Marine Ecosystems

BI 201 Natural History of Guam

Class Presentation 35

- The marine environment is an aquatic ecosystem influenced by presence of various salts, usually chlorides and sulfates of sodium, magnesium and calcium

Composition of Seawater

- Seawater is essentially freshwater with large numbers dissolved materials, primarily

Cl^-	19.4 ppt
Na^+	10. 8 ppt
Mg^{++}	1.3 ppt
$SO_4^=$	2.7 ppt

Principle of Constant Proportions

- The composition of the dissolved materials varies little throughout the world's ocean
- The Principle of Constant Proportions states that "the relative amounts of the various ions in seawater are always the same"
- That is, the proportions of dissolved salts are relatively constant, although the total amount of dissolved salts in seawater may vary geographically

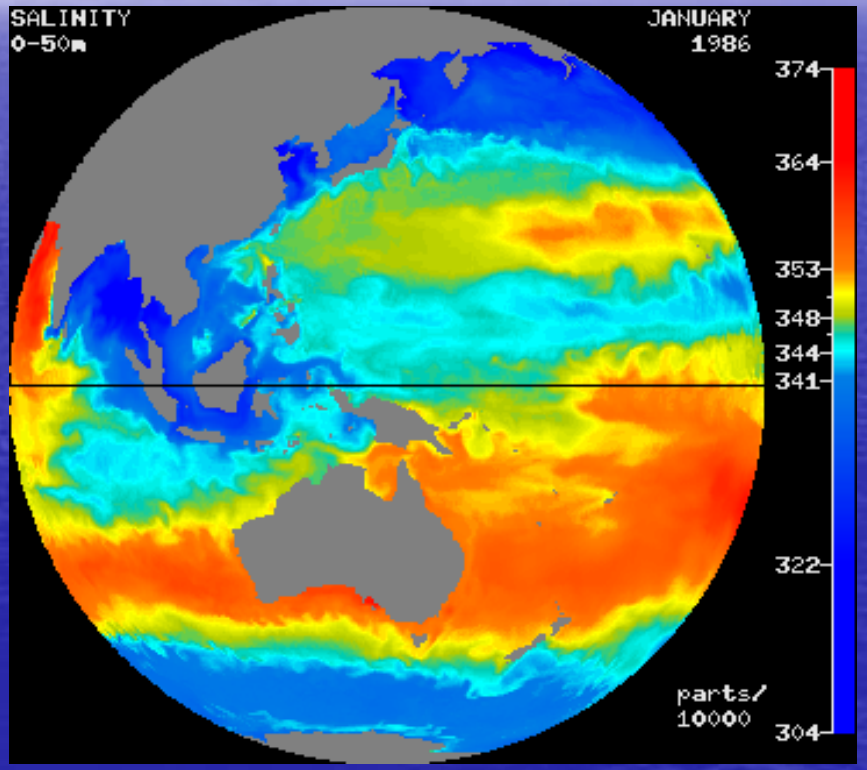
Salinity

- Salinity is the termed used to describe the amount of dissolved materials in seawater
  - Salinity originally referred to the dry weight of salts per kg seawater
  - Later, salinity referred to the chloride content of seawater
  - Now, salinity refers to conductivity
    - That is, the conductivity of a sample of seawater in comparison to a standard solution of potassium chloride (KCl) in which the mass fraction of KCl is 32.4356 × 10–3, the temperature is 15°C, and the pressure is 1 atm

- Salinity is expressed as the ratio of dissolved materials to the amount of water
  - That is, g dissolved solids/1000 g H_2O
- Therefore, if the salinity is 34.7 ‰, then there are 34.7 g of dissolved materials in 1000 g of seawater
  - This could also be written as 3.47 %
  - What are the other 96.53 % ?
    - Water!

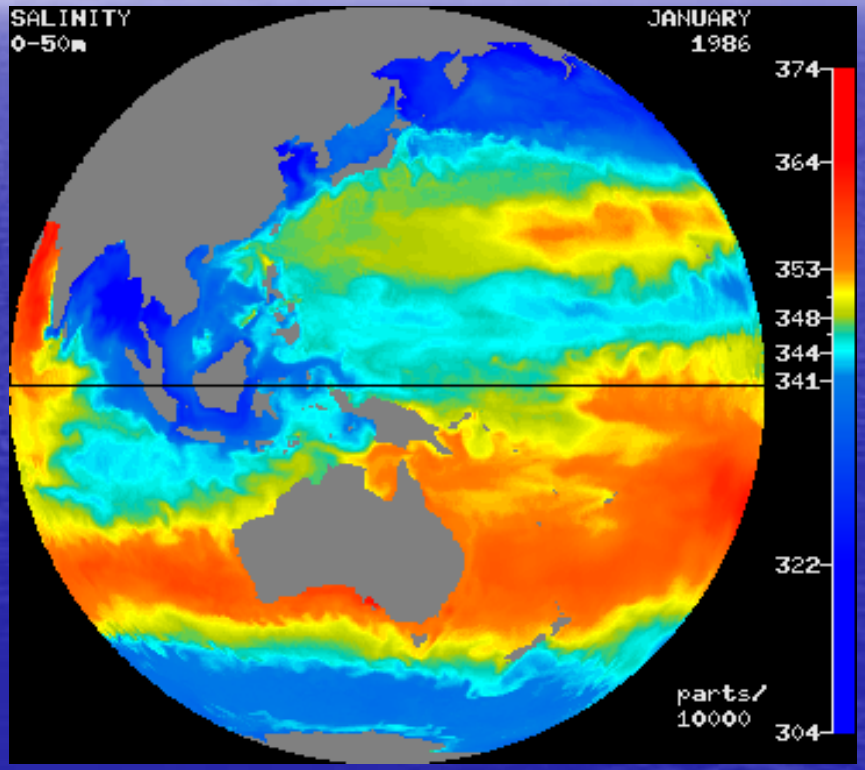
- Variability of salinity within the ocean:
  - Although the proportions of dissolved salts are relatively constant, the concentration of salts changes with the addition or removal of water
  - Therefore, salinity variation caused by:
    a) The local rate of **evaporation**
    b) The local rate of **precipitation** (i.e., rain and snow)
    c) The volume of **freshwater discharge** into the ocean basin (i.e., rivers and melting of polar ice)

Region	Salinity
Red Sea	40 ‰
Mediterranean Sea	38 ‰
Black Sea	18 ‰
Baltic Sea	8 ‰
Guam	34 ‰

