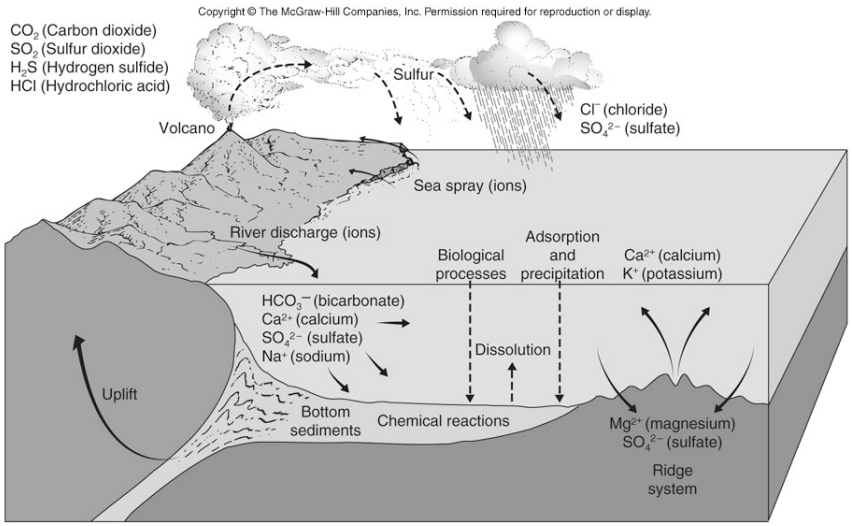
Processes Affecting Seawater Composition



Steady State Ocean

Is the ocean becoming saltier?

●Salinity in the ocean is in a steady-state condition because amount of salt added (input from sources) equals the amount removed (output to sinks)

- ●Ocean is in approx. chemical equilibrium; proportion and amounts of dissolved solids remain constant.
- ●Known as the “steady state ocean”

2

Residence Time

- Average length of time that an ion or element remains in solution in the ocean
  - Ions with long residence times tend to accumulate in the sea; those with short residence times are removed.
  - Rapid mixing and long residence times explain constant composition of sea water.

3

Residence Time

Residence time can be calculated by the equation:

$$\text{Residence Time} = \frac{\text{Conc. of element in the ocean}}{\text{Rate of addition or removal}}$$

The residence time of any element depends on its chemical activity.

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Conservative and Nonconservative Constituents

●Conservative constituents of seawater occur in constant proportions.

●Conservative elements have long residence times and are the most abundant dissolved salts in the ocean.

●Nonconservative constituents have short residence times, and are usually associated with seasonal, biological or short geological cycles.

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Residence Time

Table 7.3 Approximate Residence Times for Constituents of Seawater

Constituent	Residence Time (years)
Chloride (Cl^{-})	100,000,000
Sodium (Na^{+})	68,000,000
Magnesium (Mg^{2+})	13,000,000
Potassium (K^{+})	12,000,000
Sulfate (SO_4^{2-})	11,000,000
Calcium (Ca^{2+})	1,000,000
Carbonate (CO_3^{2-})	110,000
Silicon (Si)	20,000
Water (H_2O)	4,100
Manganese (Mn)	1,300
Aluminum (Al)	600
Iron (Fe)	200

Sources: Data from Broecker and Peng, 1982; Bruland, 1983; Riley and Skirrow, 1975.

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Dissolved Gases

Affected by biological activity

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Solubility and Saturation Value of Gases

- **Both increase as T and S decrease and pressure increases**
- **Solubility - tendency to dissolve and go into solution**
- **Saturation value - equilibrium amount of gas dissolved in water at an existing temperature, salinity and pressure**

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Dissolved Gases: Required for Life Processes

Concentration of dissolved gases:

- Increases with decreasing T (cold water holds more dissolved gas)
- Increases with decreasing S
- Increases with increasing P

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Gases in Seawater

- Undersaturation - contains less than maximum amount of dissolved gas
- Saturation - maximum amount of gas
- Supersaturation - contains more gas than saturation value (excess gas comes out of solution)
  - Surface layer - usually saturated due to gas exchange with the atmosphere
  - Below surface layer -gas content reflects respiration, photosynthesis, decay and input from volcanic vents

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Oxygen Content

- Solubility depends on T and Salinity
  - Warm, saline water holds less O_2
- Oxygen consumption in water column
  - Respiration by animals
- Mixing rate of oceans
  - Sluggish mixing - low rate of O_2 replenishment

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Oxygen Concentration With Depth

- Surface layer is rich in oxygen because of photosynthesis and diffusion from atmosphere
- Oxygen minimum layer occurs at about 150 to 1500m below the surface and coincides with the pycnocline.
  - Sinking food particles settle into this layer and are slowed down by the density gradient.
  - The food draws large numbers of organisms which consume oxygen.

