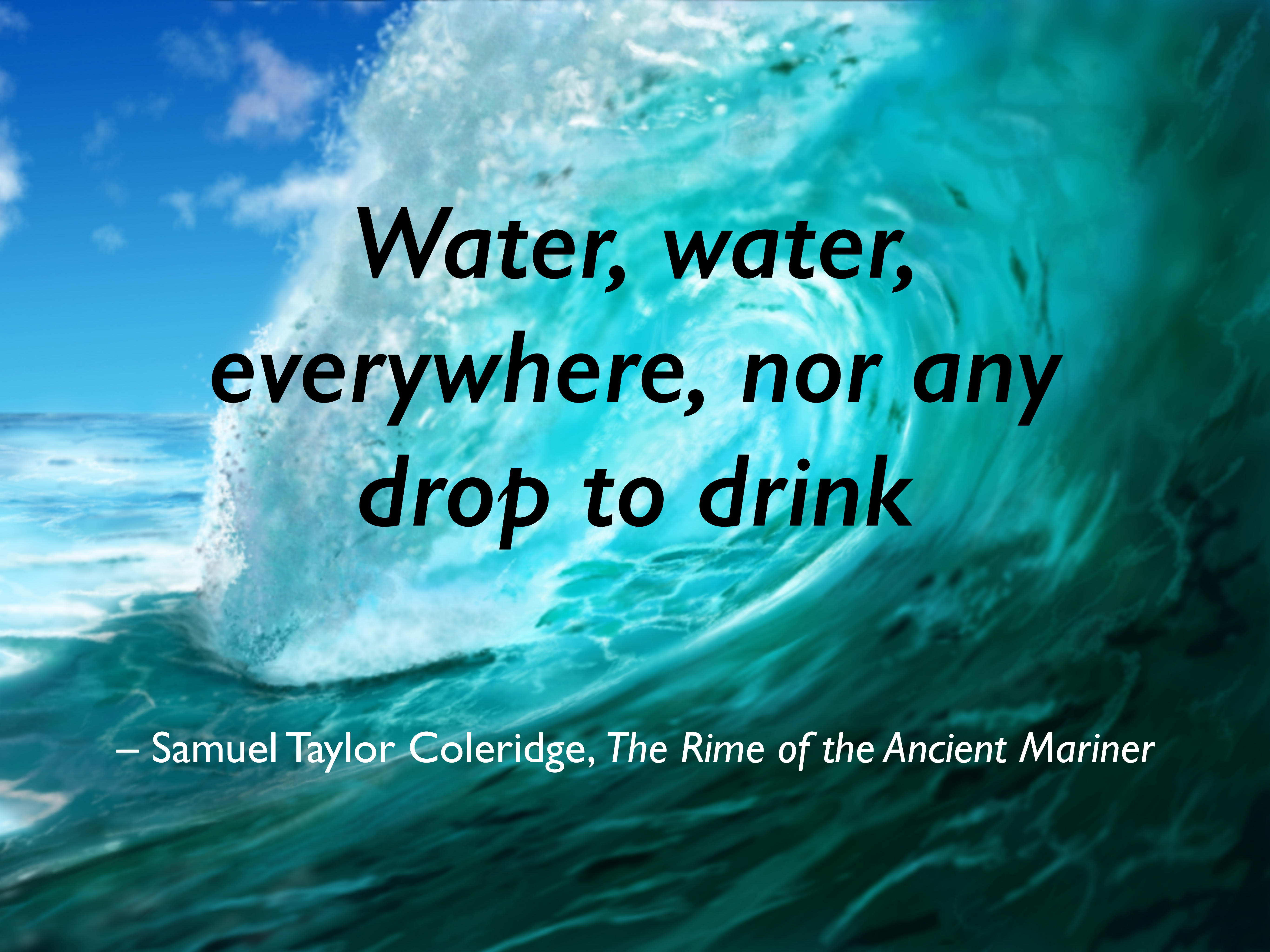

Water, water, everywhere, nor any drop to drink
– Samuel Taylor Coleridge, *The Rime of the Ancient Mariner*

Water Sources: Challenges & Strategies

- Freshwater aquatic organisms:
  - –Constantly gain water, or are water impermeable
- Saltwater aquatic organisms:
  - –Drink seawater and excrete salt
  - –Drink no seawater and obtain water from less salty food
- Terrestrial organisms:
  - –Drink freshwater
  - –Drink seawater and excrete salt
  - –Drink no water and obtain water from food
    - Free water & Metabolic water
  - –Obtain water from condensation

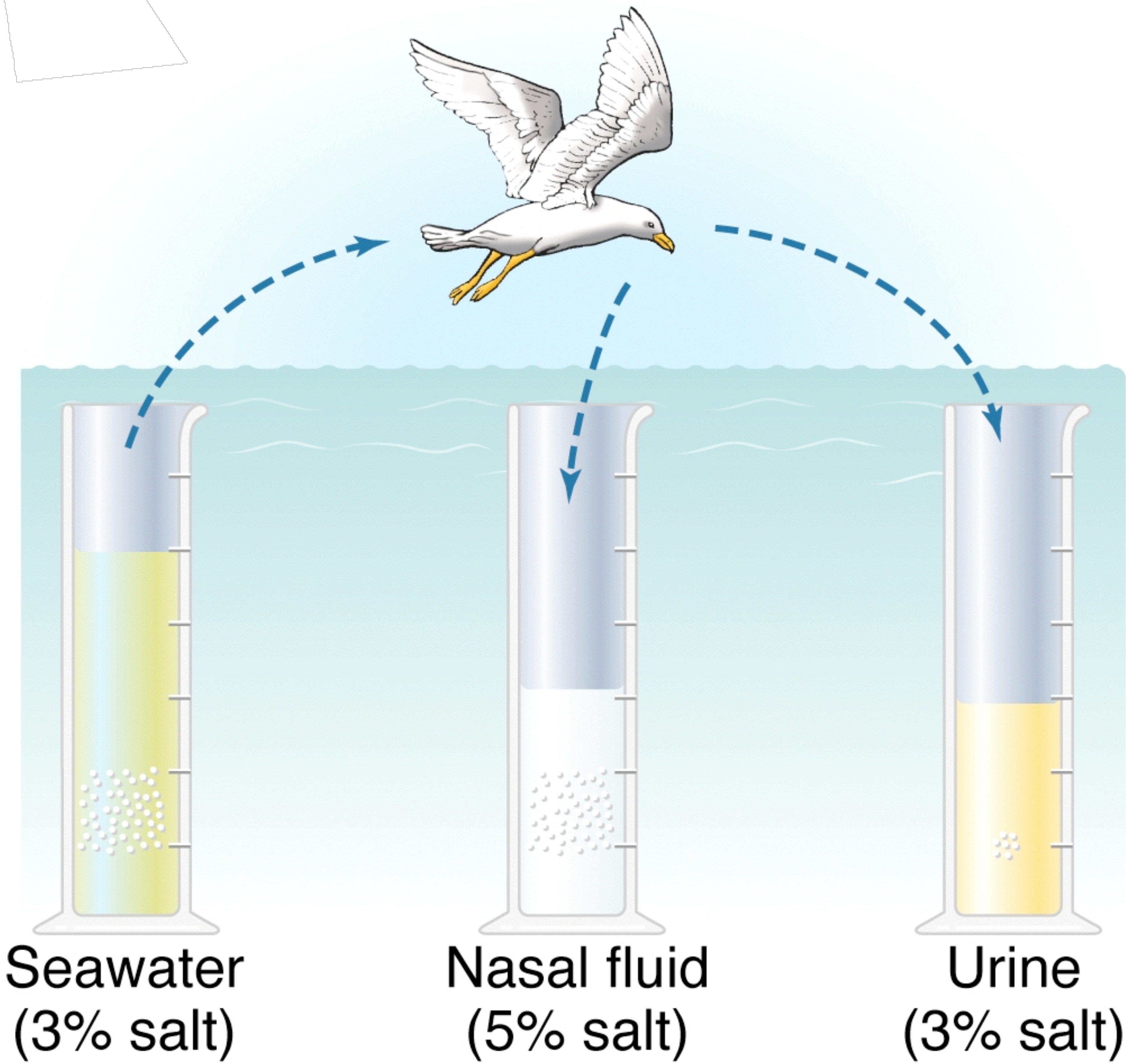
Table 14-1 Composition of extracellular fluids of representative animals*