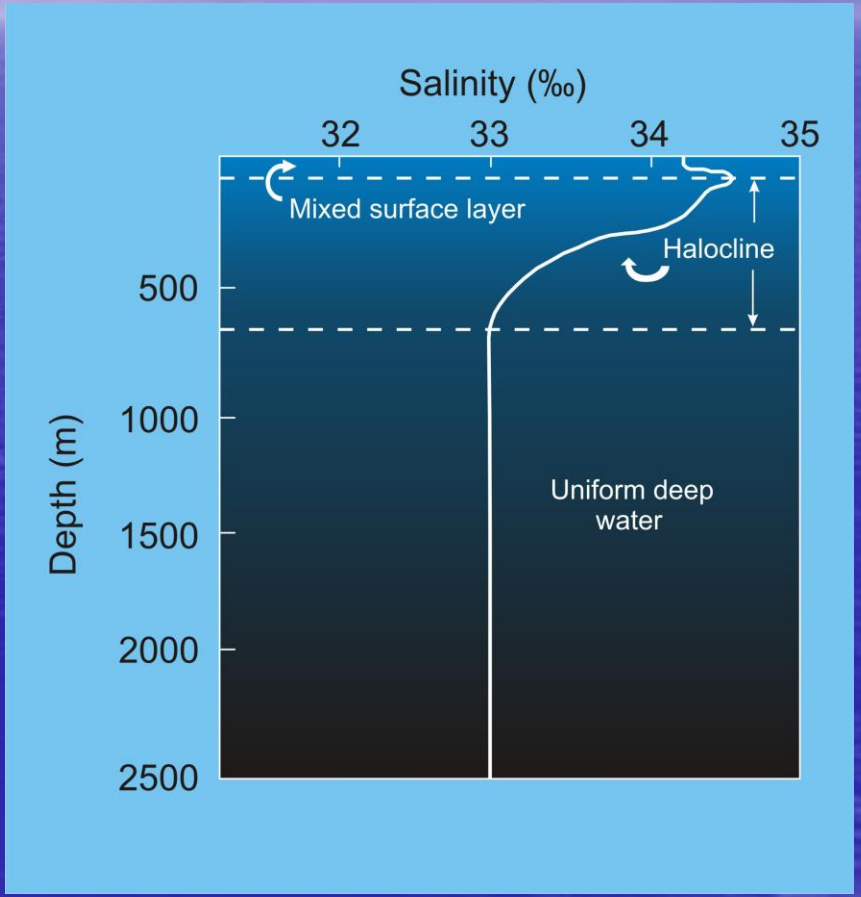


Global salinity, January 1986

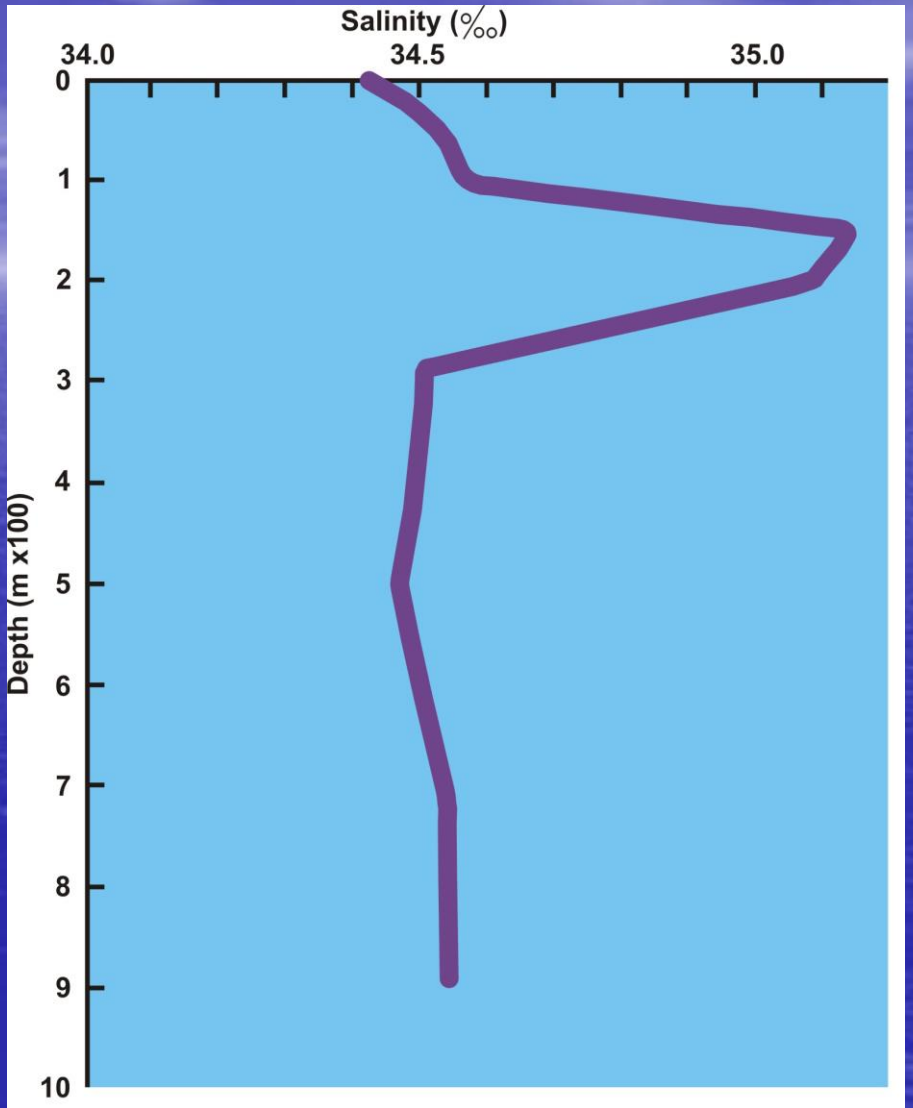
- Notice that the salinity is below the global average in the subpolar and temperate region between 40° and 70° latitude
  - Precipitation is generally greater than evaporation in this zone
- In the tropics and temperate region between 10° and 40° latitude, the salinity is greater than average
  - Evaporation is greater than precipitation in this zone



- Salinity varies not only geographically, but vertically in the water column
  - **The halocline is** a water layer characterized by large salinity changes over small changes in depth



- In Guam, the halocline is found at about 100 m depth



Mean salinity of seawater in the vicinity of Cabras Island, Luminao Reef, and Glass Breakwater, Guam (February 1978 - February 1979). {Modified from Lassuy, 1979].

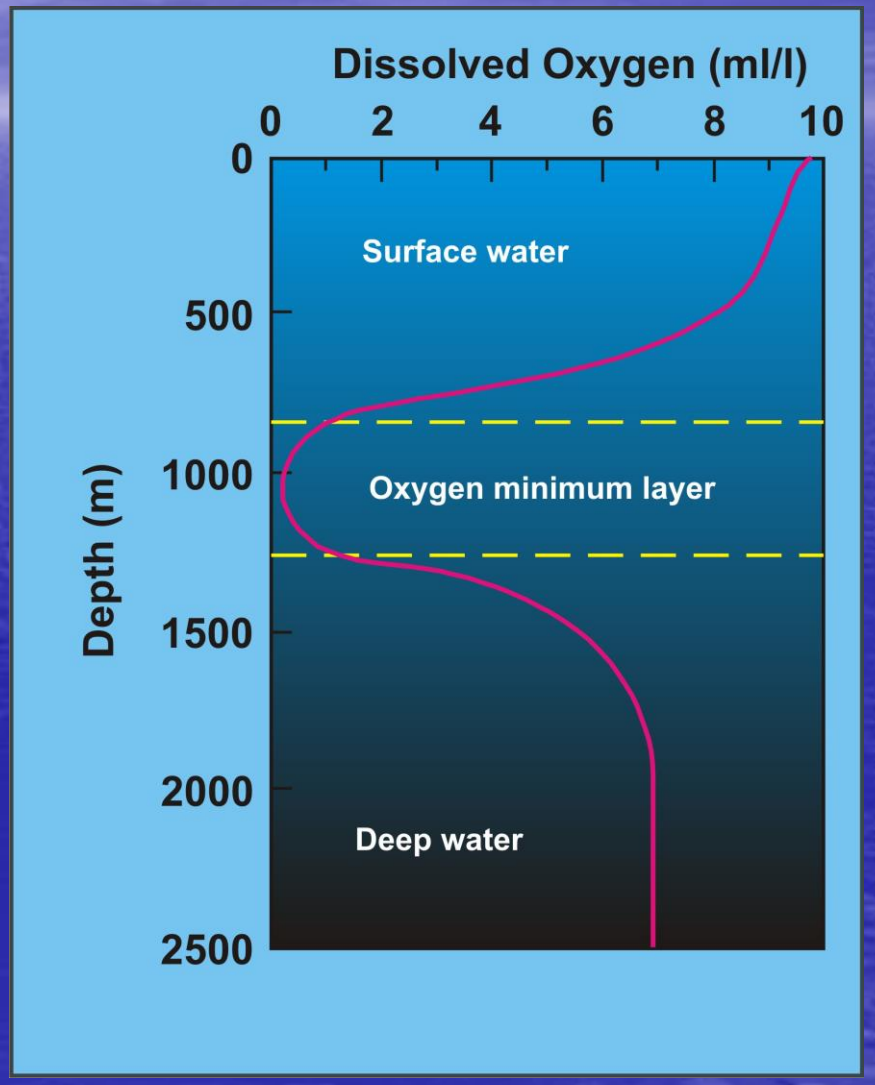
- Despite the global variability, the salinity of the ocean is not increasing, because inputs of ions are balanced by outputs of ions
  - Inputs:
    - River discharge adds ions, especially Mg^{++} ions
    - The mid-oceanic ridge and hydrothermal vents
    - Submarine and terrestrial volcanoes add ions, especially HS^{-} and Cl^{-}
  - Outputs:
    - Chemical precipitation, especially Mn crusts and nodules
    - Ions incorporated into living organisms, especially carbonate and siliceous shells
    - Removal by wind and wave action

