AQUATIC ECOLOGY (BIOL 463)

F. E. Awortwi, PhD

"Water is the most critical resource issue of our lifetime & our children's lifetime. The health of our waters is the principal measure of how we live on the land" Luna Leopold

Overall Aim of the course

“To facilitate the acquisition of **knowledge** & **understanding** of the earth’s aquatic ecosystems - investigate & learn about the ecology of these systems.”

Intended Learning Outcomes (ILOs)

- **know** the origin, distribution, availability, & benefits of aquatic systems & **understand** the basic properties of water which impact on the conditions of existence for aquatic organisms.

- **explore** the physical, chemical, & biological characters of aquatic ecosystems & **learn** some methods for determining or assessing these factors in these systems.

Intended Learning Outcomes (ILOs)

- **know** & **understand** the distribution & adaptations of aquatic plants & animals.

- **know** & **understand** the community structure & dynamics of aquatic ecosystems.

- **know** & **understand** productivity, nutrient cycling, & eutrophication in aquatic ecosystems & their importance in sustaining them.

Intended Learning Outcomes (ILOs)

- Be **actively** involved in **advocacy** through **environmental education** for the protection of our water resources to secure it for:
  - **drinking** & other **domestic uses** (washing, cooking, fish & fish products, etc);
  - **agricultural** activities;
  - **industrial** activities;

Intended Learning Outcomes (ILOs)

- *The following **SDG**s are directly related to water & water resources in particular:*
  - **6** – ensure <u>availability</u> & <u>sustainable management</u> of **water** & **sanitation** for all;
  - **14** – <u>conserve</u> & <u>sustainably use</u> **oceans**, **seas**, & **marine resources** for **sustainable development**;

Course Requirements

- Students are expected to:
  - Participate in **lectures/seminars**
  - Do out of class projects, **assignments**, practicals, etc & complete them on time
  - Take impromptu/<u>scheduled</u> quizzes & **tests**
  - Write lab, field, & <u>research</u> **reports**

Course Assessments

- A 3-part assessment involving:

Part of Assessment	% of marks
Continuous assessment: Assignments/seminars/labs or field practicals, mid-semester, etc	30
Final examination	70

Course Assessments (cont)

- **Questions types**:
  - <u>Objective tests</u>
    - Multiple choice
    - True/false
    - Matching
    - Short answer
  - <u>Essay tests</u>
    - *

Nature of test items expected

- Mixture of these:

1. Knowledge
2. **Understanding**
3. **Application**
4. **Analysis**
5. **Synthesis**
6. **Evaluation**

Mid semester & end of semester exams

- **Mid semester exams**
  - Monday, February 27th to Friday March 3rd 2023.

- **Semester exams**
  - Tuesday, April 11th to Friday April, 28th 2023.

Course Instructor

- F. E. Awortwi, PhD
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Course Outline

- **UNIT 1:** INTRODUCTION TO THE AQUATIC ENVIRONMENT
- **UNIT 2:** THE PHYSICAL STRUCTURE OF AQUATIC ECOSYSTEMS
- **UNIT 3:** FACTORS IMPORTANT IN THE STUDY OF AQUATIC SYSTEMS
- **UNIT 4:** AQUATIC PLANTS & ANIMALS
- **UNIT 5:** COMMUNITY STRUCTURE & DYNAMICS IN AQUATIC SYSTEMS
- **UNIT 6:** PRODUCTIVITY, NUTRIENT CYCLING, & EUTROPHICATION OF AQUATIC SYSTEMS

UNIT 1

INTRODUCTION TO THE AQUATIC ENVIRONMENT

UNIT 1: INTROD. AQUATIC ENVT - ILOs

- **know** & **understand** origin, evolution, distribution, & availability of aquatic systems;
- **know** the different life zones in aquatic systems & associated life forms & understand their interactions;
- **understand** the ecological & economic importance of aquatic systems;

UNIT 1: INTROD. AQUATIC ENVT - ILOs

- **know** & **understand** the major threats to the **ecological** & **economic** benefits provided by aquatic systems;

- **know** & **understand** some key properties of water - the medium of aquatic systems & their importance to the conditions of existence of aquatic biota

UNIT 1: INTROD. AQUATIC ENVT – origin & evolution

- O**rigin** of water bodies linked to that of Earth & our **solar system** & **galaxies**.

- Earth's atoms, its water bodies & life forms formed in **stars** BYA.

- Star growth & the big bang concept.

UNIT 1: INTROD. AQUATIC ENVT – origin & evolution

- Formation of sun/planets from **clouds** of dust/gas from elements of exploded stars though the force of gravity.

- Formation of world's waters through volcanic activity & comets.

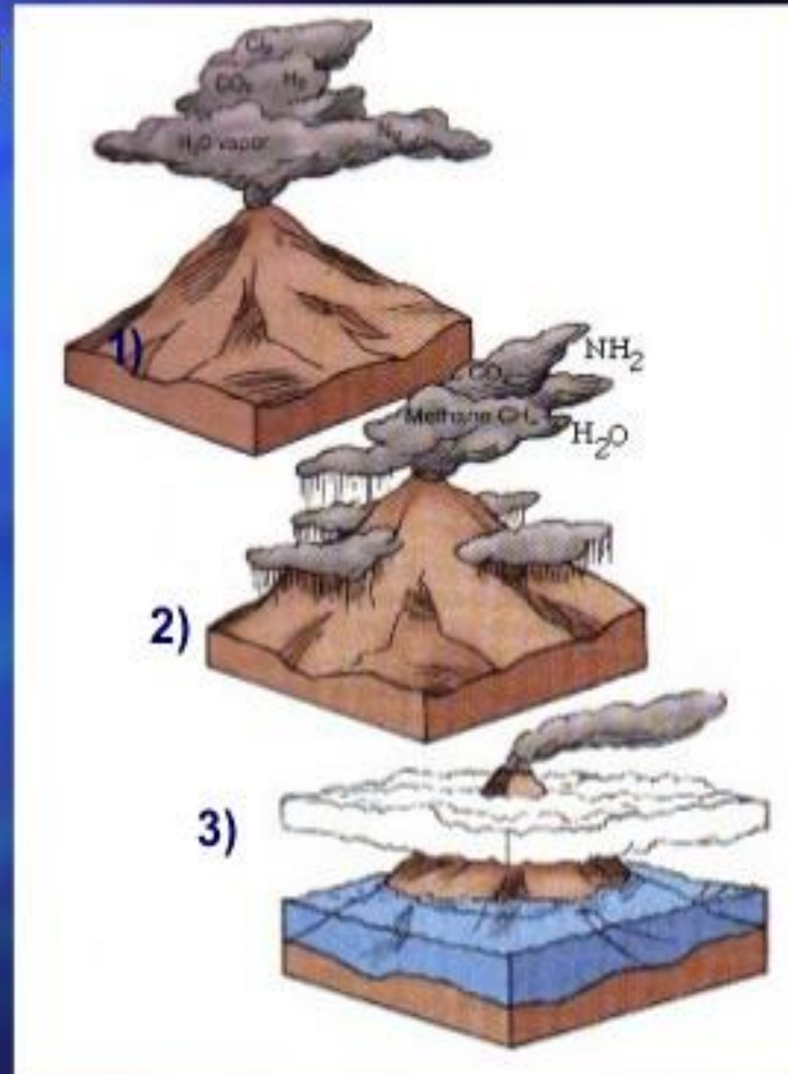
-

UNIT 1: INTROD. AQUATIC ENVT – <u>origin & evolution</u>

Formation of Our Ocean

<u>Three Phase History</u>

1) Initially there was only water vapor in atmosphere – Air and ground surface too hot for liquid
2) Cooling of atmosphere led to condensation and rain – Ground surface still too hot for pooling
3) Further cooling of ground surface finally led to the accumulation of liquid water on surface – Ocean formed by 4 billion years ago



UNIT 1: INTROD. AQUATIC ENVT – origin & evolution

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

Earth's water system:

- Salty oceans, inland waters, H_2O vapour:
  - salty ocean (Atlantic, Pacific, Indian)*, &
  - inland waters, (lotic & lentic)*
  - water vapour

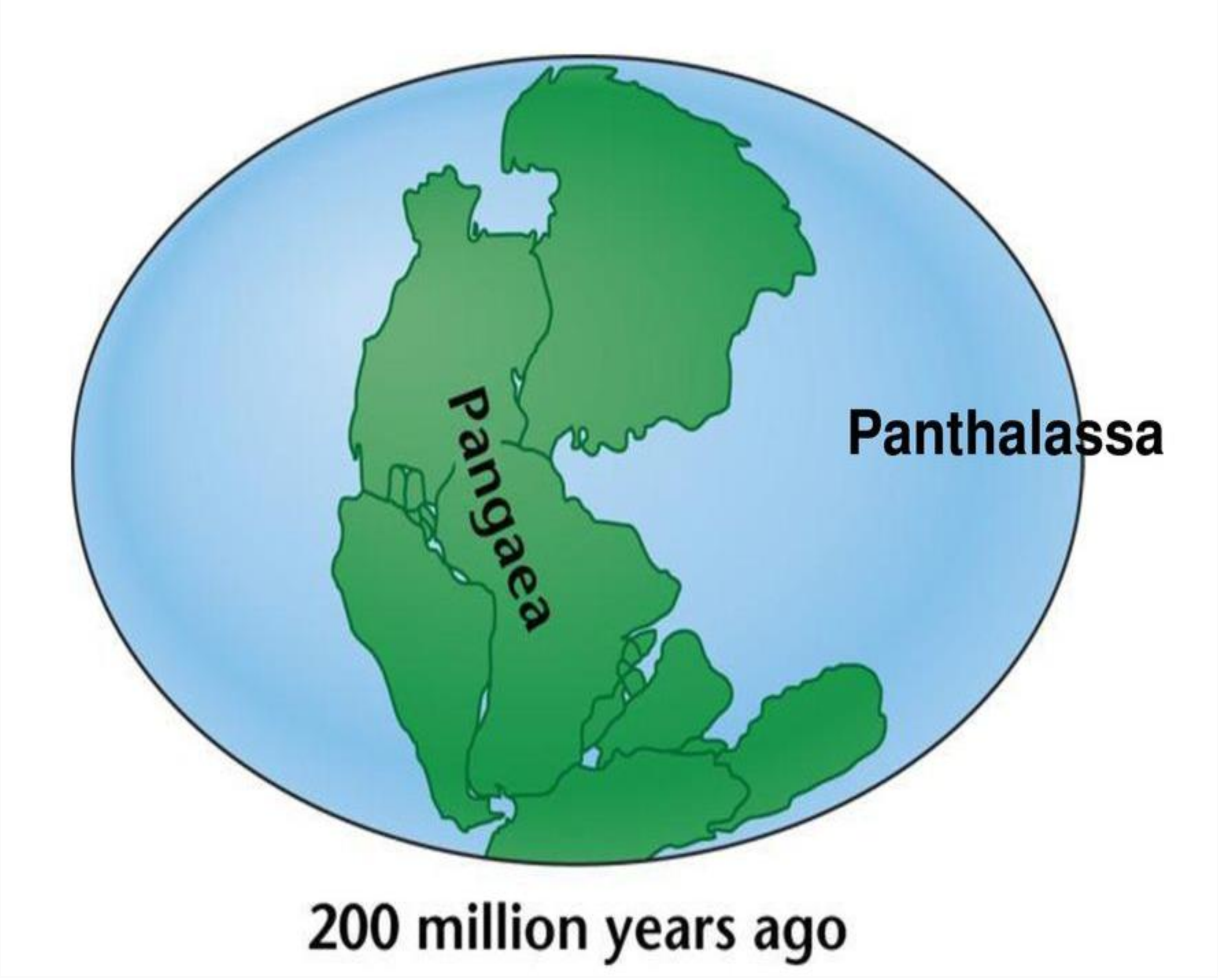
UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

Ocean	Surface area (millions of km^2)	Average depth (m)	Volume (%)
Pacific	**181.34**[1]	**4188**[1]	**50**
Atlantic	106.57[2]	3736[3]	29
Indian	74.12[3]	3872[2]	21

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

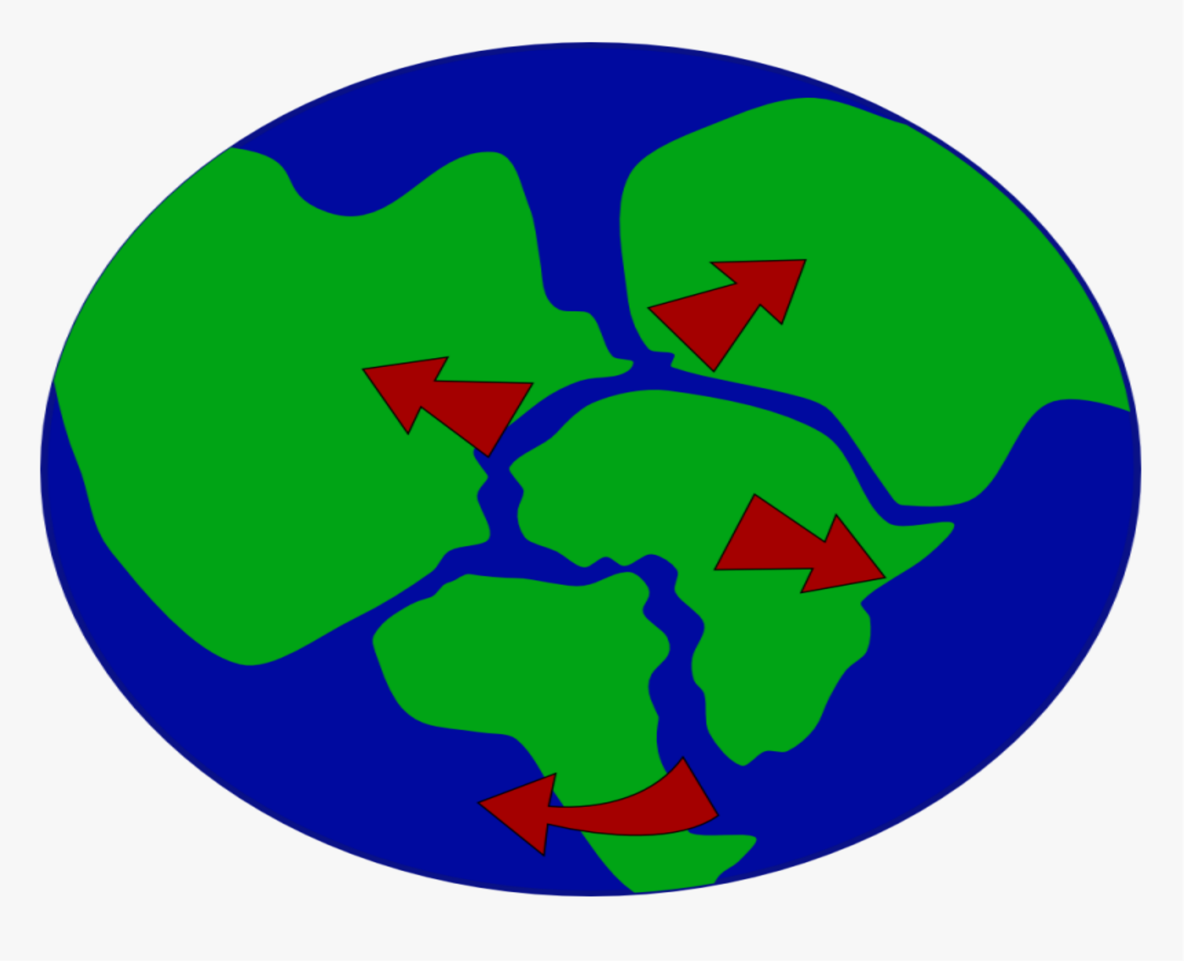
UNIT 1: INTROD. AQUATIC ENVT – <u>types</u>, <u>distribution & availability</u>

- Concept of **Pangaea** & **Panthalassa**



UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- Concept of **Pangaea** & **Panthalassa**



UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- Study of oceans? **Oceanography**
- Study of inland waters? **Limnology**.
- What is **aquatic ecology**?

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- Examples of Inland waters:
  - Lakes & reservoirs
  - Ponds & pools
  - Streams & rivers
  - Wetlands
  - Underground water
  - Phytotelmata

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- Lotic and lentic system differences

Lotic	Lentic
Running waters	Standing waters
Unidirectional flow	Not unidirectional
Flow imposed by gravity	flow imposed by wind and heat
Organized horizontally	Organized vertically
Etc	

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- The ocean contain **97%** of earth's water, the remaining been mostly freshH_2O…

Site	Contribution (%)
Ocean	**97.1**
Glaciers & ice caps	2.24
Groundwater	0.61
All lakes	**0.016**
Atmospheric moisture	0.001
Rivers	**0.0001**

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- Rivers constitute < 2 % of water held in freshwater lakes.

- Lentic systems contain about 100x more water than lotic ones.

- Rivers, their bothering wetlands, & linked aquifers, are home to extensive biota.

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- Rivers are also major source of water for;
  - **irrigation**,
  - **agriculture**,
  - **industry**,
  - **human consumption**, &
  - **water purification, etc**

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- Some physical features of **oceans** include:
  - Of the earth's surface, **71**% is covered by the oceans (361 x 10^6 km^2);
  - The deepest oceanic trench is **11,022 m** (**Mariana**);

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- The major depth zones of the ocean (**78**%) lies between **3 & 6 km**;

- 50% of ocean water have a **temperature** range between 1.3 – 3.8^{o}C (mean = 3.5^{o}C),

- **salinity** is between 34.6 & 34.8‰; (mean salinity = 35‰)

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- Oceans supply about ½ earth's oxygen;
- Oceans store about **50 times more carbon** than the atmosphere;
- Evaporation from the oceans brings **rain** to much of the earth's inland surfaces.

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- Only about 3% of the earth's continental land surface is covered by water.

- Salinity of inland water systems = **0.5‰** (freshwaters) or more (some even greater than **340‰**).

- Inland freshwaters are even more important for several reasons:

UNIT 1: INTROD. AQUATIC ENVT – <u>types</u>, <u>distribution & availability</u>

1. salty ocean & its inland equivalents can't be consumed by humans, etc.
2. It is not suitable for irrigation;
3. It is not suitable for most industrial purposes.

4. Most freshwater locked up in ice caps or groundwater too deep to be used.

UNIT 1: INTROD. AQUATIC ENVT – <u>types</u>, <u>distribution & availability</u>

- Saline lakes contribute ½ of the water volume of inland lakes.

- There are 2 types of saline/salt lakes –
  - *Athalassohaline lakes* &
  - *thalassohaline lakes*

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- E**conomic importance** of saline lakes is small.

- But they have other relevance e.g.
  - Extraction of precipitated salts;
  - Contain unusual species

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- important help in understanding changes in community structure & function along salinity gradients;
- help to predict effects of increasing river salinity in poorly irrigated areas
- help in understanding projected impacts of a rise in evaporation in global warming

UNIT 1: INTROD. AQUATIC ENVT – <u>types</u>, <u>distribution & availability</u>

- Lake <u>Superior</u> (USA) has largest **surface area** among freshwater lakes.

- Lake <u>Baikal</u>, (Russia) is the **deepest** freshwater lake on Earth.

- Lake Baikal, (Russia) holds much larger **volume** of water than any freshwater lake.

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- Lake Baikal contributes about 20% of all surface freshwater world-wide.

- Together, lakes **Baikal**, **Superior**, & **Tanganyika** contain about 44% of surface freshwater in the world.

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

Origin	# of lakes[1]	% of total lakes	Total lake area (km^2)	% total area
Glacial	3875000	74	1247000	50
Tectonic	249000	5	893000[2]	35
Coastal	41000	<1	60000	2
Riverine	531000	10	218000	9
Volcanic	1000	<<1	3000	<<1
Miscellaneous	567000	10	88000	4
TOTAL	**5264000**	**100**	**2509000**	**100**

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- State of freshwaters in **recent times**:
  - major sites of irresponsible waste disposal, mining activities, etc;
  - high demand for irrigation, etc due to high human population;
  - overconsumption

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- **Assumption**:
  - World's water supply = **100 L** (26 gallons)
  - usable supply of freshwater = **0.014 L** (2.5 tea spoons).

- The small % of fresh water, increasing human population, overconsumption, & increasing pollution cause **water stress** & **scarcity** in many parts of the world.

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- **Water stress**
  - UN SDG 6
  - Falkenmark water stress index

- **Water scarcity**
- **Water deprivation**

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

UN SDG 6

- **No stress** - < 25%
- **Low stress** - 25 – 50%
- **High stress** - 50 – 75%
- **Critical stress** - > 100%

Falkenmark Water Stress Index

- A country is water stressed if water availability is **< 1700** m^3 per person per yr

- below **1000** m^3 per person per year is considered water scarcity*; &

- below **500** m^3 per person per year is considered absolute water scarcity

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- **Water scarcity** i.e. the chronic lack of renewable freshwater supply every year.
- Four causes of water scarcity are noted:
  - A *dry climate*; *Drought*; *Desiccation*; & *Water stress*
- Social scientists have introduced the term **water deprivation** as a basic index of poverty.

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- Uneven water distribution divides countries into **water haves** & **water have-nots**.
  - e.g., Canada = 0.5 % of world's population has 20 % of the world's freshwater,
  - China = over 21 % of world's population has only 7 %.

UNIT 1: INTROD. AQUATIC ENVT – types, distribution & availability

- These problems continue to affect water quantity & quality **(availability)** in many parts of the world.

- Has adverse effects on **aquatic biodiversity** globally.

UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

- **Aquatic life zones**

- **Advantages** of life in water:
  - Physical support (buoyancy)
  - Accessibility of 3-dimensional space
  - Passive movement by water currents
  - Dispersal of motile gametes in a liquid medium

UNIT 1: INTROD. AQUATIC ENVT – <u>Aquatic Life Zones</u>

- **Advantages** of life in water (cont):
  - Minimal loss of water
  - Lower extremes of temperature & solar radiation
  - Ready availability of soluble organic & inorganic nutrients, etc

UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

- Potential disadvantages of life in aquatic environments:
  - Osmotic differences between organism & surrounding medium
  - High degree of physical disturbance
  - Restriction of **photosynthetic organisms** at top of water column for light availability

UNIT 1: INTROD. AQUATIC ENVT – <u>Aquatic Life Zones</u>

- High species competition due to fewer microhabitats in many water bodies.

- **<u>NB</u>**:.. in aquatic systems, distribution of organisms is largely based on the water's **salinity** or the <u>amount of salts dissolved in a given volume of it</u>.

UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

- Classes water bodies based on salinity

	Salinity (ppt)	Nomenclature
1	0.0 – 0.5	Freshwater
2	0.5 – 3.0	Oligohaline brackish water
3	3.0 – 10.0	Mesohaline brackish water
4	10.0 – 17.0	Polyhaline brackish water
5	17.0 – 30.0	Oligohaline sea water
6	30.0 – 34.0	Mesohaline sea water
7	34.0 – 38	Polyhaline sea water
8	> 38.0	Brine

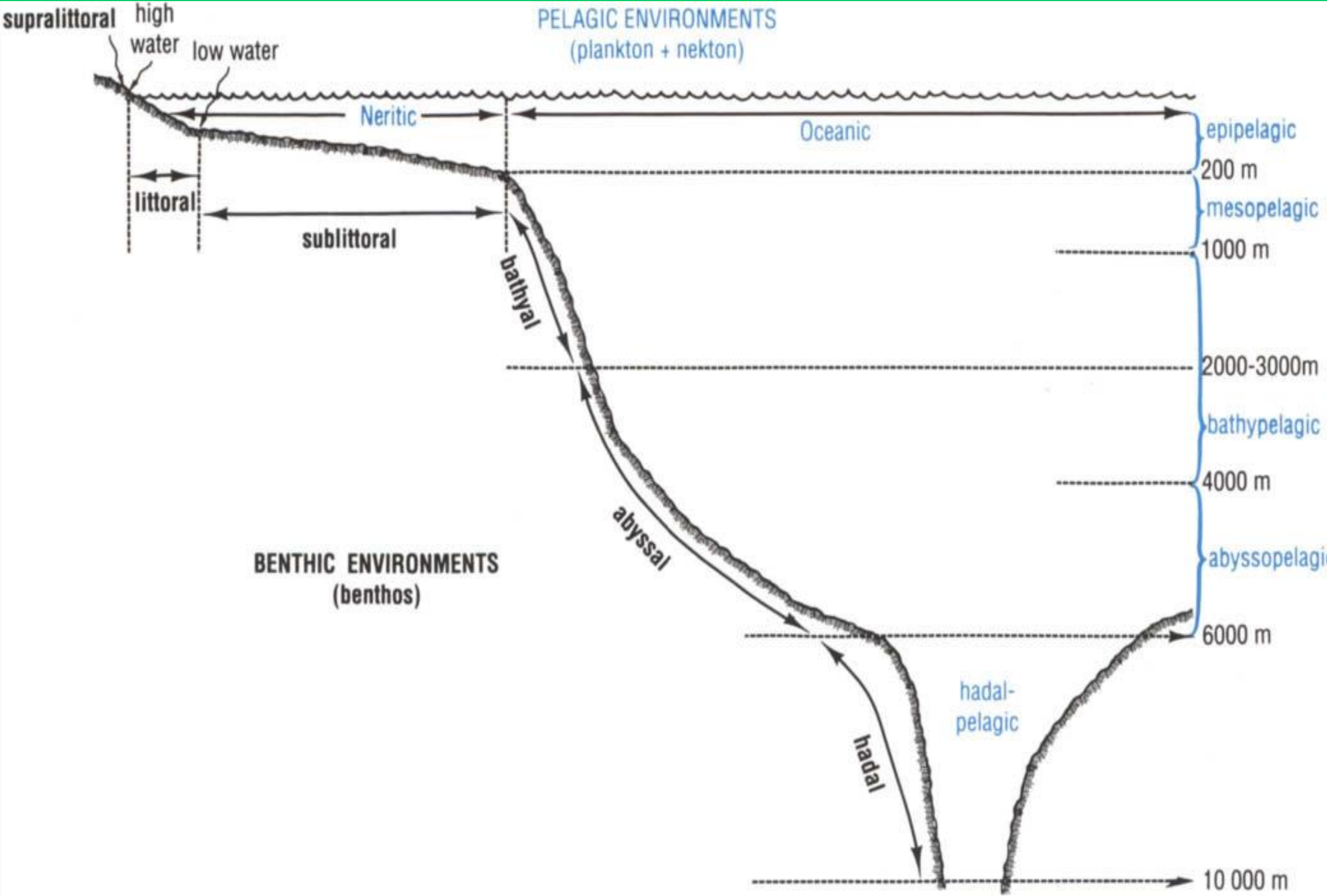
UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

- And also, aquatic life zones are grouped into 2 major types based on salinity viz;
  - **salt/ocean life zones**
  - **Inland water life zones**

UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

- **Salt/ocean** water life zones also called marine life zone –
  - Shallow ocean waters (coastlines),..
  - Open ocean waters,..
  - Deep ocean waters,..
  - Coastal wetlands,
  - Coral reefs,
  - Mangrove swamps,
  - Estuaries, etc

UNIT 1: INTROD. AQUATIC ENVT – <u>Aquatic Life Zones</u>



Coastal wetland

Coral reefs

Mangrove forest

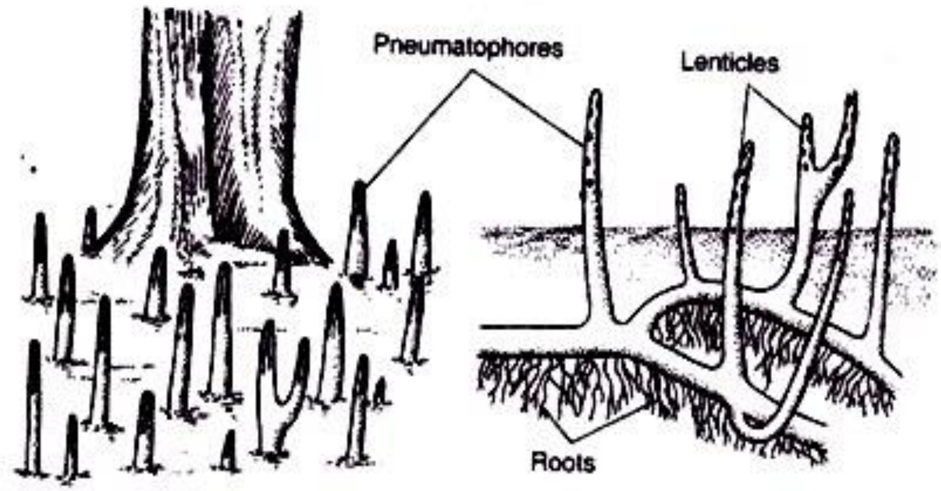
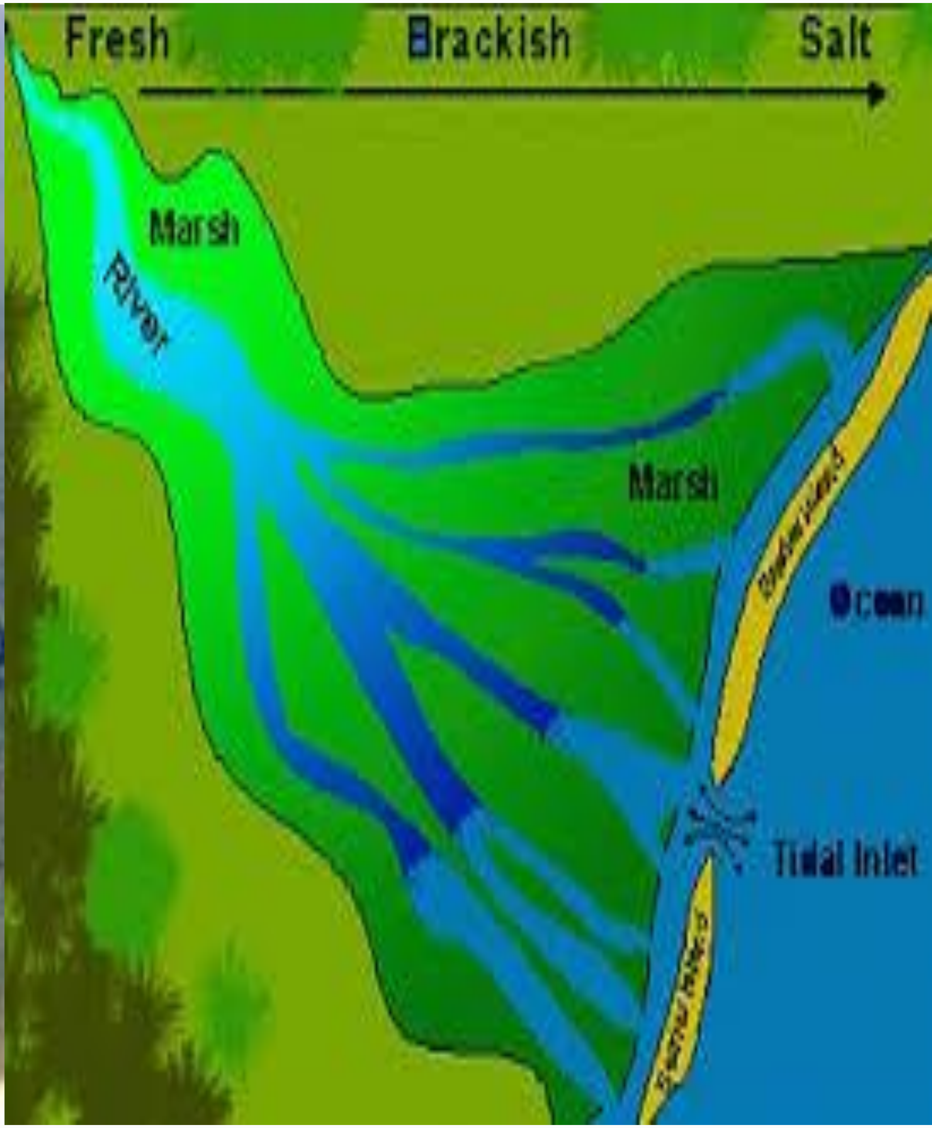


Fig. 10.1. Pneumatophores of mangrove plant.

