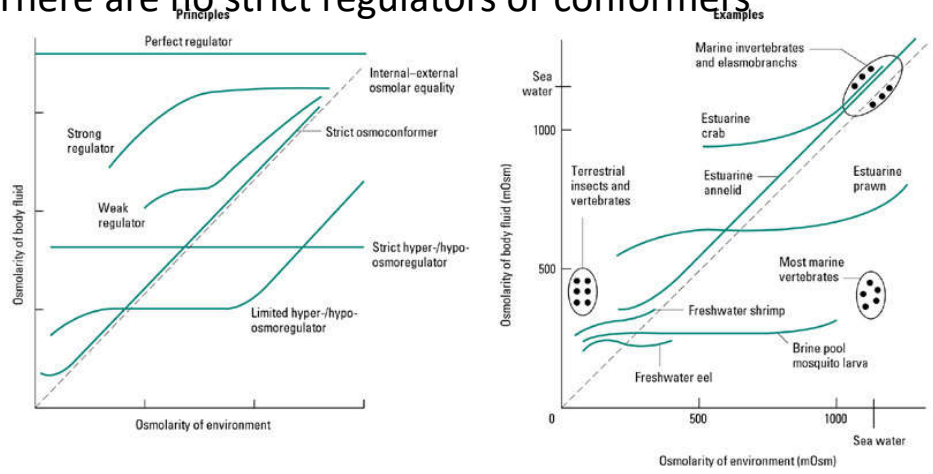
Marine	Freshwater	Estuary	Terrestrial
Stable ~ 1030 Osm	Spatially and temporally variable. 0-100 mOsm Most cells require >10 Osm	Spatially and temporally variable. Tend to be predictable and highly productive.	Not applicable. Ions acquired from food, water loss often a concern.
Invertebrates – stenohaline, osmoconformers	Invertebrates – mostly hyperosmotic, soft bodied sometimes less than100 mOsm. Euryhaline, osmoregulators	Invertebrates – many avoiders, morphological or behavioral	Invertebrates – Osmoregulators, tolerance of water loss variable.
Elasmobranchs – compensatory osmolytes, osmoconformers	Elasmobranchs – loss of compensatory osmolytes, osmoconformers		
Teleosts – hypoosmotic osmoregulators, derived from freshwater, 300 mOsm	Teleosts – hyperosmotic osmoregulators, 300 mOsm		
Mammals, birds, reptiles – secondarily aquatic, morphological avoiders, typically 300 mOsm	Mammals, birds, reptiles – secondarily aquatic, morphological avoiders, typically 300 mOsm		Mammals, birds, reptiles – keratinized skin, amniotic egg, scales prevent water loss. ~300 mOsm
Only one "marine" amphibian – crab eating frog	Amphibians – 300 mOsm		Amphibians – humid environments, access to water, lipid or wax covering to prevent dessication, ~300 mOsm

Table 5.3 Comparative measures of 'permeabilities' across the skins of animals.

Habitat	Animal group	Resistance (s cm^{-1})	Water flux (mg cm^{-2} h^{-1})	Transpiration rate (μg cm^{-2} h^{-1} Torr^{-1})	Water turnover (ml g^{-1} day^{-1})	P_{H_2O} (μm
Marine	Crabs	6–14	14–25			
	Echinoderms					
	Reptiles	33	0.5			30
	Fish	7–35				0.2
Hypersaline	Crustaceans	20–100				
Estuarine/littoral	Amphipods and isopods	3–6		200–300		
	Crabs	4–40		80–200		1.4
Freshwater	Insect larvae	10				0.0
	Insect adults	200				0.05
	Crustaceans	11–46				0.3
	Fish	2–8				
Amphibious	Frogs	3–100	5–40	2400		5–2
	Crocodile	5	70	400		
Terrestrial	Snails active (inactive)	2 (46)		2500 (16)		
	Earthworms	9				
	Isopods	3		80–160		
	Crabs	30–75	1–3			
	Scorpions			8–80		
	Spiders and mites	80		30–60		
	Myriapods		2–4	40–270		
	Collembolans			700		
	Termites			28–37		
	Orthopterans	200	1–2	20–70	0.1–0.4	
	Caterpillars			190		
	Dipteran flies			50–76		
	Beetles			24–50		
	Ants			25		
	Frogs	1.5		2000–2500		
	Lizard	198	0.2			0.00
	Birds	50–70	0.7–2.7			
	Mammals		1–10			
Arid/desert	Isopods			14–30		
	Scorpions, spiders, mites	1300–4000		0.6–2.0		
	Millipedes	430		8		
	Apterygotes			15		
	Hemipteran bugs			12–14		
	Cockroach, cicadas			12–100		
	Beetles	5030	0.1–0.2	3–15	0.05	
	Beetle pupa			1		
	Tsetse fly			8		
	Tsetse fly pupa			0.3		
	Caterpillars			40		
	Ants and wasps			4–26		
	Frog, cocooned	457				
	Tortoises	120	1.6		0.003	
	Birds	158	1.7		0.09	
	Lizards	1360	0.1		0.03	
	Small mammals (rodents)		0.5–0.7		0.03–0.13	
	Large mammals		2–6		0.03–0.09	