Dissolved gases in seawater

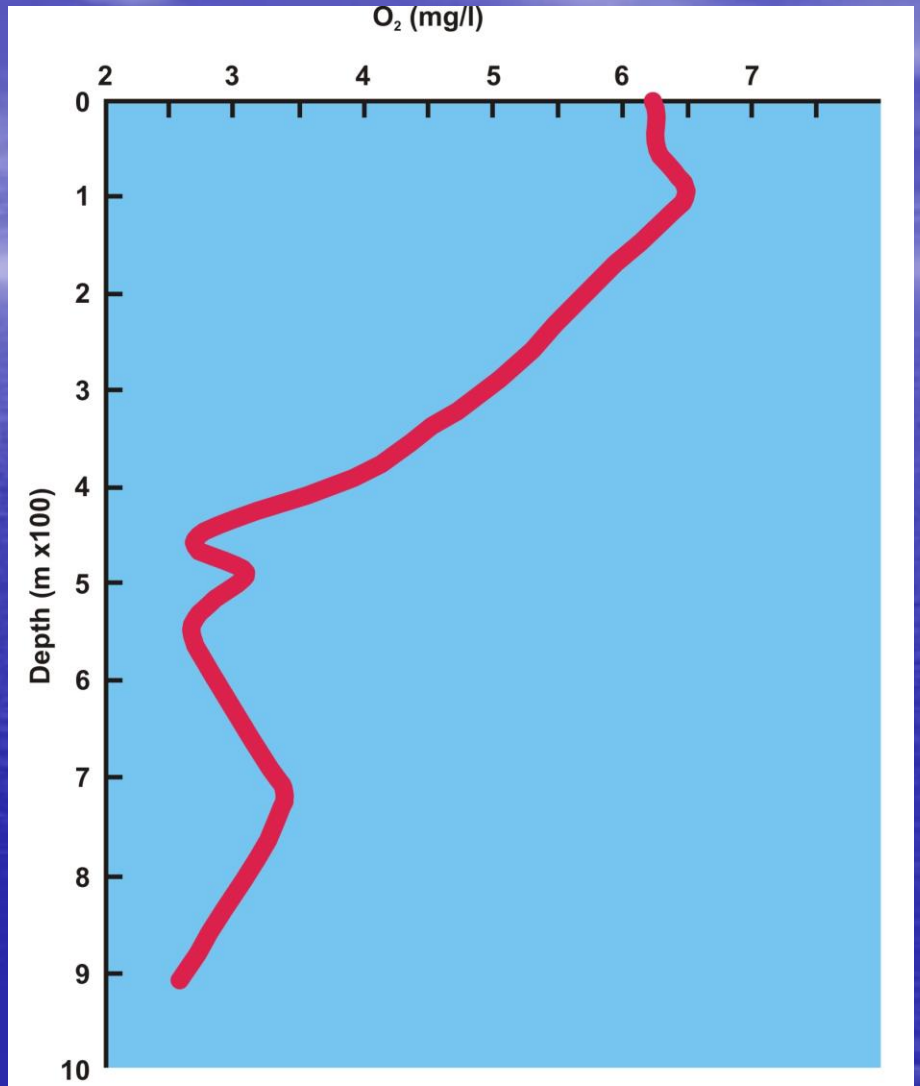
- **Dissolved Oxygen (DO)**
  - Organisms use DO to release energy during cellular respiration
  - Although the atmosphere contains about 21% O_2, DO in seawater varies from 0 to 9 mℓ/ℓ (ppm)
  - Major sources of DO:
    a) The primary source of DO is photosynthesis by phytoplankton
      - Because plants produce more O_2 than seawater can dissolve, excess O_2 diffuses into the atmosphere
      - About 50 % of atmospheric O_2 comes from oceanic photosynthesis

    b) The secondary source of DO is turbulence; i.e., water movement, especially surface winds and waves

- The concentration of dissolved oxygen varies with depth
  - DO is abundant in surface waters because of photosynthesis and turbulence
  - DO concentrations decline with depth down to the oxygen minimum layer



- DO concentrations approach 0 ppm in the oxygen minimum layer because of oxygen consumption by bacterial respiration
- DO levels rise below the oxygen minimum layer, because fewer animals are present, and organisms inhabiting colder water have lower metabolic rates and slower rates of oxygen consumption

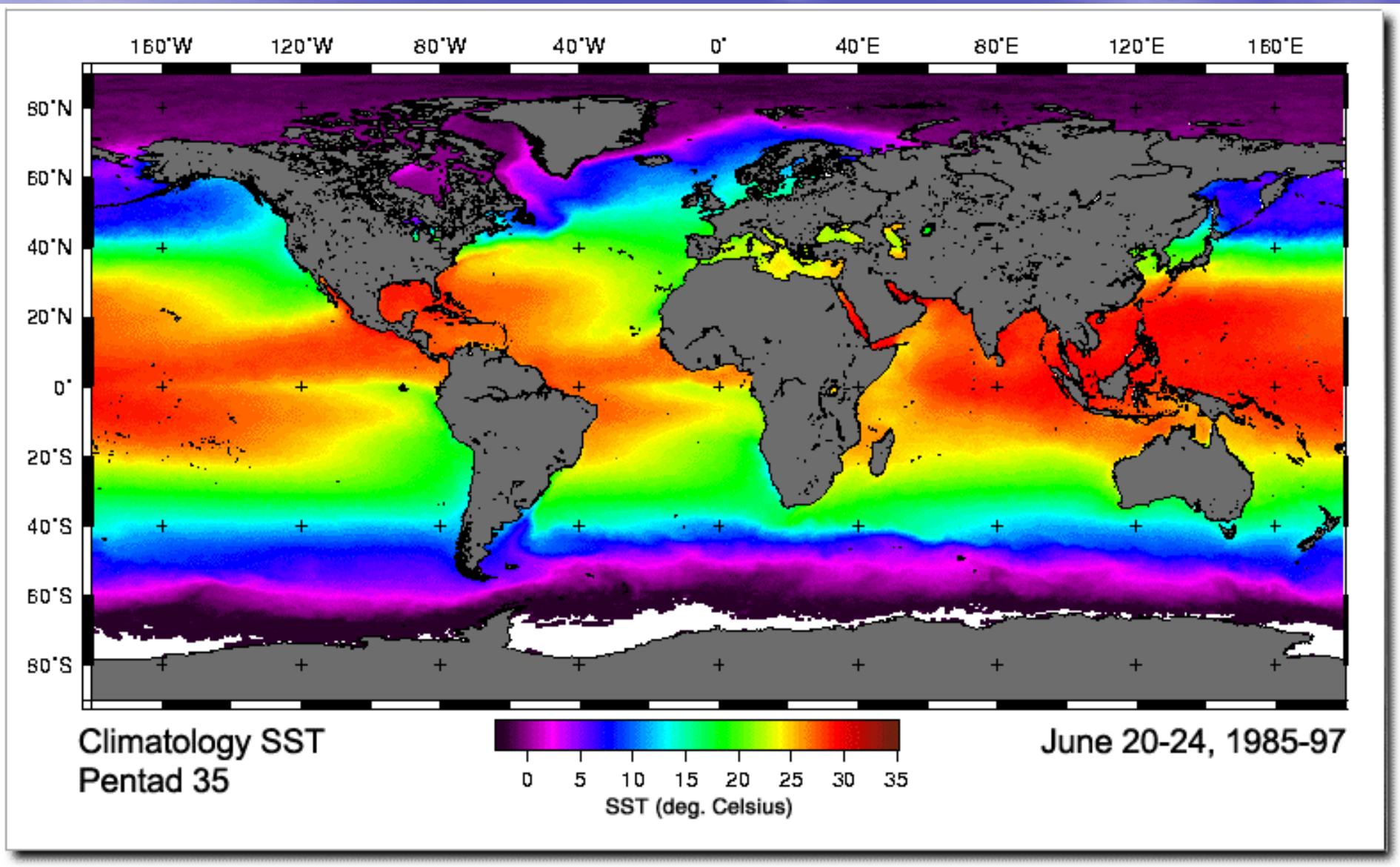


Mean dissolved oxygen (O_2) from surface down to 905 m (2970 ft) in the vicinity of Cabras Island, Luminao Reef, and Glass Breakwater, Guam (February 1978 - February 1979). [Modified from Lassuy, 1979].