Estuary



UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

- **Inland water**, mostly freshwater, life zones
  - Rivers & streams
  - Lakes
    - Fresh
    - Salty
      - **Thalassohaline**
      - **Athalassohaline**
  - Inland wetlands
  - Phytotelmata…, etc

Lakes and rivers


UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

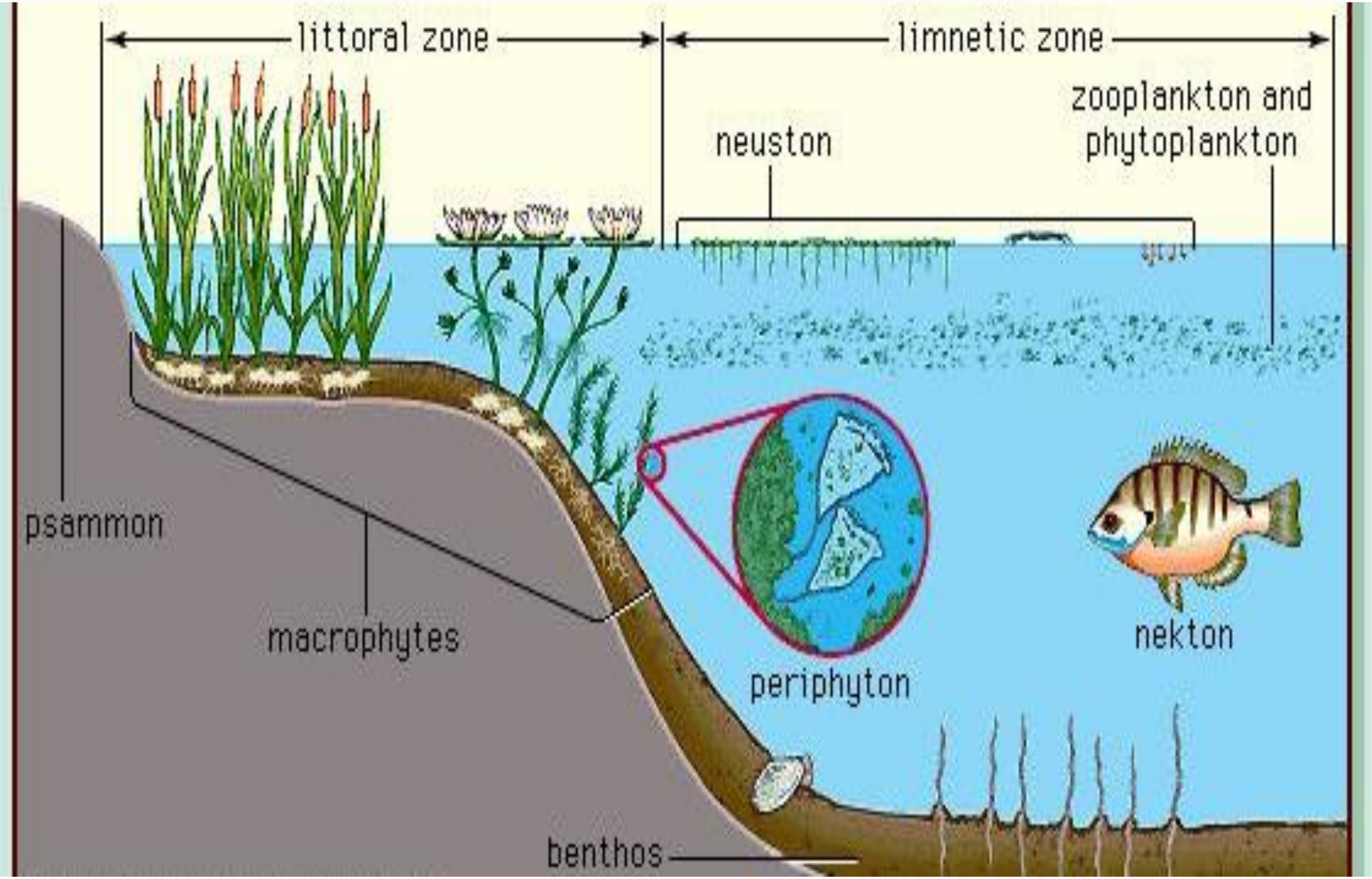
Sararcinia purpurea* – *pitcher plant*. *Photograph courtesy of R. Wallace.

UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

- Life zones have distinct geological & or morphological micro-habitats.

- The microhabitats contain several major types of **adapted** aquatic organisms…..

UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones



UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

- The major adapted organisms include:
  - **Plankton…**
    - Cellular complexity
    - Different sizes..
    - Different types..
  - **Nekton**
  - **Benthos**
  - **Decomposers**

UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

- Size categories:
  - < 0.2 μm – **femtoplankton**
  - 0.2 - 2 μm – **picoplankton**
  - 2 - 20 μm – **nanoplankton**
  - 20 - 200 μm – **microplankton**
  - > 200 μm – **macroplankton**

UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

- In terms of types, plankton are also varied:
  - Virioplankton – **viral** plankton
  - Bacterioplankton – **bacteria** plankton
  - Phytoplankton – **algal** plankton*
  - Zooplankton – **animal** plankton
  - Mycoplankton – **fungal** plankton, etc

NB: Saproplankton = bacteria + fungi

UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

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UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

- The major adapted organisms include:
  - **Plankton**
    - Cellular complexity
    - Different sizes
    - Different types
  - **Nekton * e.g.s?**
  - **Benthos***
  - **Decomposers***

UNIT 1: INTROD. AQUATIC ENVT – Benefits of Aquatic Systems

- Benefits to human societies:
  - **Ecological services?**
  - **Economic services?**

- Serve the needs of human societies directly or indirectly.

- Ecological services* include:

UNIT 1: INTROD. AQUATIC ENVT – Benefits of Aquatic Systems

1. Climate moderation
2. CO_2 absorption
3. Nutrient cycling
4. Waste treatment
5. Habitats & nursery areas
6. Reduced **storm impact** (mangroves, barrier islands, coastal wetlands)
7. Genetic resources & biodiversity

UNIT 1: INTROD. AQUATIC ENVT – Benefits of Aquatic Systems

- Scientific information
- Flood control
- Groundwater recharge , etc

UNIT 1: INTROD. AQUATIC ENVT – <u>Benefits of Aquatic Systems</u>

- <u>Economic services</u> include:
  1. Food e.g. fish, prawns, etc
  2. Animal & pet feed
  3. Pharmaceutical products
  4. Harbours & transportation routes
  5. Coastal habitats for humans
  6. Recreation
  7. Employment

UNIT 1: INTROD. AQUATIC ENVT – Benefits of Aquatic Systems

- Economic services (cont):
  8. Oil & gas resources
  9. Mineral resources
  10. Building materials,
  11. Drinking water,
  12. Water for irrigation,
  13. Hydroelectricity production, etc

UNIT 1: INTROD. AQUATIC ENVT –
Threats to Aquatic Systems

- **Human activities** are affecting aquatic systems & the benefits they provide due to
  - **population** growth,
  - **overconsumption** of resources, &
  - Water-dependent & polluting **technology**
- Concept of **demophora** & the **IPAT Model**

UNIT 1: INTROD. AQUATIC ENVT – Threats to Aquatic Systems

- Specific threats to **oceans** include:
  - Coastal development;
  - Runoff of non-point sources of pollutants;
  - Point source pollution;
  - Pollution & degradation of coastal wetlands & estuaries;
  - Overfishing;
  - Use of trawlers;

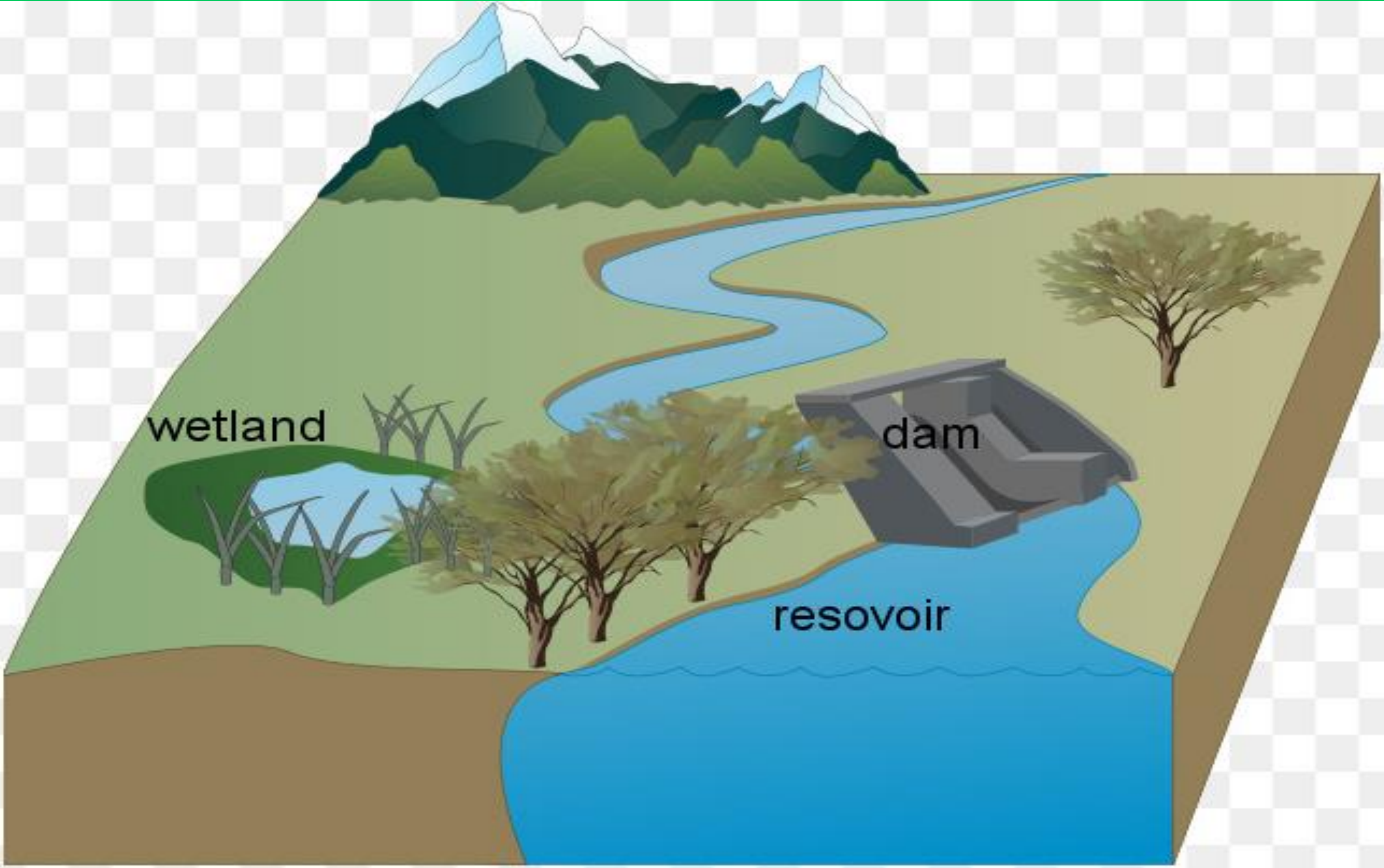
UNIT 1: INTROD. AQUATIC ENVT – Threats to Aquatic Systems

- Specific threats to **oceans (cont)**:
  - Introduction of invasive species;
  - Climate change.

UNIT 1: INTROD. AQUATIC ENVT – Threats to Aquatic Systems

- Specific threats to **freshwaters** include:
  - Dam & canal construction & effects..
  - Construction of flood control levees & dikes..
  - Addition of excess plant nutrients to water bodies..
  - Loss of wetlands due to human actvities

UNIT 1: INTROD. AQUATIC ENVT – <u>Threats to Aquatic Systems</u>



Embarkment

Fish kills due to pollution

UNIT 1: INTROD. AQUATIC ENVT – Properties of Water

- **Water** is a unique liquid.

- Uniqueness determine largely the physico-chemical properties of water bodies.
  - E.g. high dissolving power
  - High specific heat capacity
  - Low heat conductivity
  - High melting point
  - High heat of vaporization, etc

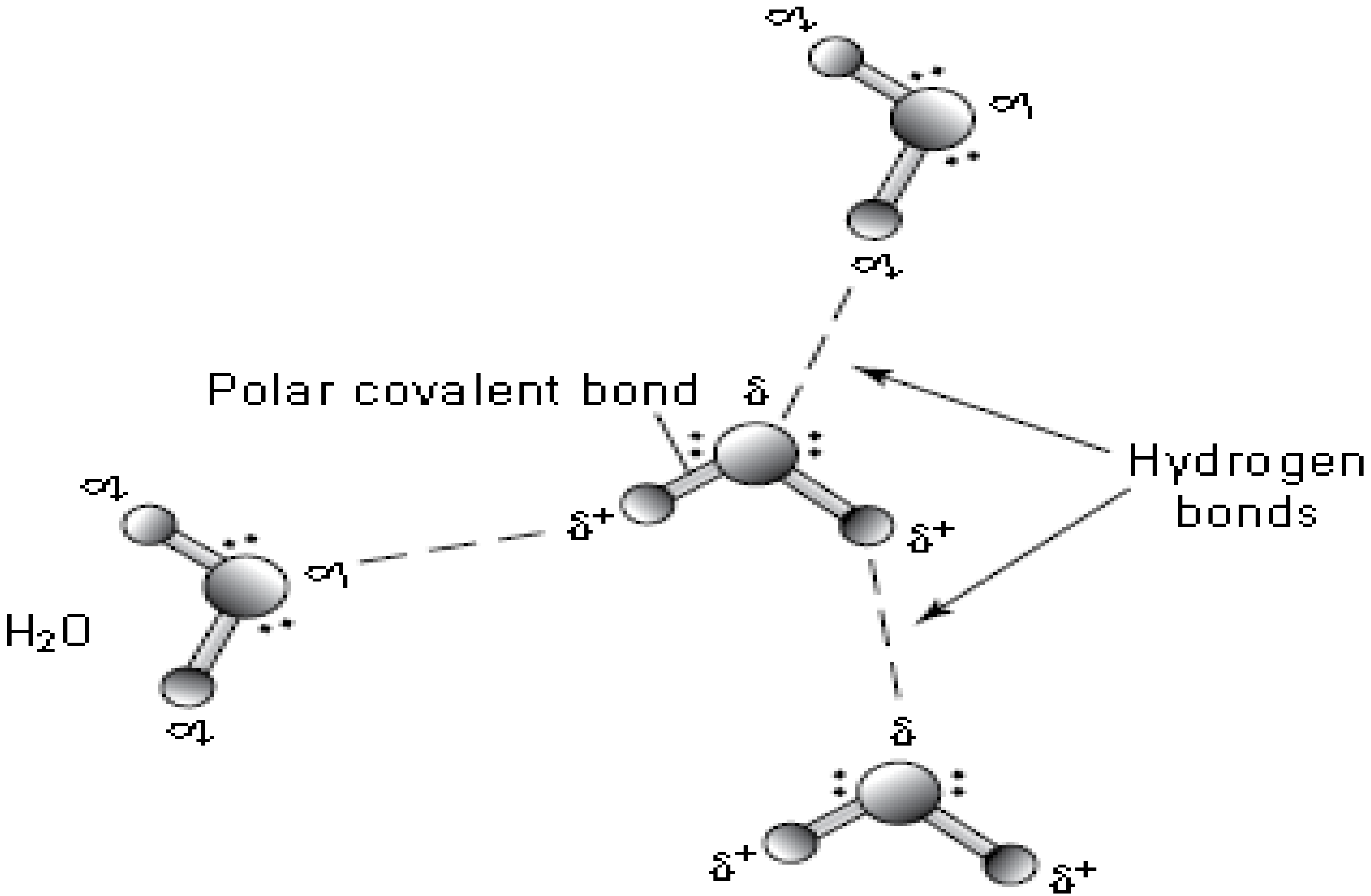
UNIT 1: INTROD. AQUATIC ENVT – Properties of Water

- Necessity of examining water as a substance in aquatic ecology
- Water’s anomalous behaviour

UNIT 1: INTROD. AQUATIC ENVT – Water molecule & H-bonding

- Molecular structure of water determines most of its unusual properties

- Bonds in water, its crystal lattice structure, & effects:
  - Polar covalent
  - H-bonding



Polar covalent bond
δ
Hydrogen bonds
δ+
δ+
δ
δ+
δ+
H2O

UNIT 1: INTROD. AQUATIC ENVT – Water molecule & H-bonding

- *Dipolar* or **dielectric** nature of water & its effects:
  - Excellent solvent for dissolving substances
  - Universal solvent

UNIT 1: INTROD. AQUATIC ENVT – Dissolving Ability of Water

- The excellent dissolving power of water is essential for:

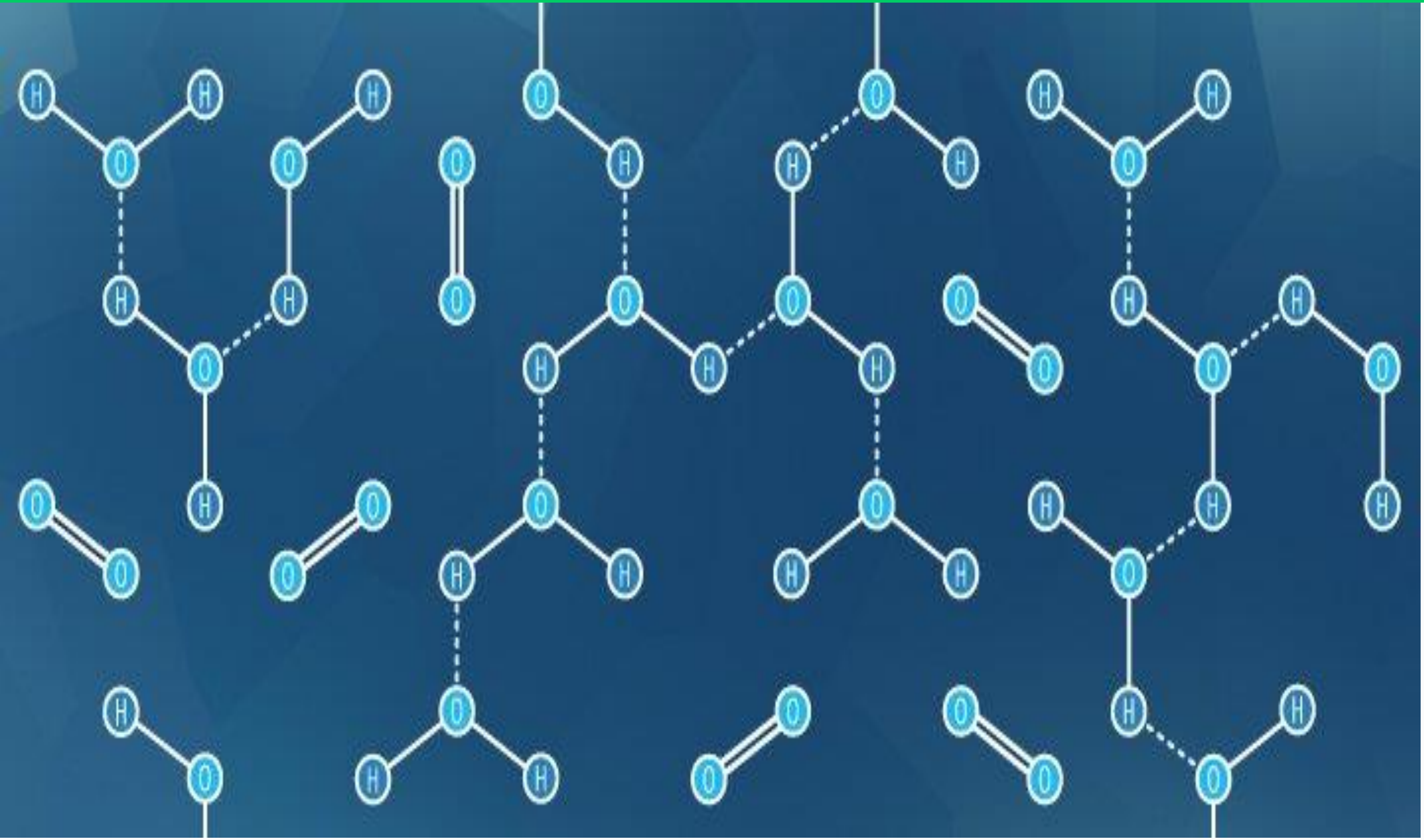
  - Plants to take up nutrients; &

  - Animals to take up dissolved compounds & their tissues to release waste.

UNIT 1: INTROD. AQUATIC ENVT – Dissolving Ability of Water

- Differences in charges on atoms of water molecules allow O-atom to form a weak **H-bond** with oppositely charged H-atom of adjacent H_2O molecule…….

UNIT 1: INTROD. AQUATIC ENVT – <u>Dissolving Ability of Water</u>



UNIT 1: INTROD. AQUATIC ENVT –
H-bonding & H_2O's Crystal Lattice Structure

- H-bonds between H_2O molecules, requires a lot of energy to break
  - e.g.1 liquid → water surface to vapour
  - e.g.2 separating water molecules from rigid ice → liquid water.

- H-bonding responsible for many of water's unique properties e.g. *high melting & boiling points* relative to similar compounds

UNIT 1: INTROD. AQUATIC ENVT – Thermal conductivity & Heat Capacity

- Low thermal conductivity.

- High specific heat capacity (SHC).
  - For water, it is defined as unity since it takes 1 cal to heat 1 g of water by 1 °C….

- High specific heat capacity & low thermal conductivity allows it to absorb large amounts of heat with a small temperature increase.

UNIT 1: INTROD. AQUATIC ENVT – Thermal conductivity & Heat Capacity

- Heat capacities of selected substances

Material	Heat capacity (cal/g/°C)
Water	1.00
Mercury	0.03
Acetone	0.51
Wood	0.42
Sand	0.18

UNIT 1: INTROD. AQUATIC ENVT –

Thermal conductivity & Heat Capacity

- Low thermal conductivity & high SHC allow water organisms to survive intense solar radiation at the equator.
- It also causes localized surface heating & stratification in standing waters.
- It alters surrounding coastline climate of a water body that receives its breezes

UNIT 1: INTROD. AQUATIC ENVT – Density of Water

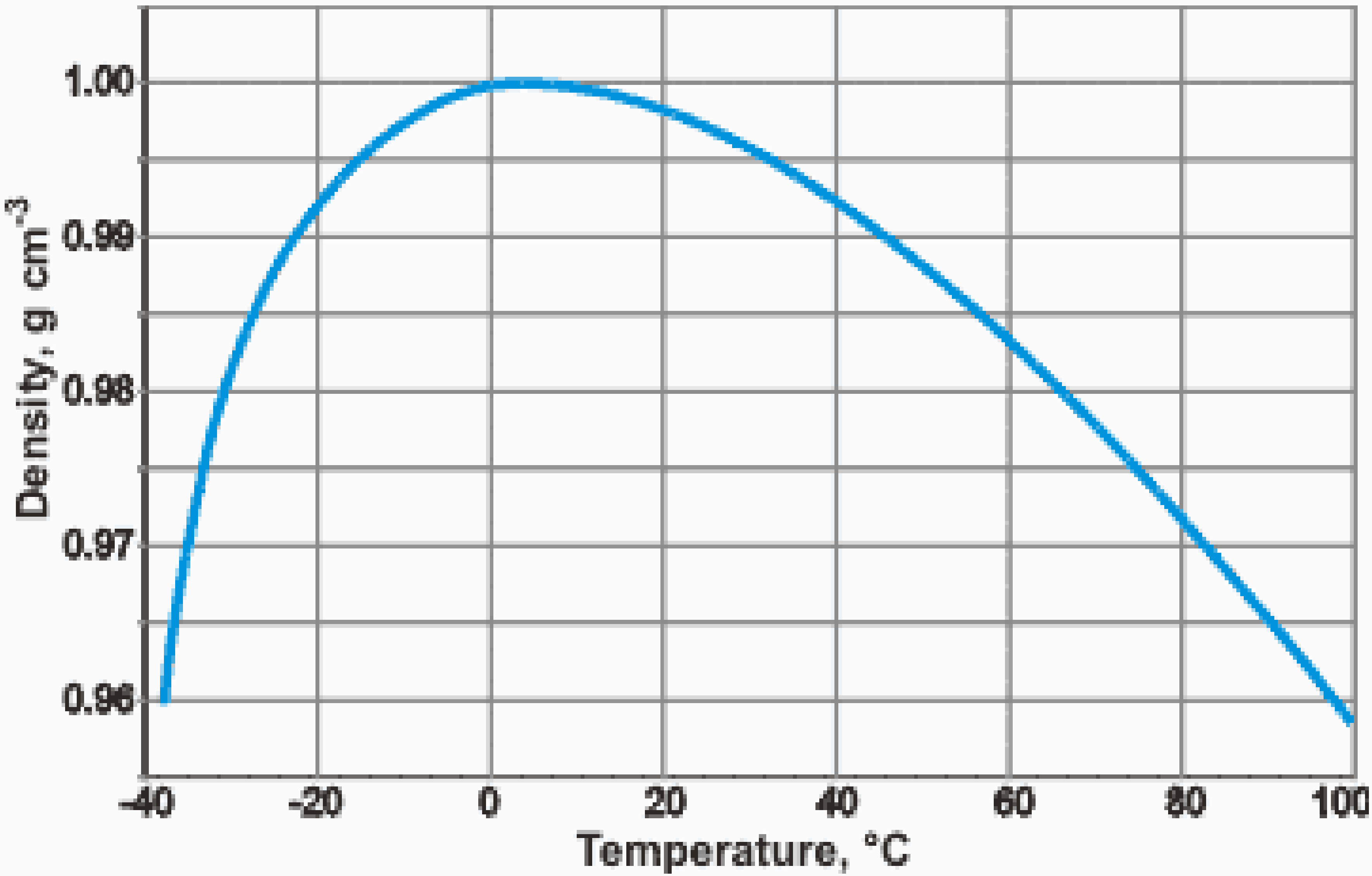
- Density?