There are no strict regulators or conformers



Tolerance of water loss

- Water loss → increase in osmolarity
- Loss of intracellular water is last, most dangerous
- Organisms with higher body osmlarity typically tolerate more loss

Table 5.2 Tolerance of water loss (as maximum % weight loss tolerated) in a variety of animals from terrestrial or semi-terrestrial habitats.

Annelids	
Allolobophora (earthworm)	75
Molluscs	
Patella (limpet)	35–60
Chitons	75
Helix (snail)	45–50
Limax (slug)	80
Sphincterochila (desert snail)	50–55
Crabs	
Gecarcinus	15–18
Uca	18
Insects	
Temperate beetles	25–45
Temperate roaches	25–35
Desert cicada	25
Desert ants, grasshoppers	40–70
Desert tenebrionid beetles	60–75
Frogs	
Rana	28–35
Hyla	35–40
Bufo	42–45
Scaphiopus	45–48
Birds and mammals	
Small birds	4–8
Rat	12–15
Human	10–12
Camel	30

Rates of Water Loss

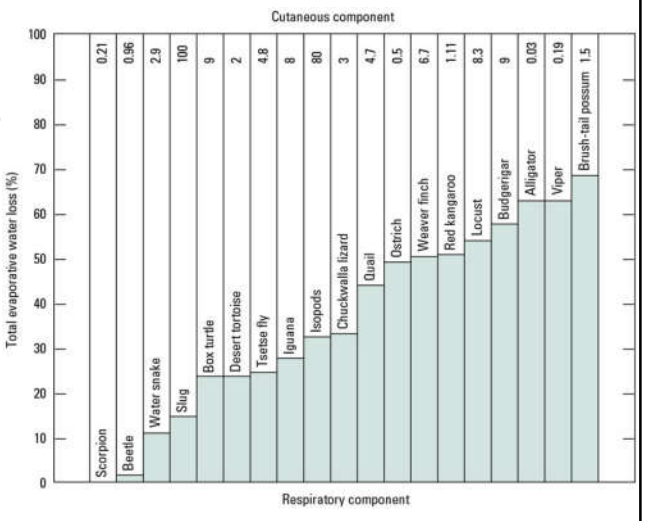
- Primarily passive
  - Surface area
  - Permeability of outer covering
  - Temperature
  - Relative humidity or osmolarity
- Cutaneous vs. respiratory loss

R (resistance) to water loss

- R – combines the diffusion coefficient and distance. Measure of resistance of water loss or gain.

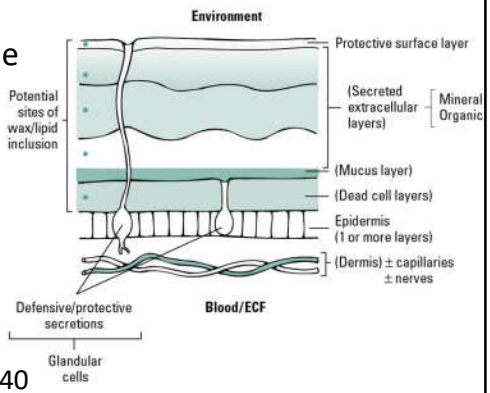
$$EWL = \frac{\Delta X}{R}$$

- Where X = internal/external water concentrations
- P - permeability, another way of expressing R.



Variability in R or P

- Epithelium alone
  - Low R: Frogs 1.5, terrestrial snail 2.0
- Epithelium plus secreted cuticle or other coating
  - Keratinized skin
    - Lizards ~ 200
    - Birds ~ 50-70
    - Desert lizard ~ 1300
  - Exoskeletons
    - Marine crabs ~15
    - Freshwater crustacean ~ 15-40
    - Terrestrial crab 30-70
    - Desert beetle ~5000
    - Scorpion 1300-4000