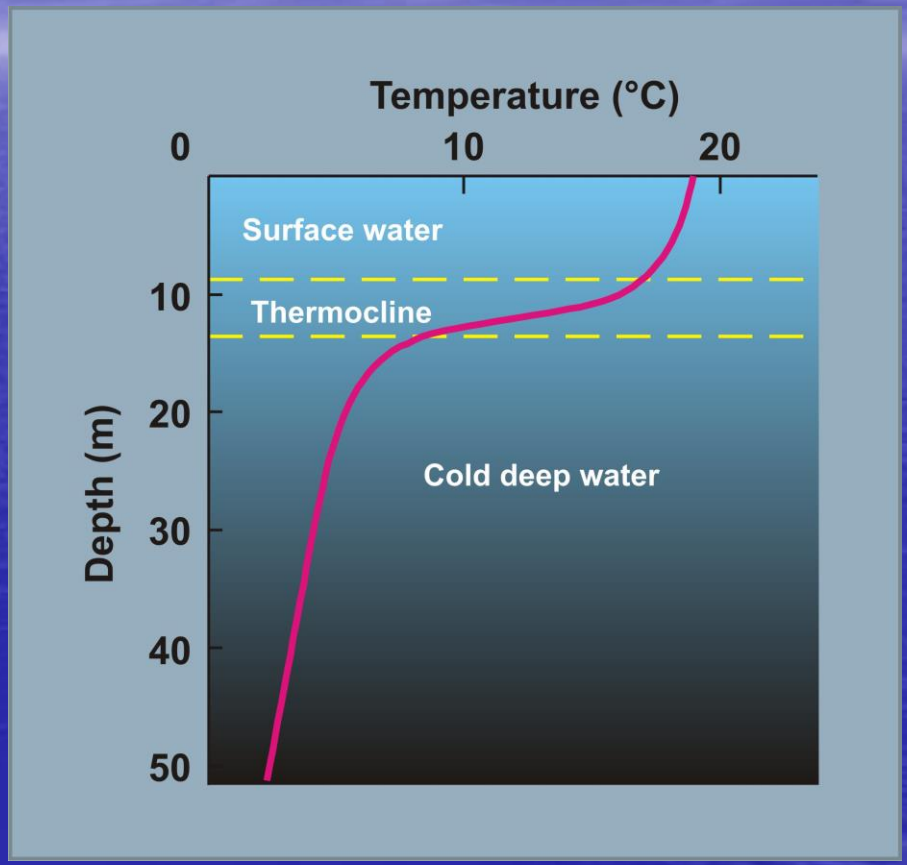
Temperature

- Temperature is one of most important physical factors in the ocean, because it affects density, viscosity, salinity, and the concentration of dissolved gases, as well as influencing the metabolic and reproductive rates of organisms

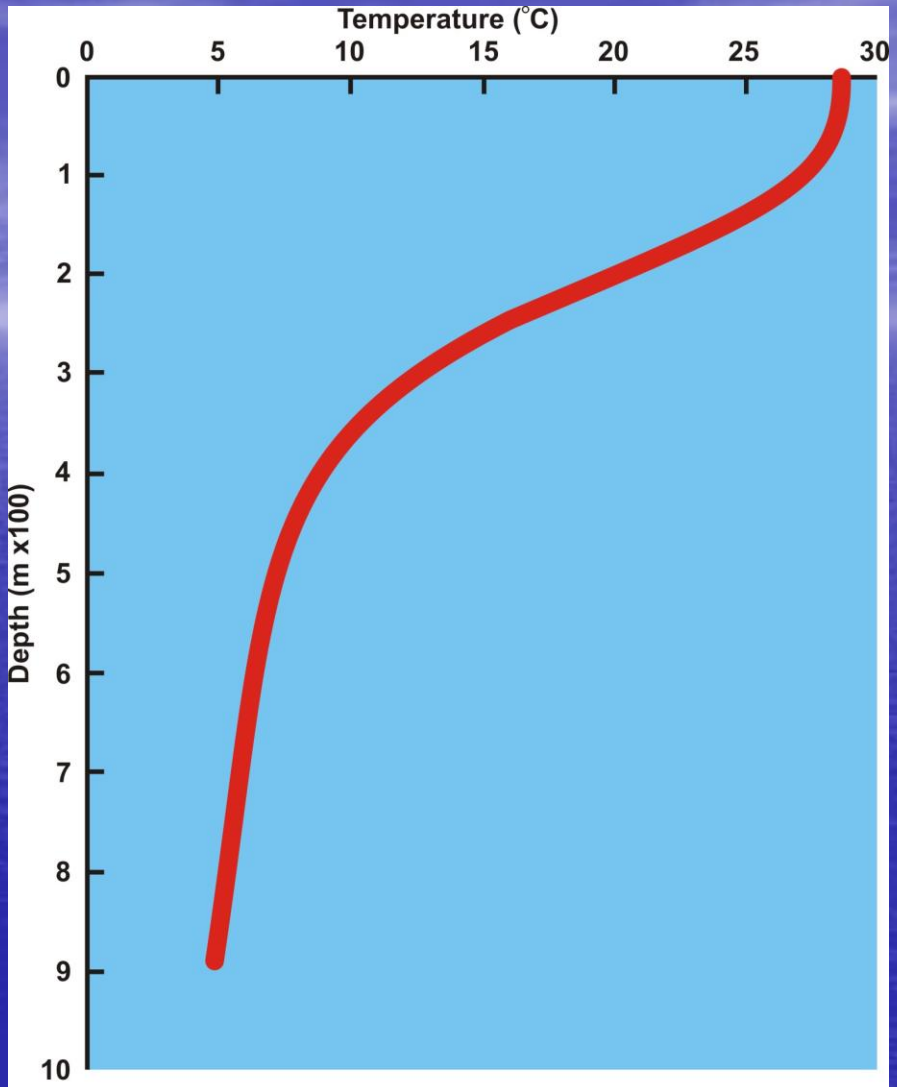
- Temperature varies seasonally with solar radiation
- The seasonal range of temperatures at any locality is affected by
  a) latitude
  b) depth
  c) nearness to shore


160°W
120°W
80°W
40°W
0°
40°E
80°E
120°E
160°E
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S
Climatology SST
Pentad 35
0
5
10
15
20
25
30
35
SST (deg. Celsius)
June 20-24, 1985-97

- Temperature decreases gradually with depth down to the thermocline, where temperature increases rapidly with depth
- Below the thermocline, temperature decreases gradually down its minimum in the deepest part of the ocean



- In the tropics, the thermocline is deeper

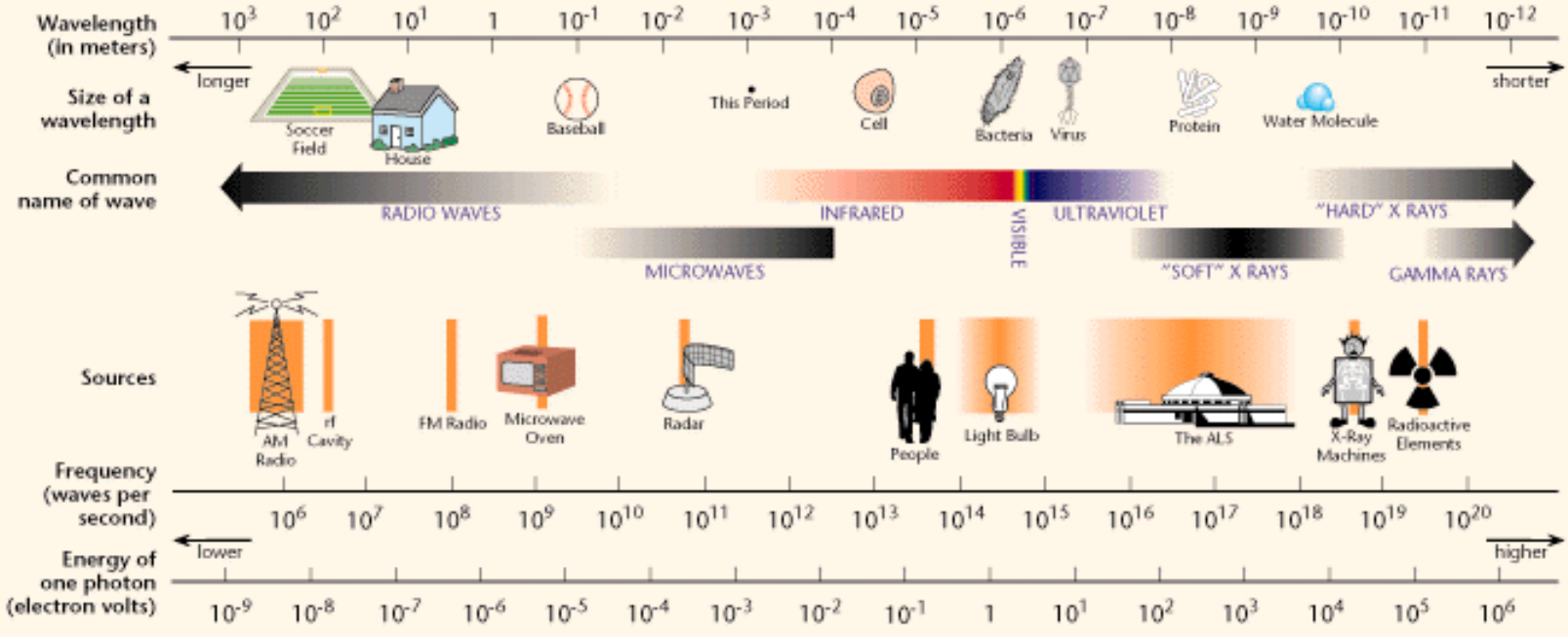


Mean monthly seawater temperature in the vicinity of Cabras Island, Luminao Reef, and Glass Breakwater, Guam (February 1978 - February 1979). [Modified from Lassuy, 1979].