- Relationship between density & a water body's temperature, salt content, & pressure.

- Relationship between **temperature** (T, in °C) & **density** (D, in g/ml) is estimated as

$$\mathbf{D = 1-6.63 \times 10^{-6} *(T-4)^2}$$

UNIT 1: INTROD. AQUATIC ENVT – Density of Water



UNIT 1: INTROD. AQUATIC ENVT – Density of Water

- **NB**: Salinity-induced density effects, dominate over temperature effects in estuaries & oceans.
- E.g. pure water density at 4 °C = 1 mg cm^{-3}
- When salinity changes to normal ocean water = 35 ‰, density increases to 1.028 mg cm^{-3}.

UNIT 1: INTROD. AQUATIC ENVT – Density of Water

- This decreases ocean water temperature of maximum density to -3.5 °C.
- Thus, water's freezing point is lowered as its salinity increases.
- Pressure also affects density?

UNIT 1: INTROD. AQUATIC ENVT – Anomalous expansion of Water: implication

- Anomalous expansion of water & implication for aquatic organisms.

UNIT 1: INTROD. AQUATIC ENVT –
Viscosity & Surface Tension

- **Viscosity** or dynamic viscosity? Effects?
  - It produces viscous drag on organisms moving through water.
  - It slow rate of sinking of plankton.
  - Affects shape of some aquatic organisms e.g. fish & insect larvae in streams.

UNIT 1: INTROD. AQUATIC ENVT – Viscosity & Surface Tension

- It may also limits:
  - mixing of water bodies;
  - sedimentation of particulate matter; &
  - velocity of circulation

- **Viscosity** is affected by
  - Temperature…
  - Salinity

UNIT 1: INTROD. AQUATIC ENVT – Viscosity & Surface Tension

Temperature (°C)	Viscosity (cP)
0	1.79
5	1.52
10	1.31
15	1.14
20	1.00
25	0.89
30	0.80
35	0.72
40	0.65

UNIT 1: INTROD. AQUATIC ENVT – Viscosity & Surface Tension

- **Surface tension**?

- Also, results from cohesive H-bonding in water.

- enables some animals & plants to maintain position in water surface e.g., water strider

UNIT 1: INTROD. AQUATIC ENVT – Aquatic Life Zones

UNIT 1: INTROD. AQUATIC ENVT – Viscosity & Surface Tension

- Relationship between temperature & salt content of water.

- Organic surfactants & surface tension.

UNIT 2

PHYSICAL STRUCTURE OF AQUATIC ECOSYSTEMS

UNIT 2: PHY. STRU. AQ. ECOSYS - ILOs

- To **know** different types of aquatic systems & their morphometric features;

- To **know** how various morphometric features affect the dynamics of aquatic ecosystems, & **understand** how they affect the occurrence & distribution of organisms in them;
  - Oceans & inland waters e.g. lakes, rivers, etc

2: PHY. STRU. AQUATIC ECOSYSTEMS

- The structure & form of an aquatic system determines very important features of it.

- The **morphology** - study of its structure & form or the overall shape/dimensions.

- *Morphometry* – the measurement of morphological features of aquatic basin.

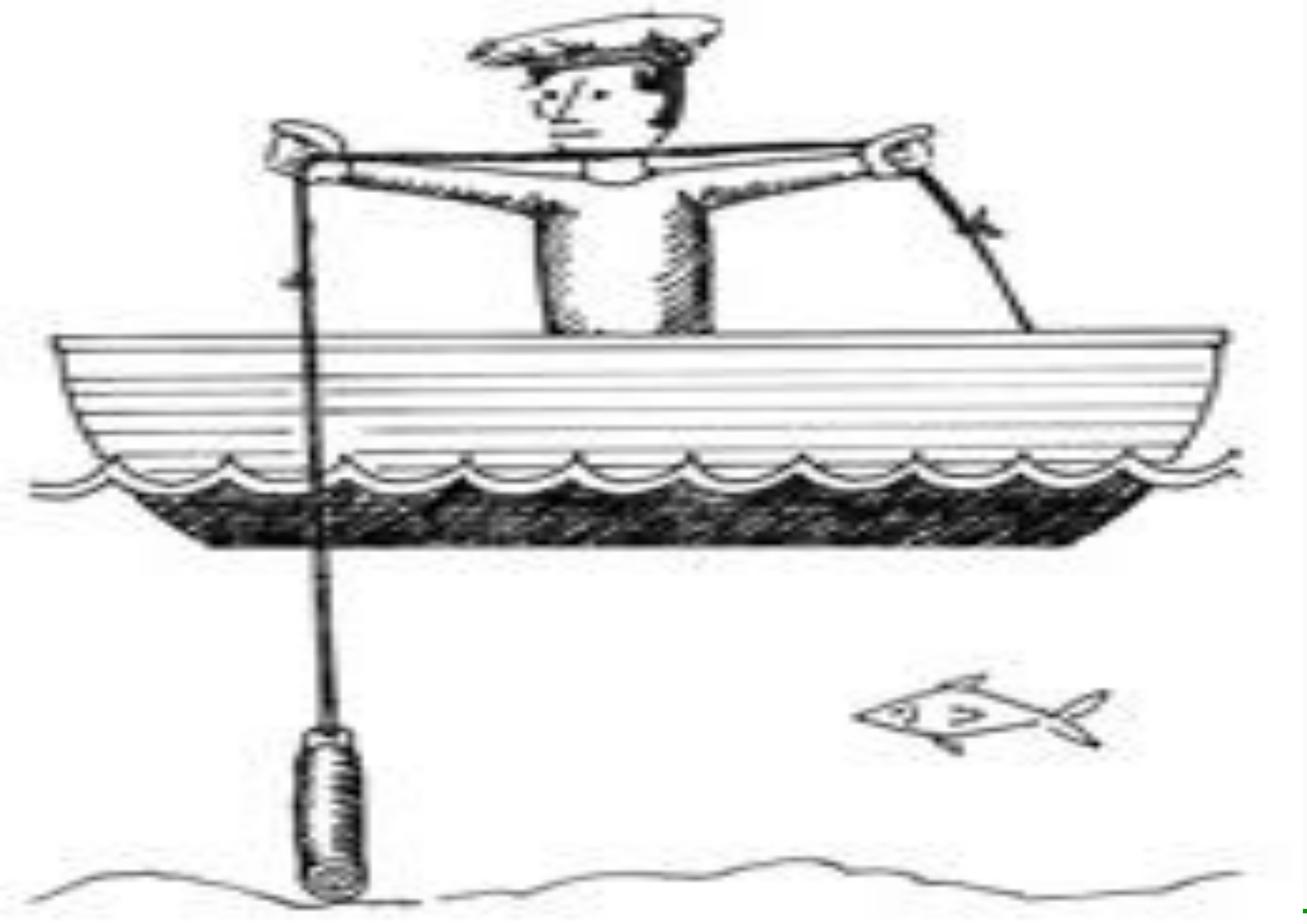
2: PHY. STRU. AQUATIC ECOSYSTEMS

- Challenges of early morphometric measurements in **large aquatic systems**.

- E.g. measurements such as **depth**, surface area, length, volume, etc.

- E.g. **depth** measurements were initially done using a rope tied to a stone (**soundings**).

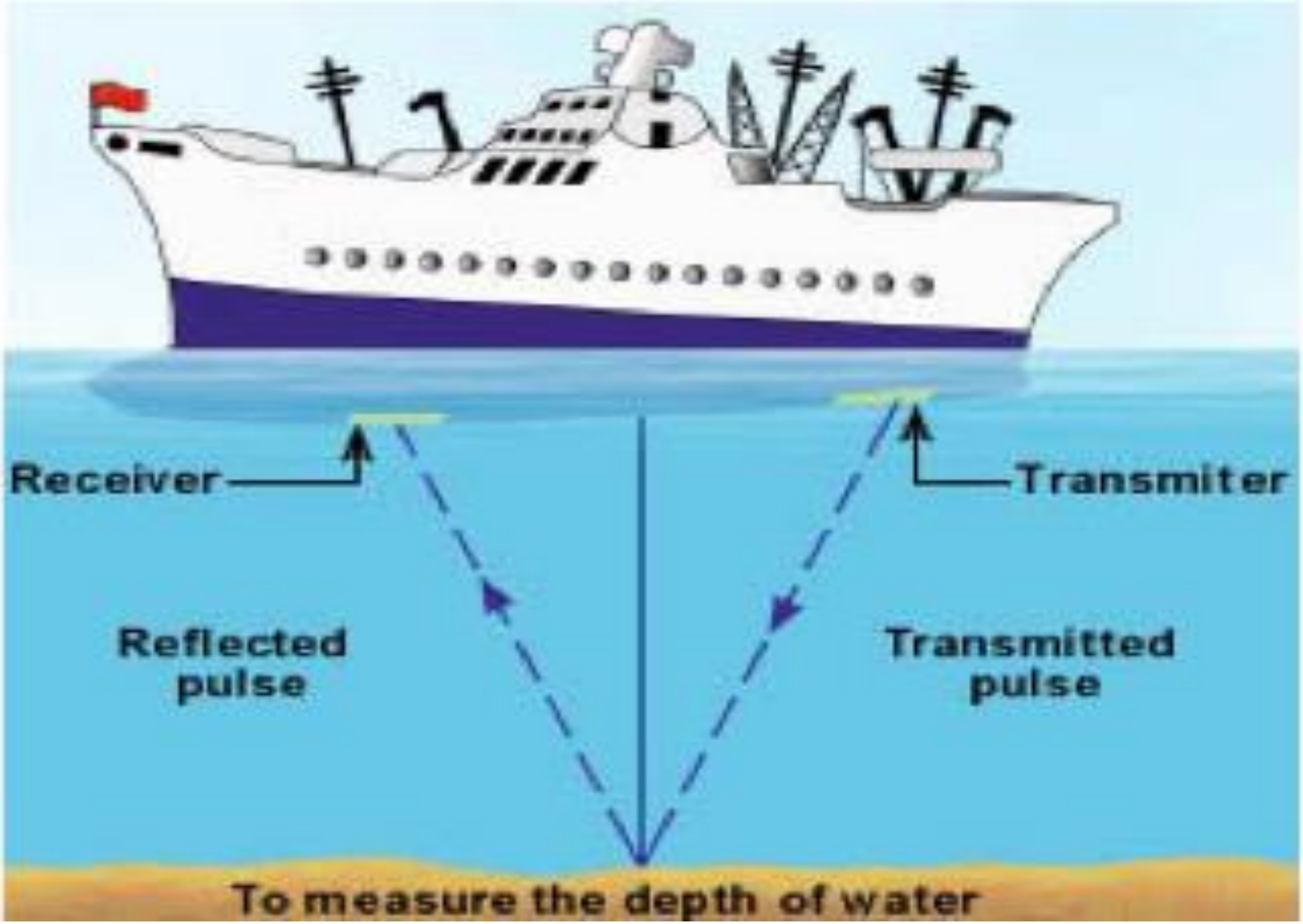
2: PHY. STRU. AQUATIC ECOSYSTEMS



2: PHY. STRU. AQUATIC ECOSYSTEMS

- Modern day depth measurements done in two ways:
  - 1) using **acoustic echo sounders** on ships…
  - 2) using data from **satellite altimeters…**

2: PHY. STRU. AQUATIC ECOSYSTEMS



2: PHY. STRU. AQUATIC ECOSYSTEMS

- b) **Satellite Altimetry:** profile the shape of these aquatic systems using satellites.

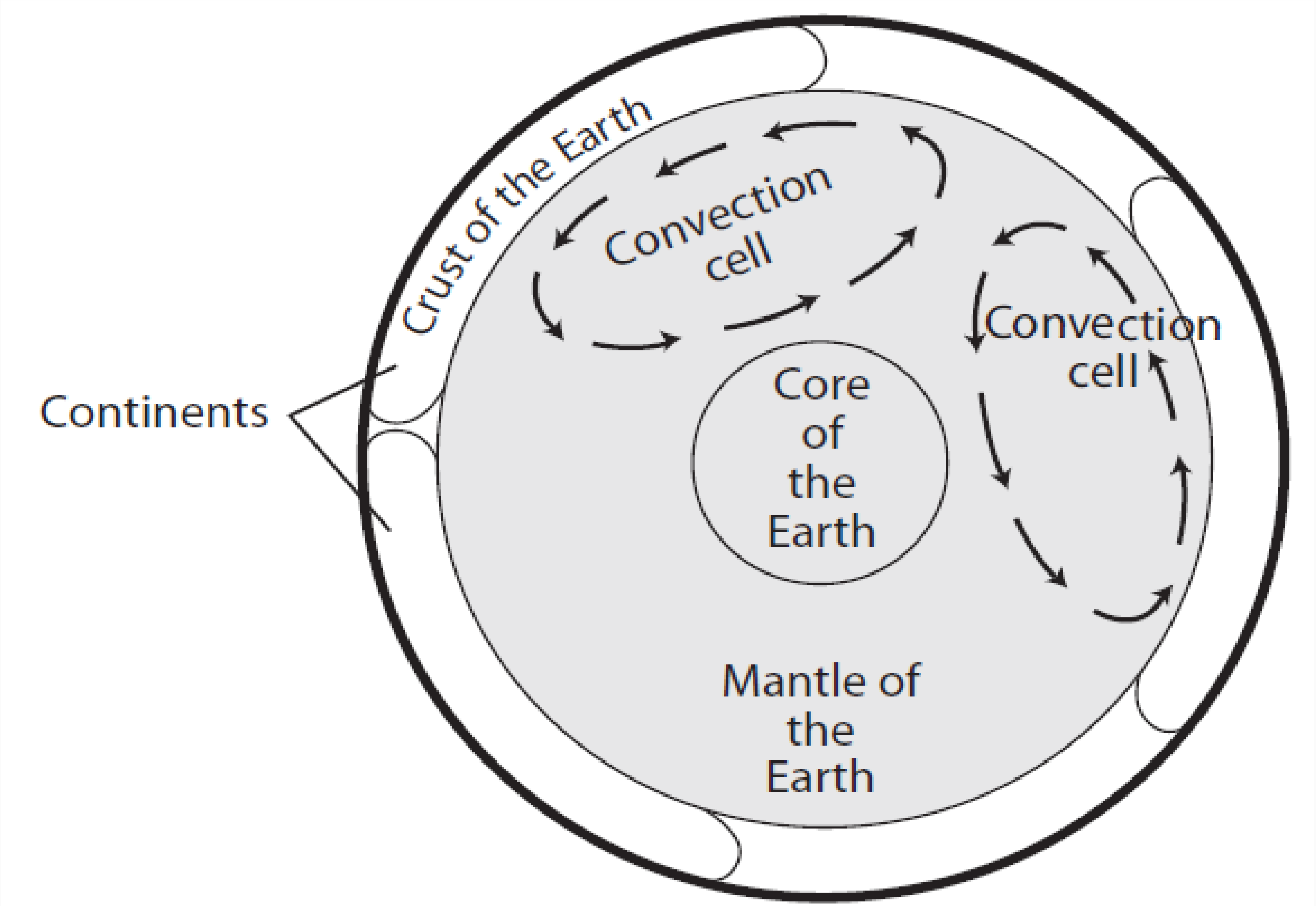
- Satellite-based maps based combined with acoustic ship data have high depth accuracy….

- Morphology of an aquatic system also affects its hydrology

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem

- Earth's surface not a static arrangement of continents & water bodies of jostling rocky surfaces divided into 2 types:
  - oceanic plates
  - continental plates

2: PHY. STRU. AQUATIC ECOSYSTEMS



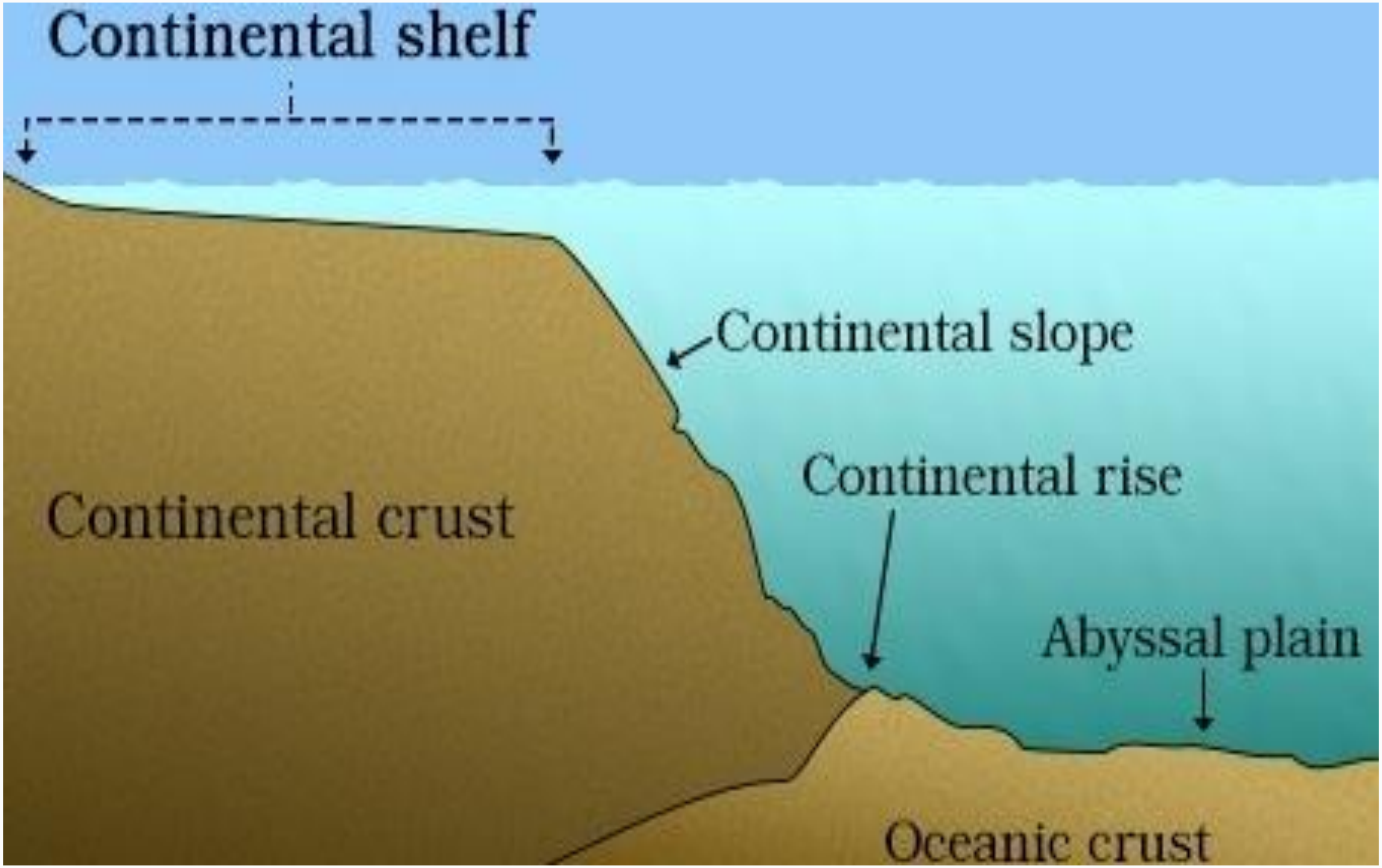
2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem

Parameter	Oceanic	Continental
Density	**2.9 (g/cm^3)**	**2.7 (g/cm^3)**
% Silica	< 55	> 65
Rich elements	Ca, Mg, Fe	Na, K, Al
Thickness	10 km	40 km
Nature	**Basaltic**	Granitic
Colour	Dark	light

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem

- Relative density of the 2 plates determine which one is at the upper & which one is below…

2: PHY. STRU. AQUATIC ECOSYSTEMS



2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: ocean provinces

- Ocean shores have floor features similar to those of adjacent continents since they have same granitic basement.

- Basalt transition true edge of continent & divides ocean floors into 2 provinces:

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: ocean provinces

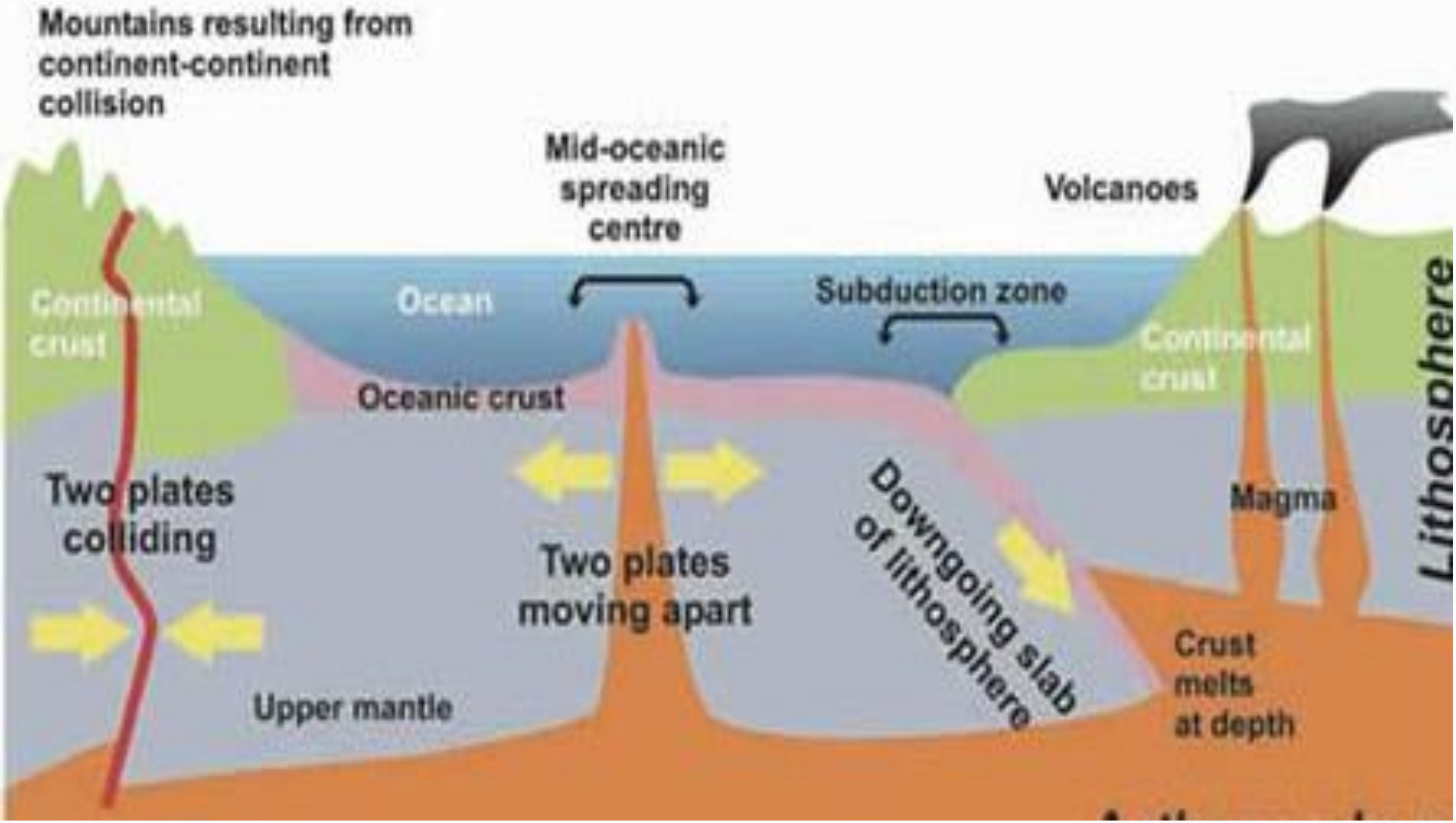
- Submerged outer edge of a continent - **continental margin**.

- Deep-ocean floor beyond continental margin - **deep ocean basin**…..

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: ocean provinces

- Continental margins are **active** or **passive**
- Moving plates can **converge**, **diverge**, or **slip past** one another.
- Continental margins, are greatly affected by these tectonic activities …

2: PHY. STRU. AQUATIC ECOSYSTEMS

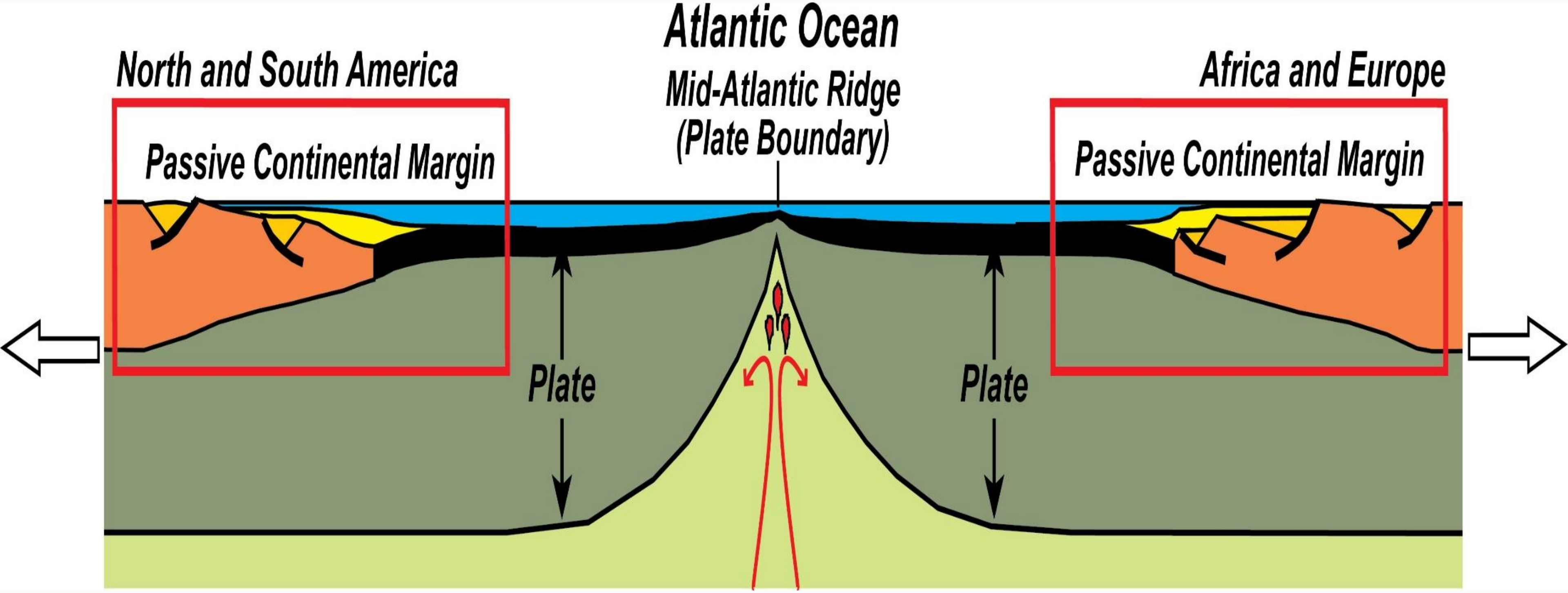


2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: ocean provinces

- **Passive** continental margins faces edges of diverging plates & have little tectonic activities is associated with them.