	Habitat*	Osmolarity (mosM)	Ionic concentrations (mM) Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	HPO_4^{2-}	Urea
Seawater†		1000	460	10	10	53	540	27		
Chondrichthyes										
Dogfish shark	SW	1075	269	4.3	3.2	1.1	258	1	1.1	376
Carcharhinus	FW		200	8	3	2	180	0.5	4.0	132
Coelacantha										
Latimeria	SW		181	51.3	6.9	28.7	199			355
Teleostei										
Paralichthys (flounder)	SW	337	180	4	3	1	160	0.2		
Carassius (goldfish)	FW	293	142	2	6	3	107			
Amphibia										
Rana esculenta (frog)	FW	210	92	3	2.3	1.6	70			2
Rana cancrivora	FW	290	125	9			98			40
	80% SW	830	252	14			227			350
Reptilia										
Alligator	FW	278	140	3.6	5.1	3.0	111			
Aves										
Anas (duck)	FW	294	138	3.1	2.4		103		1.6	
Mammalia										
Homo sapiens	Ter.	260	142	4.0	5.0	2.0	104	1	2	
Lab rat	Ter.		145	6.2	3.1	1.6	116			

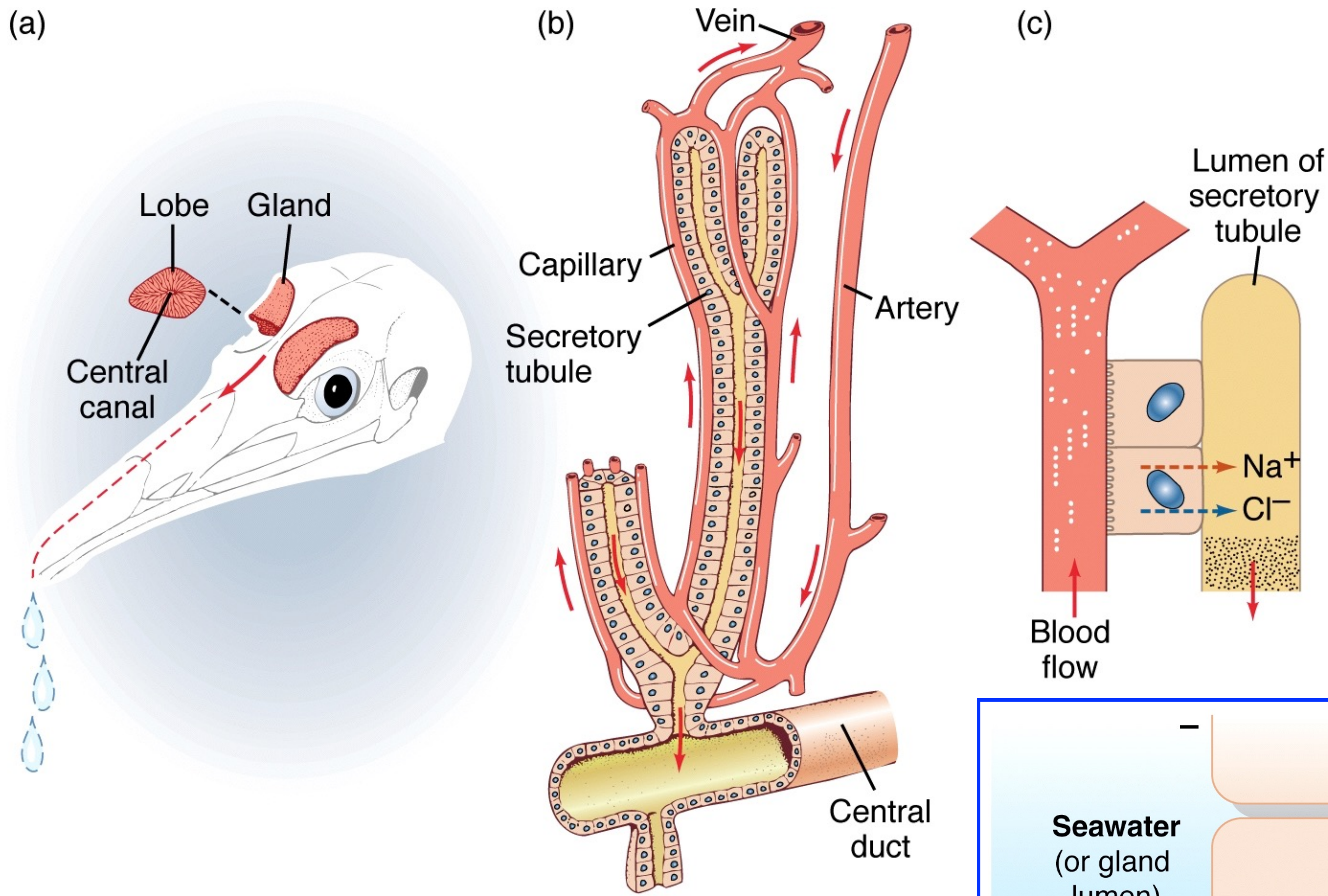
* The osmolarity and composition of seawater vary, and the values given here are not intended to be absolute. The composition of body fluids of osmoconformers will also vary, depending on the composition of the seawater in which they are tested.
† SW = seawater; FW = freshwater; Ter. = terrestrial.
Sources: Schmidt-Nielsen and Mackay, 1972; Prosser, 1973.

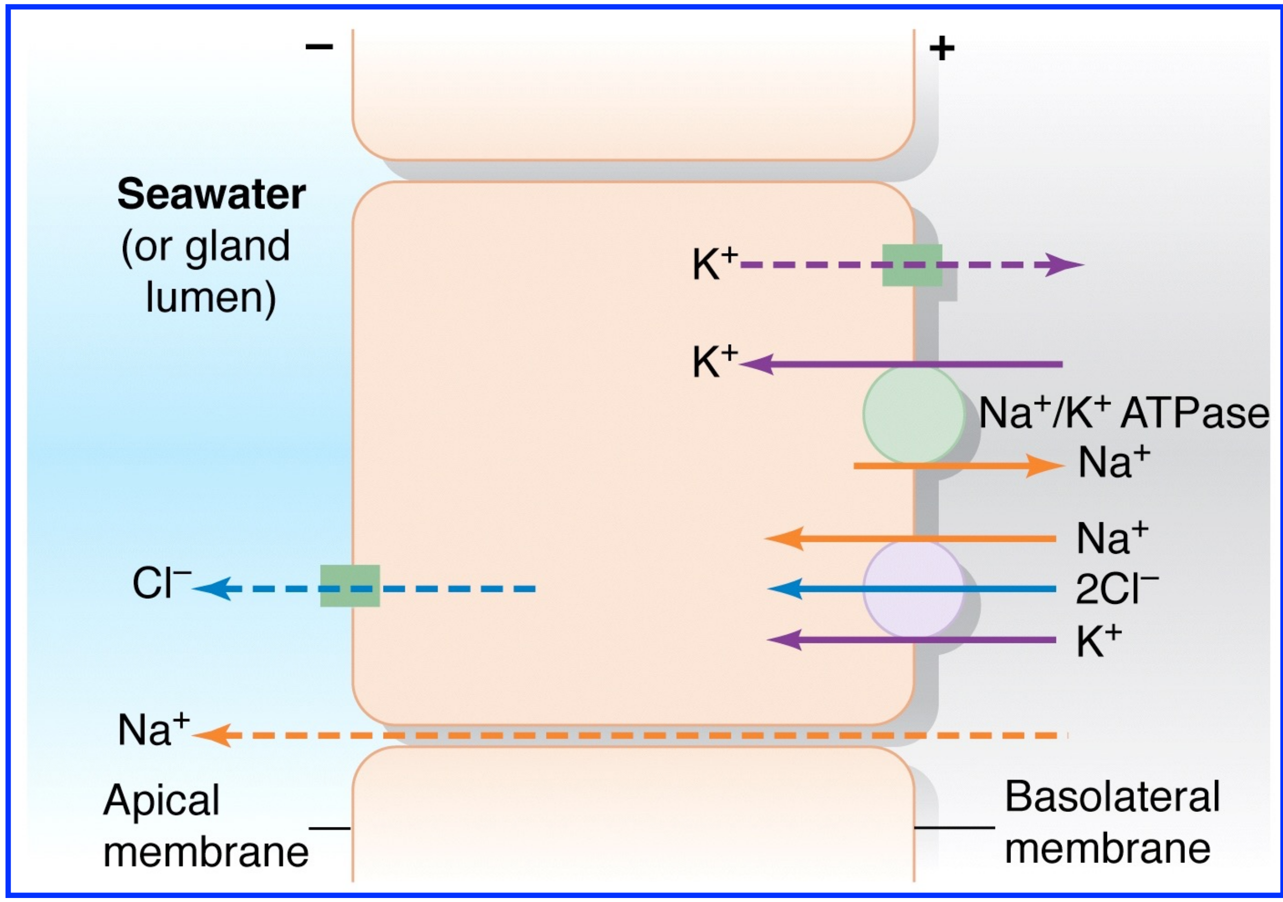
Drinking seawater is a losing strategy for most terrestrial vertebrates

