.1 µm).
  1. large collecting duct ; 2. distal tubule; 3. brush border; 4. low columnar epithelial cells;
  5. intercalating cell; 6. rodlet cell; 7. pseudostratified columnar epithelial cell; 8. mucous cell;
  9. melanomacrophage; 10. artery; 11. fibrous connective tissue and smooth muscle.

Excretory Processes-Kidneys

- Excretory systems produce urine by refining a **filtrate** derived from body fluids
- Key functions of most excretory systems
  - **Filtration**: Filtering of body fluids
  - **Reabsorption**: Reclaiming valuable solutes
  - **Secretion**: Adding nonessential solutes and wastes from the body fluids to the filtrate
  - **Excretion**: Processed filtrate containing nitrogenous wastes, released from the body


1 Filtration
Capillary
Filtrate
Excretory tubule
2 Reabsorption
Monovalent ions in FW. Urea in elasmobranchs
3 Secretion
Water, Na+, CL+, Mg2+, So4-
Nit. wastes
Urine
4 Excretion

Structure & number of Nephron

- Extreme diversity among spp.
- Numerous, highly vascularized glomeruli in FW fish
- less, small, poorly vascularized glomeruli in SW fish
- Avascular glomeruli in sea horses

Urine

- Renal portal system
- Venous blood supply except to glomeruli
- Systemic pressure is average 20 mm HG
- FW spp. produce 0.1 – 1.4 ml of urine per hour per 100 g of BW
- SW spp. produce 1/10 of these values
- Clearance of water via kidney is up to 30% in FW
- Nil in SW

Urine

- Urine is more dilute as compared to plasma in FW
- Iso-osmotic with plasma in SW
- No. of functioning glomeruli can be adjusted
- GFR and urine production will change without changing the its conc.
- E.g. 45% of nephrons functional in FW while 5% in SW

Kidneys-Fish nitrogenous wastes

- The type and quantity of an animal's waste products may greatly affect its water balance
- Among the most significant wastes are nitrogenous breakdown products of proteins and nucleic acids
- Fish typically produce toxic **ammonia** (NH_3) rather then less toxic compounds
- Abundance of water to dilute toxic materials

A Balancing Act

- Relative concentrations of water and solutes internally must be maintained within fairly narrow limits
- Internal environment influenced by external environment

Osmoregulation & Excretion

- Osmoregulation
  - Regulates solute concentrations and balances the gain and loss of water

- Excretion
  - Gets rid of nitrogenous metabolites and other waste products

Osmoregulation & Excretion

- Freshwater fishes in different environments show adaptations that regulate uptake and conservation of both water and solutes

Osmoregulation & Excretion

- Osmoregulation is based largely on controlled movement of solutes between internal fluids and the external environment

Osmosis and Osmolarity

- Cells require a balance between uptake and loss of water
- **Osmolarity**, the solute concentration of a solution, determines the movement of water across a selectively permeable membrane
- If two solutions are isoosmotic, the movement of water is equal in both directions
- If two solutions differ in osmolarity, the net flow of water is from the hypoosmotic to the hyperosmotic solution

Osmotic Challenges

- **Osmoconformers**, consisting only of some marine animals, are isoosmotic with their surroundings and do not regulate their osmolarity
- **Osmoregulators** expend energy to control water uptake and loss in a hyperosmotic or hypoosmotic environment

Hagfishes

- **Osmoconformers**
- Only vertebrate that is isotonic to seawater - much like marine invertebrates

Osmoregulators

- Aquatic vertebrates - gills are chief organs of excretion/osmoregulation
- Kidneys first evolved as osmoregulatory organs in fishes to remove water (freshwater) or conserve water (marine)