Light

- Almost all life on Earth ultimately depends upon energy from the sun
- Energy transmitted from sun reaches Earth as **electromagnetic radiation**

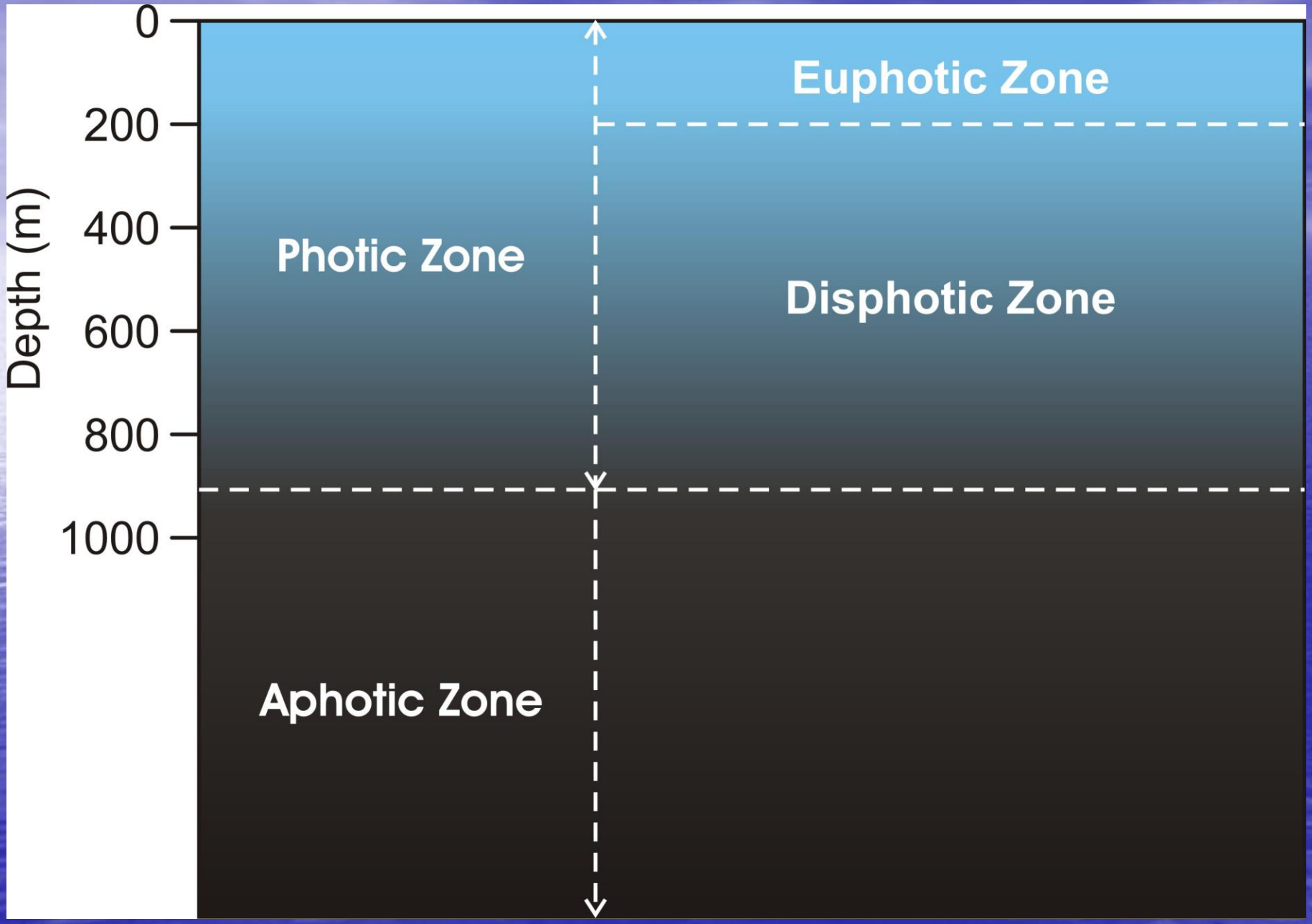
THE ELECTROMAGNETIC SPECTRUM



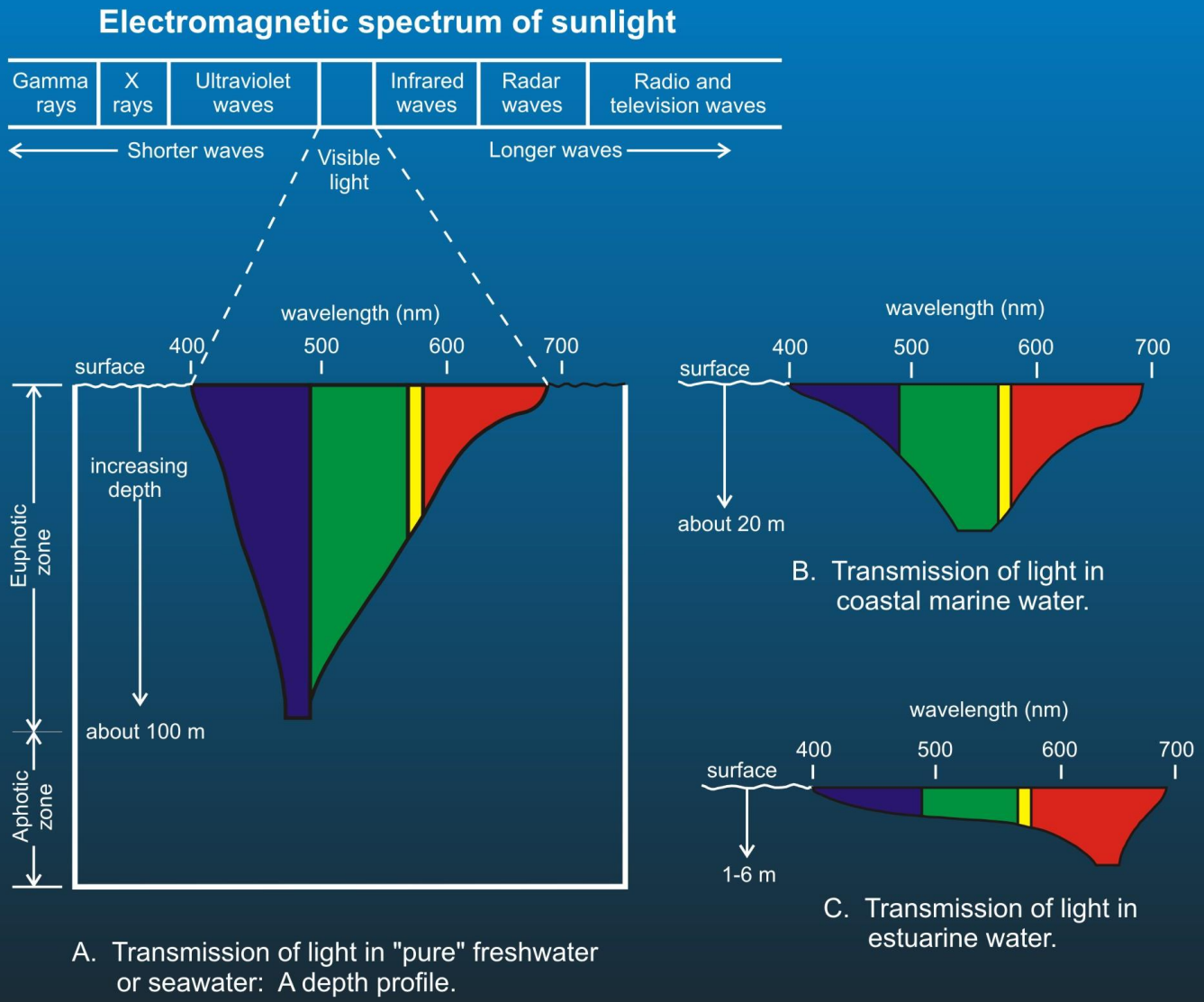
- Visible light striking the ocean surface is
  a) reflected,
  b) absorbed,
    - 65% of the light energy is absorbed in the first meter of water
  c) transmitted
    - less than 1% of the visible penetrates to 100 m depth