- Mostly surround the Atlantic Ocean & hence called **Atlantic-type** margins…

2: PHY. STRU. AQUATIC ECOSYSTEMS

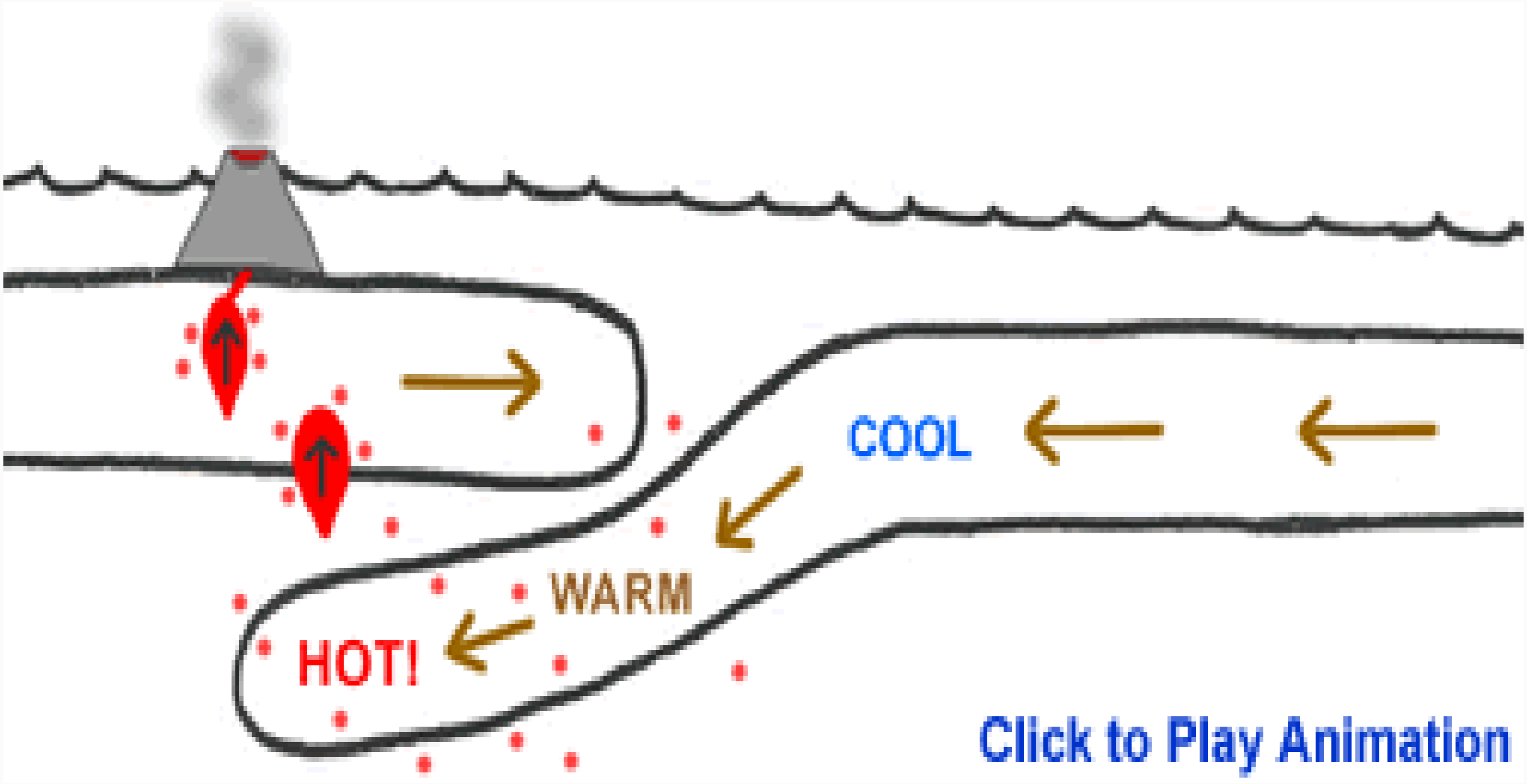


2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: ocean provinces

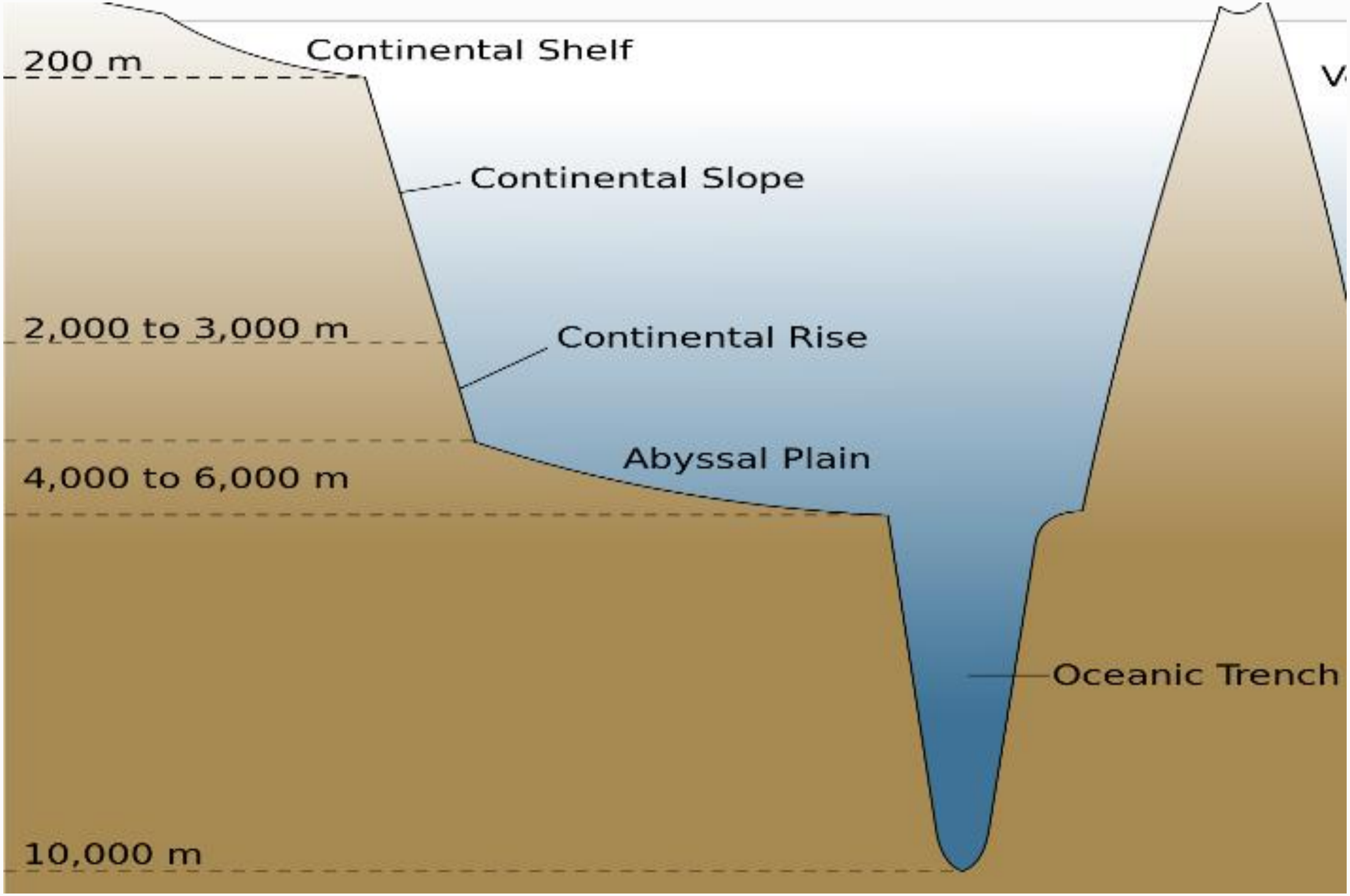
- **Active** continental margins are near edges of converging plates or where plates are slipping past one another.

- They're often associated with earthquakes & volcanic activities...

2: PHY. STRU. AQUATIC ECOSYSTEMS



2: PHY. STRU. AQUATIC ECOSYSTEMS



2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: ocean provinces

- Prevalent in Pacific Ocean, hence are sometimes called **Pacific-type margins**.
- Active margins coincide with boundaries of plates unlike passive margins
- Are confined mostly to the Pacific Ocean but Passive margins are also found outside the Atlantic.

2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: ocean provinces

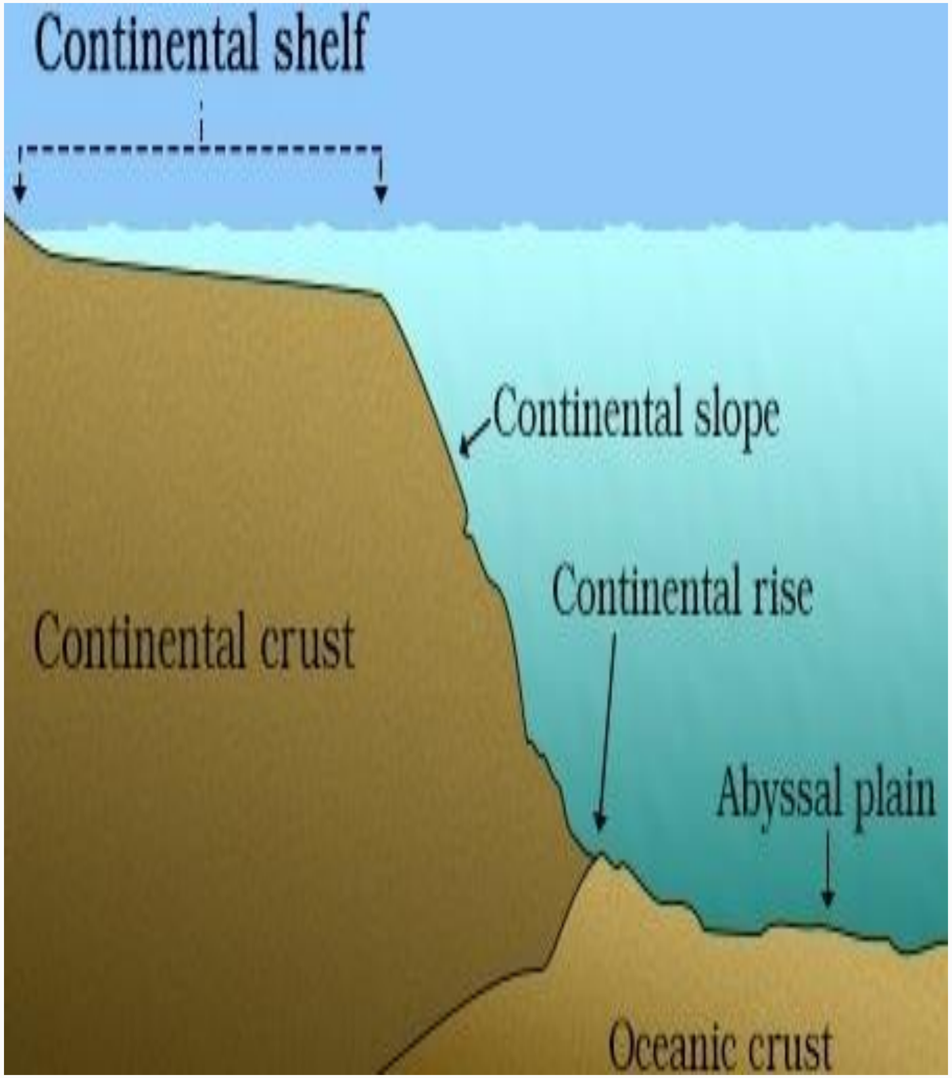
- Usually, the shelf is narrowest at active & widest at passive margins….

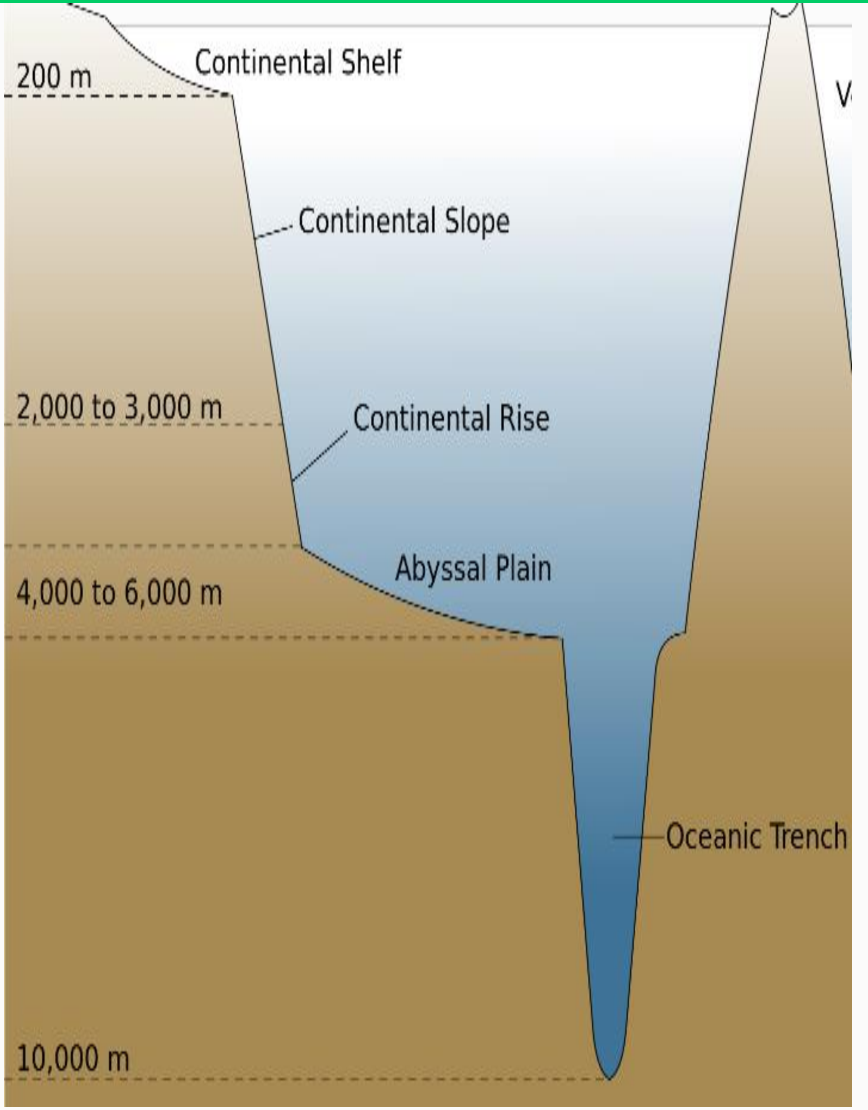
- Active margins have <u>narrow shelves</u>, <u>steep slopes</u>, & <u>little/no continental rise</u> but passive margins have the opposite...

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: division of margins

- As noted, **continental margins** have 3 main divisions:
  - a shallow, nearly flat **shelf** close to shore;
  - a more steeply sloped **slope** seaward; &
  - sediment apron, the **rise** – blends continental margins into the deep-ocean basins

2: PHY. STRU. AQUATIC ECOSYSTEMS





2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: SHELF

- Seaward extensions of continental plates that extend to a depth of about 120 m …
- …the shallow submerged extension of a continent underlain by granite & similar to the continent than the deep ocean floor…

2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: SHELF

- .. may have hills, depressions, sedimentary rocks, & mineral/oil deposits similar to those on the dry land nearby.

- Together, its area is **7.4 %** of Earth's ocean area.

2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: SHELF

- Most material of a shelf comes from the erosion of the adjacent continental mass.
- Rivers carry sediments to the shelf through transport by currents from inland areas.
- Since they have gentle slope, shelves are greatly influenced by changes in sea level.
-

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: SHELF

- Shelves at passive margins are usually wider/broader & flatter than active ones.

- Also, passive-margin shelves have less varied topography than active ones;

- Character of passive-margin shelves is determined less by faulting, volcanism, & tectonic deformation than sedimentation.

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: SHELF

- Shelves have been the focus of intense explorations for natural resources.

- Shelves are submerged margins of continents - deposits of oil/minerals along a coast are likely to continue offshore.

2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: SHELF

- Water depth over shelves averages only about 75 m, so large areas of it are accessible to mining & drilling activities.

- Hence, many of the techniques used to find & exploit natural resources on land can also be used on the shelves.

2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: SLOPE

- It is the transition between the gently descending shelf & the deep-ocean floor..
- …it <u>connects</u> the shelves with the deep ocean floor.
- The **shelf break** is the abrupt transition from the shelf to continental slope.

2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: SLOPE

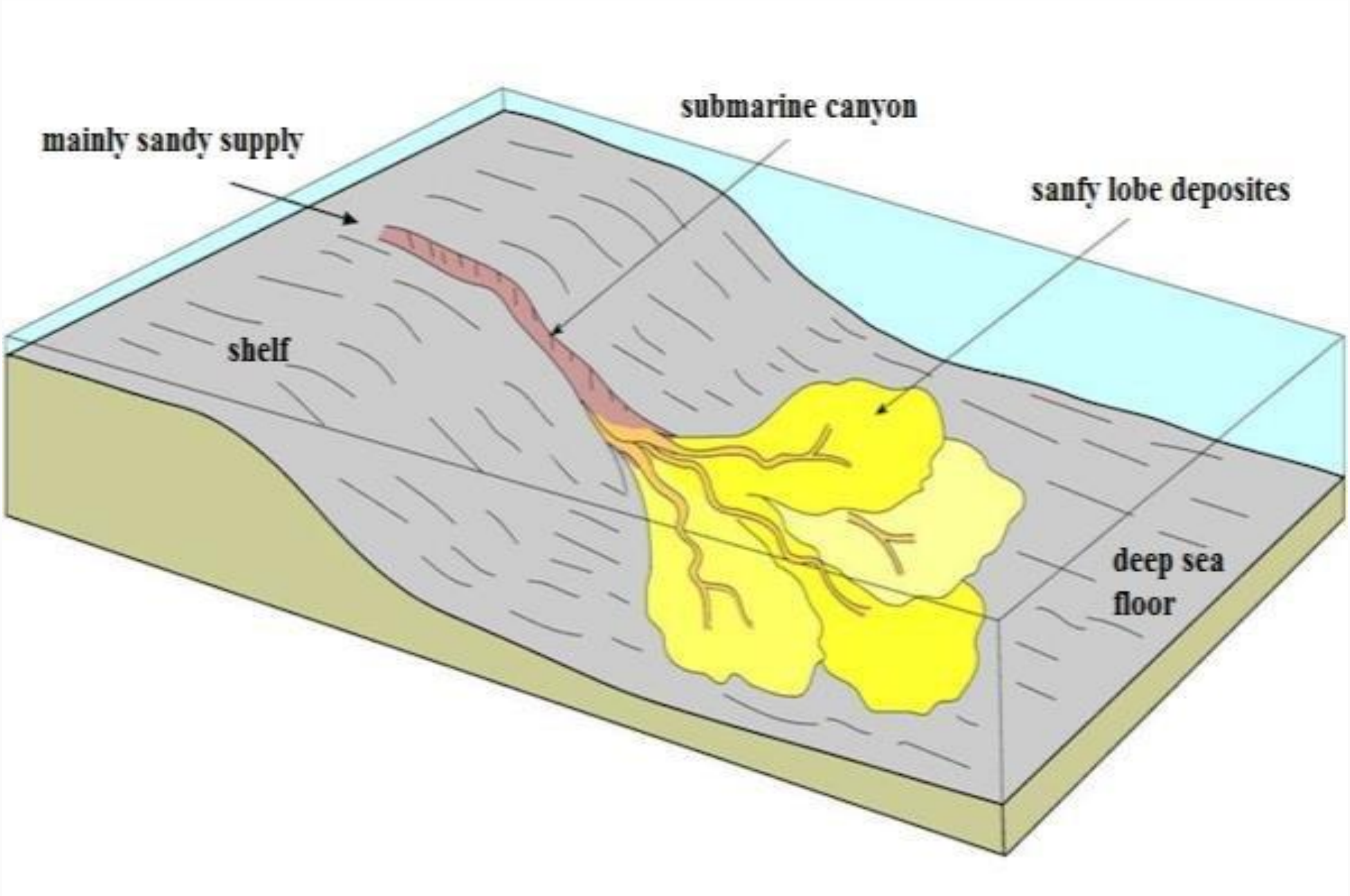
- In general, slopes at active margins are steeper than those at passive margins.
- Slopes average about 12 miles wide & end at the continental rise, usually at a depth of about 3700 m.
- The bottom of the continental slope is the true edge of a continent.

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: SLOPE

- *Submarine canyons* are narrow, deep V-shaped furrows with steep slopes that cut into the continental shelf & slope..

- …it often terminate on the deep ocean floor in a fan-shaped wedge of sediment.

2: PHY. STRU. AQUATIC ECOSYSTEMS



2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: SLOPE

- They’re formed when turbulence mixes sediments into water above a sloping bottom….

- …such mass movements of sediment are called **turbidity currents**

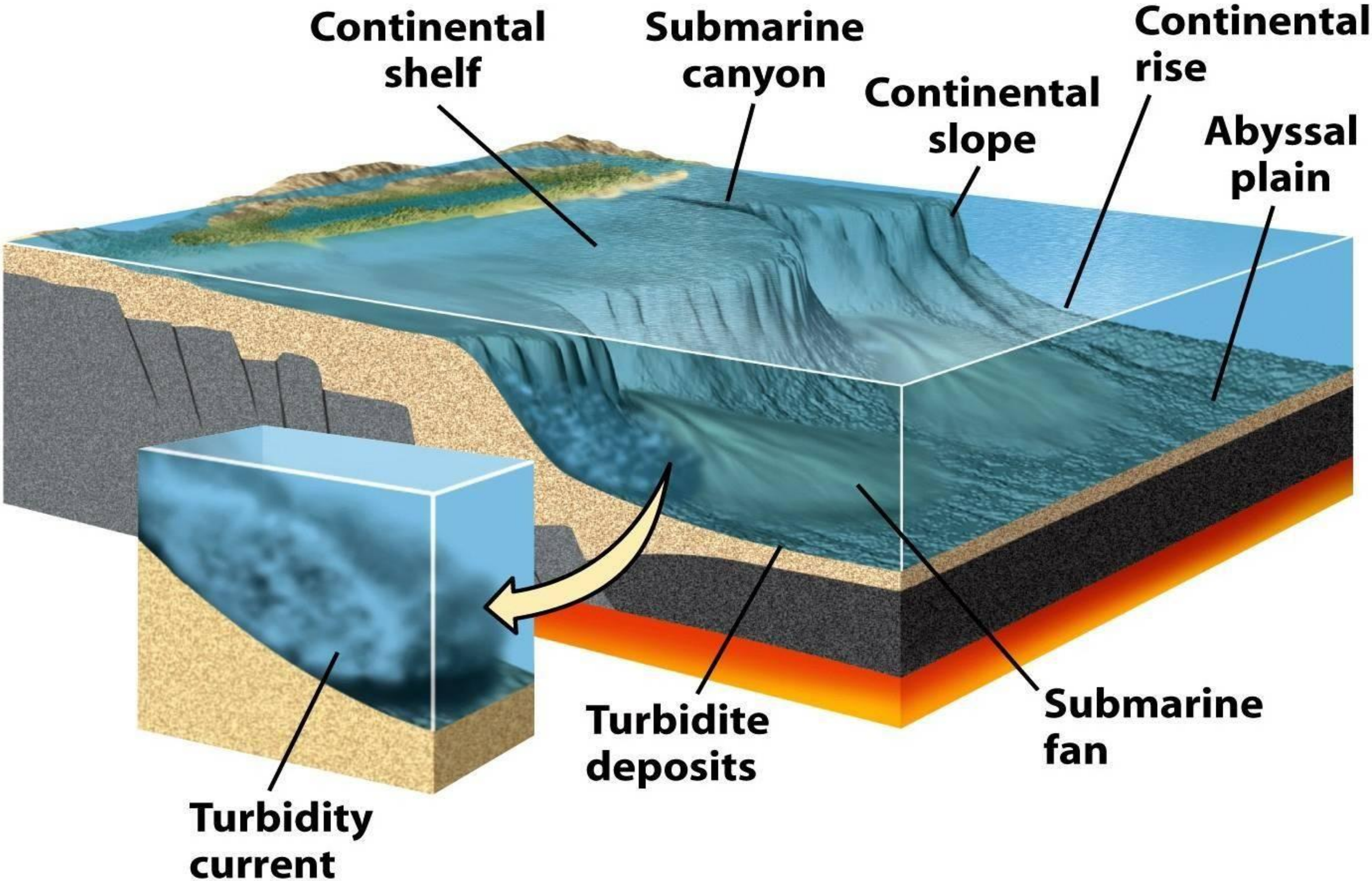


Figure 20.19a
***Understanding Earth*, Sixth Edition**

2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: RISE

- These are sediments that accumulate at the base of the continental slope…
- It is more prominent at passive margins.
- Sediments from the shelf slowly descend to the ocean floor along the slope, but most are transported by turbidity currents.

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

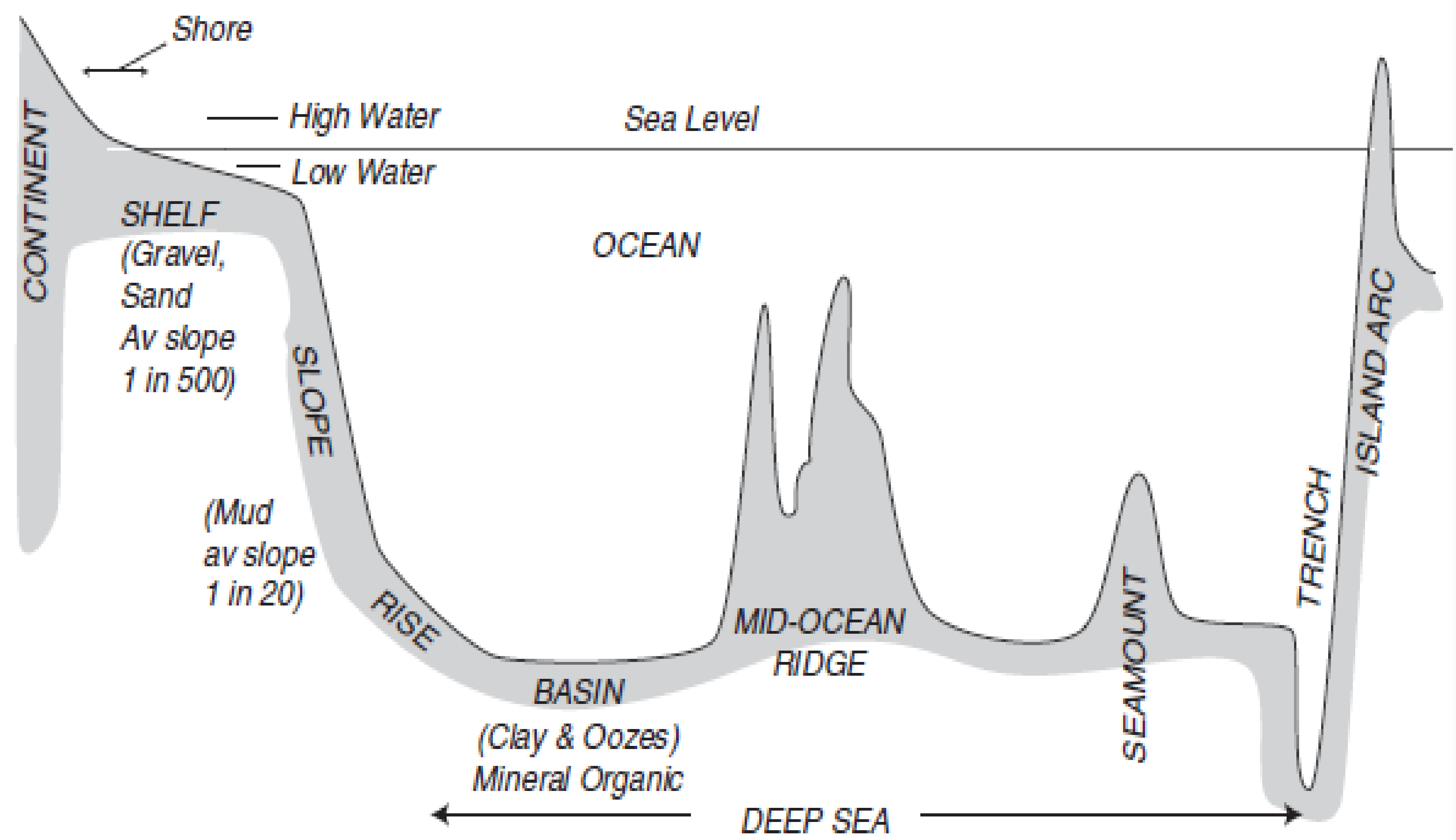
- As noted, the Earth crust is broken into large plates that move relative to each other.

- New crust is created at **mid-ocean ridges**, & old crust is lost at **trenches**.

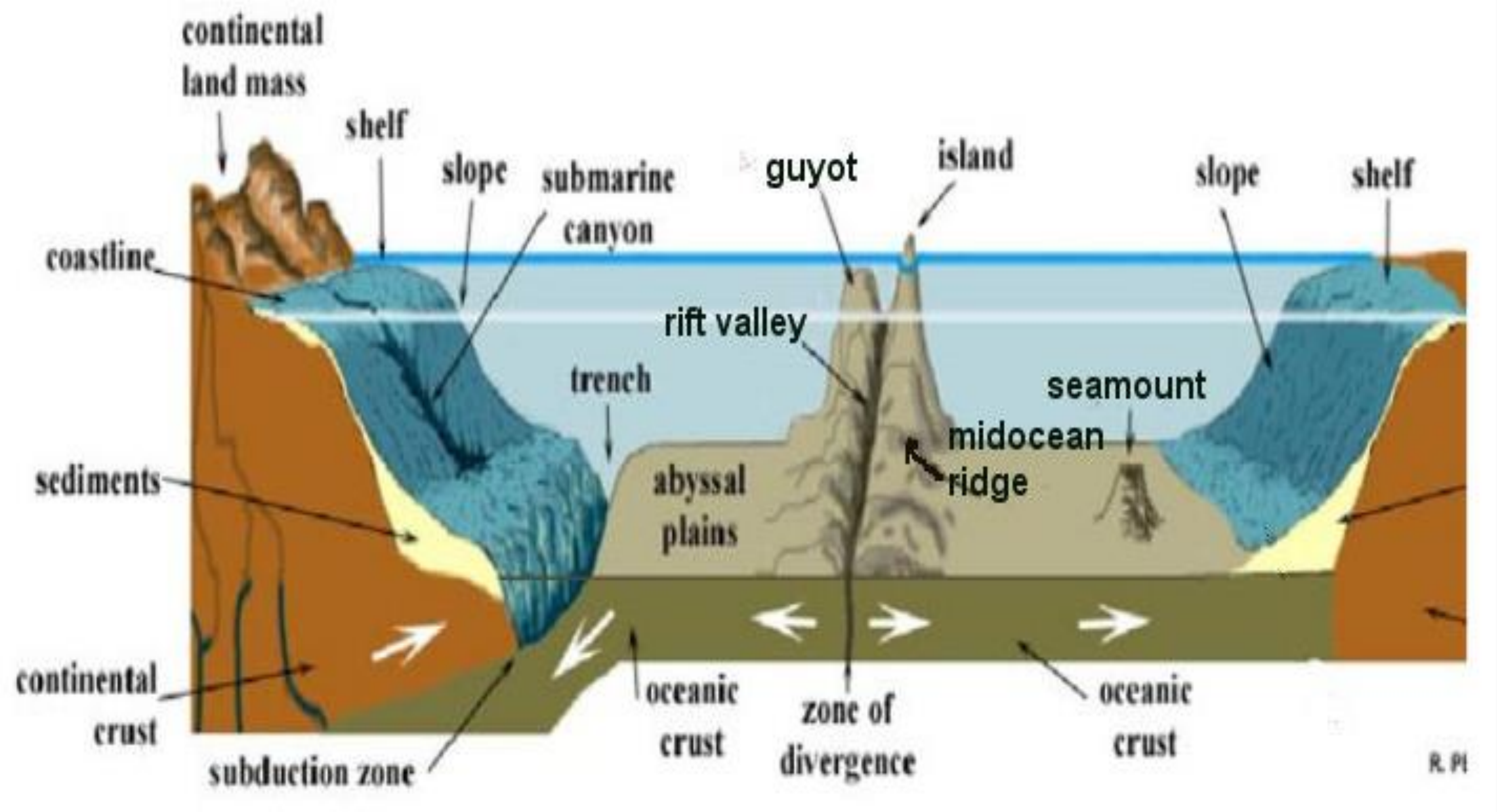
2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: deep ocean basin

- The relative motion of crust, due to plate tectonics, produces the distinctive features of the deep ocean floor including -
  - **mid-ocean ridges**,
  - **trenches**,
  - **island arcs**, &
  - **basins** ……

2: PHY. STRU. AQUATIC ECOSYSTEMS



2: PHY. STRU. AQUATIC ECOSYSTEMS



2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- The structure of the ocean floor is quite different from the continental margins.