Marine Animals

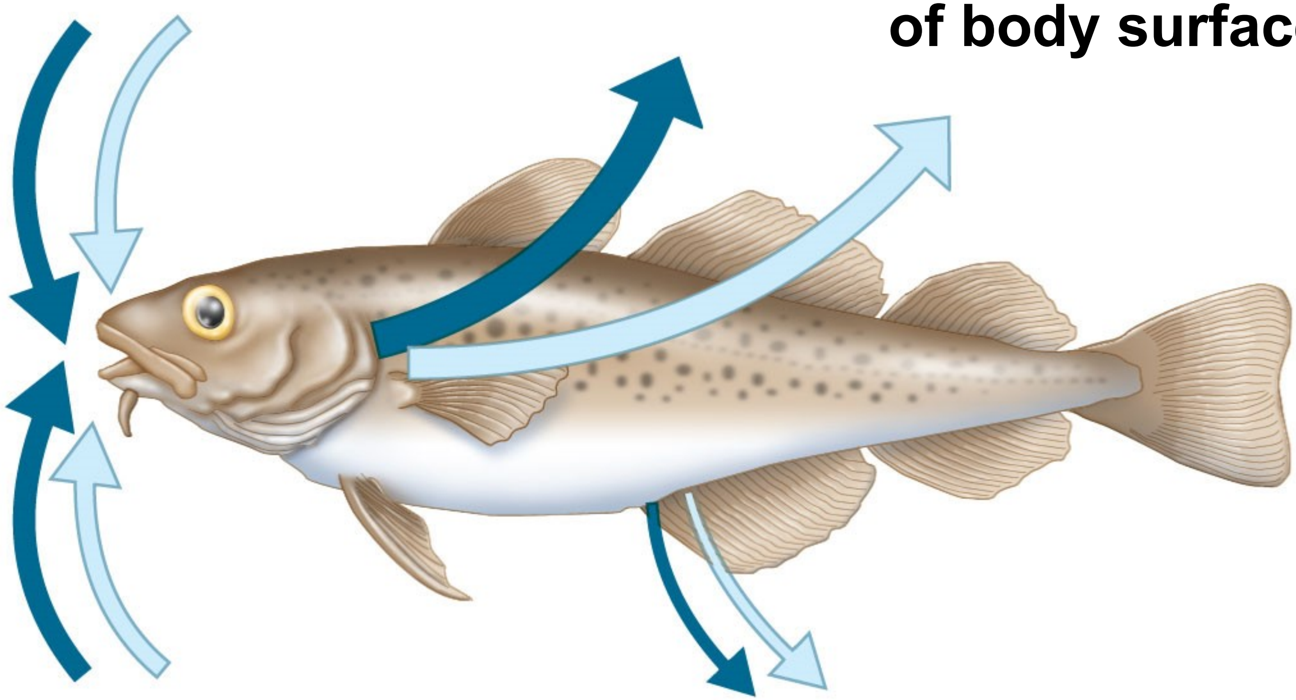
- Most marine vertebrates are osmoregulators
- Marine bony fishes are hypoosmotic to sea water
- They lose water by osmosis and gain salt by diffusion and from food
- They balance water loss by drinking seawater and excreting salts
- Kidney excretes creatinine, creatine and TMO
- Gills excretes ammonia & urea