Marine birds, reptiles, and fish excrete salt, so can obtain pure water from seawater

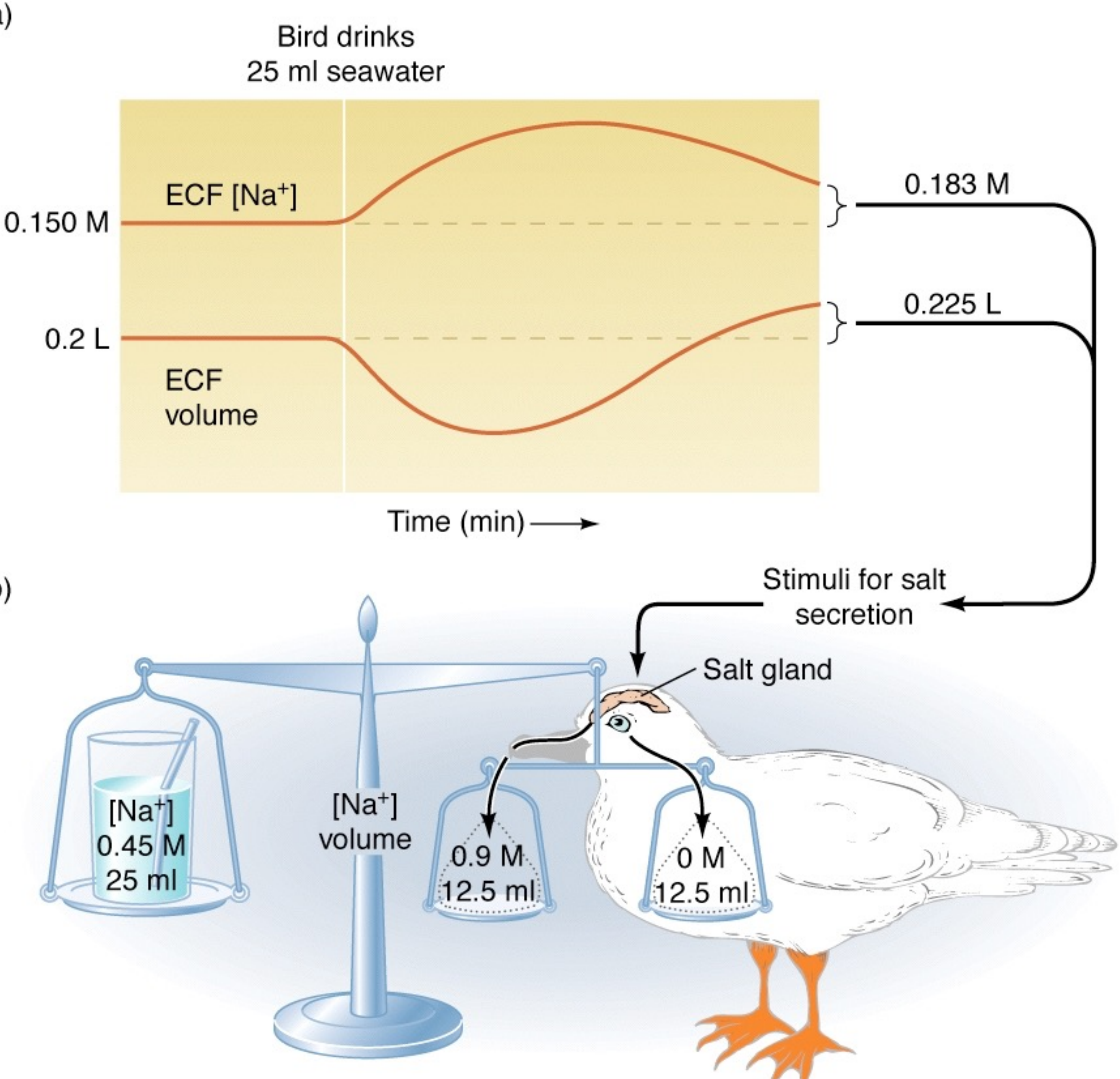


Salt Gland also a countercurrent multiplier





Salt balance in seabirds



Stimulus for nasal salt gland operation is the extracellular fluid volume and Na+ concentration

If a bird drinks 100ml of seawater (1000mOsm) and produces a salty secretion (1200mOsm), how much water does it gain?

salt water → salty secretion   pure water

$$(100ml)(1000\ mOsm) = X(1200mOsm) + (100-x\ ml)(0\ mOsm)$$

volume * osmolarity

$$X = \frac{100{,}000}{1200}\ ml$$

$$= 83.3\ ml$$ of salty secretion

And

$$100-X = 16.7\ ml$$ of pure water gained

Water Flux through Skin

A duck stands in a pond. How much water is lost or gained through the skin of the feet?

Water flux ~ osmotic permeability pg. 785

$$F_{H20} = P_{osm} * SA \left(\frac{n_{s,i}}{n_{w,i}} - \frac{n_{s,o}}{n_{w,o}} \right)$$

P_{osm}: Water flux ~ osmotic permeability
$n_{s,i}$: moles solute inside
$n_{s,o}$: moles solute outside
$n_{w,i}$: moles water inside
$n_{w,o}$: moles water outside

*Remember, the Molecular Weight of Water is 18 g/mol, which you can use to calculate the number of moles H_20/L to match the Osm of the solute (moles/L) which will give you moles/moles.

*P_{osm} is in units of μ/sec. $\mu m^3/\mu m^2 sec.$

μm^3: volume
μm^2: surface area

Kangaroo Rat
A small mammal in a hot, dry environment.