- It consists of a blanket of sediments up to 3 miles thick overlying basaltic rocks.

- *Basins* are deep depressions of the ocean floor of more or less circular or oval form.

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- They constitute more than ½ of the earth's surface with most lying at a depth of 3000-5000 m.

- The **abyssal plain** at the periphery of all ocean basins is almost a flat, featureless expanse of sediment-covered ocean floor..

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- But, it is not perfectly flat, but rises gently toward the mid-ocean ridges.

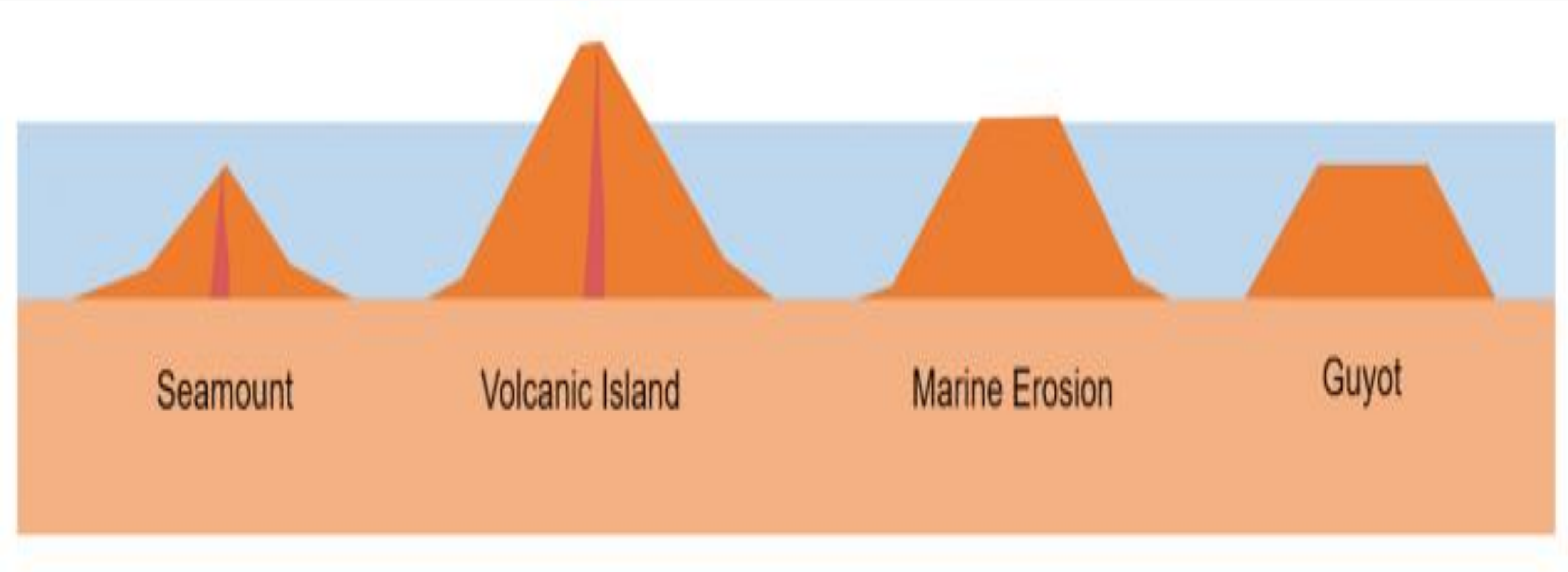
- They’re most common in the Atlantic but relatively rare in the Pacific, where peripheral trenches trap most of the sediments from the continents.

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- It is dotted with submarine volcanoes called **seamounts**, which don’t rise above the ocean surface….

- Distinct flat-topped seamounts called **guyots** are also found….

2: PHY. STRU. AQUATIC ECOSYSTEMS



2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- But, the most prominent features of the ocean basins are trenches, associated volcanic island arcs & the mid-ocean ridge systems - products of tectonic stresses.

- **Trenches:** long, narrow, deep depressions of the ocean floor, with steep sides found where a converging oceanic crust is subducted….

2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: deep ocean basin

- At trenches, where the plates descend into the mantle, the ocean floor slopes steeply downward.

- Trenches are the deepest parts of not just the world ocean but also the earth & the **Mariana Trench** in the western pacific is the deepest part of the ocean, measuring 11,022 m deep.

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- Little or no continental rise occurs along coasts with trenches since sediments that would form the rise ends up at the bottom of the trench….

- Like trenches, **volcanic island arcs** are formed by tectonic & volcanic activity associated with subduction…..

2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: deep ocean basin

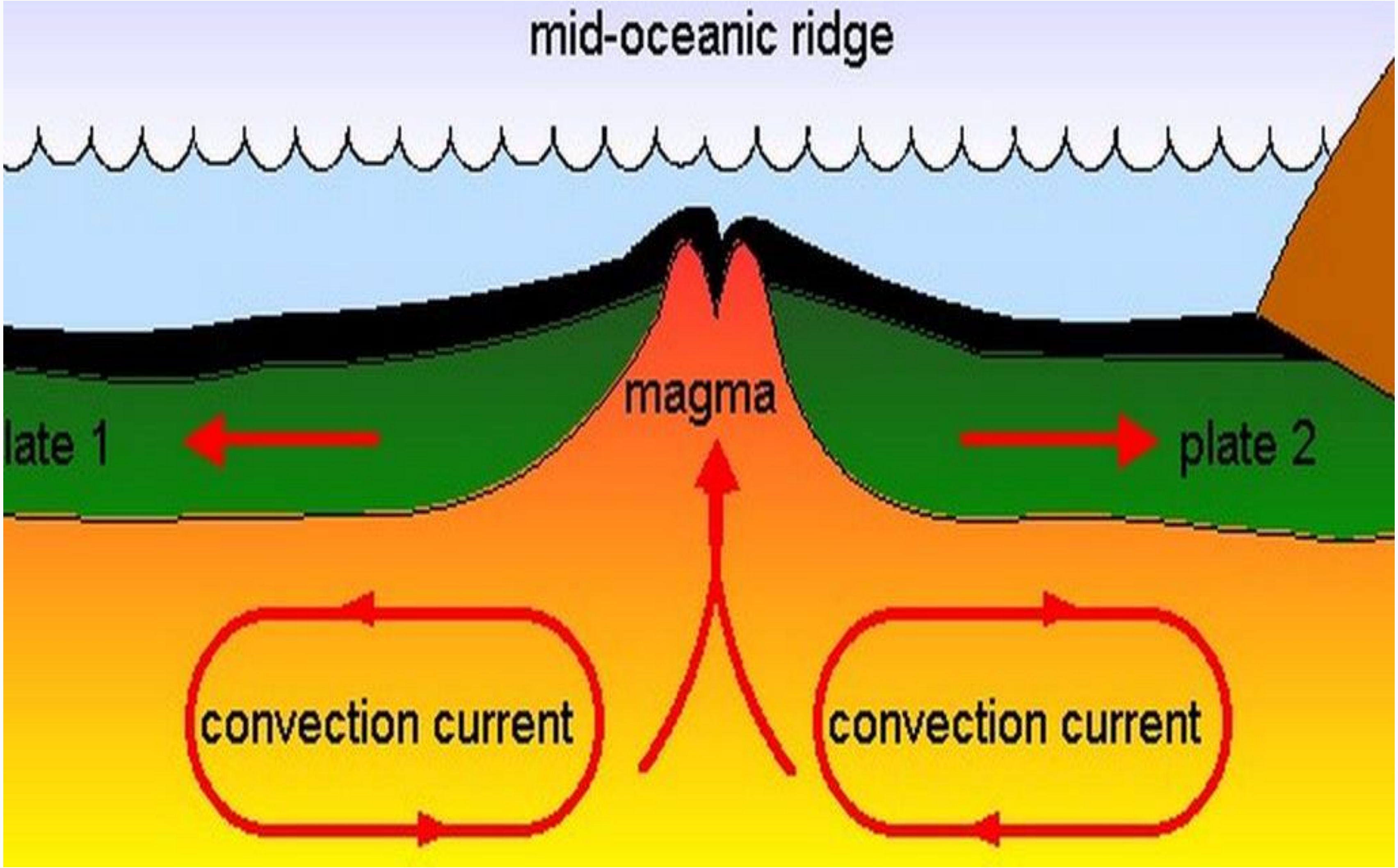
- The descending basaltic lithospheric plate contains materials that melt as the plate sinks into the earth's mantle.
- These materials rise to the surface as magmas & lavas that form the chain of islands behind the trench….

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- The Aleutian Islands, most Caribbean, & the Mariana Islands are island arcs.

- The **mid-ocean ridges** are long, narrow elevations of the ocean floor with steep sides & rough topography formed when material rising from the earth's mantle pushes up the oceanic crust….

2: PHY. STRU. AQUATIC ECOSYSTEMS



2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- The ridges, which often are devoid of sediment, rise about 2 km above the ocean floor.

- In some places, they project above the surface to form islands such as Iceland, the Azores, & Easter Island, etc.

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- Right at the centre, the ridge is pulling apart (i.e. diverging) leaving a great gap called the **central rift valley** - "a wound in the earth's crust…."

- **Sills** are the low parts of the ridges separating ocean basins from one another or from the adjacent ocean floor.

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- **NB**: As a plate carrying a continent move away or diverge from the spreading centre, the continental margin closest to the mid-ocean ridge is called the ***trailing margin*** or ***edge***.

- The edge of the continent moving towards a deep-sea trench or subduction zone is called the ***leading margin*** or ***edge***.

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- The floor & sides of the mid-ocean ridge valley are riddled with crevices & fractures.
- Ocean water seeps down through these cracks until it gets heated to very high temperatures by the hot mantle material.
- ..heated water is forced back up the crust in ***hydrothermal vents/deep-sea hot springs***

2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- The water from hydrothermal vents is warmer than the surrounding water.
- At some vents, water temperature can be up to 350 ^{o}C.
- As this hot water seeps through cracks in the earth's crust, it dissolves a variety of minerals, mainly those known as sulfides.

2: PHY. STRU. AQUATIC ECOSYSTEMS – <u>Ocean Ecosystem</u>: deep ocean basin

- When the mineral-laden hot water comes out at vents, it mixes with the surrounding cold water & is rapidly cooled.
- This causes many of the minerals to solidify, forming mineral deposits around the vents.

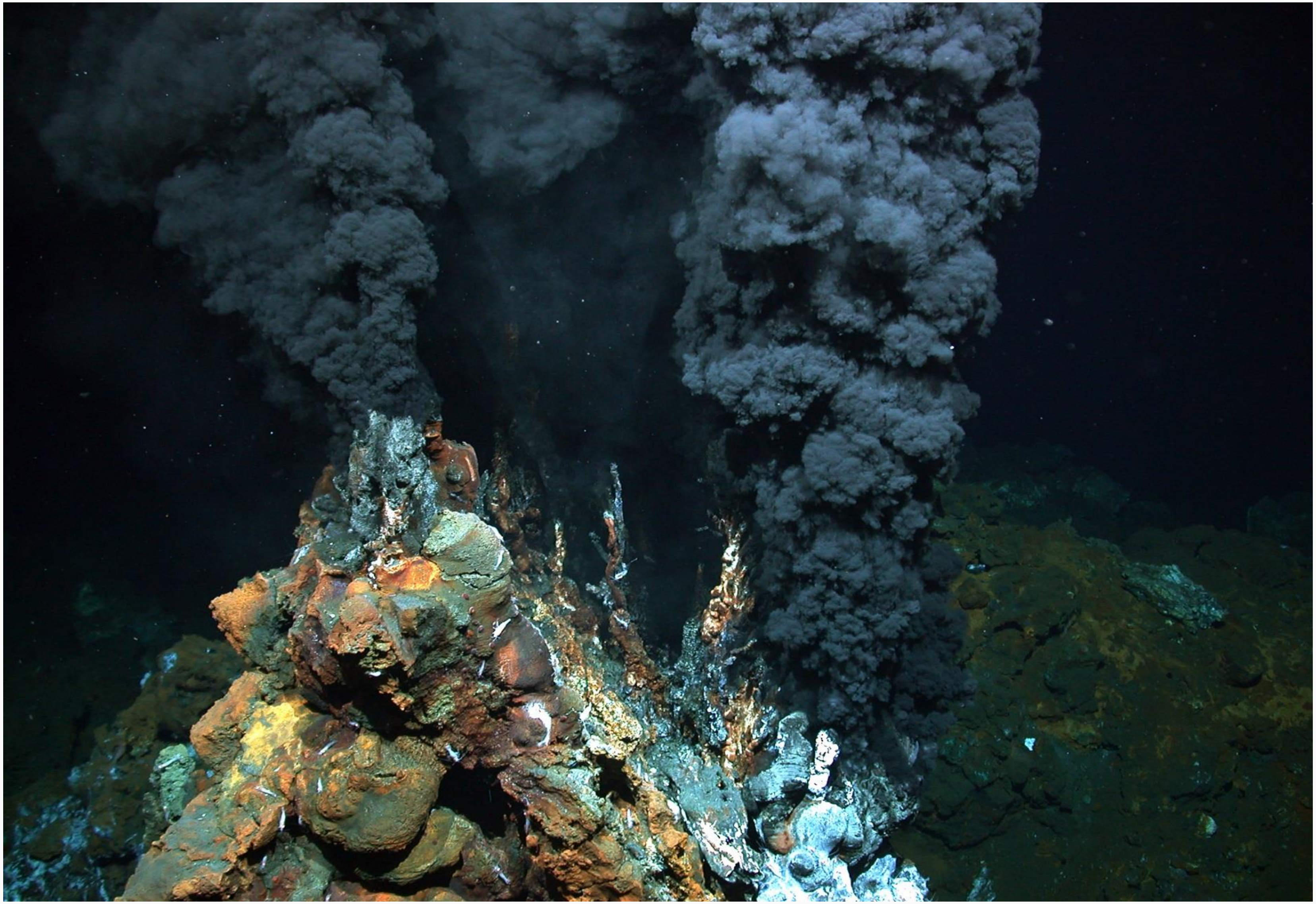
2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- **Black smokers** or chimney-like deposits of mineral found are one type of mineral deposit found at hydrothermal vents…

- Black smokers progressively build up around a vent as the minerals solidify.

- The “smoke” is actually a dense cloud of mineral particles….

2: PHY. STRU. AQUATIC ECOSYSTEMS



2: PHY. STRU. AQUATIC ECOSYSTEMS – Ocean Ecosystem: deep ocean basin

- Deep-ocean hot springs are of great interest not only to geologist, but biologists as well especially with the discovery of an unexpectedly rich marine life around hydrothermal vents.

2: PHY. STRU. AQUATIC ECOSYSTEMS – Inland Water Systems: Morphology

- Lakes have different types of shapes e.g…
  - circular,
  - subcircular,
  - lunate,
  - dendritic, etc…..

- A lake's **morphometry** is a function of underwater contours, the shape of the lake, & its **geologic origin**…

2: PHY. STRU. AQUATIC ECOSYSTEMS




2: PHY. STRU. AQUATIC ECOSYSTEMS

- Lake morphology is <u>important</u> in terms of
  - **water flow,**
  - **nutrient accumulation,**
  - **light penetration (lake depth),**
  - **water column mixing, &**
  - **separation into 2 main regions**
    - **a *littoral zone* (edge of the lake) *&***
    - ***a pelagic* (central) *zone***

2: PHY. STRU. AQUATIC ECOSYSTEMS

2: PHY. STRU. AQUATIC ECOSYSTEMS

- **Drainage basin/**catchment & **lake basin**.

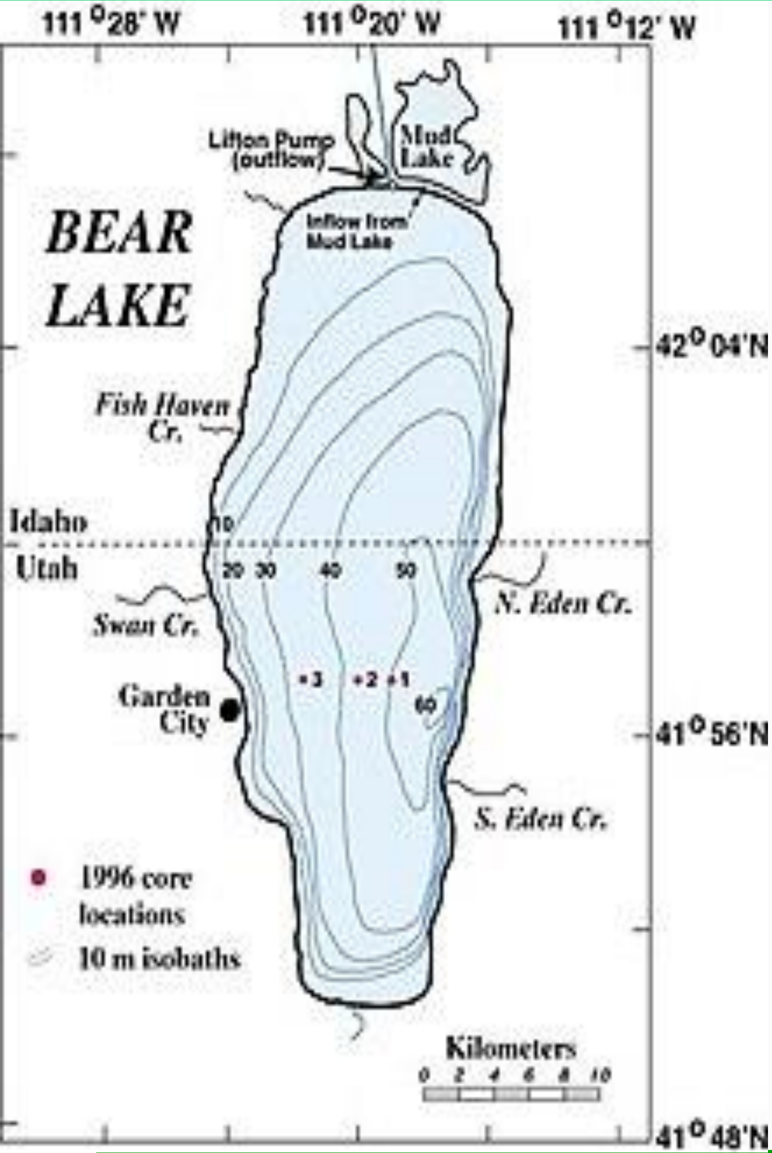
- Several **morphometric parameters** are often used to describe **lakes-**
  - Bathymetric map
  - Shoreline & shoreline development
  - Maximum length, width
  - Maximum depth, mean depth
  - Surface area, volume & volume devt, etc

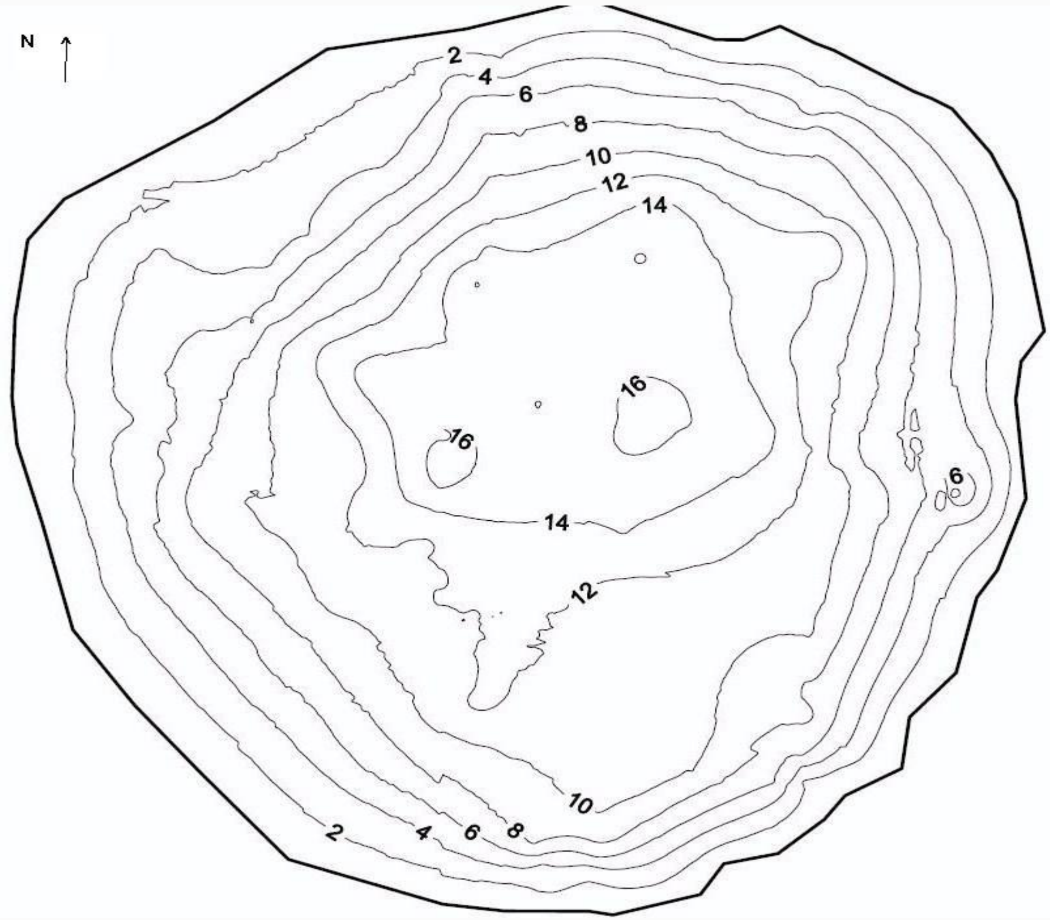
UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: (a) Bathymetric map

- Map showing the **submerged equivalent of an above-water topographic map**..

- Topographic maps of the aquatic basin floors.

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: a) Bathymetric map





UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: b) shoreline

- Outermost part of a water body where it meets the land…

- On a **bathymetric map**, it is represented by the outermost contour line…

- It defines the area where a water body interfaces with the land.

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: b) shoreline

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: b) shoreline

- Changes in a lake's shoreline & aquatic plant management.

- E.g.,
  - high & low water levels
  - slope effects – steep vs low slope

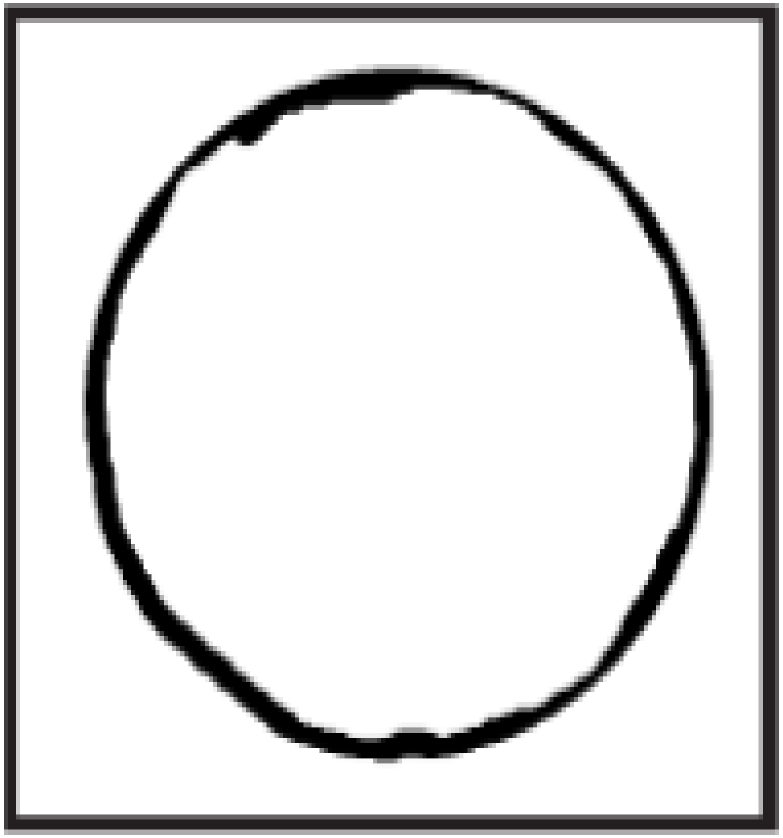
UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: c) shoreline dev (D_L)

- D_L - lake's shoreline relative to the length of a circle of the same area.

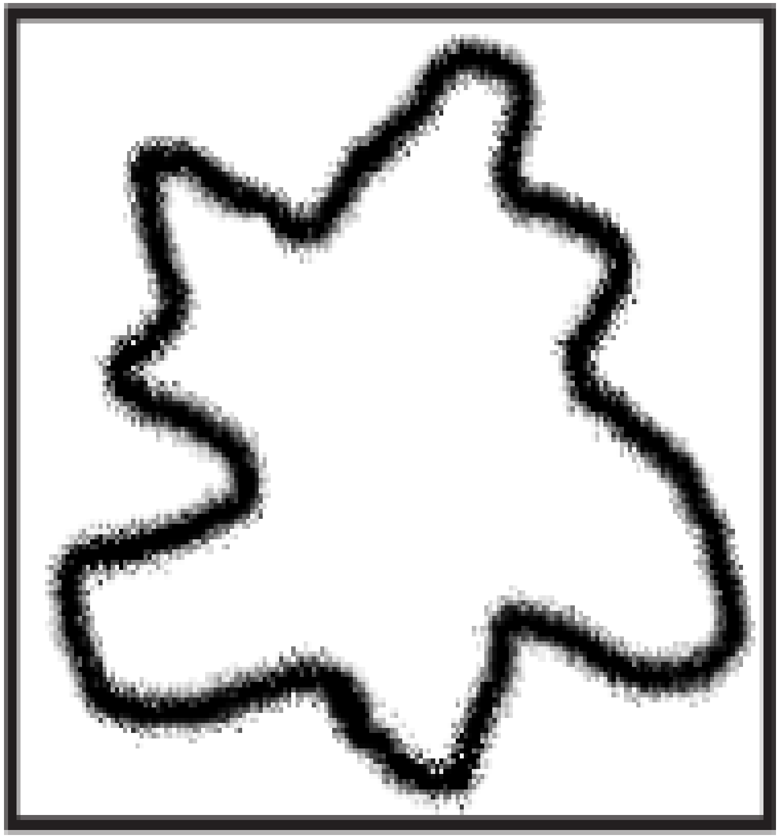
- …or **ratio** of shoreline length to the circumference of a circle with area equal to the area of the lake.

- E.g. consider lakes A & B…

UNIT 2: SOME FRESHWATER SYSTEMS – <u>Lentic Systems:</u> c) shoreline dev (D_L)



Lake A



Lake B

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: c) shoreline dev (D_L)

- Importance of lake's D_L is important.
  - assess amount of potential wildlife habitat available for a lake
  - Lake A & B which will have more D_L?

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: c) shoreline dev (D_L)

- Mathematically, D_L is calculated using:

$$D_L = \frac{L}{2 \sqrt{(\pi * A)}}$$

- Where **L** = Shoreline length & **A** = surface area of the lake.