Tradeoffs

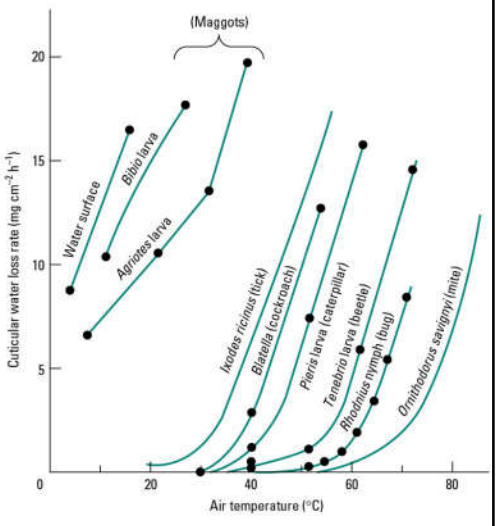
- Increasing water loss comes at a price
  - Typical amphibian R very low
    - Ionic, osmoregulatory and gas exchange over skin
  - Reptile, bird and mammal R higher
    - Skin no longer does any exchange
- Desert adapted amphibians secrete lipid coverings, increase R

Allometry and other sources of water loss

- Larger animals will loose less water
  - Large desert vertebrates (R 150-500)
  - Small invertebrates (R 400-5000)
- Many animals use evaporative cooling when heat stressed
  - Mammal sweat glands
  - Some insects and amphibians

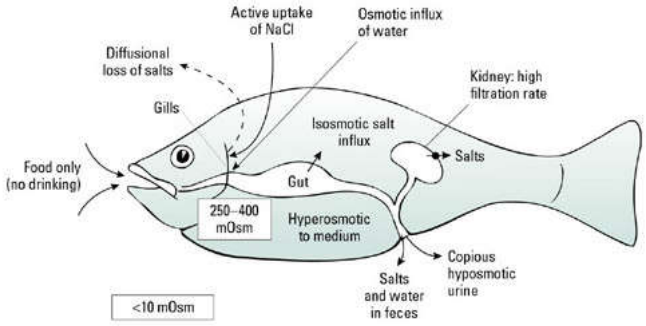
Acclimation of R

- Transition temperatures for cuticles
- Regulating intracellular vs. extracellular water content
  - Create or destroy various membrane structures or properties
    - Ion pumps
    - Ion channels
    - Water pores
    - Lipid composition



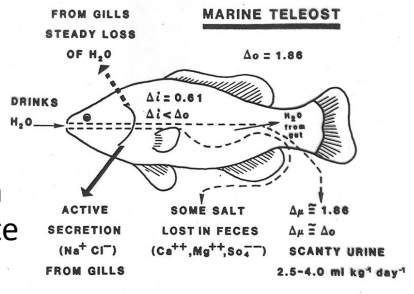
Hyperosmotic regulation – salt uptake

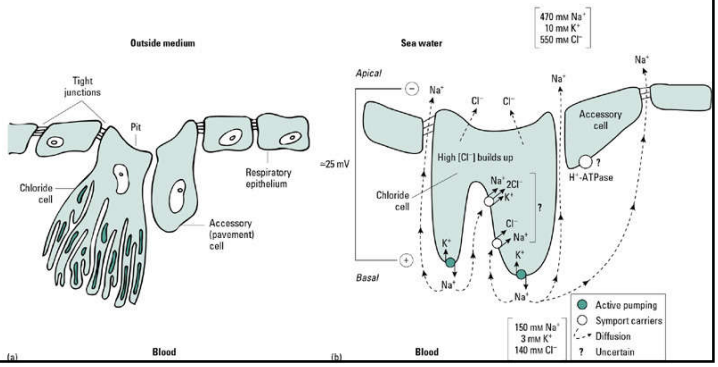
- Freshwater teleost and invertebrates
  - Decreased R of skin
  - Most exchange at respiratory surface (gills)
  - Active uptake of ions, passive water gain
  - High volume of dilute urine



Hyposmotic regulation – salt secretion

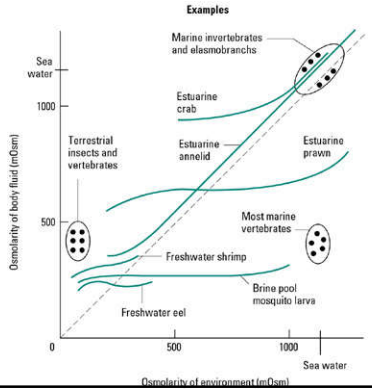
- Marine inverts, elasmobranchs generally isosmotic
- Marine teleosts, reptiles, birds, mammals
  - Loss of water, gain salts through surfaces, drink water and secrete salts.
- Chloride cells





Hyposmotic regulation – salt secretion

- Mosquite larvae
  - rectal papillae actively secrete ions
  - Size of gland is plastic, related to salinity
  - Euryhaline
  - Osmoregulators



Marine reptiles, birds and mammals

- Kidneys and salt glands facilitate salt loss through hyperosmotic secretions
- No gills, large body size, high skin R reduces exposure