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Carbon Dioxide Concentration

- Solubility depends on T and S
- CO_2 is released by animals
- Mixing rate of oceans
- Affects pH of seawater
- Similar to concentration profiles of nutrients (PO_4^{-3}, NO_3^-)

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Carbon Dioxide Controls Acidity of Seawater

- **Major sources - respiration and decay**
- **Major sinks - photosynthesis and construction of carbonate shells**
  - pH measures how acid or base water is.
    - - pH of 0 to 7 is acidic.
    - - pH of 7 is neutral.
    - - pH of 7 to 14 is basic.

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Gases in Seawater

- pH is related to amount of CO_2 dissolved in water; combines with water to produce carbonic acid which releases H^+ ions.
  - $CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^- \longleftrightarrow H^+ + CO_3^{-2}$
- H_2CO_3 is carbonic acid, HCO_3^- is the bicarbonate ion and CO_3^{-2} is the carbonate ion.

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Gases in Seawater

- Changing the amount of CO_2 shifts the reaction to the right or left of the equation.
  - Adding CO_2 shifts the reaction to the right and produces more H^+ ions making the water more acid.
  - Removing CO_2 shifts the reaction to the left, combining H^+ ions with carbonate and bicarbonate ions and decreasing the acidity.

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Acid-Base Balance

●An acid is a substance that releases a hydrogen ion in solution.

●A base is a substance that combines with a hydrogen ion in solution.

●A solution containing a base is called an alkaline solution.

●Acidity or alkalinity is measured on the pH scale.

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Gases in Seawater

- Dissolved CO_2 - buffers against large shifts in pH
- Carbonate shells dissolve in deep water; cold water under pressure holds more CO_2 making the water more acidic (pH = 7.8)
- Warm, shallow water contains less dissolved CO_2 and is less acidic than the deep water; carbonate sediments do not dissolve (pH = 8.2)

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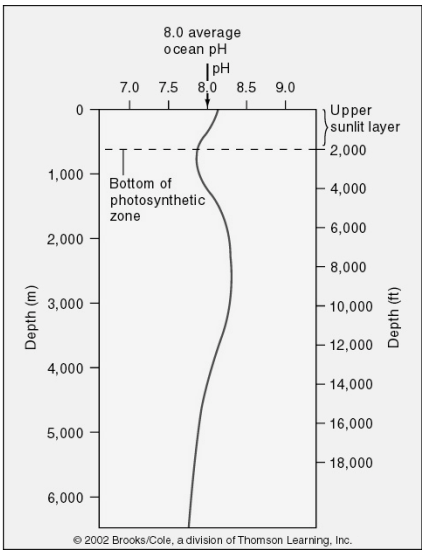
pH of Seawater



Note that the pH of seawater varies slightly with depth.

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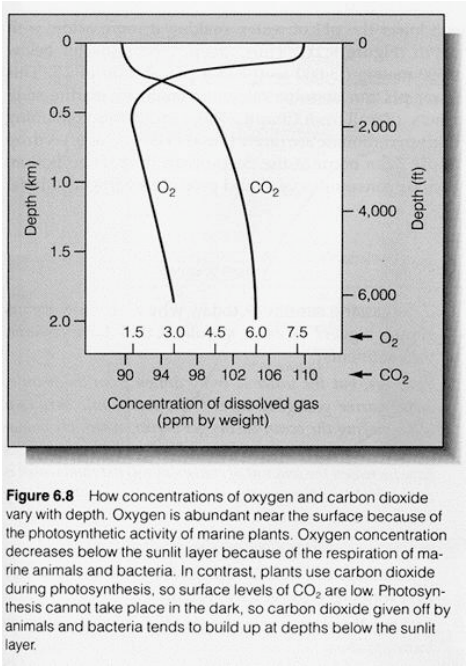

Figure 6.8 How concentrations of oxygen and carbon dioxide vary with depth. Oxygen is abundant near the surface because of the photosynthetic activity of marine plants. Oxygen concentration decreases below the sunlit layer because of the respiration of marine animals and bacteria. In contrast, plants use carbon dioxide during photosynthesis, so surface levels of CO_2 are low. Photosynthesis cannot take place in the dark, so carbon dioxide given off by animals and bacteria tends to build up at depths below the sunlit layer.