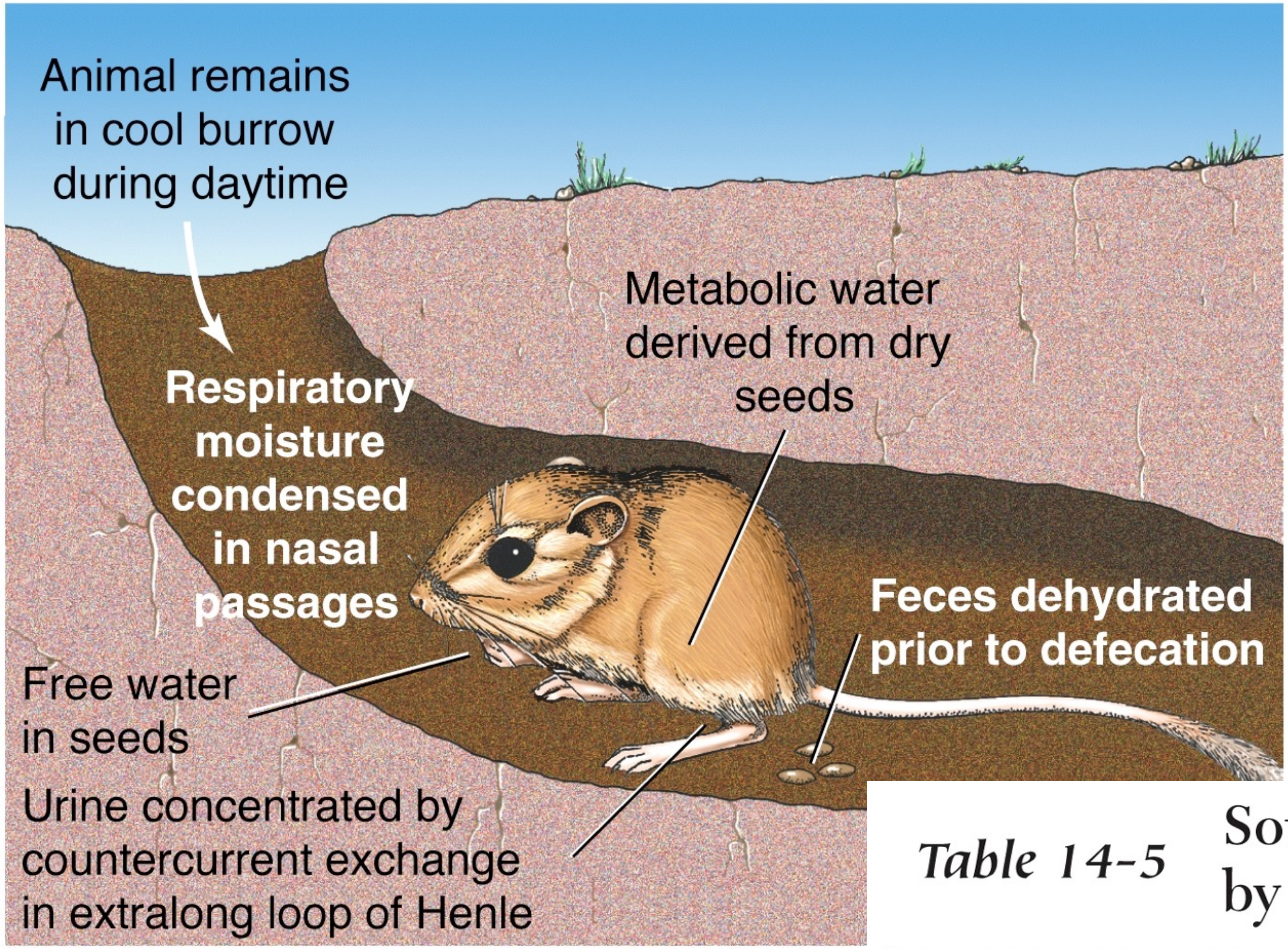


Table 14-5 **Sources of water gain and loss by the kangaroo rat**

Gains		Losses	
Metabolic water	90%	Evaporation and perspiration	70%
Free water in "dry" food	10%	Urine	25%
Drinking	0%	Feces	5%
	100%		100%

Source: Schmidt-Nielsen, 1972.

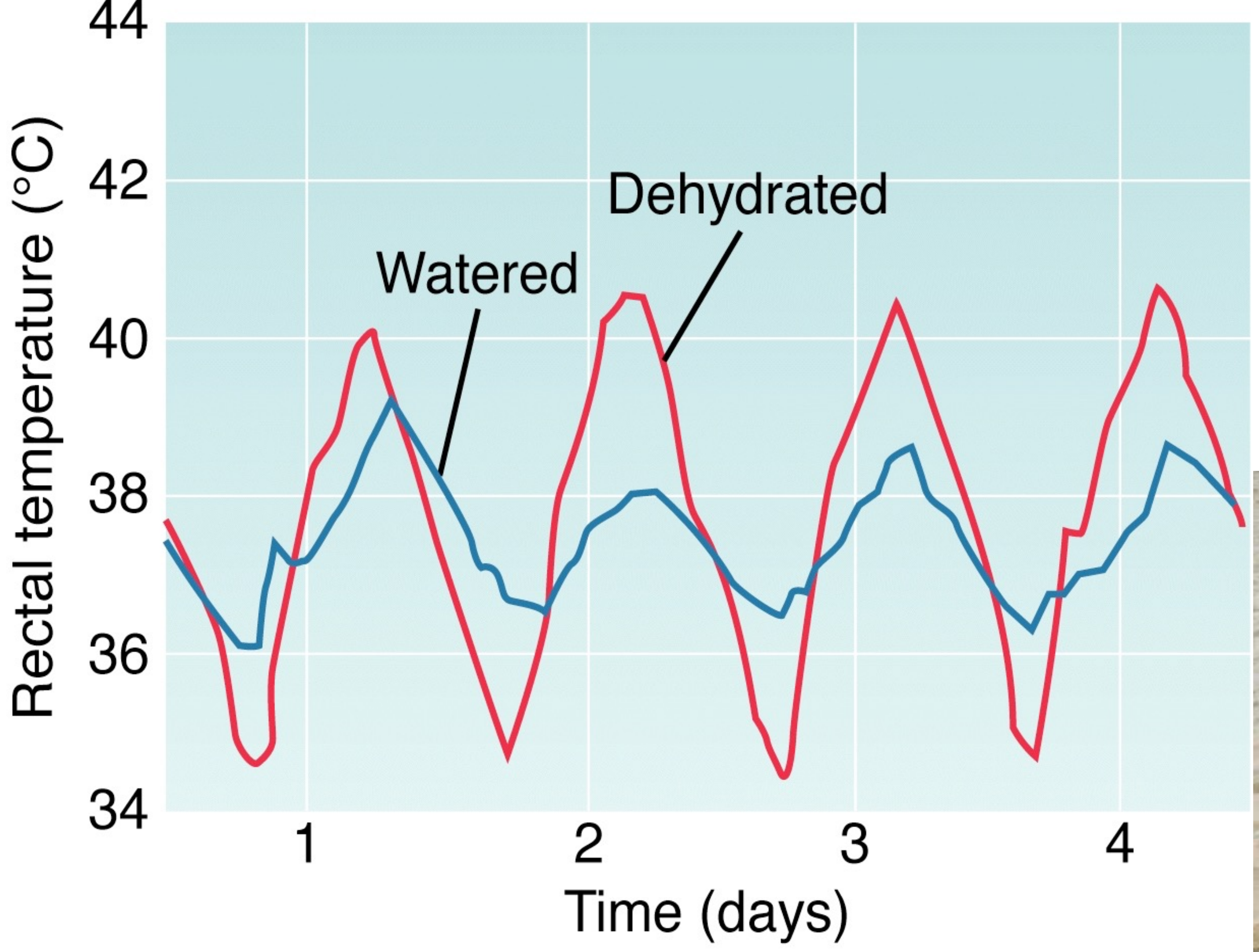
Metabolic Water - Easy!

