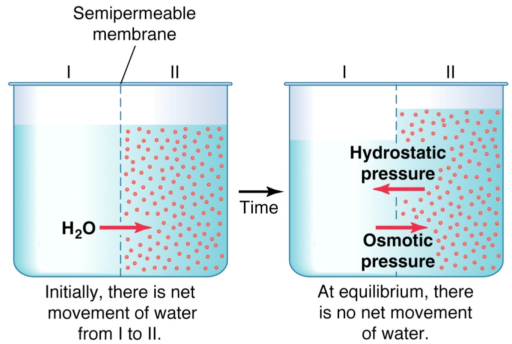
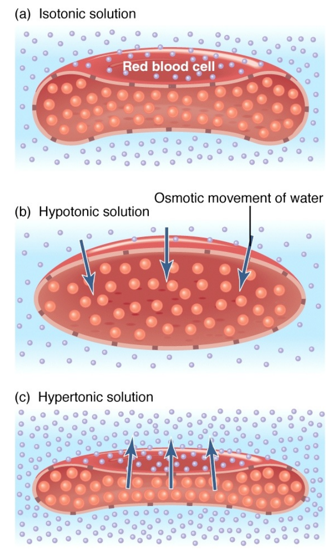
Osmoregulation & Excretion

Osmosis & Tonicity are defined by the solutes that can't move across the semi-permeable membrane!



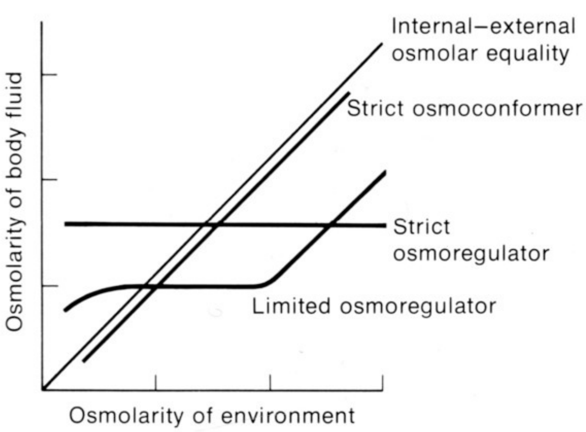
Osmosis: movement of H_2O down it's concentration gradient
Hydrostatic Pressure: (fluid mechanical pressure) or "water pushing" against membrane
Osmotic Pressure: tendency for water movement to balance concentration gradient

Tonicity: Defined by cell's response.
hypotonic solution <- causes cells to swell by water moving in to balance
hypertonic solution <- causes cells to shrink



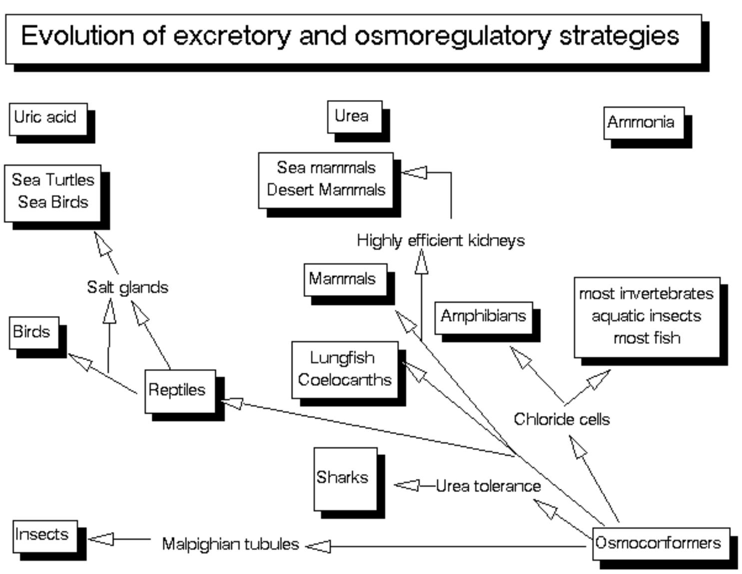
Osmolarity (note "R")= Moles of solute per liter of solution
Osmolality (note "L") = Moles of solute per kg of solvent (H_2O)

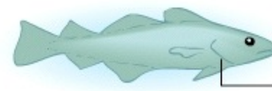
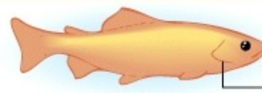
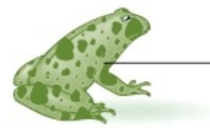
Osmolarity of seawater 1000 m osM, freshwater 10-50 m osM