Oxygen and CO_2 Profiles are Opposite

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Dissolved Oxygen in Seawater

- Decay of organic matter consumes oxygen
- Deep water has more oxygen because it is forms from cold surface waters sinking to the bottom; oxygen usage is low die to fewer organisms in the deep water
- Anoxic waters contain no oxygen and are inhabited by anaerobic organisms (bacteria).

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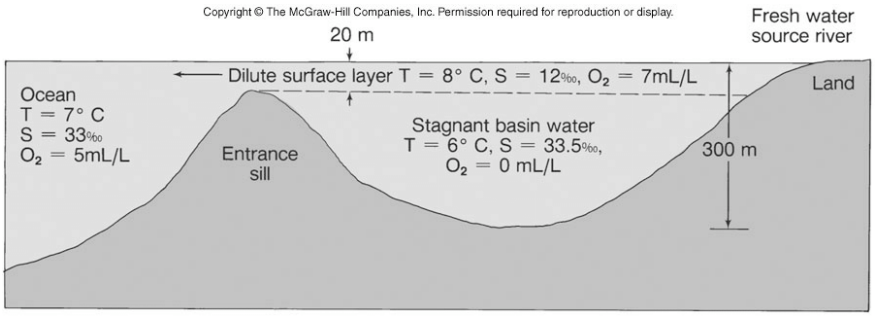
Absence of Oxygen in Stagnant Basins



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Nutrients: Essential Chemicals for Life

- Major nutrients are compounds of nitrogen, phosphorus and silicon
- Because of usage, concs. are very low at the surface - parts per million (ppm)
- Concs. vary greatly over time and space; a nonconservative property of seawater

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Table 5.6 Nutrients in Seawater

Element	Concentration μg/kg[1]
Nitrogen (N)	500
Phosphorus (P)	70
Silicon (Si)	3000

1. Parts per billion.

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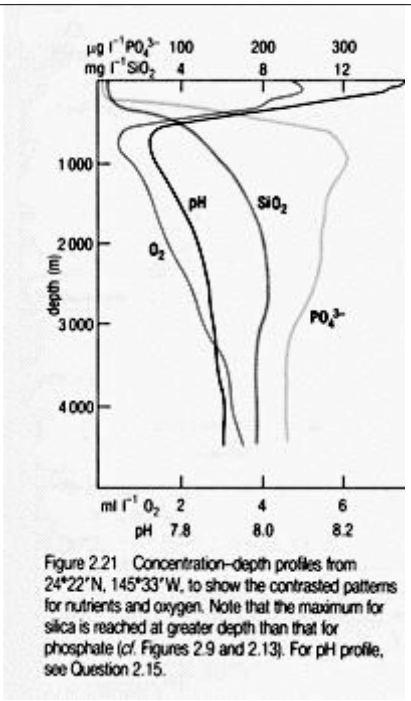

Figure 2.21 Concentration–depth profiles from 24°22′N, 145°33′W, to show the contrasted patterns for nutrients and oxygen. Note that the maximum for silica is reached at greater depth than that for phosphate (*cf.* Figures 2.9 and 2.13). For pH profile, see Question 2.15.