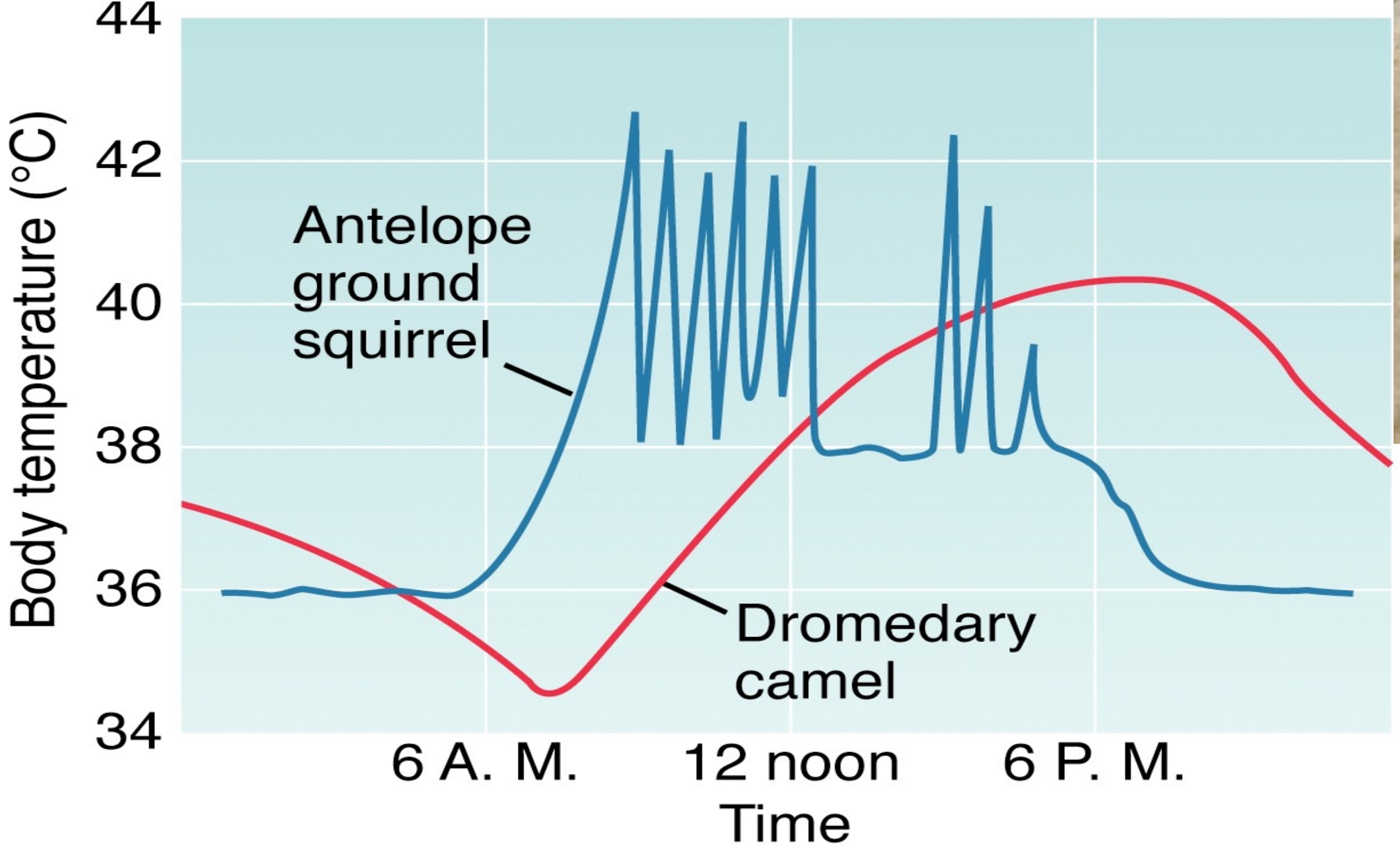
Produced by **Metabolism** of foods (not water content of foods)

Table 14-4 **Production of metabolic water during oxidation of foods**

	Food		
	Carbohydrates	Fats	Proteins
Grams of metabolic water per gram of food	0.56	1.07	0.40
Kilojoules expended per gram of food	17.58	39.94	17.54
Grams of metabolic water per kilojoule expended	0.032	0.027	0.023

Source: Edney and Nagy, 1976.





Camel
Large mammal in a hot, dry environment. - nowhere to hide!

Maximum concentrating ability of the kidney

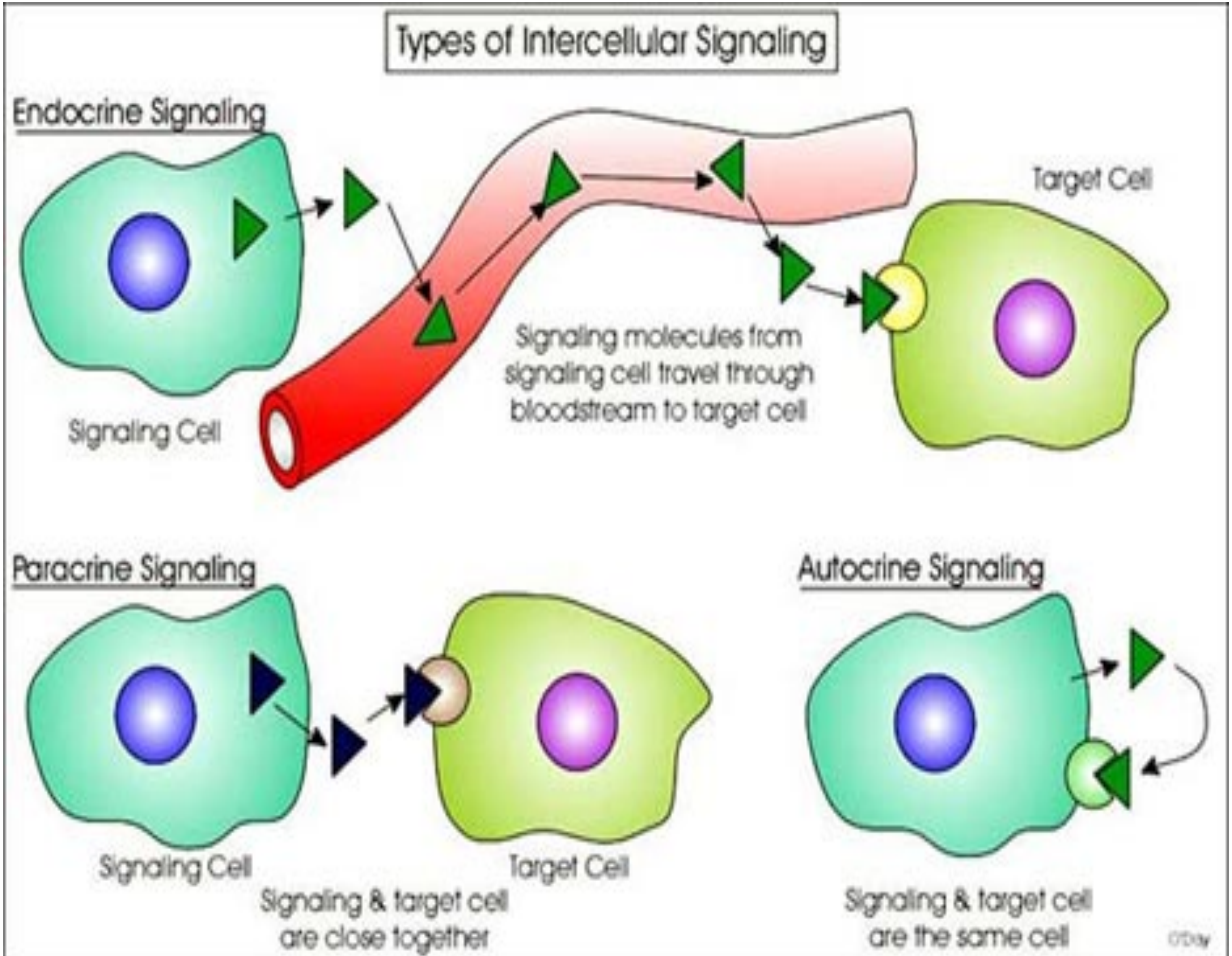
Animal	Urine maximum osmotic concentration (Osm liter^{-1})	Urine/plasma concentration ratio
Beaver[a]	0.52	2
Pig[a]	1.1	3
Man[b]	1.4	4
White rat[b]	2.9	9
Cat[b]	3.1	10
Kangaroo rat[b]	5.5	14
Sand rat[b]	6.3	17
Hopping mouse[c]	9.4	25

[a] B. Schmidt-Nielsen and O'Dell (1961).
[b] K. Schmidt-Nielsen (1964).
[c] MacMillen and Lee (1967).