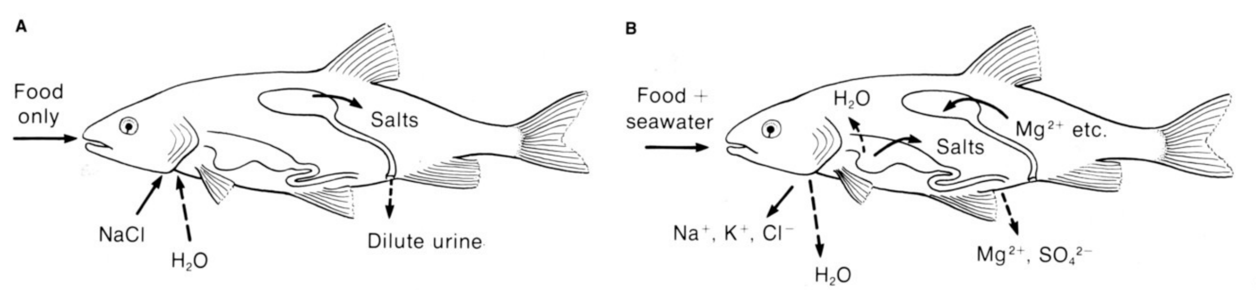


Osmoconformers
Osmoregulators
Ionoregulators

Isoosmotic: Solutions with same osmolarity. Can have different ion composition, but [water] is the same.
Hypoosmotic: Solution with lower osmolarity is hypoosmotic to solution with higher osmolarity
Hyperosmotic: Solution with higher osmolarity is hyperosmotic to solution with lower osmolarity



Type of animal	Blood concentration relative to environment	Urine concentration relative to blood	Osmoregulatory mechanisms
Marine elasmobranch	Slightly hyperosmotic	Iso-osmotic	 Does not drink seawater; Hyperosmotic NaCl from rectal gland
Marine teleost	Hypo-osmotic	Iso-osmotic	 Drinks seawater; Secretes salt from gills
Freshwater teleost	Hyperosmotic	Hypo-osmotic	 Drinks no water; Absorbs salt with gills
Amphibian	Hyperosmotic	Hypo-osmotic	 Absorbs salt through skin
Marine reptile	Hypo-osmotic	Iso-osmotic	 Drinks seawater; Hyperosmotic salt-gland secretion
Desert mammal	–	Hyperosmotic	 Drinks no water; Depends on metabolic water
Marine mammal	Hypo-osmotic	Hyperosmotic	 Does not drink seawater
Marine bird	–	Hyperosmotic	 Drinks seawater; Hyperosmotic salt-gland secretion
Terrestrial bird	–	Hyperosmotic	 Drinks freshwater



Freshwater teleost **Marine teleost**

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

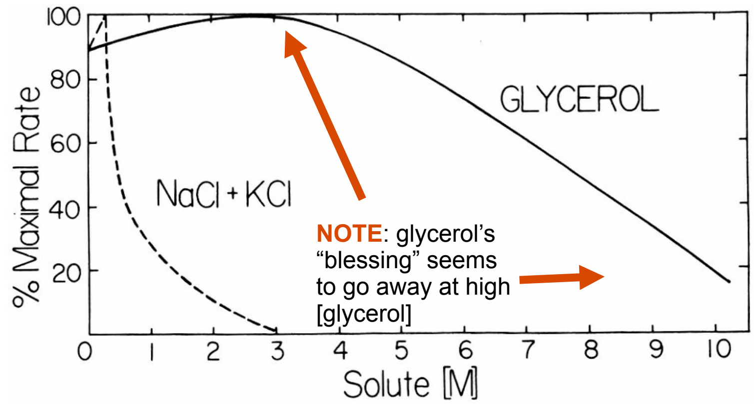
	Food		
	Carbohydrates	Fats	Proteins
Grams of metabolic water per gram of food	0.56	1.07	0.40
Kilojoules expended per gram of food	17.58	39.94	17.54
Grams of metabolic water per kilojoule expended	0.032	0.027	0.023

Source: Edney and Nagy, 1976.