Nutrient, Oxygen and pH Profiles in Typical Seawater

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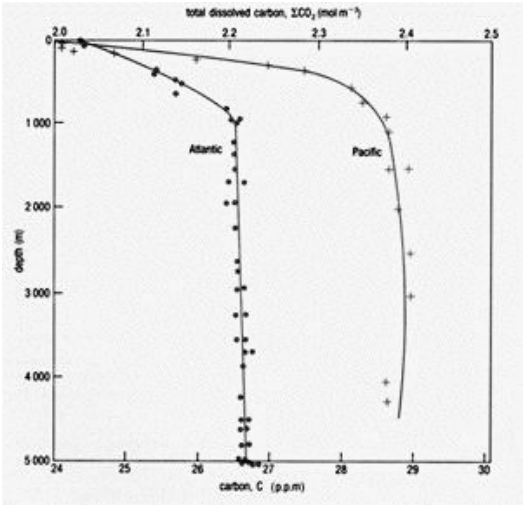
Total Dissolved Inorganic Carbon Profiles



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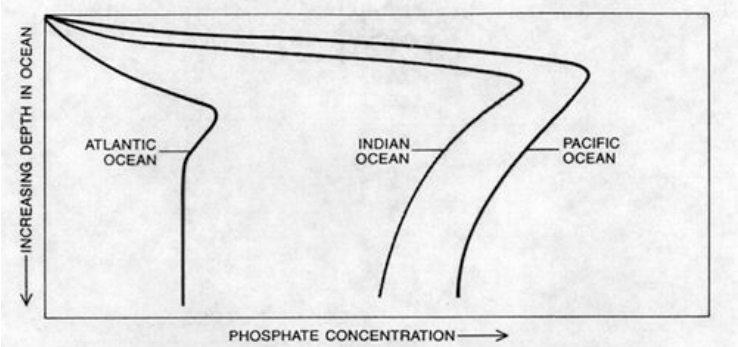
Nutrient Profiles



DISTRIBUTION OF PHOSPHATE in the ocean varies with depth. Essentially all the phosphate in surface water is taken up by marine plants and falls into the deep sea in soft-tissue residues. Much of it is released into solution as the residues are decomposed by animals and bacteria, a process that takes place primarily at intermediate depths. Superimposed on this vertical variation there is an Atlantic-to-Pacific increase in the deep-water phosphate content. It results from the flow of newly sunken deep water, much of which now originates in the northern Atlantic and tends to purge the Atlantic of the products of decomposition. The horizontal gradient complicates attempts to reconstruct the chemical composition of the glacial ocean: climatic events may have altered the deep-current pattern as well as the ocean's bulk chemistry.

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The Hydrologic Cycle

- Describes exchange of water among ocean, land and atmosphere
- Reservoirs are:
  - Oceans - contain 97% of Earth's water
  - Rivers, lakes and glaciers
  - Groundwater - larger volume than all of the combined water in lakes and rivers