(a) Osmoregulation in a marine fish

Gain of water and salt ions from food

Excretion of salt ions from gills

Osmotic water loss through gills and other parts of body surface



Gain of water and salt ions from drinking seawater

Excretion of salt ions and small amounts of water in scanty urine from kidneys

Key

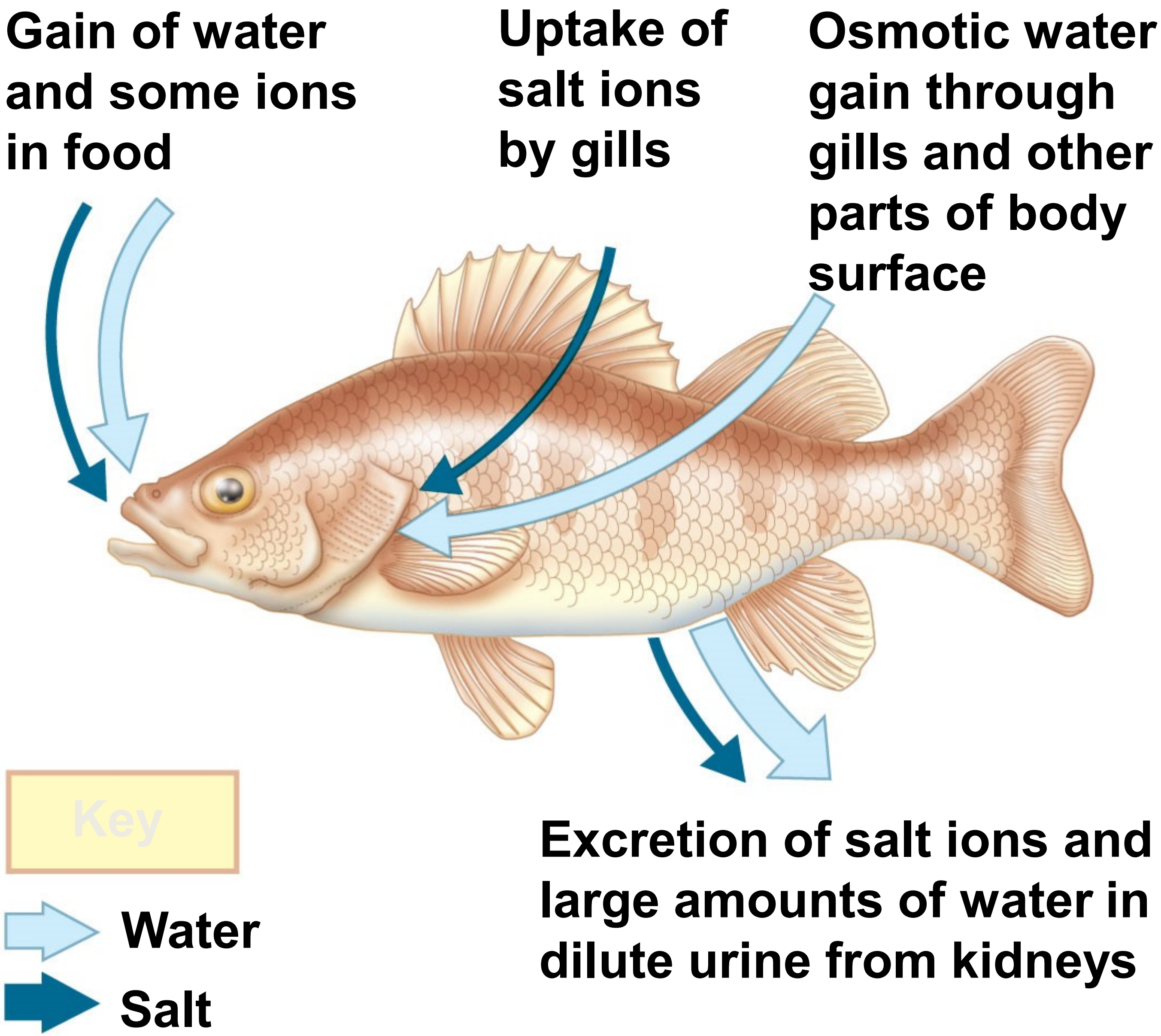
Water

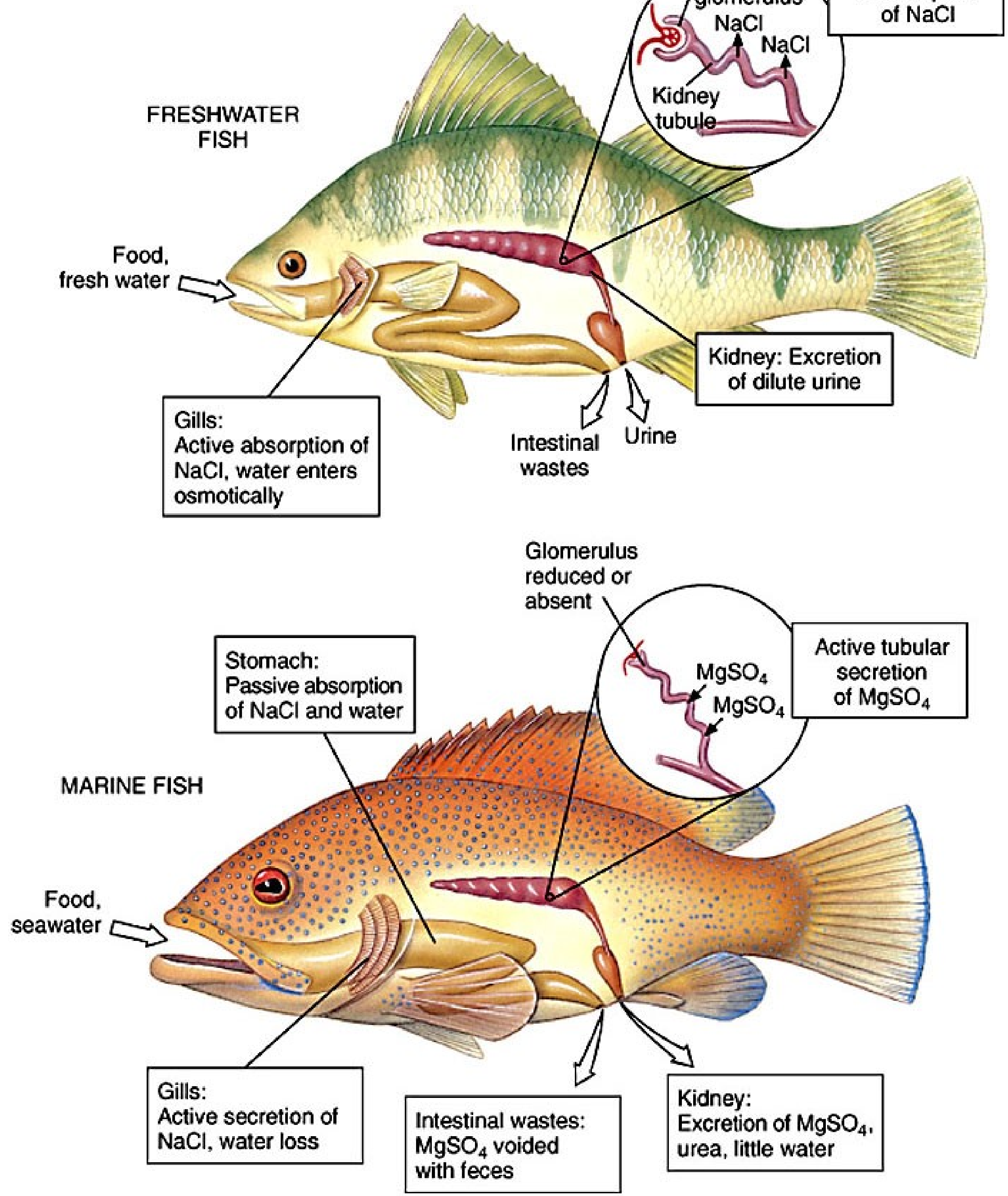
Salt

Freshwater

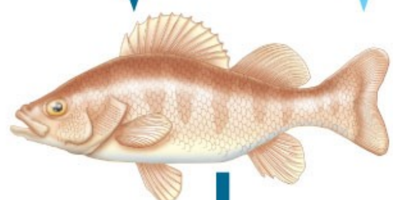
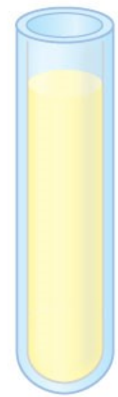
- A different form of osmoregulator
- Freshwater animals constantly take in water by osmosis from their hypoosmotic environment
- lose salts by diffusion and maintain water balance by excreting large amounts of dilute urine
- Salts lost by diffusion are replaced in foods and by uptake across the gills
- N2 wastes are excreted more from gills than kidney (6-10 times in carps)
- Kidney excretes creatinine & uric acid
- Gills excretes ammonia & urea

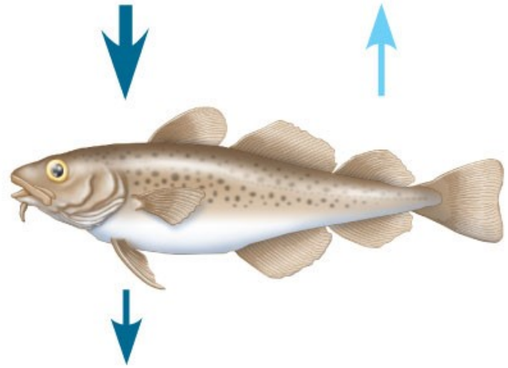
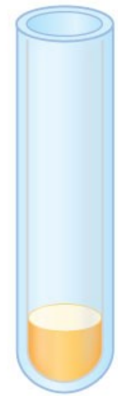
(b) Osmoregulation in a freshwater fish





NaCl
NaCl
of NaCl
Kidney tubule
FRESHWATER FISH
Food, fresh water
Kidney: Excretion of dilute urine
Gills: Active absorption of NaCl, water enters osmotically
Intestinal wastes
Urine
Glomerulus reduced or absent
$MgSO_4$
$MgSO_4$
Active tubular secretion of $MgSO_4$
Stomach: Passive absorption of NaCl and water
MARINE FISH
Food, seawater
Gills: Active secretion of NaCl, water loss
Intestinal wastes: $MgSO_4$ voided with feces