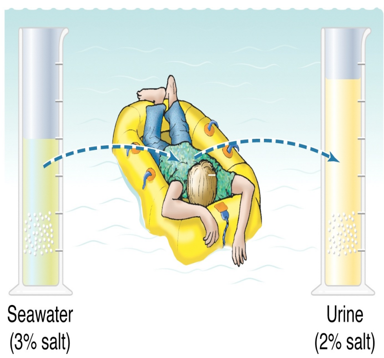
Solute "compatibility": rate of reaction

"Glycerol may be regarded as God's gift to solute-stressed eukaryotes"
A.D. Brown (1990)

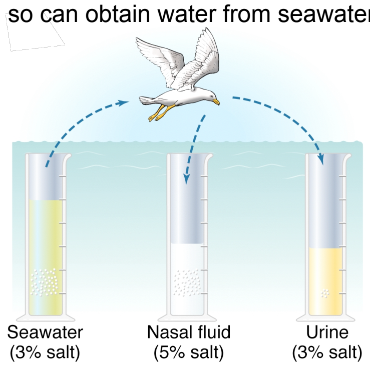
L. Borowitzka & A. D. Brown (1974) *Arch. Microbiol.* 96:37-52.

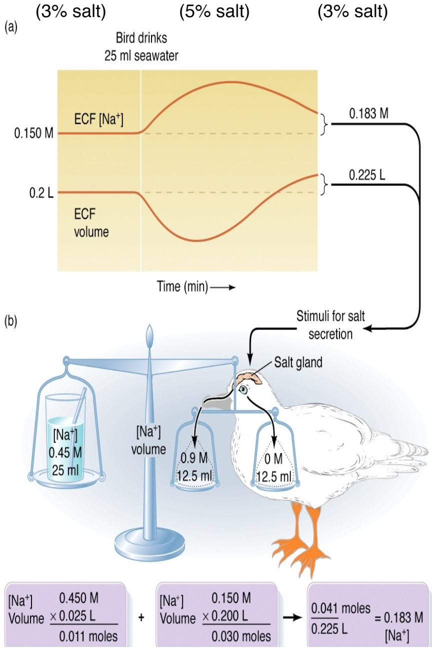


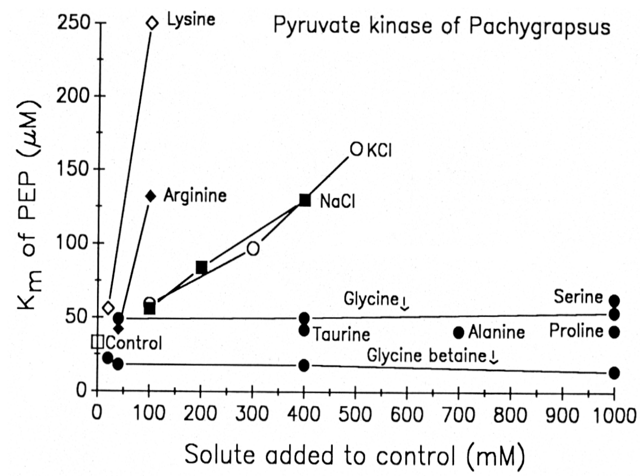
Drinking seawater is a losing strategy for most terrestrial vertebrates



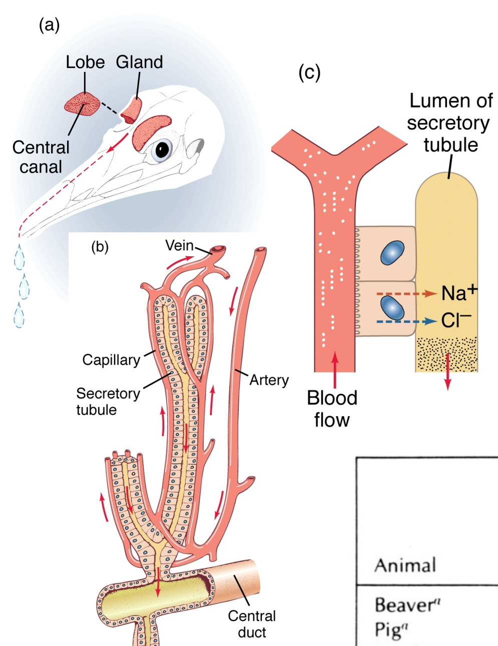
Marine birds and fish excrete salt, so can obtain water from seawater







Bowlus & Somero (1979) J. Exp. Zool. 208: 137-152



The nasal salt glands of birds and reptiles is powered by active transport of ions and supplemented by passive counter-current exchange (see arrangement of capillaries and blood flow relative to secretory tubule). The secretory cells have many mitochondria.