- Energy in the visible wavelengths is captured by marine plants possessing chlorophyll and accessory pigments
- Marine plants use the energy to combine H_2O and CO_2 to manufacture their own food in the process known as photosynthesis
- Because they are capable of manufacturing the organic compounds necessary for their metabolism, they are called autotrophs

- Vertical zonation of light in the ocean
  - **photic zone**
    - The photic zone, the upper layer of water that receives sunlight, is subdivided into:
      - **euphotic zone**
        - the relatively brightly lit upper layer where light intensity is sufficient to support photosynthesis
        - the extent of this zone depends upon turbidity ("cloudiness"), but ranges from 0 to 200 m
      - **P/R compensation depth**
        - The P/R compensation depth is the narrow zone in which the rate of O_2 production by photosynthesis equals the rate of O_2 consumption for respiration
      - **disphotic zone**
        - The disphotic zone is the twilight zone where light is insufficient to support photosynthesis but sufficient enough for animal responses
  - **aphotic zone**
    - The dark lower regions; no light; no photosynthesis; ca. 90 % of ocean water, by volume


0
200
400
600
800
1000
Depth (m)
Euphotic Zone
Photic Zone
Disphotic Zone
Aphotic Zone

- Absorption of light by water is selective
  - Longer wavelengths (the red end of the spectrum) of light are absorbed first, and shorter wavelengths (the violet end of the spectrum) penetrate to greater depth
  - The order of absorption is red, orange, yellow, green, blue, violet, and indigo (ROY G BIV)
  - All of the red wavelengths are absorbed the top 1 m of the ocean

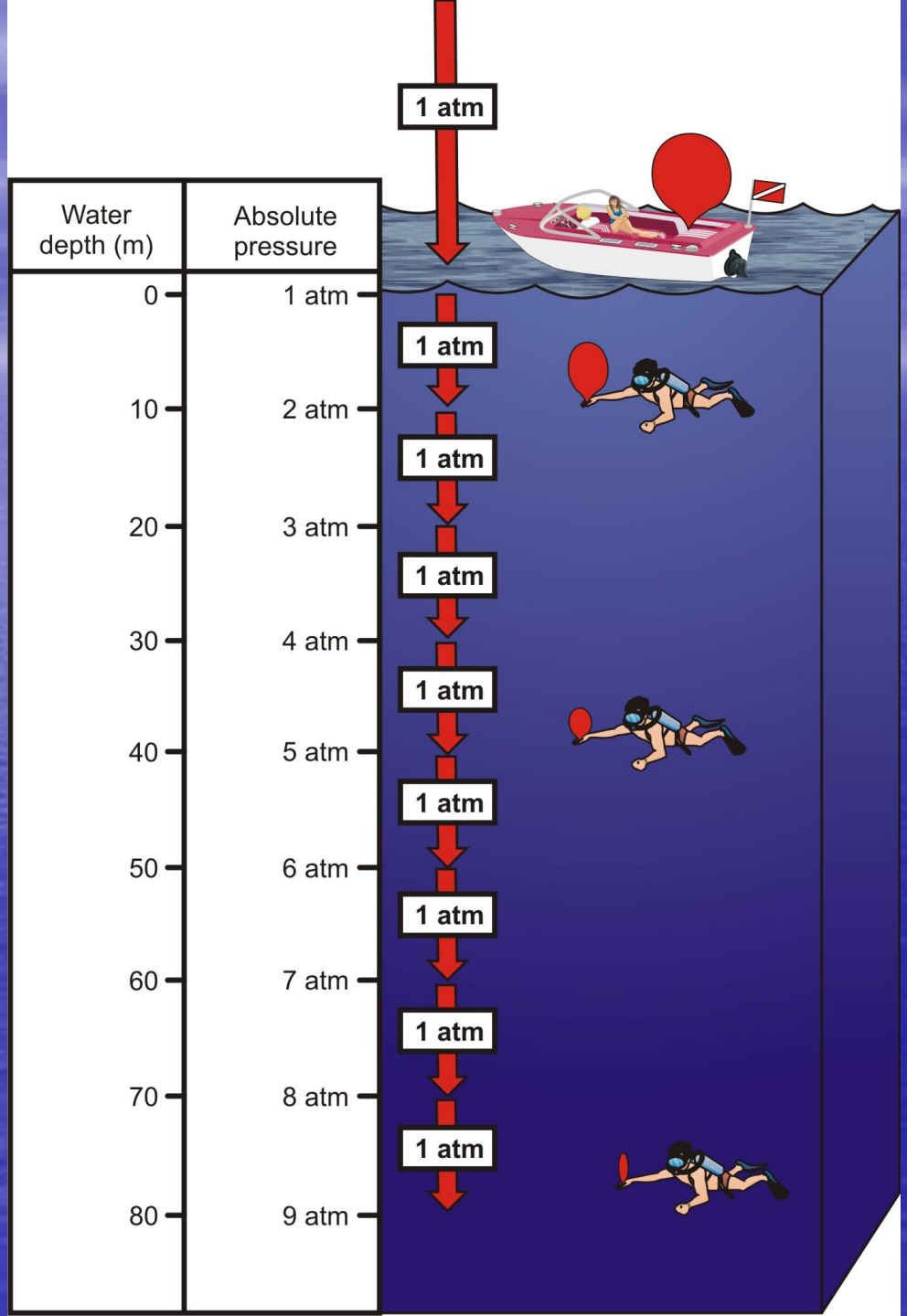


Light in the marine environment. Selective absorption and transmission of light entering: A. Clear ocean water, B. Coastal marine water, C. Estuarine water. (Adapted from J.S. Levine. 1980. Vision underwater. Oceanus 23(3):19-26).

Pressure

- As matter, water has mass
- The mass of water exerts force on objects in the water
- The force of water against an object is called pressure
- Pressure is measured in
  - lb/in^2 = psi;
  - kg/cm^2;
  - bar; or
  - atm = 14.696 lb/in^2 or 1.033 kg/cm^2 or 1013 mb