Kidney: Excretion of $MgSO_4$, urea, little water

Animal	Inflow/Outflow	Urine
Freshwater fish. Lives in water less concentrated than body fluids; fish tends to gain water, lose salt	Does not drink water Salt in (active transport by gills) H_2O in  Salt out	 ▶ Large volume of urine ▶ Urine is less concentrated than body fluids

Animal	Inflow/Outflow	Urine
Marine bony fish. Lives in water more concentrated than body fluids; fish tends to lose water, gain salt	Drinks water Salt in H_2O out  Salt out (active transport by gills)	 ▶ Small volume of urine ▶ Urine is slightly less concentrated than body fluids

Freshwater fishes

- Large volume of urine, salts are reabsorbed in the distal tubules

Rainbow trout
(*Oncorrhynchus mykiss*)

Marine bony fishes

- Problem: gain salts from environment and tend to lose water
- Lack distal tubule, smaller glomerulus, can adjust amount of urine

Northern bluefin tuna (*Thunnus thynnus*)

- Marine cartilaginous fishes:
  - Shark tissue contains a high concentration of urea
  - To prevent urea from damaging other organic molecules in the tissues, they have trimethyl amine oxide (TMAO)
  - Because of high solute concentration in tissue, water enters the cells (sharks don't drink)
  - Produce concentrated urine

- Euryhaline organisms like salmon:
  - In sea, they drink sea water and discharge salt through their gills
  - In freshwater, they stop drinking and produce large volumes of dilute urine, gills take up salt