Maximum concentrating ability of the kidney of various mammals is correlated with habitat.

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).

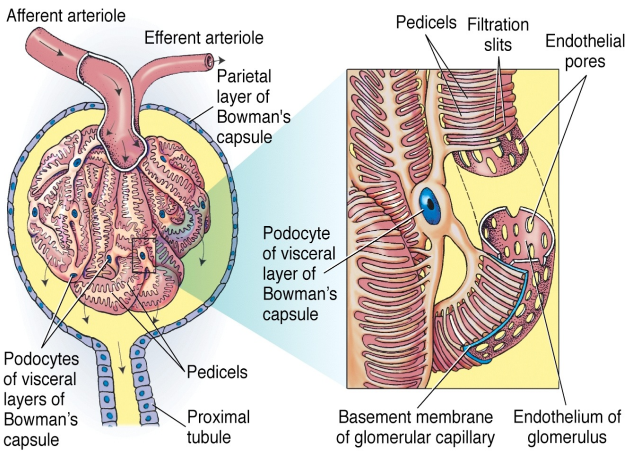
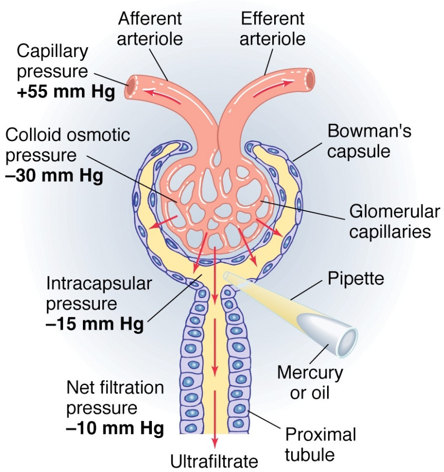


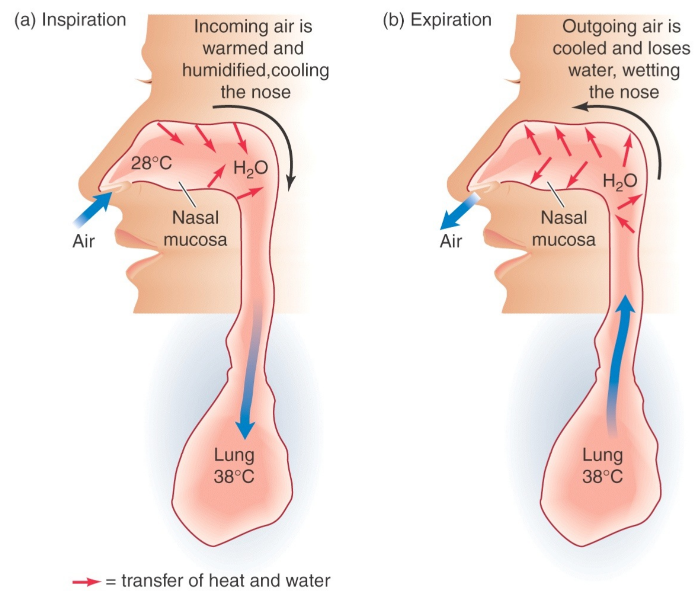
Table 14-8 Relation between the molecular size of a substance and the ratio of its concentration in the filtrate appearing in Bowman's capsule to its concentration in the plasma [filtrate]/[filtrand]

Substance	Mol. wt.	Radius from diffusion coefficient (nm)	Dimensions from X-ray diffraction (nm)	[filtrate]/[filtrand]
Water	18	0.11		1.0
Urea	62	0.16		1.0
Glucose	180	0.36		1.0
Sucrose	342	0.44		1.0
Insulin	5500	1.48	54 × 8	0.98
Myoglobin	17,000	1.95	88 × 22	0.75
Egg albumin	43,500	2.85		0.22
Hemoglobin	68,000	3.25	54 × 32	0.03
Serum albumin	69,000	3.55	150 × 36	<0.01

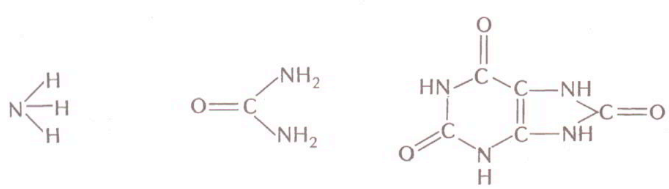
Source: Pitts, 1968.