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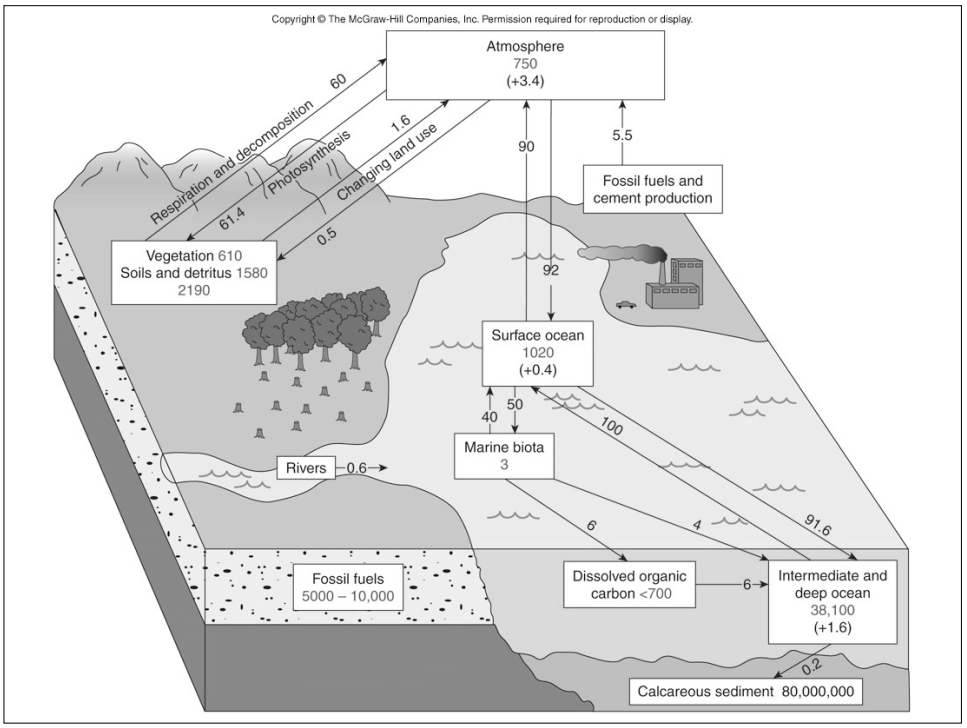
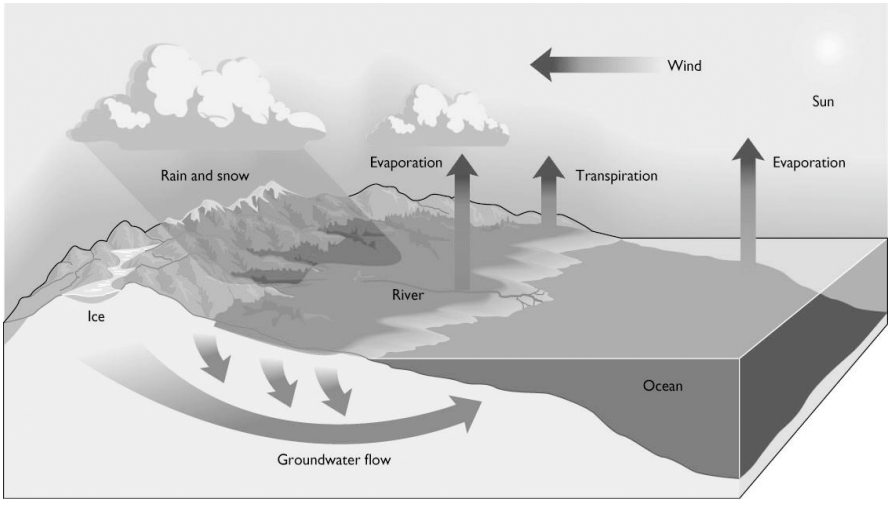


The Hydrologic Cycle



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Desalinization of Seawater

- Produces potable water by:
  - Distillation - evaporation of seawater and condensation of vapor
  - Freezing - produces salt-free ice to be melted for water
  - Reverse osmosis - seawater under pressure is forced through a semi-permeable membrane

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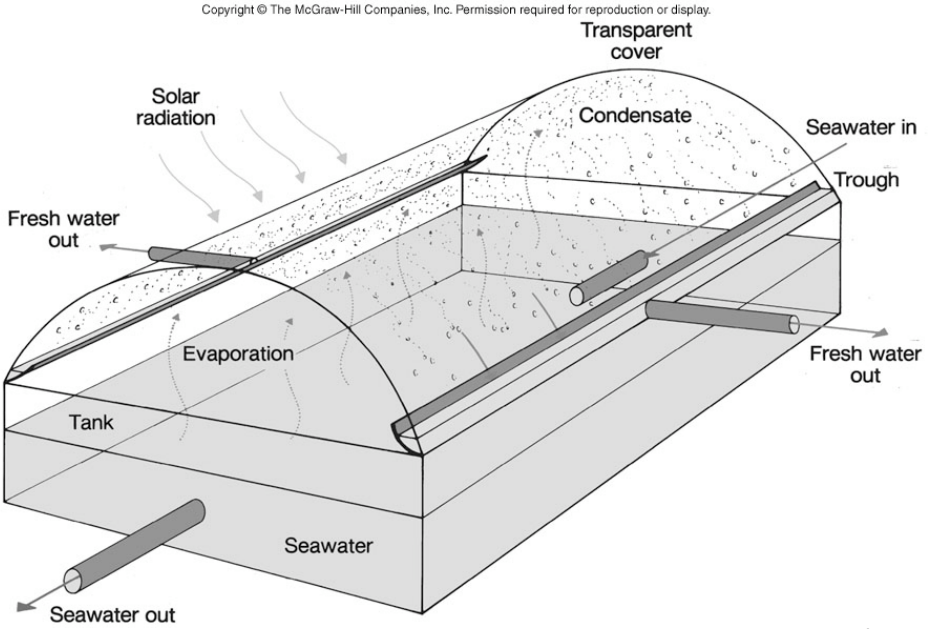

