(a) Hyper-isosmotic regulators

- Blue crab
- Amphipod
- Carp

Isosmotic line

(b) Hyper-hyposmotic regulators

- Lined shore crab
- Fiddler crab
- Ghost crab
- Brine shrimp

1000 mOsm is the approximate osmotic pressure of full-strength seawater.

(c) Actual relations of three marine invertebrates

- Green crab
- Mussel
- Shrimp
a) Complejo criptonefridial

b) Papilas rectales
(a) Freshwater teleost
Salt loss by diffusion
Water uptake by osmosis
Gills
Salts and water in food (generally do not drink)
Large amounts of urine, very hyposmotic to plasma

(a) Fish living in ordinary fresh water
Individual secondary lamellae
Chloride cell

![Diagram of fish and chloride cell structure]

![Diagram of sodium transport across membranes]

**ATPase**
**Countertransporter**
**Channel**
**Transport against the electrochemical gradient**
**Transport in the direction of the electrochemical gradient**
4

b. Marine teleost

Salt gain by diffusion

Water loss by osmosis

Gills

Salts and water in food

Hyposmotic to ambient water

Salts and water in seawater ingested (source of net water gain)

Small amounts of urine, nearly isosmotic to plasma, rich in Mg^{2+} and SO_{4}^{2-}

Active extrusion of Cl^{-}, active or passive outflux of Na^{+}

Chloride cells are dense with mitochondria (accounting for their alternative name, mitochondria-rich cells).

Chloride cells have an extensive intracellular system of branching tubules, continuous with the basal and lateral portions of the cell membrane. Although the parts of the tubular system seen here appear to be disconnected, the parts are believed to be relatively continuous in intact cells.

Blood

Ambient water (or duct solution)

ATP

ADP

\( 3 \text{ Na}^{+} \)

\( 2 \text{ K}^{+} \)

\( \text{Cl}^{-} \)

\( \text{Na}^{+} \)

\( \text{Na}^{+} \)

\( \text{Cl}^{-} \)

\( \text{K}^{+} \)
Each gland consists of many longitudinal lobes, each of which contains a great many branching, radially arranged secretory tubules that discharge into a central canal.
Seawater (or gland lumen)

Apical membrane

Basolateral membrane

Na⁺/K⁺ ATPase

Na⁺

K⁺

Cl⁻

Na⁺

K⁺

The roles of the gills in salt excretion are uncertain.

Salt gain by diffusion across gills

Water gain by osmosis across gills

Hyperosmotic but hypoionic to ambient water

Rectal gland secretions rich in NaCl, plus salts and water in feces

Modest amounts of urine, modestly hyposmotic to plasma, rich in Mg²⁺ and SO₄²⁻

Salts and water in food (generally do not drink)
The kangaroo rats can stay in water balance at humidities higher than those at which the "total water intake" line crosses the "total water loss" line.

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

<table>
<thead>
<tr>
<th>Gains</th>
<th>Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metabolic water</td>
<td>Evaporation and perspiration</td>
</tr>
<tr>
<td>Free water in &quot;dry&quot; food</td>
<td>Urine</td>
</tr>
<tr>
<td>Drinking</td>
<td>Feces</td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

ARQUINEFROS (embriones de mixines)

PRONEFROS (mixines adultos, embriones de peces y anfibios)

MESONEFROS (adultos de peces y anfibios, embriones de amniotas)

METANEFROS (adultos de amniotas)