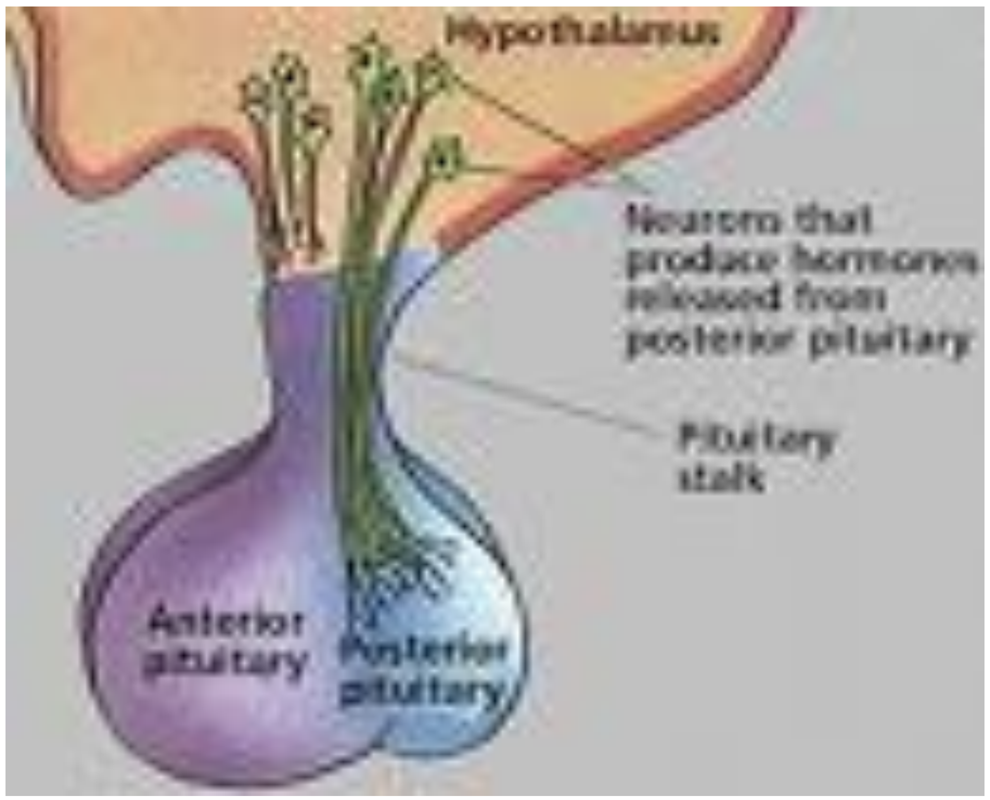
Knut Schmidt-Nielsen 1997. Animal Physiology: Adaptation and Environment. Cambridge University Press