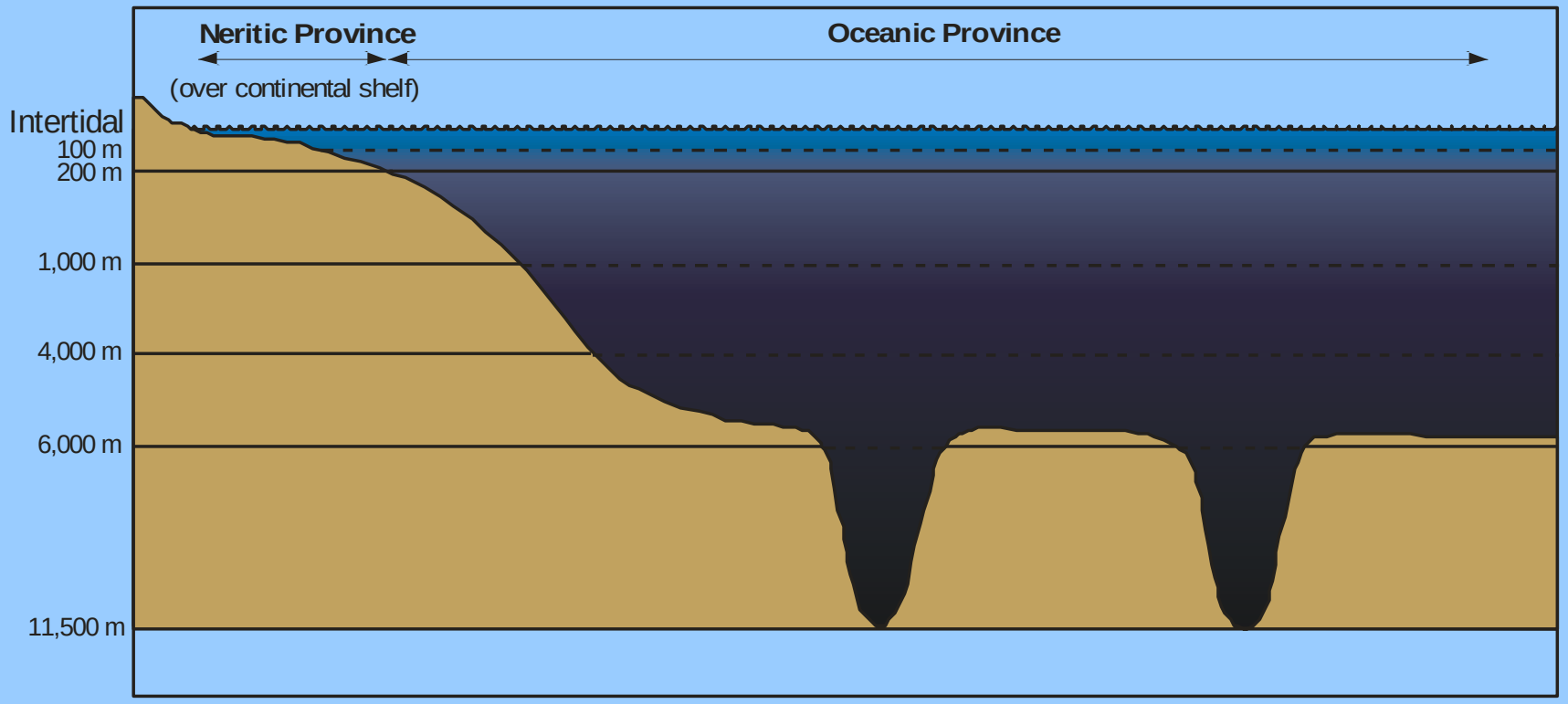
- Pressure in the ocean is directly proportional to depth
- The pressure at sea level is 1 atm because of the mass of the atmosphere
- Pressure increases by 1 atm with every increase of 10 m in depth of seawater
  - What would the pressure be at 30 m depth?
  - What is the pressure in the Challenger Deep?


Water depth (m)
Absolute pressure
0
1 atm
10
2 atm
20
3 atm
30
4 atm
40
5 atm
50
6 atm
60
7 atm
70
8 atm
80
9 atm
1 atm
1 atm
1 atm
1 atm
1 atm
1 atm
1 atm
1 atm

Zonation

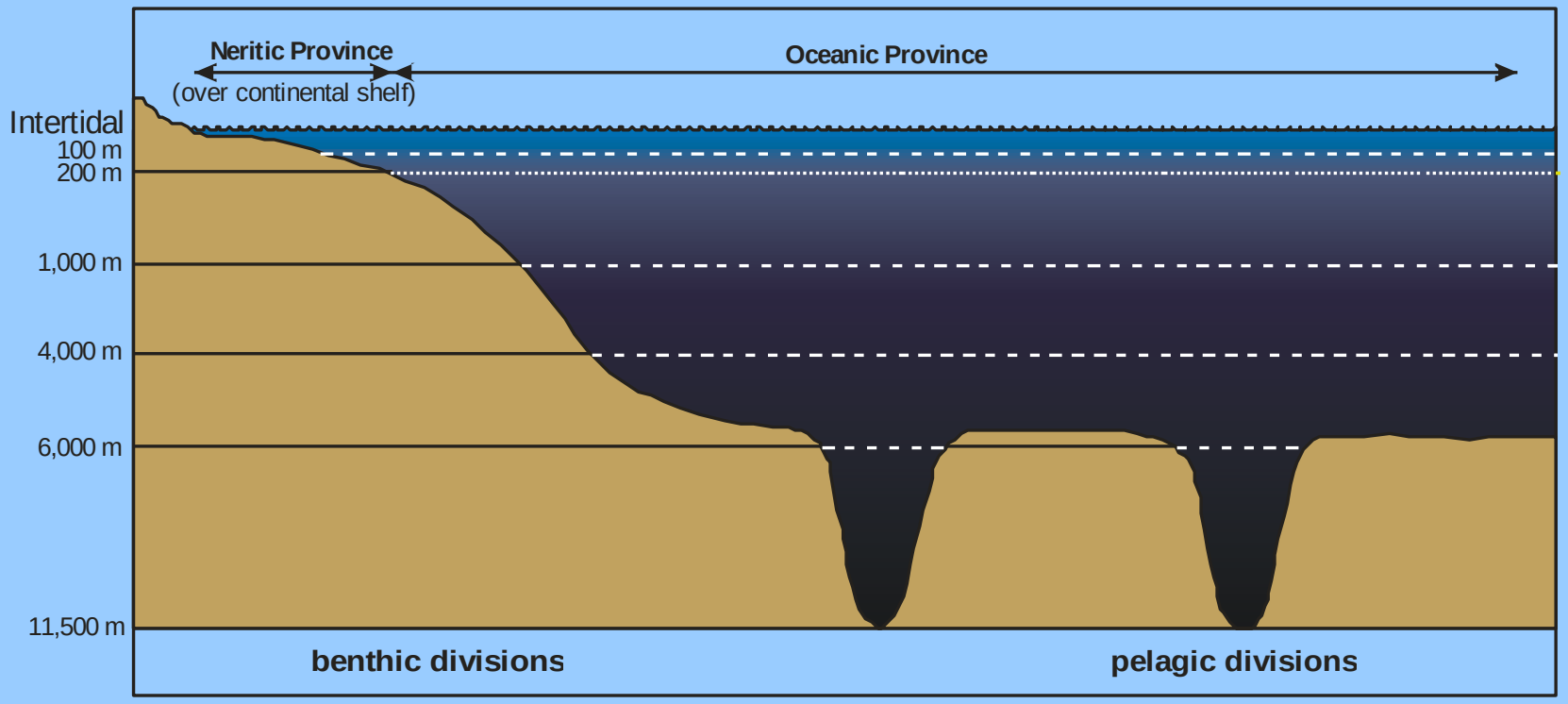
- Marine biologists subdivide the marine environment into distinct zones to facilitate communication about their studies

- There are two broad provinces of the marine environment
  1) neritic province
     - Seawater lying over the continental shelf is the neritic province
  2) oceanic province
     - Seawater lying beyond the continental shelf is the oceanic province


Neritic Province
Oceanic Province
(over continental shelf)
Intertidal
100 m
200 m
1,000 m
4,000 m
6,000 m
11,500 m

- Ecologists further characterize the organisms in these provinces as occupying either the
  - pelagic zone
    - waters of the ocean