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: c) shoreline dev (D_L)

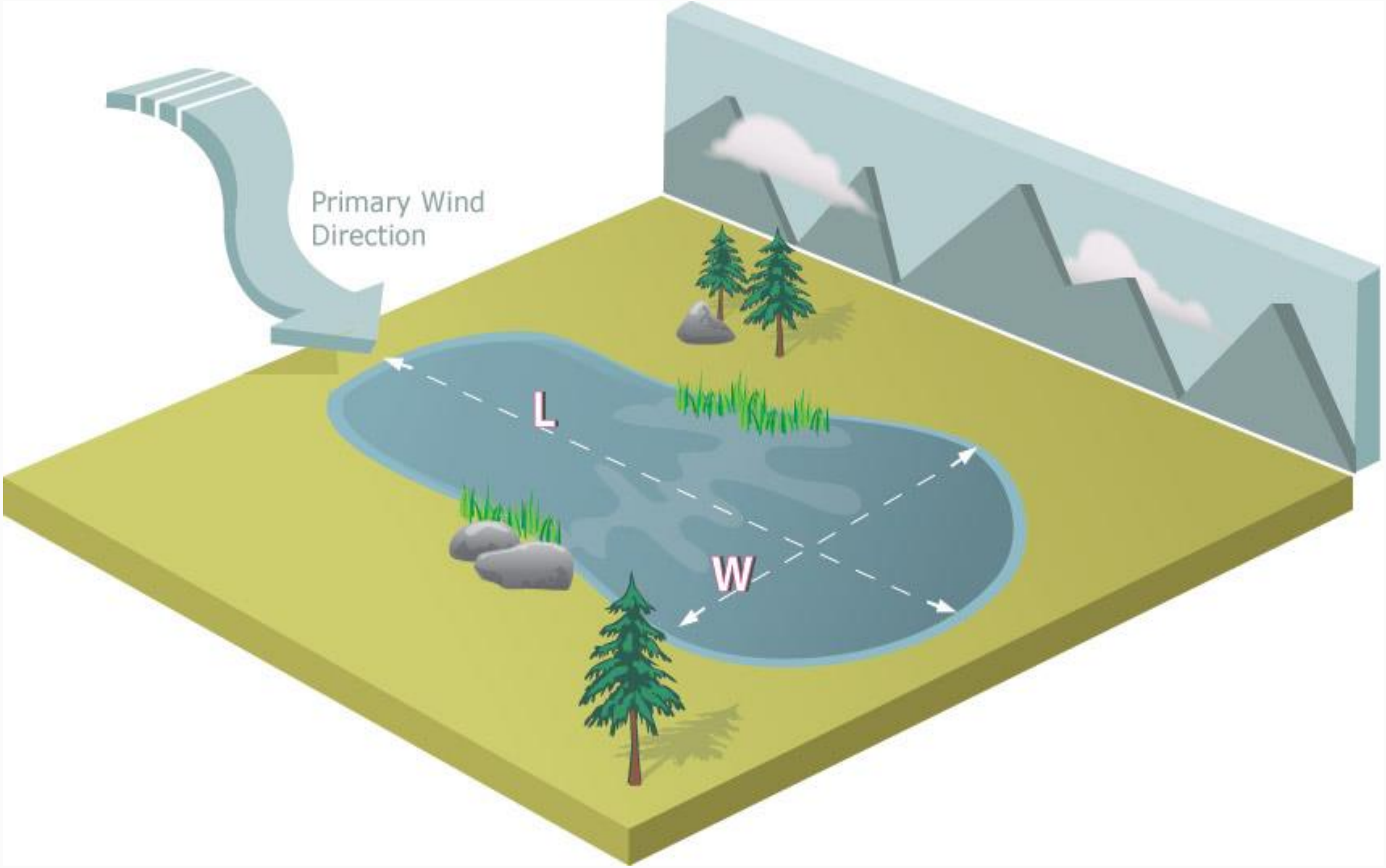
- **Note**:
  - A lake in the shape of a perfect circle will have a D_L value of 1.
  - Longer irregularly shaped shorelines have greater D_L.

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: d) maximum length

- **L_{max}** – shortest distance between 2 most distant points on the lake shore..

- It is measured without intersecting a land mass…

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: Morph. parameters



UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: d) (L_{max})

- Importance of L_{max}.

- L_{max}, amount of waves created, & strength of mixing all directly related.

- But a lake's orientation to prevailing winds also affects the depth of mixing….

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: e) width

- The length of a line from shore to shore at right angles to the L_{max}….

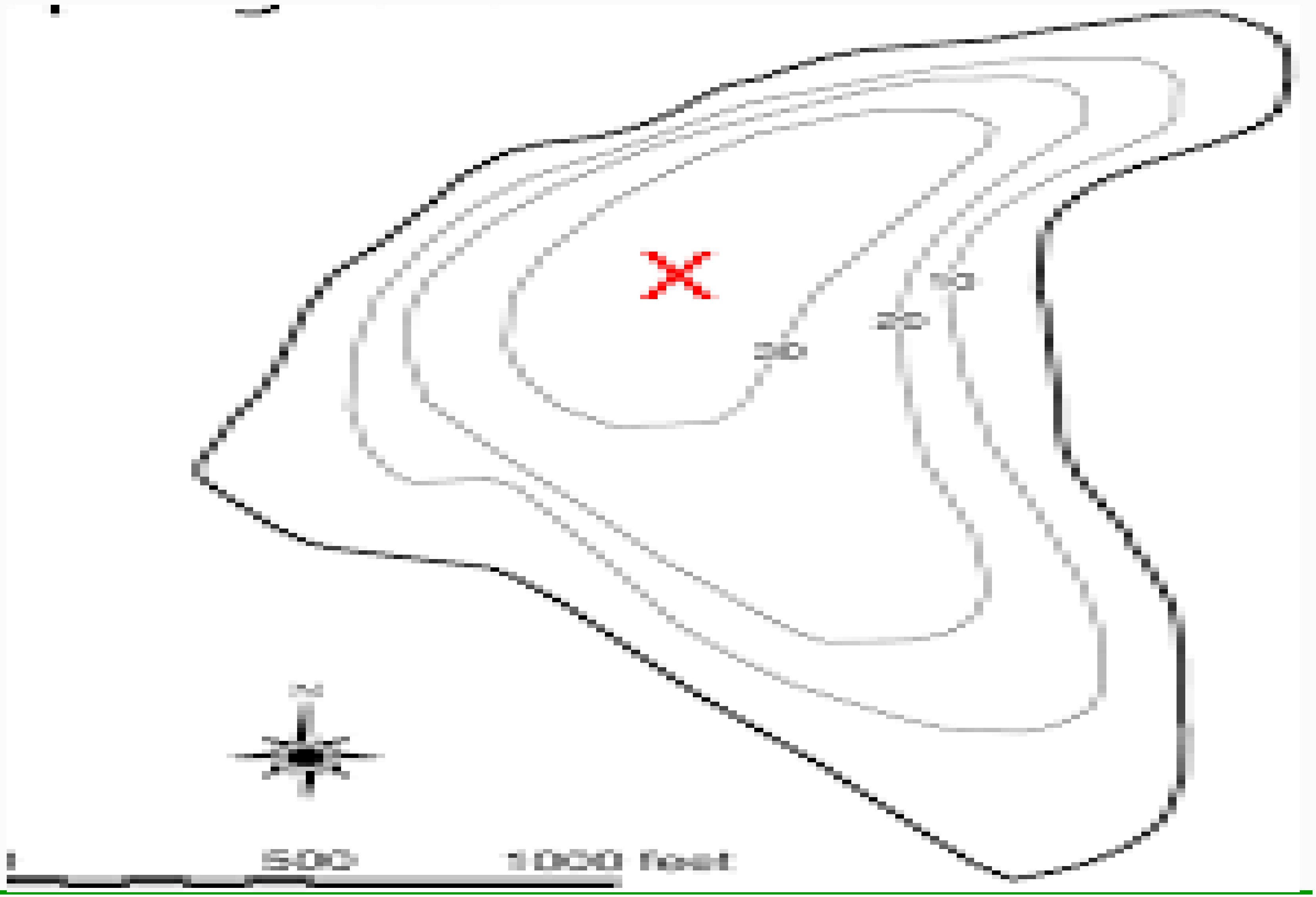
UNIT 2: SOME FRESHWATER SYSTEMS – <u>Lentic Systems:</u> f) Max. depth (Z_{max})

- **Z_{max}** = deepest depth of the lake that can't be estimated, it's obtained by locating & measuring it..

- It's is sometimes (not always) indicated in bathymetric maps with an "X"….

- It <u>influence movement of fine organic sediments found on the bottom of a lake</u>.

UNIT 2: SOME FRESHWATER SYSTEMS – <u>Lentic Systems:</u> f) Z_{max}



UNIT 2: SOME FRESHWATER SYSTEMS – <u>Lentic Systems:</u> g) Mean depth (Z_{ave})

- This is the average water depth of a lake.

- It is estimated by ratio:

$$\mathbf{Z_{ave} = Volume\ (V)/Area\ (A)}$$

- It's a very useful morphometric feature for several reasons;

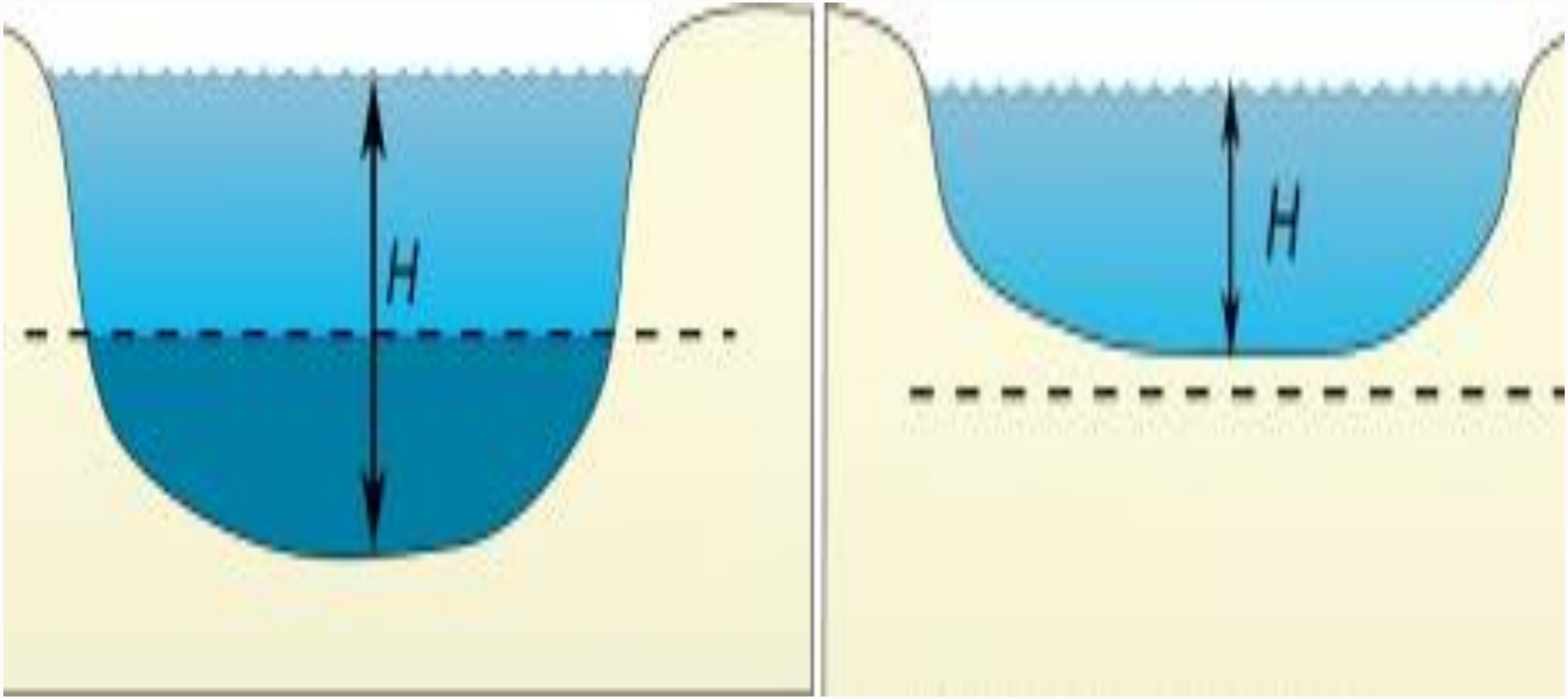
UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: g) Mean depth (Z_{ave})

- Studies show that shallow lakes are more productive than deep lakes.

- It also has much to do with the potential for waves to disrupt bottom sediments.

- E.g., greater mean depths imply less mixing of bottom sediments due to reduced wave action.

UNIT 2: SOME FRESHWATER SYSTEMS – <u>Lentic Systems:</u> g) Mean depth (Z_{ave})



UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: h) surface area

- Size of an area covered by the water…

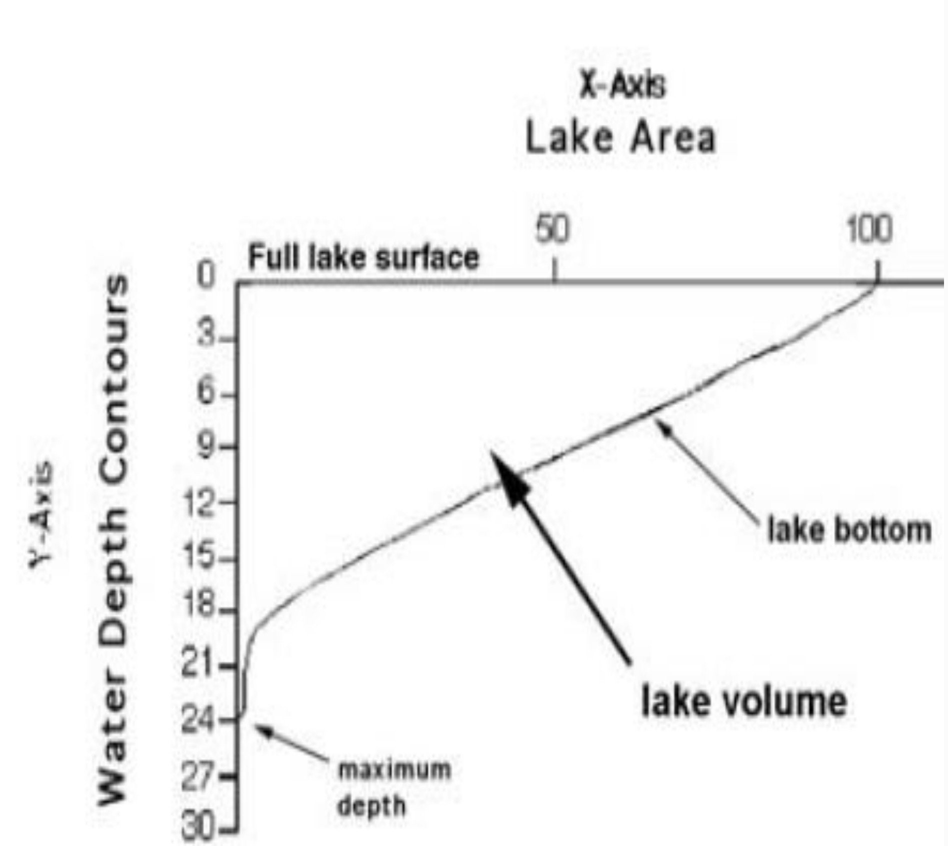
- Importance of lake area.
  - shows size of a lake
  - predict potential effects of wind on a lake….
  - influence **dilution capacity*** of a lake
  - useful in choice of boat to use on a lake

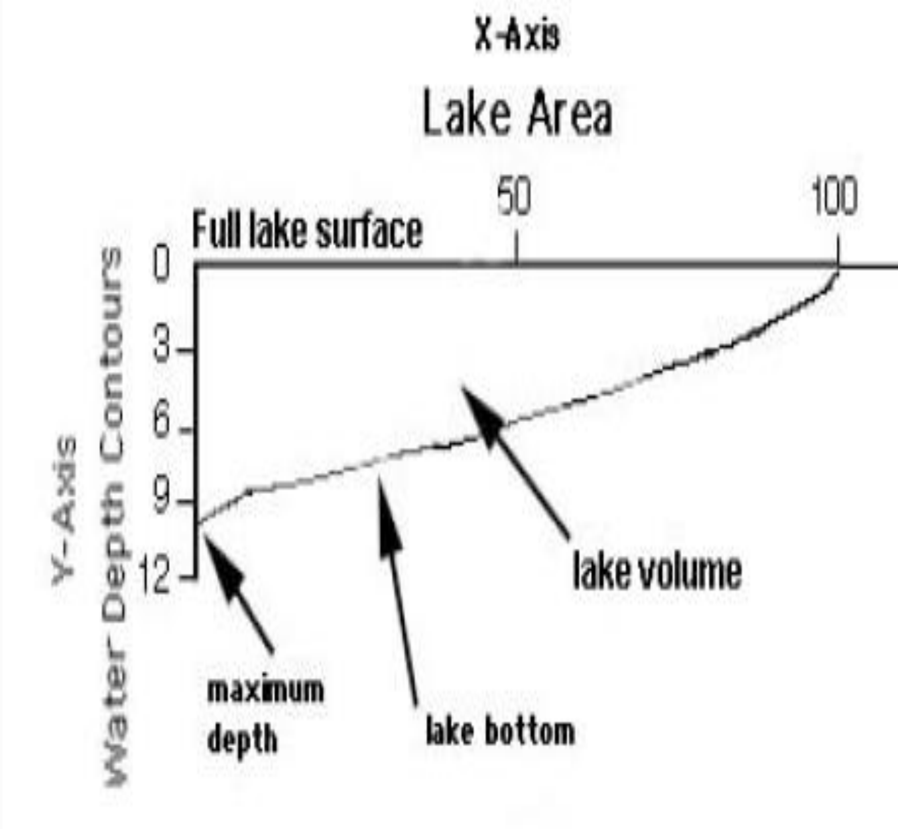
UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: i) Hypsographic curve

- A plot of **depth** along the vertical axis & **area** along the horizontal axis.

- Used to provide a **picture** of surface area of a lake basin & its depth…

UNIT 2: SOME FRESHWATER SYSTEMS – <u>Lentic Sys:</u> i) Hypsographic curve





UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: i) Hypsographic curve

- Can be **used**:
  - predicting how a lake's surface area could change based on changes in water depth.
  - depict shape relationships of a lake basin.
  - **predicting** best time to implement some lake mgt strategies e.g. aquatic plant mgt, habitat restoration, etc.

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: i) Hypsographic curve

- use them for **predicting** two lake dynamics in particular:
  - **a lake's ability to dilute incoming materials,**
  - **the potential for lake water mixing**

- Both affect lake nutrient levels & its ability to support life — its **productivity**.

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: j) volume (V)

- The total volume of a lake's water.

- Calculated from the bathymetric map* as:

$$V = \sum [A_1 + A_2 + \sqrt{(A_1 * A_2)}] * h/3$$ where

A_1 = area of one contour,

A_2 = area of the next contour

h = the thickness of the layer between the two contours.

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: j) volume (V)

- Effect of rainfall on volume.

- Volume effects on lake management:
  - It influence dilution capacity.
  - Estimates of nutrients loads.
  - Estimates of flushing rate.

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: j) volume (V)

- Methods for measuring lake volume:
  - **i).** Estimating from a **hypsographic curve**….
  - **ii.** Multiplying mean depth & surface area:

$$(\mathbf{V}) = \text{mean depth } (\mathbf{z}) * \text{surface area } (\mathbf{A})$$

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: k) volume devt (D_V)

- Ratio of lake volume to volume of a cone of basal area = surface area of the lake & height = maximum depth.
- A measure of departure of the shape of the lake basin from that of a cone.
- It's expressed mathematically as;

$$D_V = (3 * Z_{ave} / Z_{max})$$

UNIT 2: SOME FRESHWATER SYSTEMS – Lentic Systems: k) volume devt (D_V)

- Majority of lakes have **Dv** > 1 (i.e., are not conical depressions).

- **Dv** is **greatest** in shallow flat-bottom lakes & for deep lakes, is much greater than 1.5.

- Lakes with highly localized deep holes have very small values.

UNIT 2: SOME FRESHWATER SYSTEMS
Concept of Hydraulic residence time (HRT)

- **HRT** is the time required to refill a lake with its natural inflow.
- …or the average time taken to refill a lake basin with water if it were emptied.
- It provides a measure of the circulation of water within the aquatic system.

UNIT 2: SOME FRESHWATER SYSTEMS
Concept of Hydraulic residence time (HRT)

- HRT is also called water flushing time (**WFT**) or water residence time (**WRT**) & can be calculated using the formula:

$$\text{HRT} = \frac{\text{Volume } (m^3)}{\text{Average annual water outflow } (m^3\ yr^{-1})}$$

- E.g. if a lake's **V** is 8400 km^3; mean **HRT** is 1225 years, what's the **average annual water outflow**?

Solution

$$\text{HRT} = \frac{\text{Volume } (m^3)}{\text{water outflow } (m^3\ yr^{-1})}$$

$$\text{water outflow} = \frac{8400\,000\ (m^3)}{1225\ (yr)}$$

water outflow = **6857.14 m^3yr^{-1}**

UNIT 2: SOME FRESHWATER SYSTEMS
Concept of Hydraulic residence time (HRT)

- Some lakes have inflow but no outflow (**closed basin lakes**) & lose water entirely by evaporation.

- This leads to salt accumulation & the development of high saline environment e.g. Lake Bosomtwe (Ghana), Caspian Sea, etc.

UNIT 2: SOME FRESHWATER SYSTEMS
Concept of Hydraulic residence time (HRT)

- Other lakes lack both inflow & outflow, & are called **seepage lakes.**

- They receive water through the walls & flows of their basin.

- **Main source** of water is precipitation & runoff from the catchment.

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

- Lake ecosystems can be divided into several abiotic zones based on abiotic factor of interest to a particular study.

- Examples of such abiotic factors include:

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

- Temperature differences in water column
- Light penetration,
- Salinity & conductivity differences,
- Distance from the shore, etc

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

- A combination of these usually used for a better insight of lake physical conditions.

- These abiotic factors demarcate zones which may require special adaptations for the **biotic** community found there.

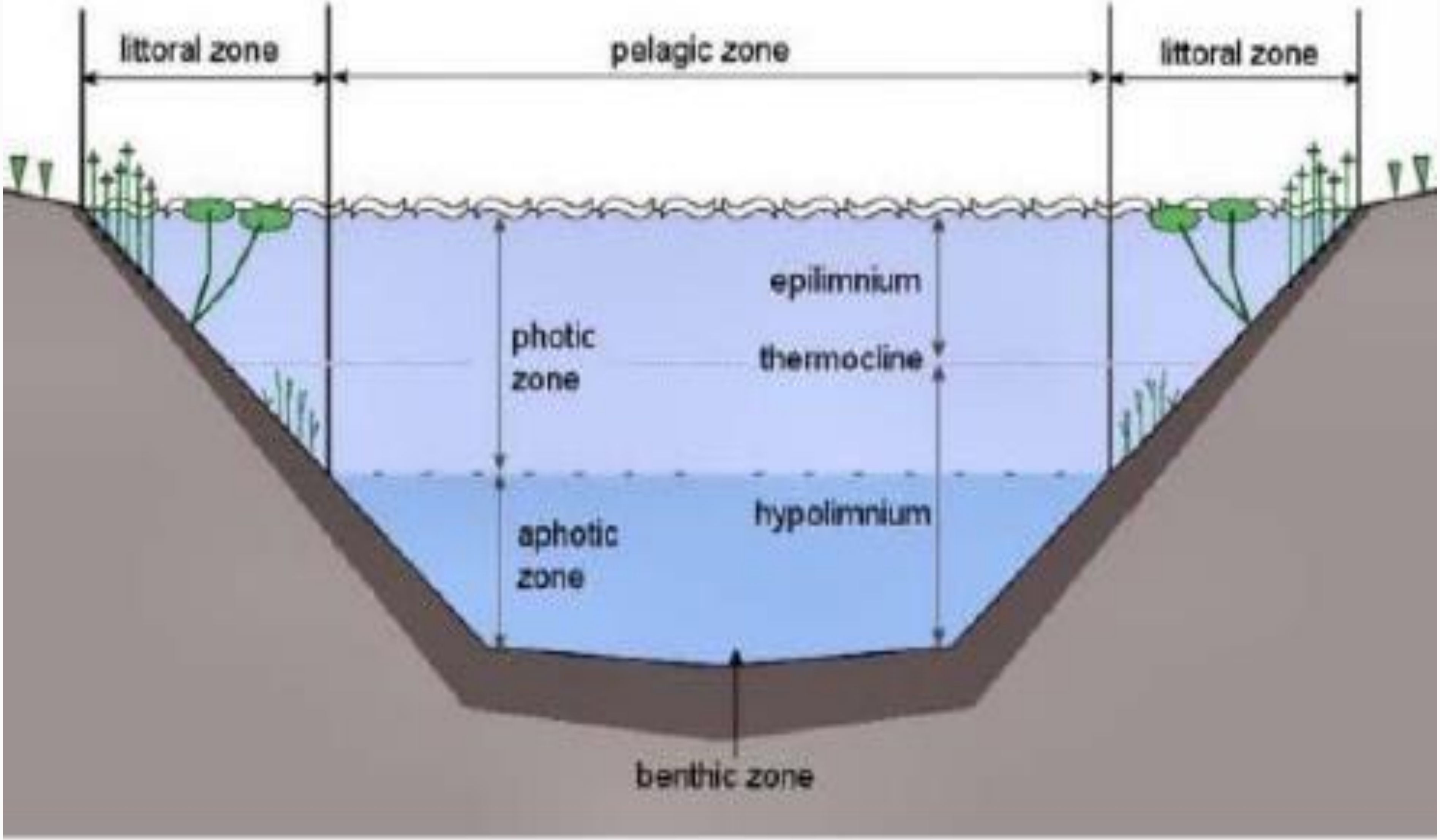
UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

- **Light penetration** –
  - Photic/euphotic/trophogenic/limnetic zone
  - Aphotic/profundal/trophylytic zone...

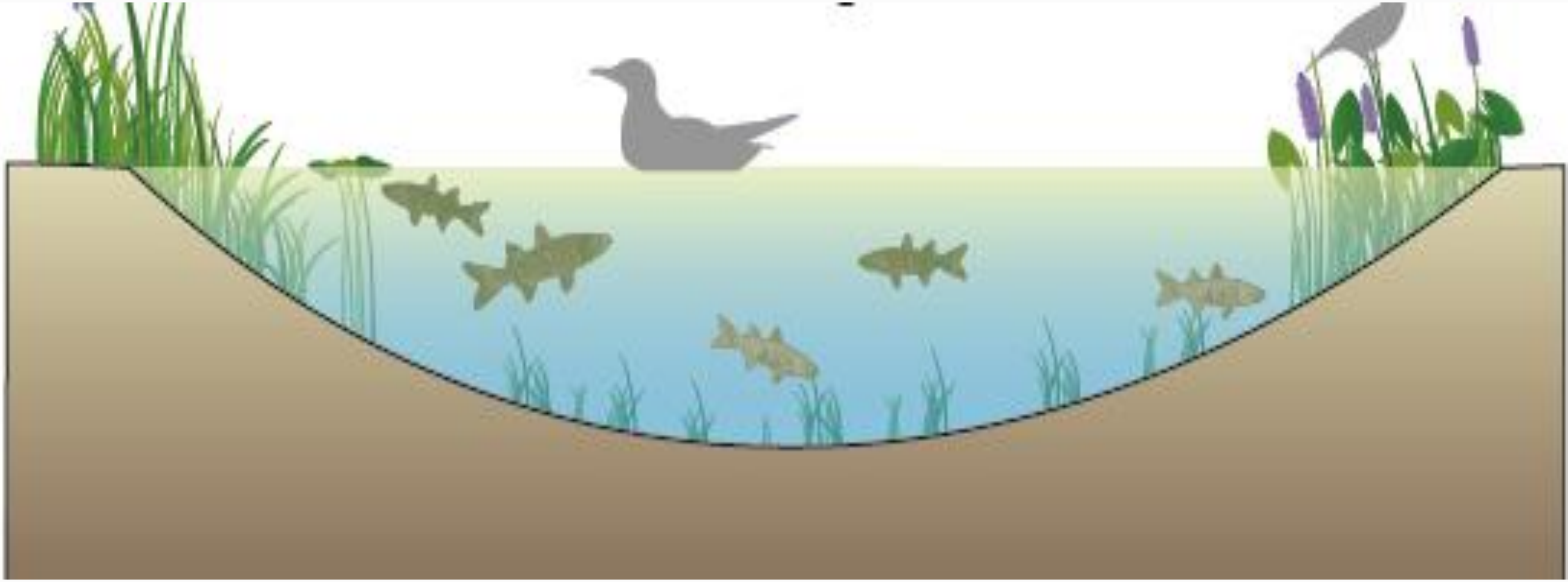
UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake



UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake



UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

- **Distance from the shore**, &
  - Littoral zone
  - Pelagic/lacustrine zone....

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

- **Temperature changes**
  - Epilimnion
  - Metalimnion
  - Hypolimnion ....