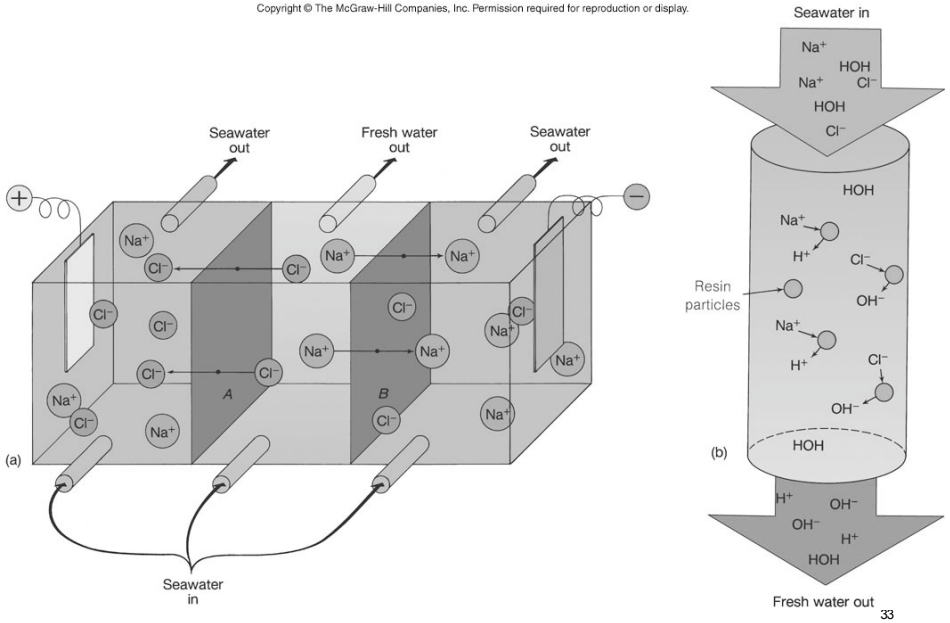

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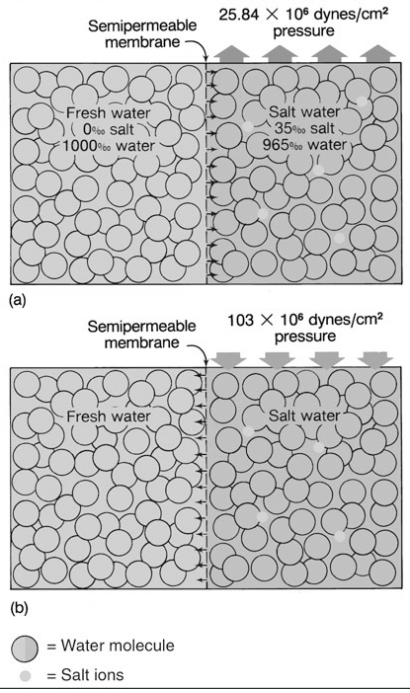

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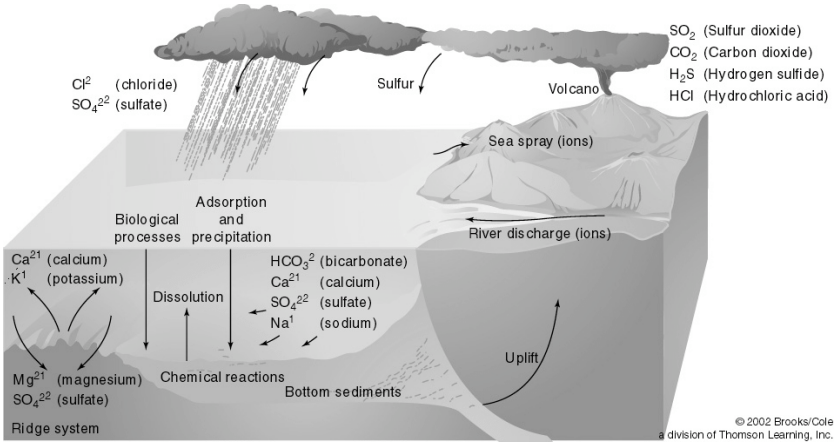
Summary



Many processes regulate the composition of seawater. The concept of a steady state ocean summarizes the idea that ions are added to and removed from the ocean at the same rate.

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