      or the
  - benthic zone
    - the sea floor

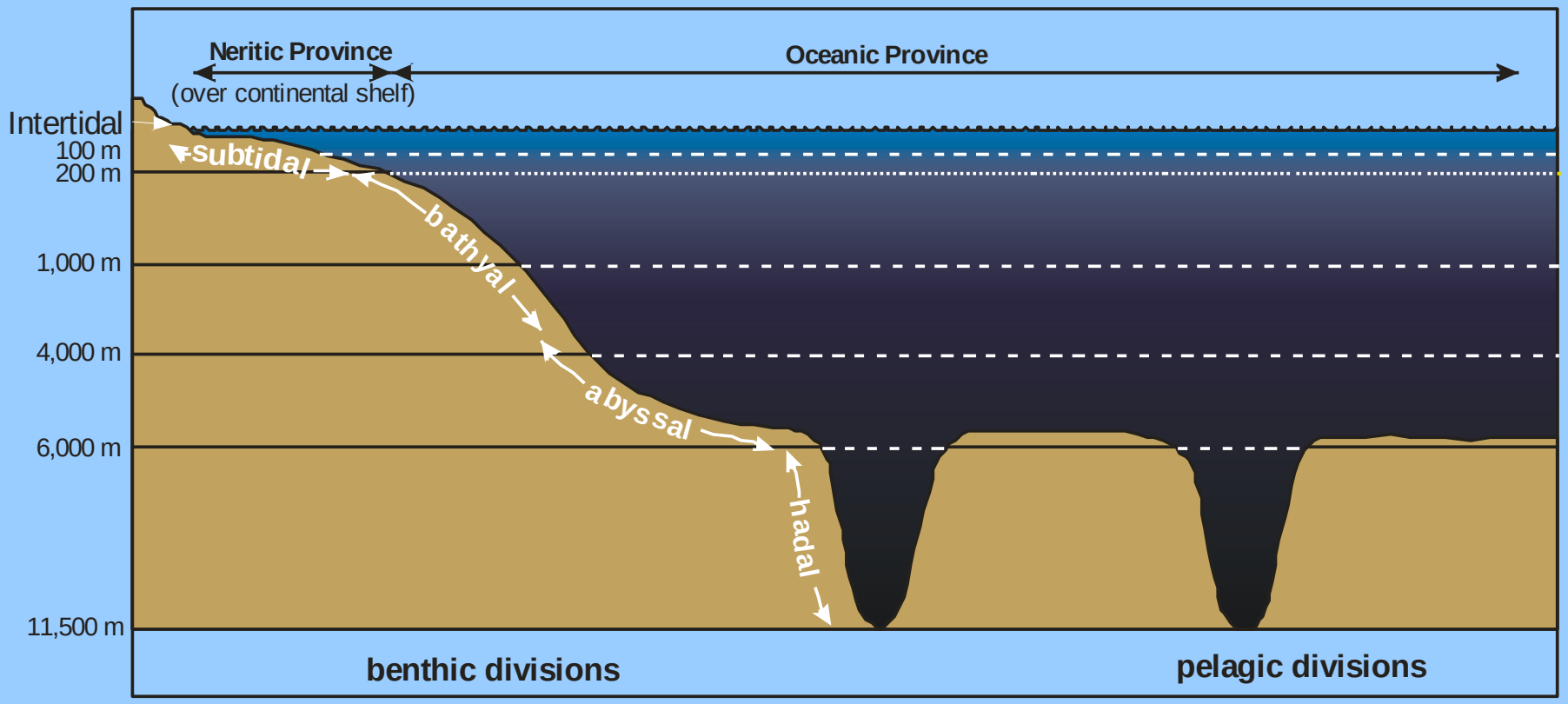


Cross section of part of an idealized ocean, with the various zones of the benthic and pelagic divisions indicated.

- Divisions of the Benthic Zone
  - intertidal, or littoral
    - This is the area of the shoreline between the high tide and low tide lines
    - The intertidal zone is the smallest division of the ocean
    - The intertidal is a very stressful environment, because it is exposed to air at low tide and inundated at high tide

- subtidal, or sublittoral
  - This is the area extending from the low tide line out to the edge of the continental shelf
  - The subtidal is never exposed to air
- bathyal
  - This is the ocean floor of the continental slope
  - The bathyal zone extends from –200 m to ca. –4000 m

- abyssal
  - This is the ocean floor of the abyssal plain
  - The abyssal zone extends from –4000 m to –6000 m
- hadal
  - This is the seafloor of submarine trenches
  - The hadal zone is found mostly below –6000 m depth



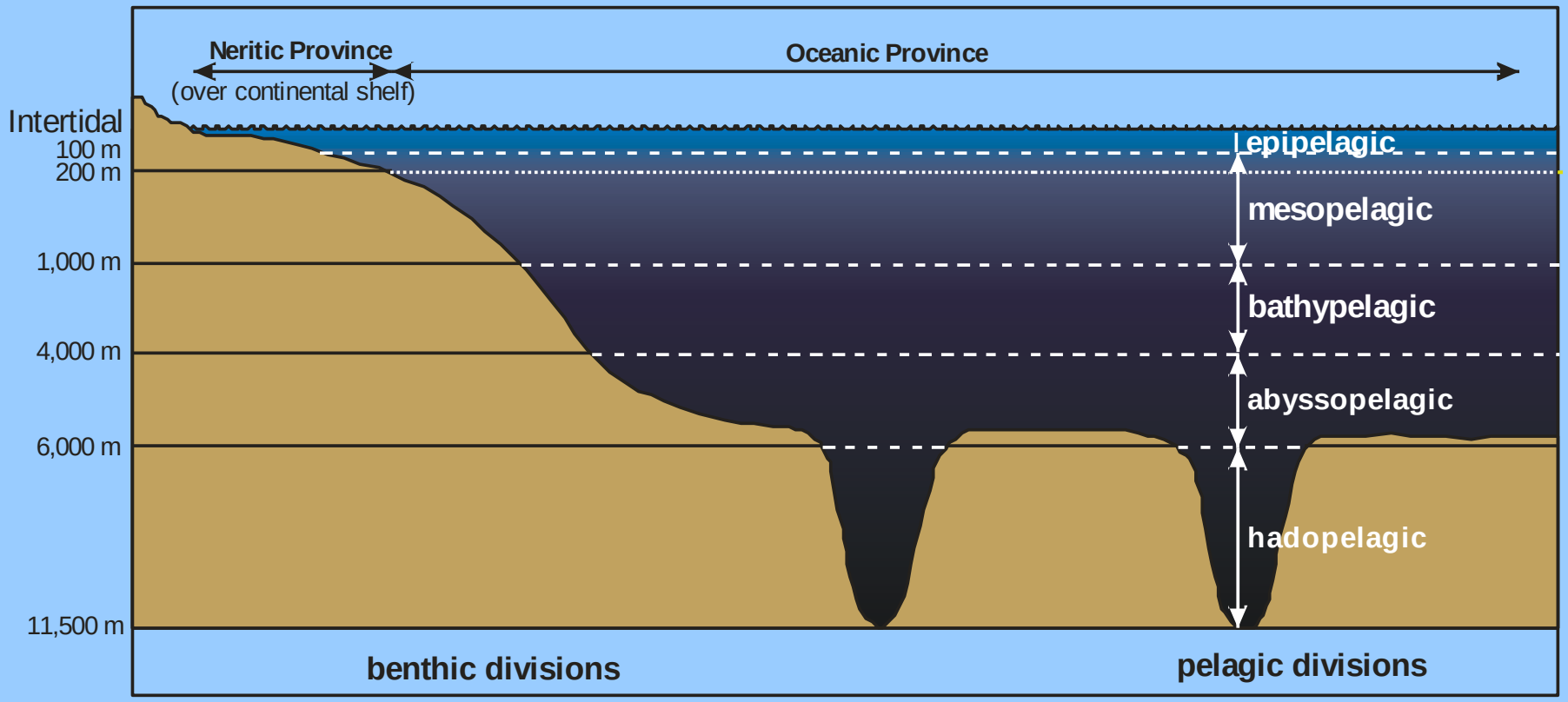
Cross section of part of an idealized ocean, with the various zones of the benthic and pelagic divisions indicated.

- Divisions of the Pelagic Zone
  - epipelagic
    - This is the well-lighted, well-mixed upper layer of oceans
    - It is also called the *euphotic zone*
    - The epipelagic zone extends from the surface down to ca. –100 to –200 m

- mesopelagic
  - This is a twilight zone, where the light intensity is too dim to support photosynthesis (i.e., this is the *disphotic zone*)
  - Plants cannot grow here
  - This zone typically extends down to depths of ca. –700 m to –1,000 m, where the water temperature drops to ca. 10° C
  - The temperature is relatively constant and the oxygen minimum layer occurs here

- bathypelagic
  - This zone underlies the mesopelagic and includes most of the water over the continental slope
  - The bathypelagic extends down to depths of ca. –2000 m to –4000 m, where the water temperature drops to 4° C

- abyssopelagic
  - The water overlying the abyssal plain is the abyssopelagic zone
  - It extends down to a depth of –6000 m
- hadopelagic
  - The open water of deep oceanic trenches is the hadopelagic zone
  - It extends from –6,000 m to –11,022 m



Cross section of part of an idealized ocean, with the various zones of the benthic and pelagic divisions indicated.

Distribution of major ecological zones of the world's ocean*

Characteristic	Intertidal and Subtidal	Bathyal	Abyssal	Hadal
Area of sea bed (%)	8	16	76	1
Depth (m)	0–200	200–4000	4000–6000	6000–11022
Pressure (atm)	1–21	21–401	401–601	601–1103
Temperature (°C)	25–5	15–5	<5	<3.5
Light	bright-dim	dim-dark	total darkness	total darkness

*[Source: Meadows, P.S., and J.I. Campbell. 1988. An introduction to marine science. 2nd edition. John Wiley & Sons, New York. ix + 285 p.]