Control via the Endocrine System

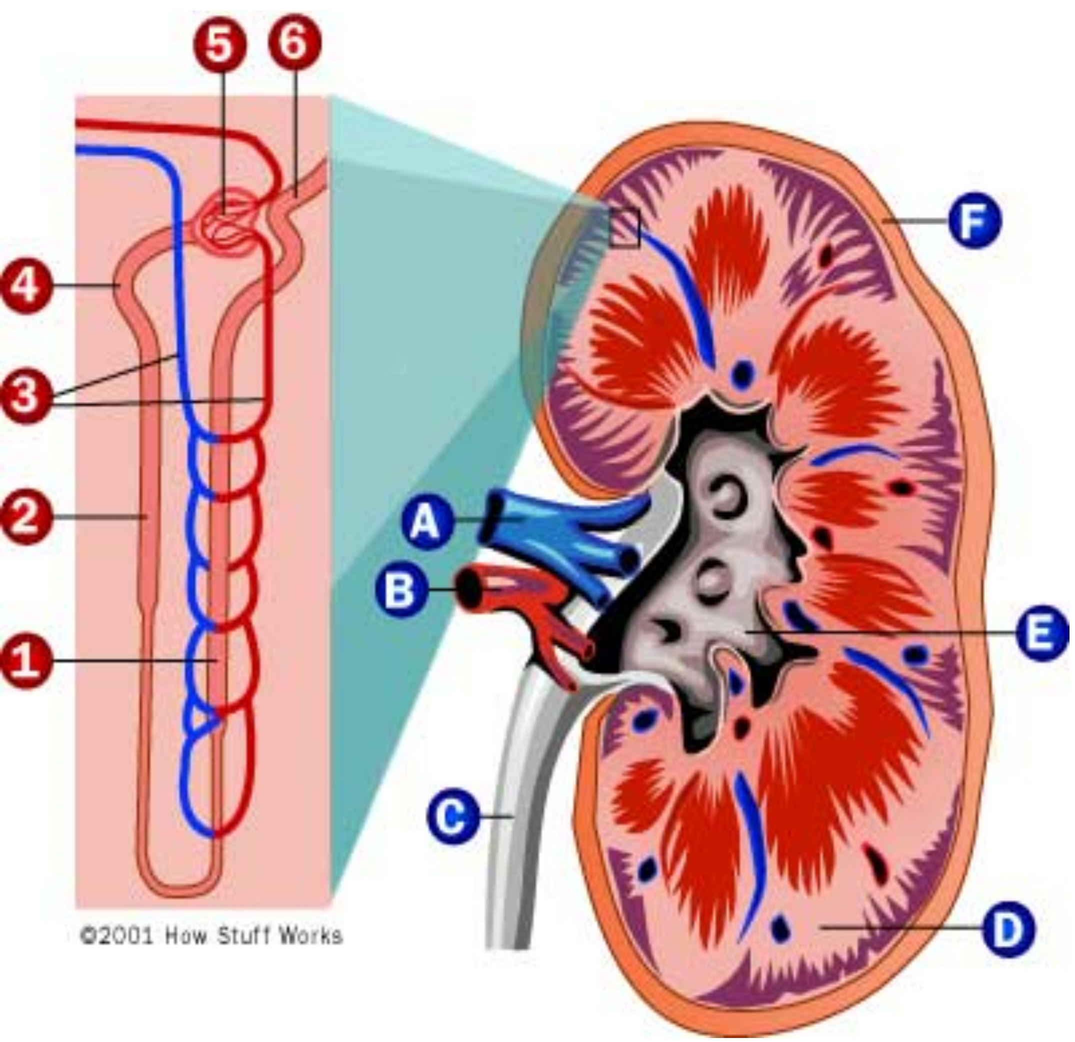
Cell to cell communication

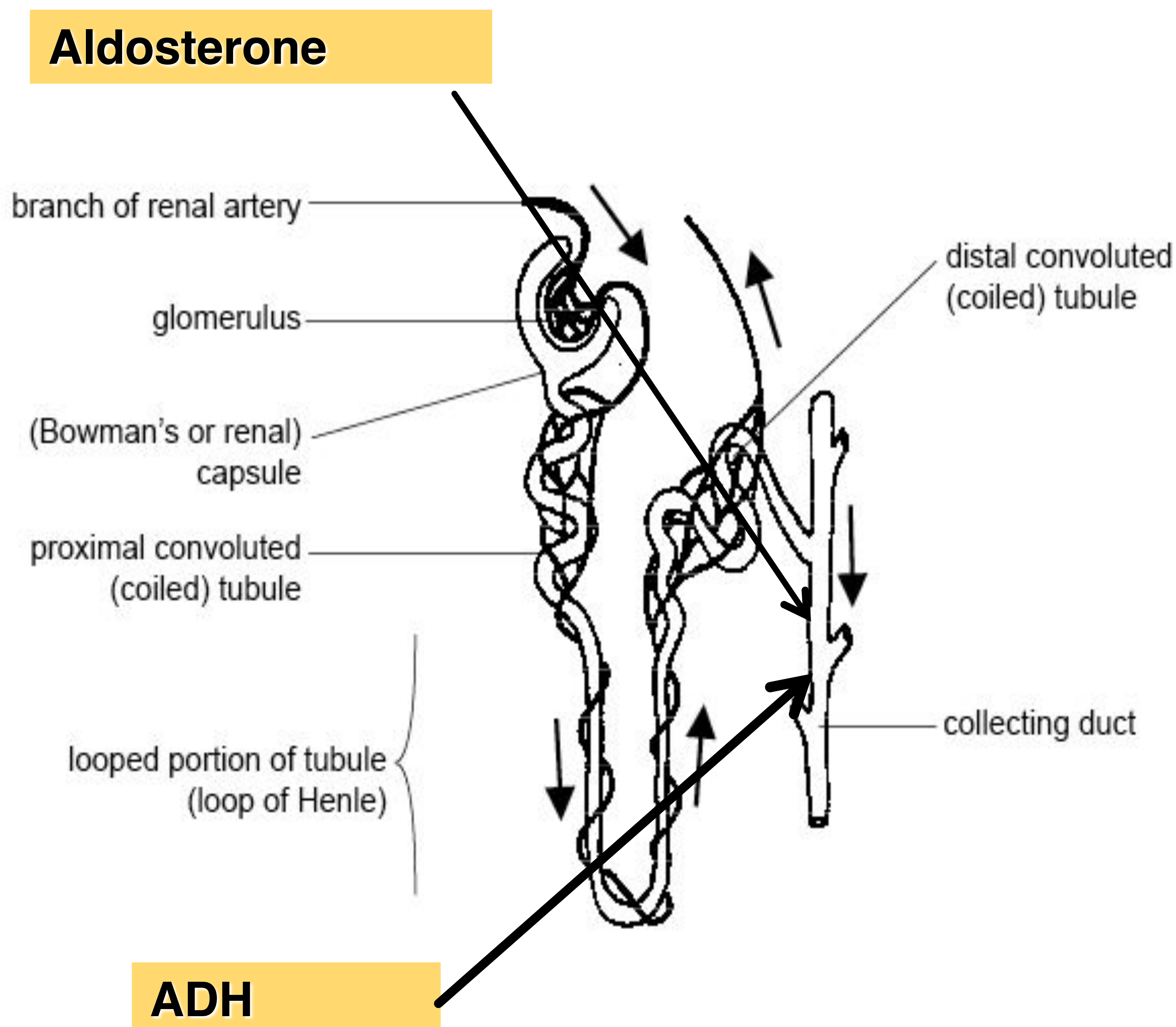


Anatomy — Major Endocrine Organs



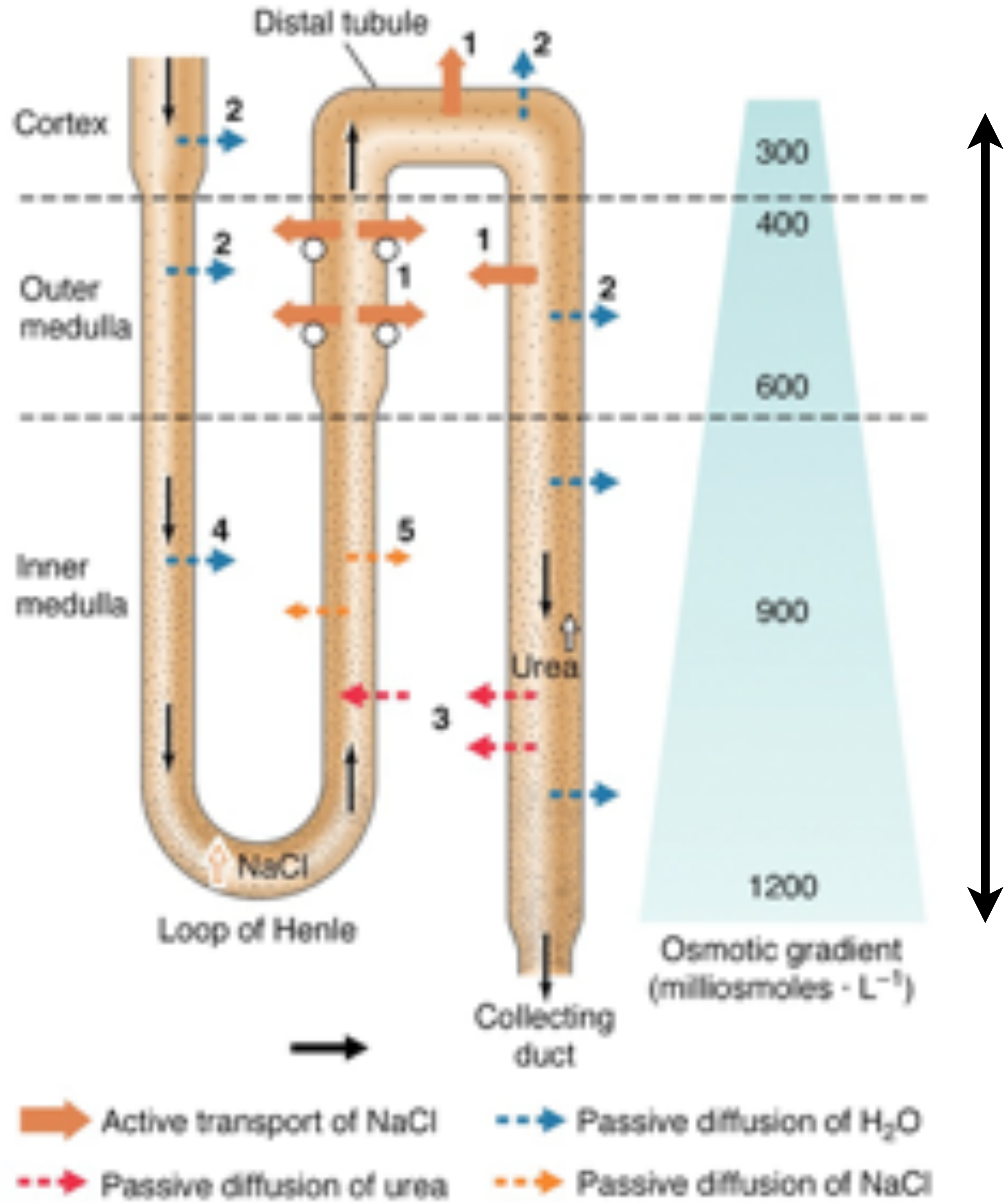
Water and Salt Balance controlled by Antidiuretic Hormone (ADH) & Aldosterone