Temperature, Exercise, Respiration, Water loss



Ammonia	Urea	Uric acid (keto-form)
NH_3	CH_4ON_2	$C_5H_4O_3N_4$

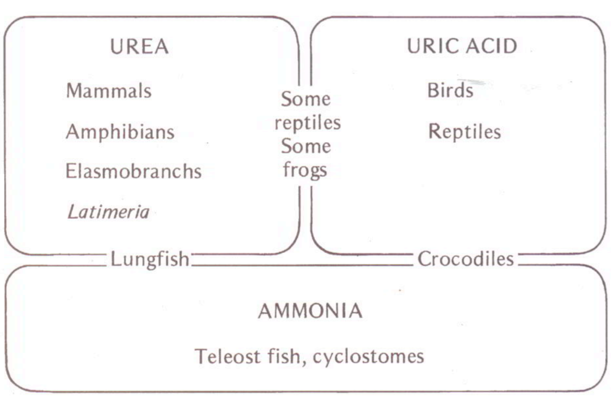


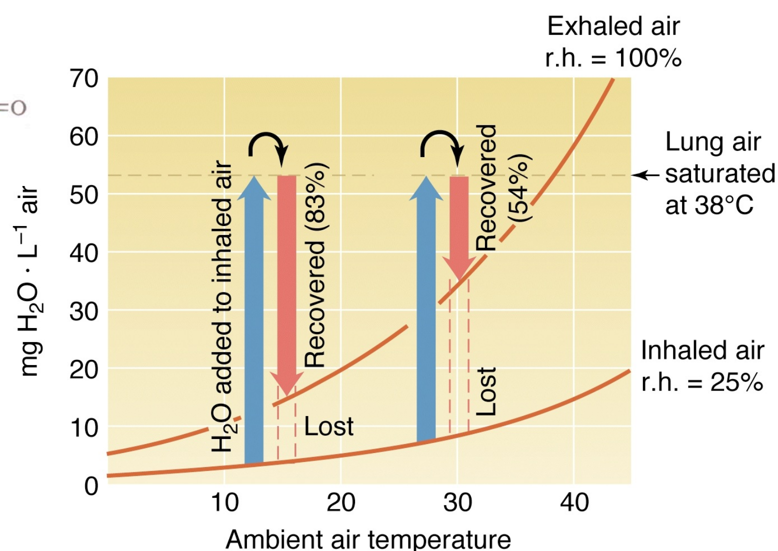
- Toxic
- Highly soluble
- must excrete

Aquatic animals only

- Much Less Toxic (But will denature Proteins in high concentration!)
- Expensive
- Need lots of water to excrete

- Inert,
- Very Expensive
- little water to excrete (water conserving)





Consider:
- a tuna hunting
- a mammal running
- a mammal in cold environment

Temporal counter-current exchange

Figures from Knut Schmidt-Nielsen (1998)

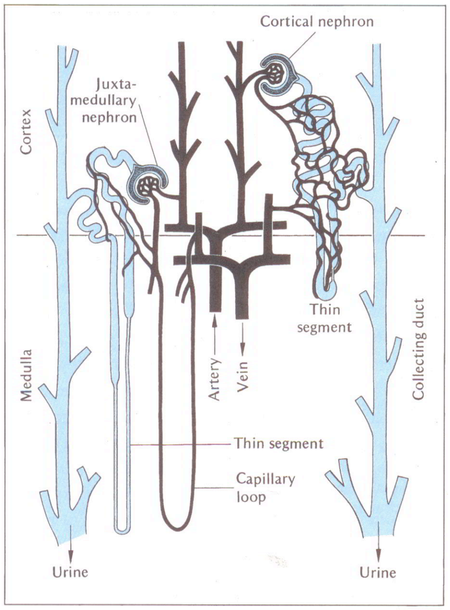


Figure 9.11 Diagram showing two typical nephrons, one "long-looped" (located close to the border of the medulla and therefore called juxtamedullary) and one "short-looped" (or cortical) nephron. The long-looped nephron is paralleled by a loop formed by the blood capillary. The short-looped nephron is surrounded by a capillary network. Most mammalian kidneys contain a mixture of the two types of nephrons, but some species have only one or the other kind. [Smith 1951]