Final concentration of Urea determined in collecting duct

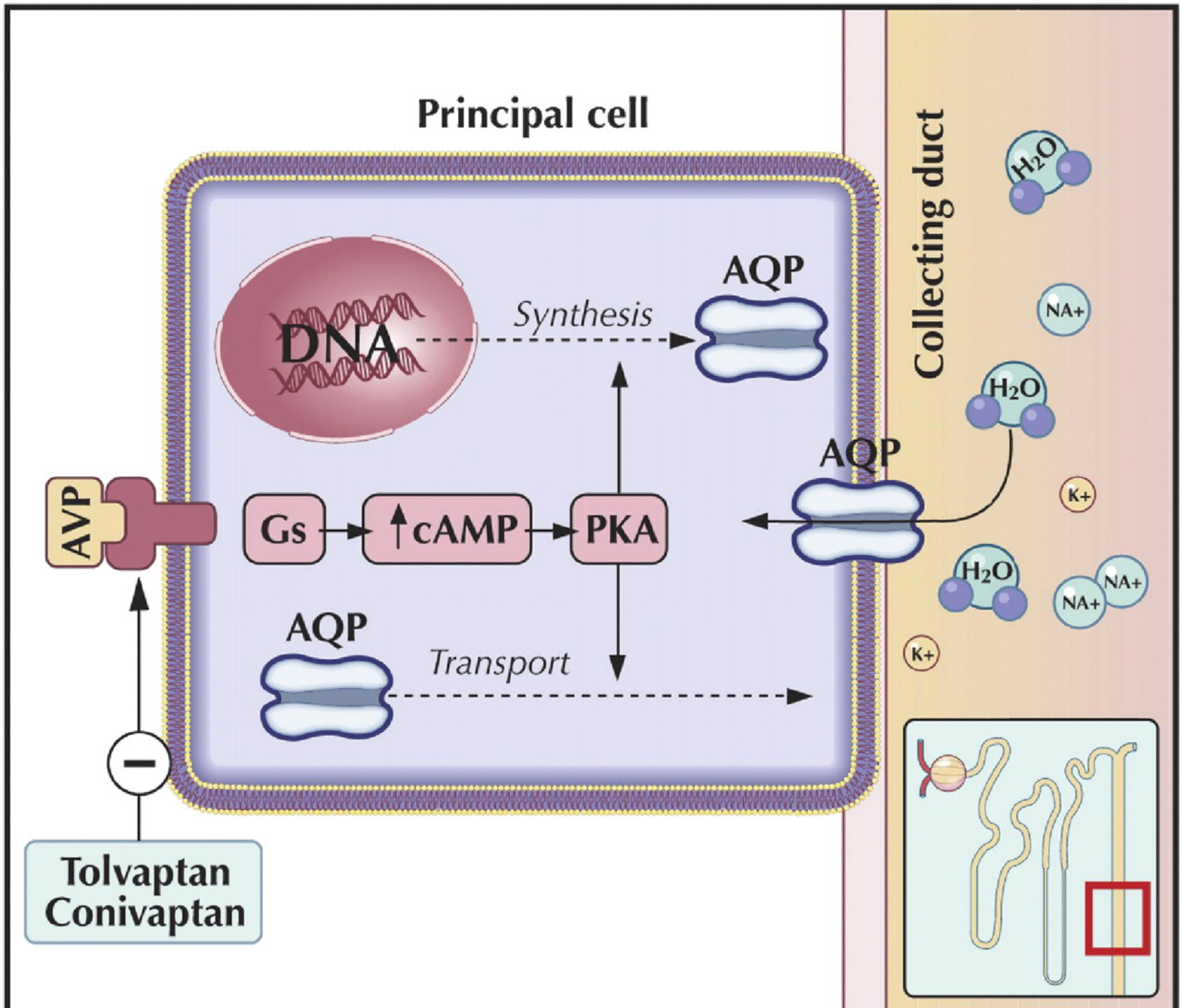
But within that limit, the urea and salt concentration of the urine is under hormonal control by its effect on the Collecting Duct



Maximum concentrating ability is determined by the length of the Loop of Henle

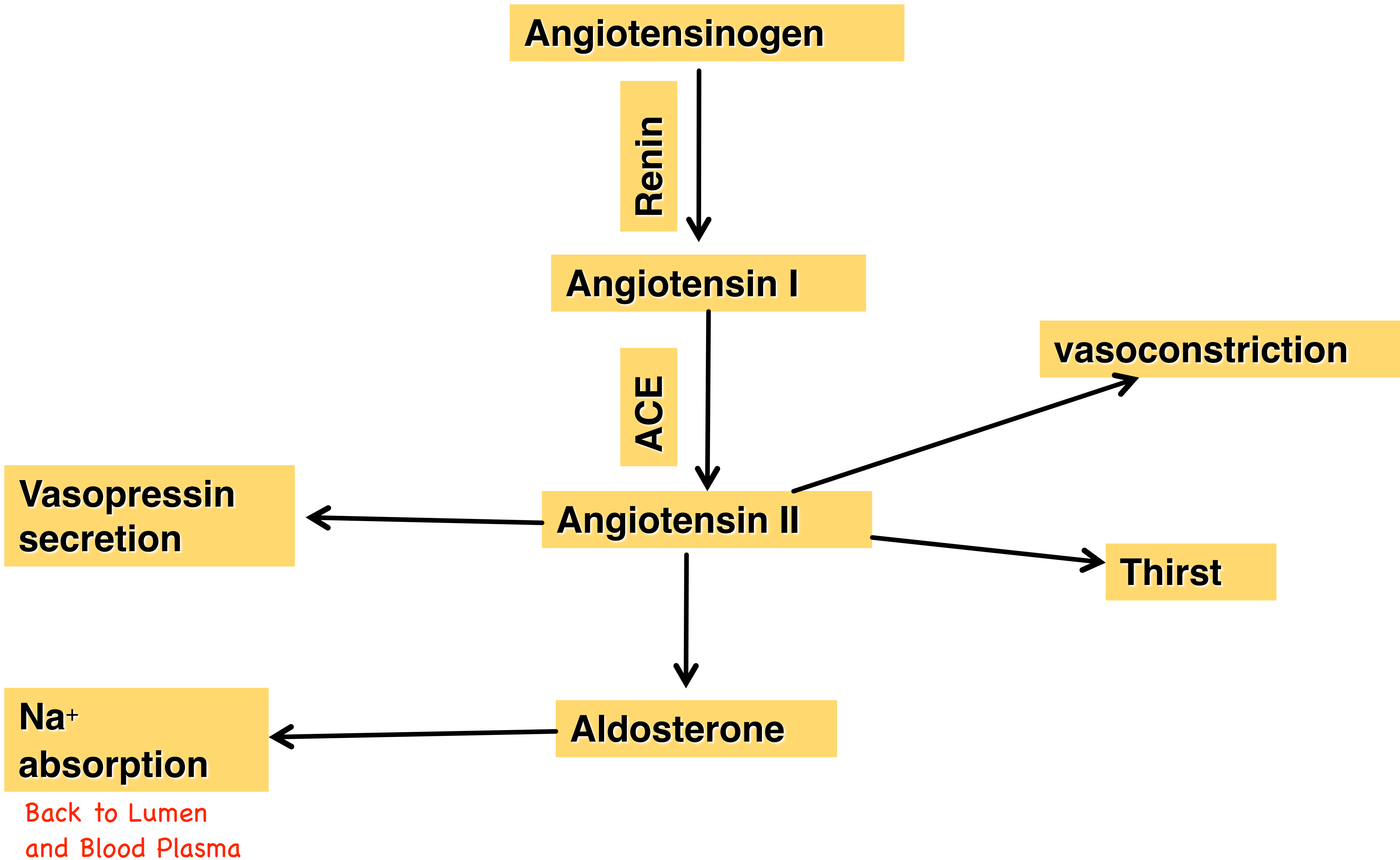
ADH = Anti Diarrhetic Hormone

(aka Vasopressin)



Vasopressin antagonists

Renin-Angiotensin-Aldosterone System conserves Na+



Aldosterone, Blood Volume and Pressure

Summary: Endocrine Control of Salt and Water Balance in Vertebrates (and Blood Pr)

- Hormones continuously regulate balance of salt and water
- Vasopressin are peptide neurohormones that stimulate conservation of water
- Aldosterone is a steroid hormone that stimulates the conservation of Na+. It is part of the renin-angiotensis-aldosterone system that is set in motion under conditions of low arterial blood pressure
- Atrial natriuretic peptide (produced from atria of heart in response to stretch!) exerts many different actions, all of which stimulate excretion of Na+ and water.