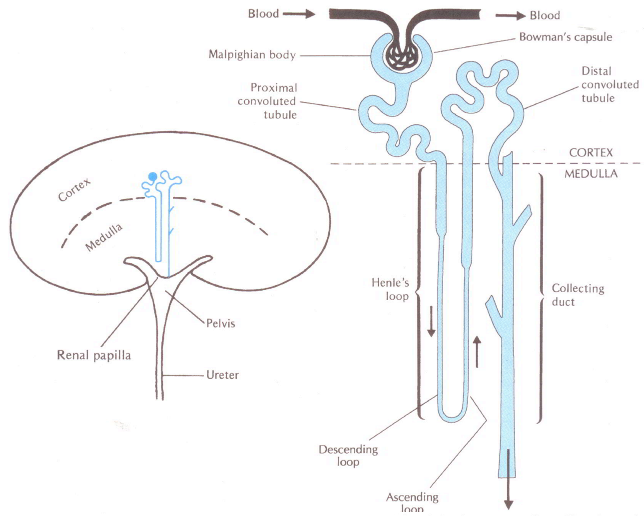


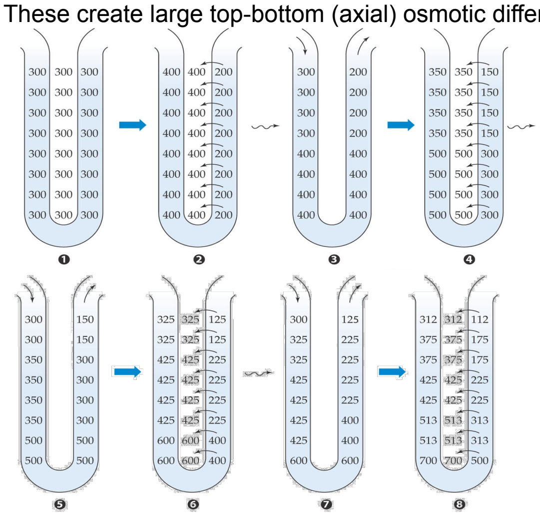
Figure 9.8 Diagram of a mammalian kidney. The kidney contains a large number, up to several million, of single nephrons. Only one nephron is indicated in this diagram and is shown enlarged to the right. The outer layer of the kidney, the *cortex*, contains the *Malpighian bodies* and the proximal and the distal convoluted tubules. The capillary network within the Malpighian body is known as the *glomerulus*. The inner portion, the *medulla*, contains *Henle's loops* and *collecting ducts*.

The urine is initially formed by ultrafiltration in the Malpighian bodies. The filtered fluid is modified and greatly reduced in volume as it passes down the renal tubule and into the collecting ducts. These empty the urine into the rena *pelvis*, from where it is conveyed via the *ureter* to the bladde

Countercurrent multiplication in the loop of Henle

- The single effect creates side-side (transverse) osmotic differences
- These create large top-bottom (axial) osmotic differences

MAMMALIAN KIDNEY The vascular system of the kidney of a desert rodent, the jird (*Meriones*). The arteries and capillaries have been injected with silicone rubber, and the glomeruli can be seen as numerous tiny, beadlike dots in the outer layer (the renal cortex). The renal papilla in the jird is longer than in rodents from less arid habitats; this enhances the concentrating ability of its kidney. [Courtesy of Lise Bankir, Institut National de la Santé et de la Recherche Médicale, Paris]



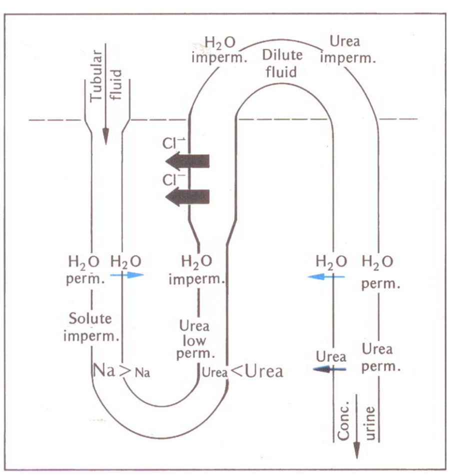


Figure 9.12 Diagram of the concentrating mechanism in the loop of Henle in the mammalian kidney during the formation of concentrated urine. Active transport of chloride ion is indicated by heavy arrows; passive flux of water and urea by light arrows. [Kokko and Tisher 1976]