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

- a) **Littoral zone**: This is the shallow edge of the lake characterized by rooted vegetation… .....

- It has distinct physical, chemical, & biological characteristics.

UNIT 2: SOME FRESHWATER SYSTEMS

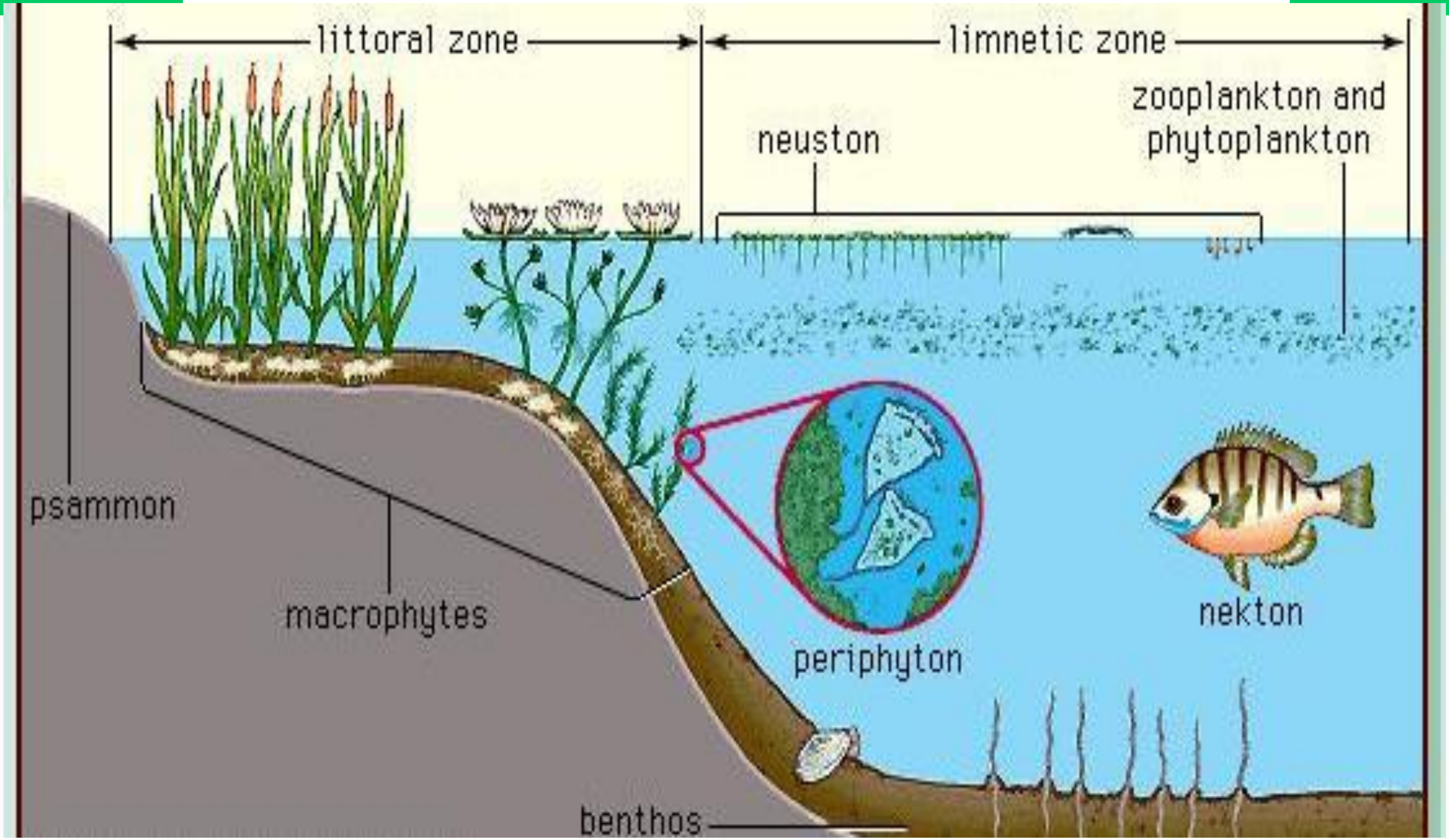
The Physical Structure of a Lake

a) **Littoral zone**:

- Physical
  - high light penetration (presence of plants),
  - wave action (need for rooting),
- Chemical
  - influx of materials from outside, &
- Biological (dominance of **macrophytes** + **periphyton** as primary producers)

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake



UNIT 2: SOME FRESHWATER SYSTEMS
The Physical Structure of a Lake

a) **Littoral zone (cont)**:

- Most lakes show clear separation between littoral & pelagic regions, each with their own distinctive communities….

- Development of macrophyte communities as part of littoral flora is typical of eutrophic & mesotrophic water bodies but not oligotrophic ones.

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

a) **Littoral zone (cont)**:

- The shallow water in the littoral zone allows light penetration to the sediments.

- These provide the base/substratum for rooting macrophytes (mainly higher plants), able to survive strong wave action & tend to dominate mesotrophic to eutrophic littoral communities.

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

a) **Littoral zone (cont)**:

- In many lakes, the littoral zone also has a rich microbial community, many of which live a life attached to a substrate.

- Such microbial communities attached to substrata are collectively called periphyton of which the algae form prominent part.

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

a) **Littoral zone (cont)**:

- **Periphytons** are typically characterized using the substrate they are attached to.

- On that basis several types can be distinguished….

- Some algae also occur as free floating masses (metaphyton).

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

Type of periphyton	Substrate
Epiphyton	Plants
Epilithon	Rocks
Episammon	Sand grains
Epipelon	Sediments
Epixylic/epidendron	Dead wood

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

a) Littoral zone (cont):

- Bacteria, fungi, & protozoa are also well represented in this part of the lake.

- The microbial community of the littoral zone differ from that of the pelagic in many ways:
  - taxonomic composition,

UNIT 2: SOME FRESHWATER SYSTEMS
The Physical Structure of a Lake

a) Littoral zone (cont):

- domination of benthic organisms (epibenthos i.e. bottom-living organisms),
- & heterotrophic consumption of mainly allochthonous dissolved organic carbon (DOC)

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

a) Littoral zone (cont):

- The littoral region is also a major site of recruitment of benthic algae* to form planktonic populations.
  - Meroplankton* – spend only a portion of their life cycle in the water column
  - Holoplankton – spend all their life cycle in the water column

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

- b) **Pelagic (lacustrine) zone** is the open water portion of the main lake body with limited light penetration especially in deep lakes. …

- It consists of a vertical water column with an air-water interface at the top & lake sediments at the base….

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

b) **Pelagic (lacustrine) zone**

- The 1st part of the pelagic zone is called the limnetic zone.
- The limnetic zone is the open water zone to the depth of effective light penetration.
- Usually, the limnetic & the littoral zones together often forms the photic zone….

UNIT 2: SOME FRESHWATER SYSTEMS

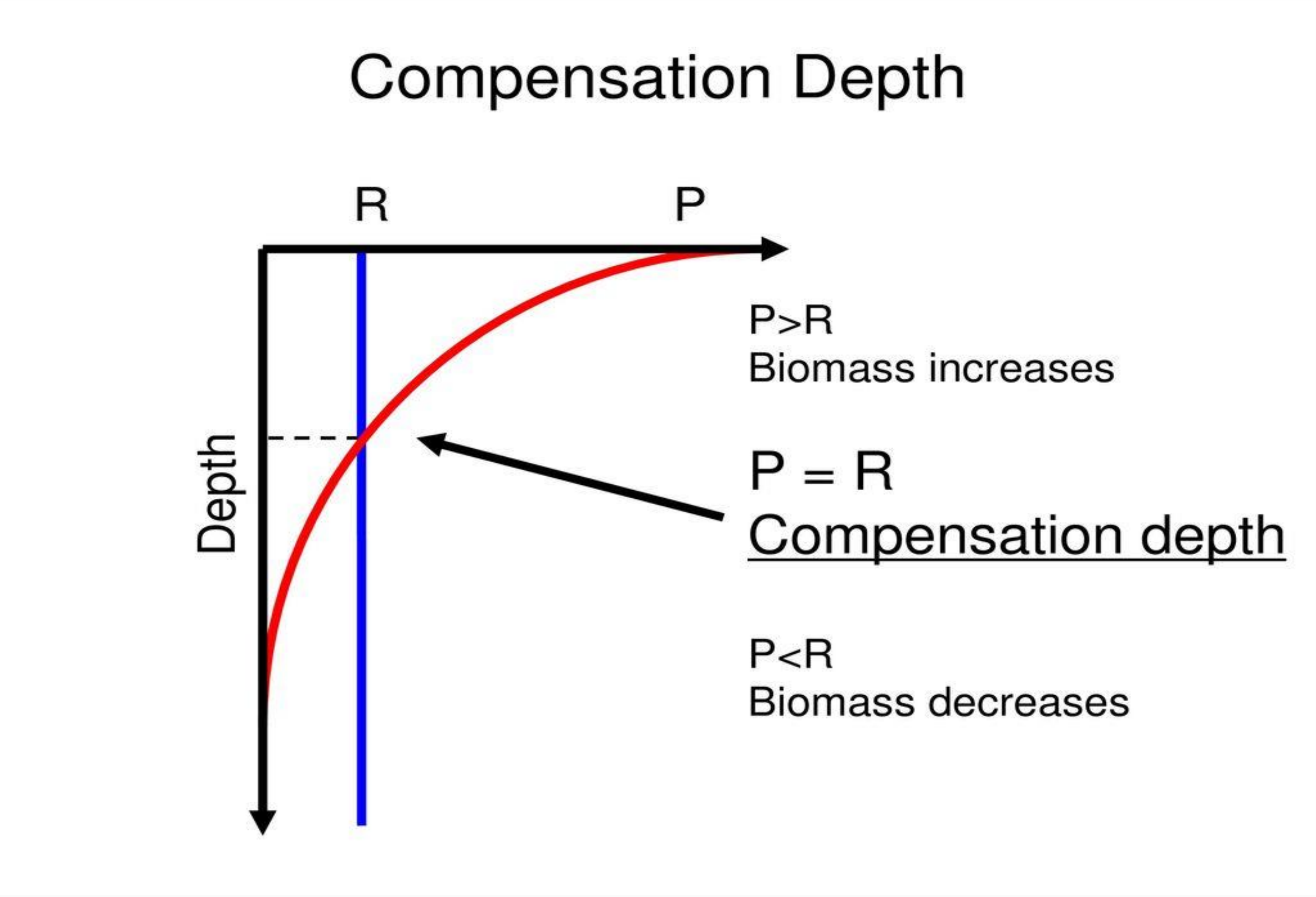
The Physical Structure of a Lake

b) **Pelagic (lacustrine) zone**

- The limnetic zone (well-illuminated zone) lies above the compensation level/point....

- Below the limnetic (trophogenic) zone is the profundal/trophylytic or photic zone.

UNIT 2: SOME FRESHWATER SYSTEMS
The Physical Structure of a Lake



UNIT 2: SOME FRESHWATER SYSTEMS

<u>The Physical Structure of a Lake</u>

b) **Pelagic (lacustrine) zone**

- Light does not penetrate through the <u>profundal zone</u> well enough to allow photosynthesis to occur…
- ... it lies beyond the depth of effective light penetration or compensation level but in shallow lentic systems, this part may be absent….

The Physical Structure of a Lake

b) **Pelagic (lacustrine) zone**

- It is dominated by free-floating microbes or plankton…..

- A number of specialized organisms called pleuston are adapted to the air-water interface.

UNIT 2: SOME FRESHWATER SYSTEMS
The Physical Structure of a Lake

b) **Pelagic (lacustrine) zone**

- The microscopic component of the pleuston is called neuston…

- ……separated into those organisms adapted to living at the upper surface of the interface (epineuston) & those living on the underside of the surface film (hyponeuston).

UNIT 2: SOME FRESHWATER SYSTEMS
The Physical Structure of a Lake

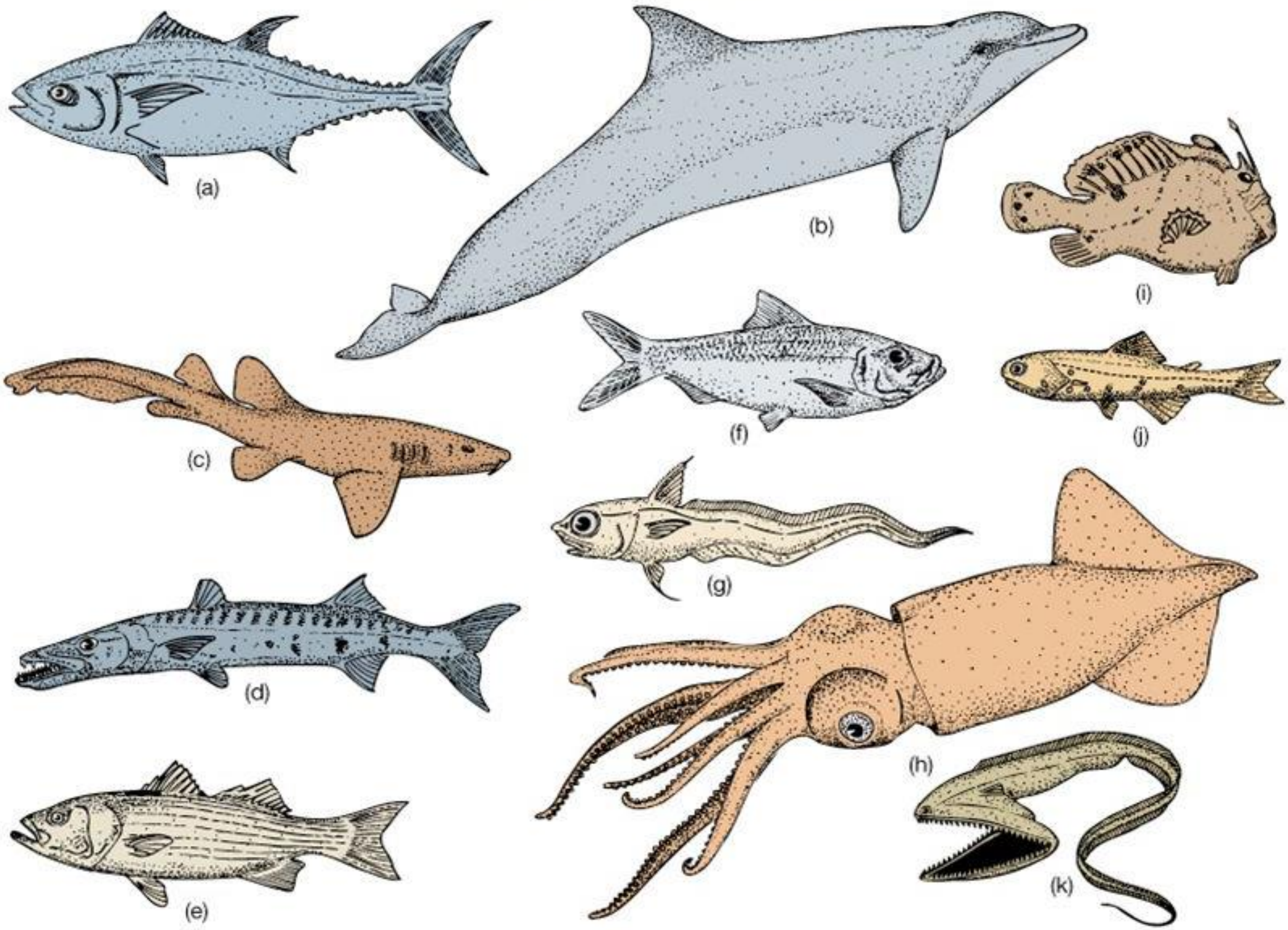
b) **Pelagic (lacustrine) zone**

- The major community within a lake in terms of area cover & total biomass is the pelagic community.

- Within this part of the lake, actively swimming animals are able to locate themselves at any depth by their own activity & are referred to as nekton…

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake



UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

c) **Benthic Zone**

- The water column of a lake is linked to the sediments in terms of *nutrient cycling* & *interchange of aquatic populations*.

- The lowermost region of the lake water body below the profundal zone is called the benthic zone.

The Physical Structure of a Lake

c) **Benthic zone**

- This zone is the interface between the lake water & the lake sediment surface.

- The sediment of lakes is inhabited by benthic organisms collectively called benthos….

UNIT 2: SOME FRESHWATER SYSTEMS

The Physical Structure of a Lake

c) **Benthic zone**

- Bacteria are particularly important in sediments.

- Lake sediments may not have light (aphotic zone) or oxygen (anoxic zone).

- The benthic zone is common to both the littoral & pelagic zones…

UNIT 2: SOME FRESHWATER SYSTEMS
The Physical Structure of a Lake

UNIT 2: SOME FRESHWATER SYSTEMS
Lake Hydrology & the Catchment Area

- Lake Hydrology - study of properties, distribution, & circulation of water within the lake & the way water flow in & out of it.

- Interest in lakes focus on the main water body but they're part of the catchment & have important interactions with it.

UNIT 2: SOME FRESHWATER SYSTEMS

Lake Hydrology & the Catchment Area

- For instance,
  - Water in lakes is partly derived from the catchment, &
  - Lake chemistry largely determined by the chemistry of the inflow water

UNIT 2: SOME FRESHWATER SYSTEMS

Lake Hydrology & the Catchment Area

- Entry of nutrients (e.g. P & N), organic materials, suspended substances, etc determines lake **trophic/nutrient status**.

- This has a major influence on the **development** & **growth** of microbes & other aquatic organisms.

UNIT 2: SOME FRESHWATER SYSTEMS

Lake classification using surface area

- Lentic systems are be classified using several criteria e.g.
  - salinity,
  - origin,
  - location,
  - trophic status,
  - **surface area…**, etc

Type	Surface area (km^2)	# of lakes	Total surface area (km^2)
Great lakes	>10,000	**19**	**997,000**
Large lakes	10,000 - 100	1504	686,000
Medium lakes	100 - 1	139,000	642,000
Small lakes	1 – 0.1	**1,110,000**	288,000
Large ponds	0.1 – 0.01	7,200	190,000
Small ponds	<0.01	ND	ND

UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Streams & Rivers

- **Lotic waters** consist of two types:
  - smaller, shallower, slower, cooler, stony-bottomed **streams**, &
  - larger, deeper, faster, warmer, silty-bedded **rivers**

- Lotic systems arise from **springs** & have <u>continuous unidirectional flow</u> & cut channels through the land surface.

UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Streams & Rivers

- **NB:** The speed of a lotic current influences several processes -
  - **composition of the channel** (e.g. rocks, sand, gravel, or mud),
  - **oxygen concentration**, &
  - **composition of organisms** found, etc

UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Horizontal zonations

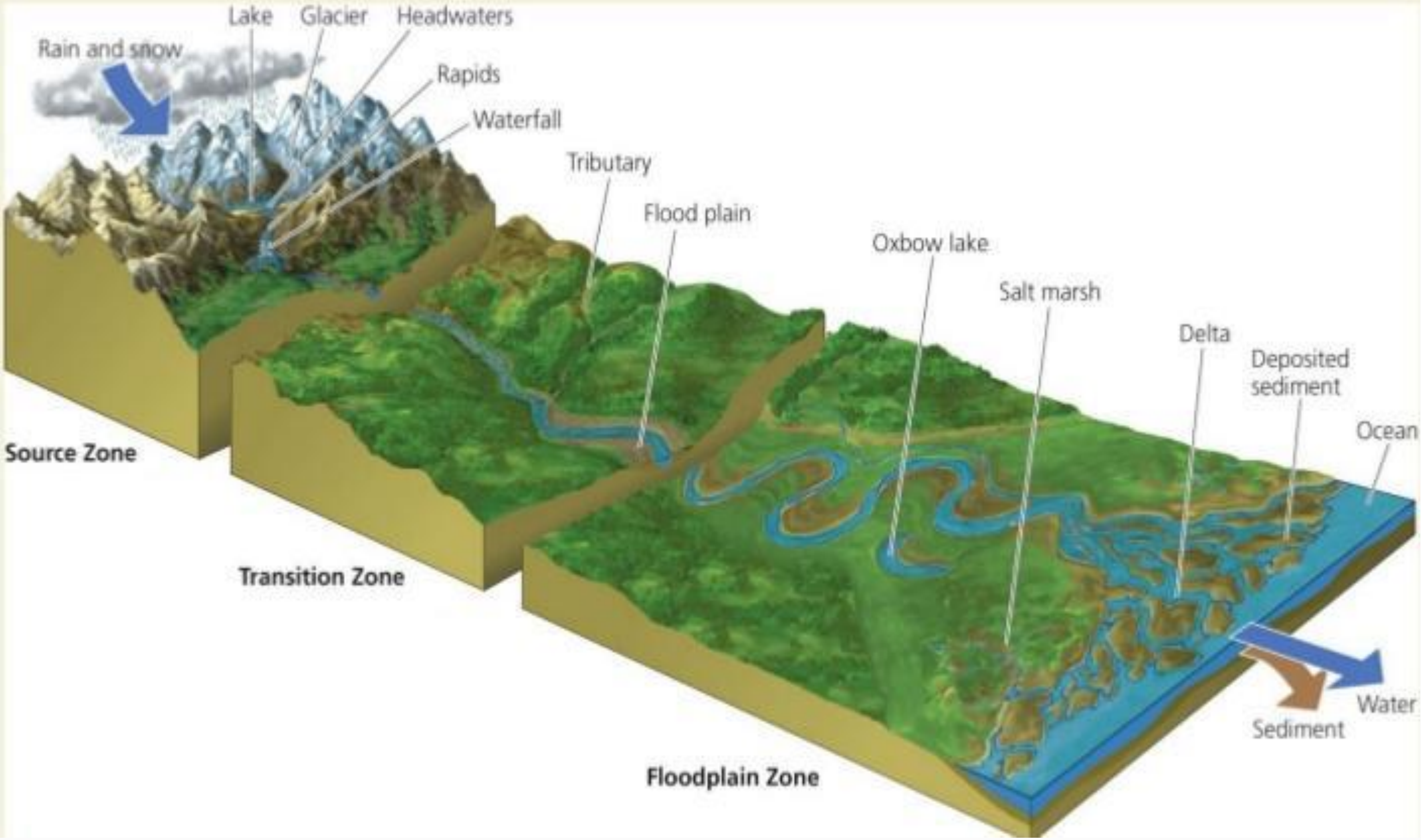
- Horizontal zonation is a continuum with a number of discontinuities.

- All river types have the same stages of structural changes from source to delta.

- The horizontal profile of every river can be divided into **three** zones….

-

UNIT 2: SOME FRESHWATER SYSTEMS
Lotic Systems – Horizontal zonations



UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Horizontal zonations

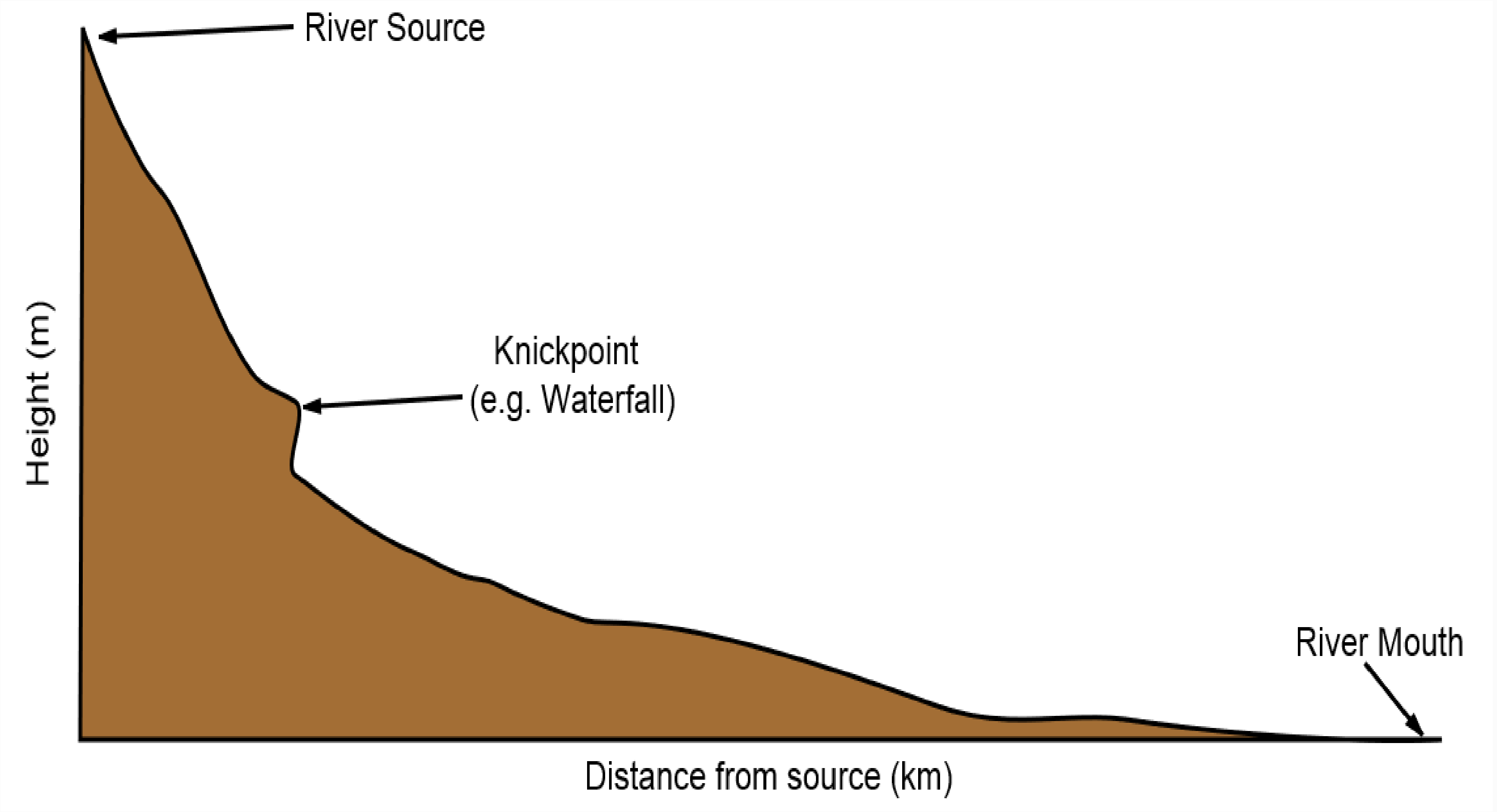
- **Source (headwaters**/crenon**)** – mountain streams with steep slopes & V-shaped valleys, forming waterfalls & rapids….

- The rapids shape & carry large-size sediments downstream.

- **Erosional** processes dominate over **depositional** ones here.

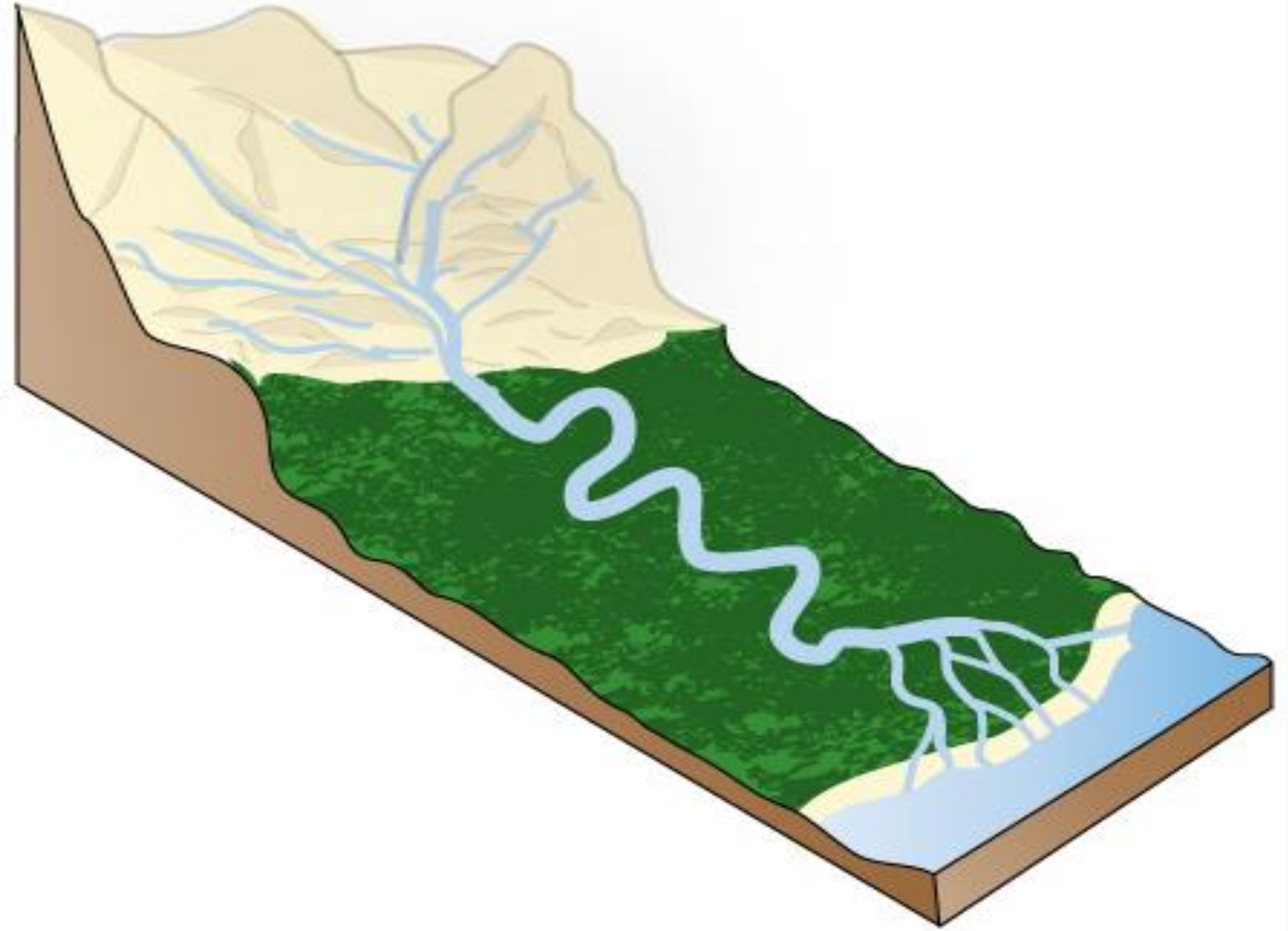
UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Horizontal zonations



UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Horizontal zonations



UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Horizontal zonations

- **Transfer**/rithron – lower altitude, slow velocity, wider river bed, & meanders form
- *Sediment cones* - larger sediments settle between source & here but fine sediments are carried downstream.
- Erosional & depositional processes are balance.

UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Horizontal zonations

Transfer/rithron (cont)

- Low temperature, high O_2 & very turbulent waters.
- River bed consist of a mixture boulders, pebbles & gravel, sand or mud.
- It favours ***rheophilous***, cold water stenotherms but plankton is rare or absent

UNIT 2: SOME FRESHWATER SYSTEMS
Lotic Systems – Horizontal zonations

Deposition/potamon (cont)

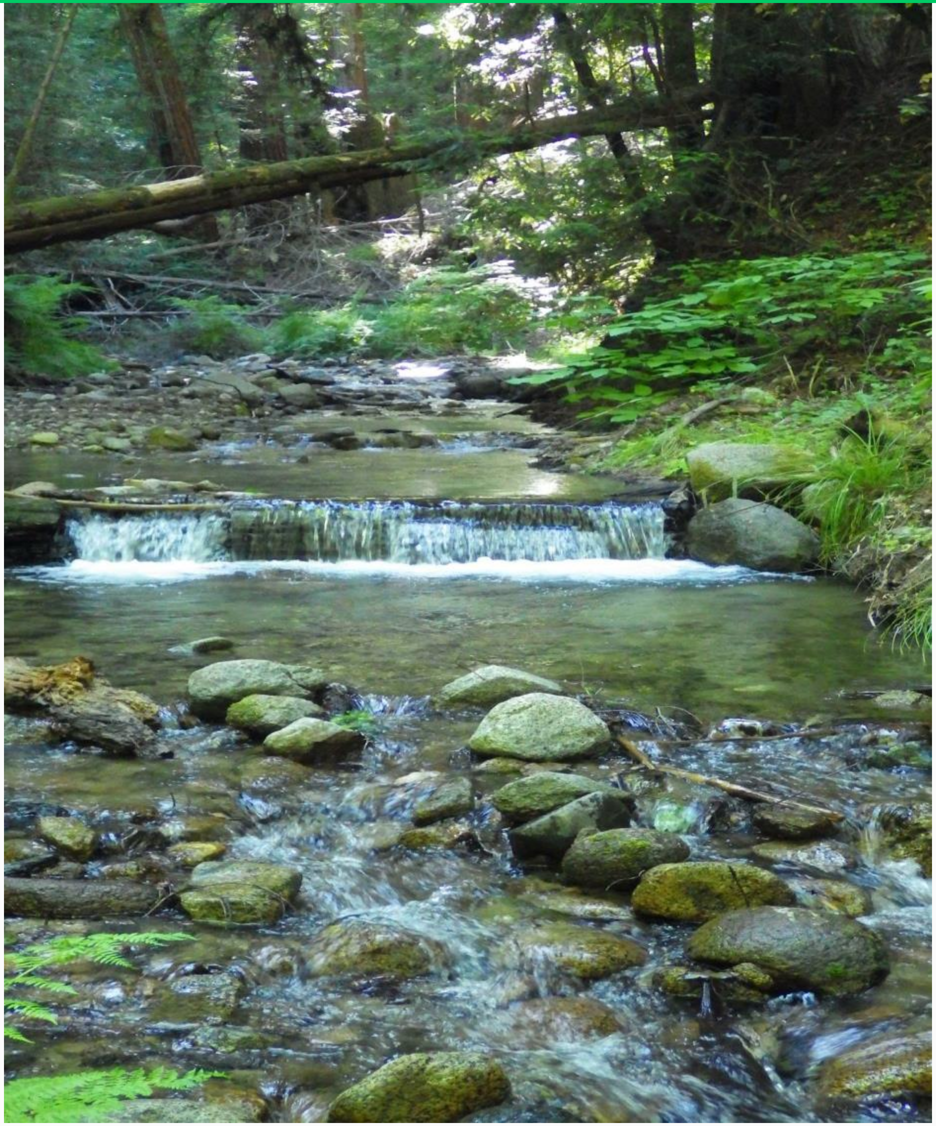
- High temperatures, occasional O_2 deficit, slow current, sandy/muddy bottom.
- Favours *limnophilous*, stenotherms & plankton can be abundant.
- **Rhitron** & **potamon** correspond to salmonid & cyprinid zones respectively…

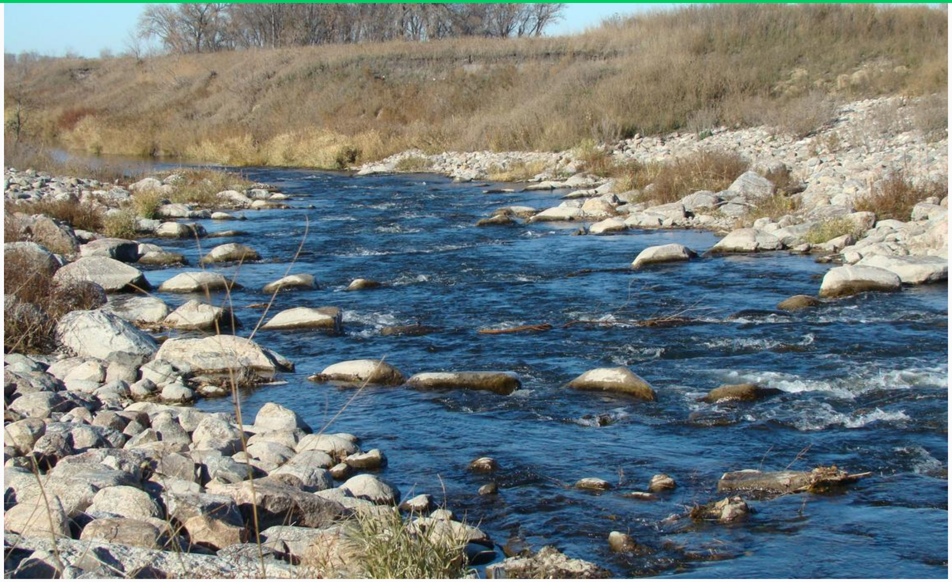
UNIT 2: SOME FRESHWATER SYSTEMS
Lotic Systems – Microbial communities

- Dominated by benthic organisms at the microbial level.

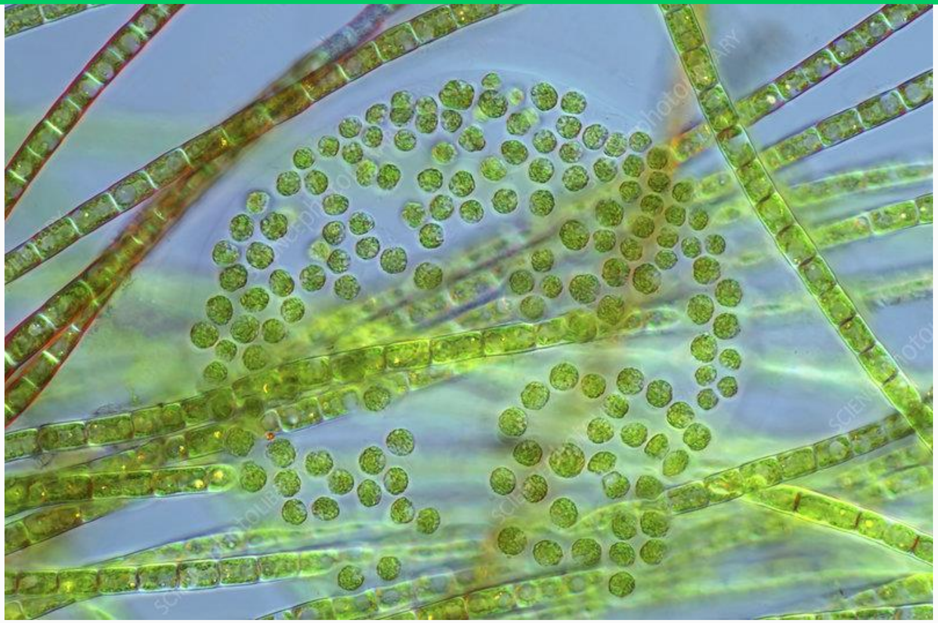
- Benthic algae *e.g.* diatoms, green algae, & cyanobacteria are the most successful photoautotrophs in lotic systems…

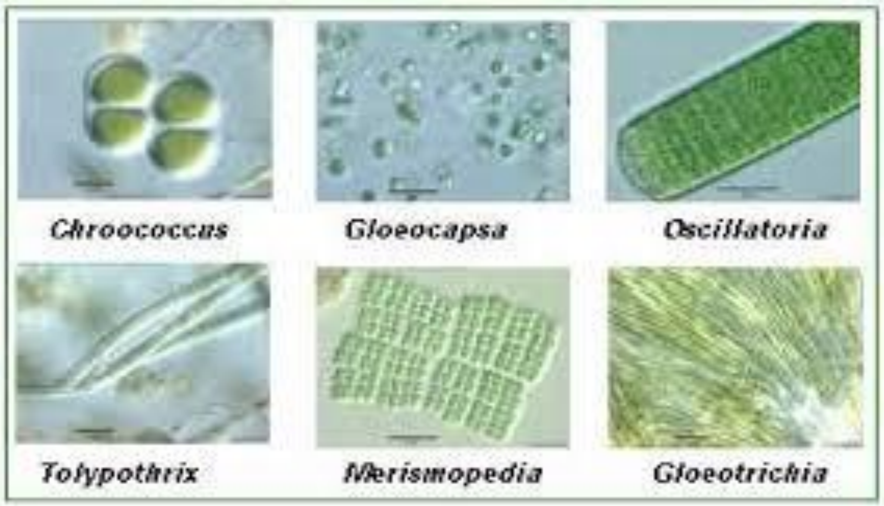
UNIT 2: SOME FRESHWATER SYSTEMS
Lotic Systems – Microbial communities





UNIT 2: SOME FRESHWATER SYSTEMS
Lotic Systems – Microbial communities





UNIT 2: SOME FRESHWATER SYSTEMS
Lotic Systems – Microbial communities

- Ecological importance of benthic areas –
  - primary production,
  - nutrient transformation,
  - sediment stabilization, &
  - habitat provision

UNIT 2: SOME FRESHWATER SYSTEMS
Lotic Systems – Microbial communities

- Benthic algae, nutrient, & management.

- Suspended algae of lotic systems are called **potamoplankton** i.e. reproduce within the water column.

UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Sys – River systems & stream order

- River system - # of rivers so connected that the water carried by the minor streams finally unite in one body of flowing water called "**master**" or "**trunk**" river.

- **River systems in Ghana?...**

UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Sys – River systems & stream order

- River system - # of rivers so connected that the water carried by the minor streams finally unite in one body of flowing water called "**master**" or "**trunk**" river.

- **River systems in Ghana?**
  - Volta river system (**transboundary**)
  - South-western river system
  - Coastal system

UNIT 2: SOME FRESHWATER SYSTEMS

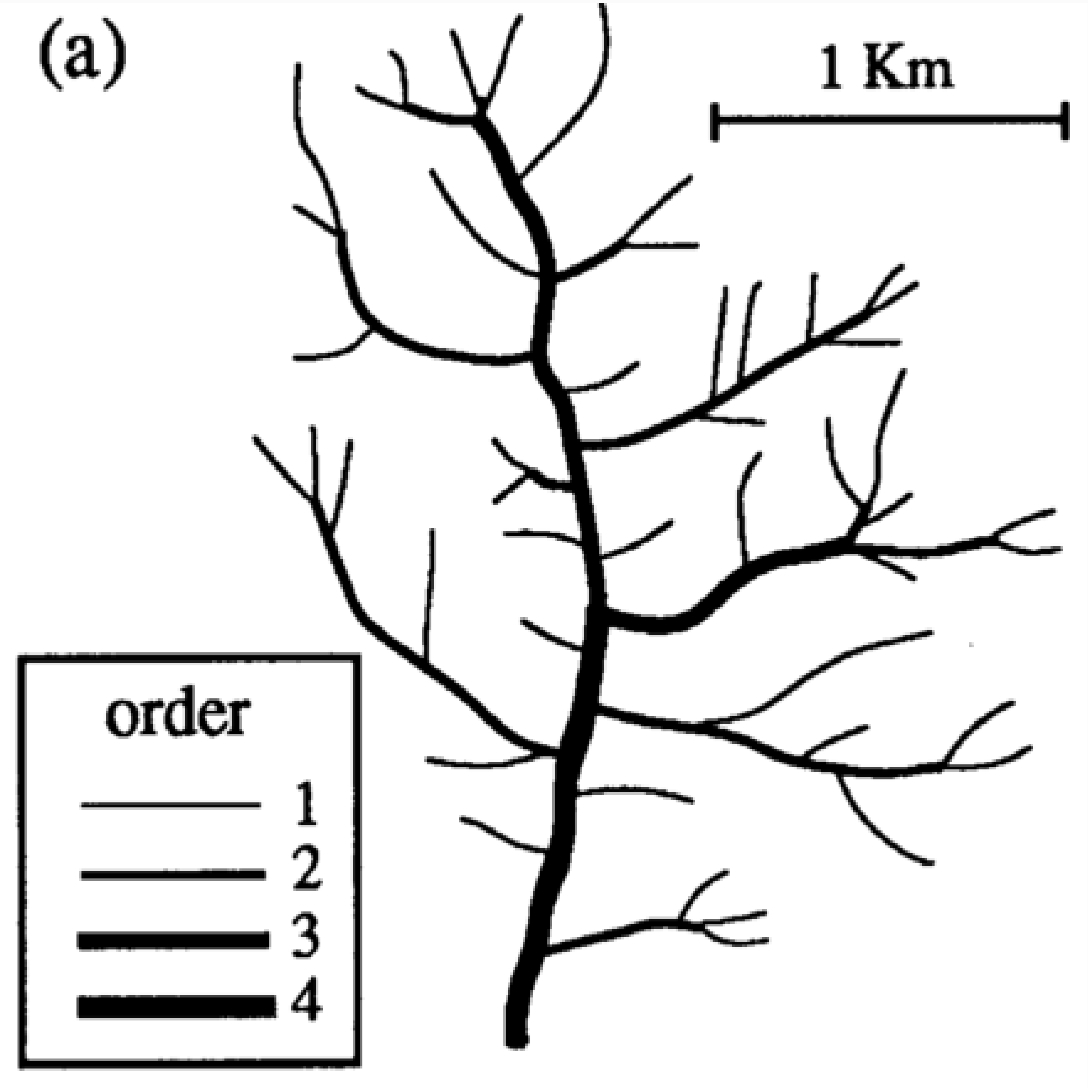
Lotic Systems – Stream Order

- A simple classification of rivers is based flow changes at confluence of the rivers.

- **Stream order** **-** relative position of a stream segment in a drainage network or systems…..

UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Stream Order



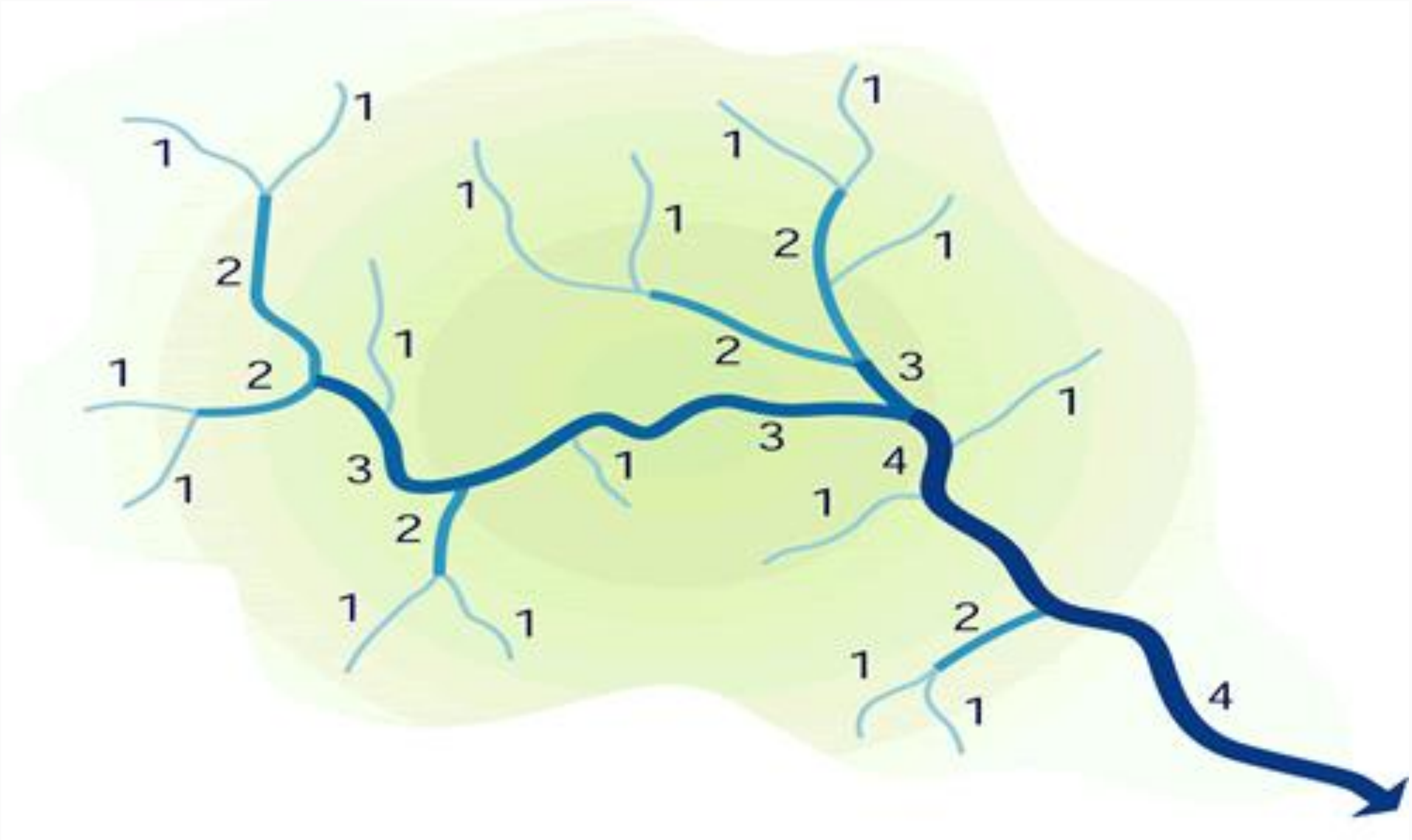
UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Stream Order

- Confluence of 2 rivers in same category leads to formation of a higher category…
- E.g. 2 rivers without tributaries (**order 1**) at their confluence form a stream of **order 2**,
- Meeting of two streams of **order 2** leads to a stream of **order 3**…..

UNIT 2: SOME FRESHWATER SYSTEMS

<u>Lotic Systems – Stream Order</u>



UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Stream Order

- **NB:** a river formed from streams of order 1 & 2 is always of order 2, etc.
- Stream's order doesn't changed by addition of a lower order stream
- Only tributaries of **equal order** joined to form a higher order.

UNIT 2: SOME FRESHWATER SYSTEMS

Lotic Systems – Stream Order

- Small, branched, upper tributaries of a permanently flowing lotic system are **1st-order**…

- The **Amazon**, the largest river in the world, is a 12th-order waterway.

- First to 3rd-order streams called **headwater streams**.

UNIT 2: SOME FRESHWATER SYSTEMS
Differences: Lotic & Lentic Systems

- 1st, **lotic** systems are transient with low water retention times at any particular site.

- 2nd, they are typically highly turbulent.

- 3rd, they typically lack thermal or chemical **stratification**.

UNIT 2: SOME FRESHWATER SYSTEMS

Differences: Lotic & Lentic Systems

- 4th, there is limited growth of a planktonic community.

- 5th, substratum is often well aerated, exposed to light, & is major site of algae & associated biota.

UNIT 2: SOME FRESHWATER SYSTEMS

Differences: Lotic & Lentic Systems

- 6th, inflow from the catchment area is typically periodic, leading to water level & velocity fluctuations (high-flow/low-flow).

- 7th, levels of dissolved & particulate matter from catchment follow this periodicity of inflow water from the catchment area.

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands

- An area of land covered with, or saturated by water for at least part of the year.
- A transitional area between **terrestrial** & **aquatic** ecosystems.
- Show greater seasonal effects than shallow lakes - seen in the periodic **desiccation** & **flooding**.

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands

- Liable to permanent changes & loss of habitat due to **human activities**.

- Main management problems are maintenance & sustainability*.

UNIT 2: SOME FRESHWATER SYSTEMS

Ramsar Convention on Wetlands

- "areas of **marsh**, **fen**, **peatland** or water, whether natural or artificial, permanent or temporary, with water that is static, flowing, fresh, brackish, or salt, including areas of marine water the depth of which at low tide does not exceed 6 metres" https://www.ramsar.org/

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands - characteristics

- They vary widely due to differences in **soils**, **topography**, **climate**, **hydrology**, **water chemistry**, **vegetation**, **human disturbance**, etc.

- But **all** wetlands, **have 3 features** in common:

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands - characteristics

- 1. Presence of **standing water**;
- 2. **Wetland soils** (low O_2 or anoxic), due to intermittent or permanent saturation causing waterlogging;
- 3. Presence of **wetland plants**.

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

- Characterization of wetlands using macrophytes called **structural classification** put them into 4 groups;
  - **Marshes**
  - **Swamps**
  - **Bogs**, &
  - **Fens**

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

- **i) Marshes:** low-lying wetlands close to a river/lake often flooded to a shallow depth.
- Dominated by emergent macrophytes & also has submerged or floating types, etc
- A major distinguishing feature is the absence of trees & shrubs…

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

i) Marshes (cont):

- Fed by external water source e.g. ground & river waters which are either nutrient rich or poor; underlain by peat deposits.

- Are the most productive of the 4 wetlands.

- E.g. tidal, non-tidal, wet meadows, prairie potholes, vernal pools, & playa lakes

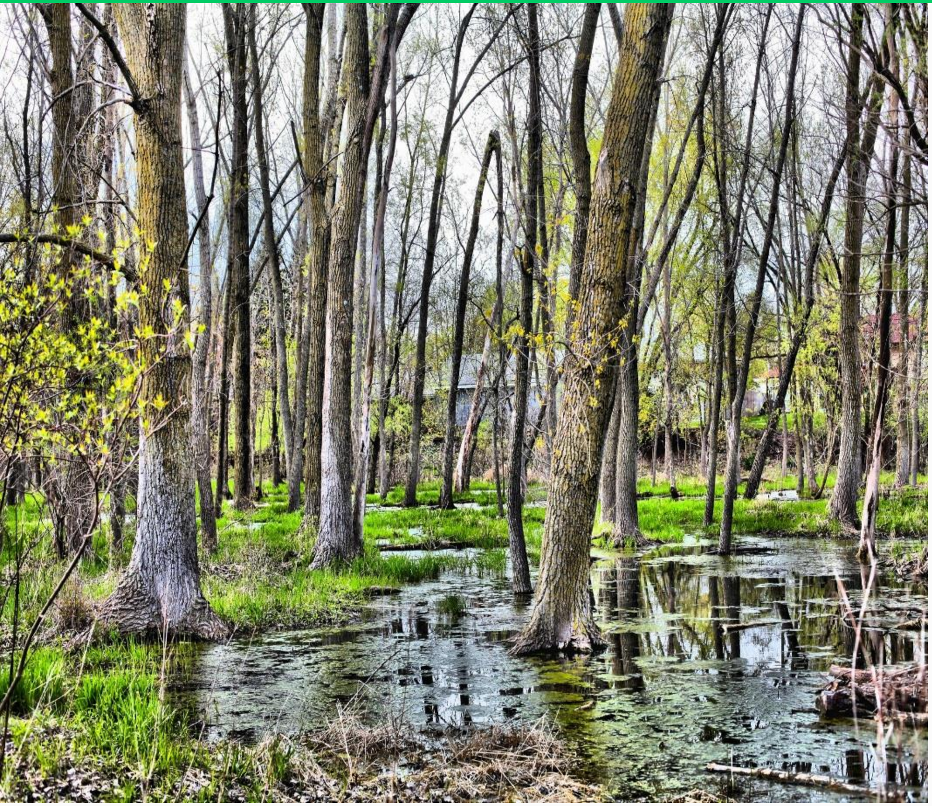
UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

- **ii) Swamps:** low-lying & usually at least partly flooded, is covered with grasses & shrubs, but large **trees** are dominant….
- Better drainage & less peat than **bogs** but more woody plants than a **marsh** = wooded wetlands….
-

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize



UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

ii) Swamps (cont):

- Fed by external water source which can be nutrient rich or poor & are the **2nd** most productive wetlands.

- E.g. include:
  - forested swamps,
  - bottomland hardwoods,
  - shrub swamps, & mangrove swamps, etc

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

- **iii) Bogs:** acidic, high water table & organic remains; develops where drainage is blocked i.e. are poorly drained….
- Have low species diversity; few/no trees or macrophytes.
- Dominated by the acidophilic peat-building *Sphagnum* moss & sedges….

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

iii) Bogs (cont):

- Little/no external water inflow; dependent on high water table replaced by rainwater.
- Bogs are the least productive wetlands.
- Examples of bogs include:
  - northern bogs, &
  - pocosins, etc

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

- **iv) Fens:** have features of bogs & marshes with mineral-rich groundwater source & higher pH than bogs.
- Species-rich with both mosses & macrophytes represented.
- Underlain by peat deposits like marshes & bogs…

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

- The presence or absence of dry periods is used to group wetlands into 2 **functional** types;
  - **Seasonal** wetlands, &
  - **Permanent** wetlands

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

- **i) Seasonal wetlands:** have a dry period when all/most of it revert to land.
- Wet-dry cycle releases nutrients from soils, making productivity quite high.
- Organic matter from the wet season decays in the O_2- rich dry season.

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

i) Seasonal wetlands (cont):

- This reduces the amount of organic matter deposition during the dry period.

- Algae, grasses, some plants, insect larvae, etc that can survive vigorous seasonal changes are dominant.

-

i) Seasonal wetlands (cont):

- Migratory birds, fish, & amphibians breed in them & feed on the abundant but short-lived insect population.

- E.g., may include:
  - Marshes, &
  - Swamps
-

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

- **ii) Permanent wetlands:** have large, long-lived trees & tall reeds that tolerate permanently waterlogged soils.

- Common at river deltas, pond & lake margins, estuaries, & flat areas of the mountains.

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – use of macrophytes to characterize

ii) Permanent wetlands (cont):

- Provide cover & breeding grounds for birds, fishes, reptiles, & mammals but less productive than seasonal wetlands.

- Net organic matter accumulators due to slow decomposition & devt of anoxia.

- E.g., may include bogs & fens.

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – natural & artificial

1. Natural wetlands - formed naturally e.g.

- **a)** *Marine wetlands* - saltwater exposed to waves, currents & tides in oceanic setting.
- E.g. coral reefs, & aquatic subtidal beds with sea grass & kelps….
- Important nursery & feeding areas for animals e.g. fish, dugongs, & turtles…

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – natural & artificial

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – natural & artificial

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – natural & artificial

1. **Natural wetlands** **-** formed naturally e.g.

- **b)** *Estuarine wetlands* - usually semi-enclosed by land with open, partly blocked or with sporadic access to open ocean.

- Common example is where a river flows into the ocean.

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – natural & artificial

1. Natural wetlands - formed naturally e.g.

- **c)** *Lacustrine wetlands* - are large, open, water-dominated systems (e.g. lakes).
- **d)** *Riverine wetlands* - mostly freshwater along edges of rivers, streams & creeks.
- E.g., rivers, floodplains, marshes, & billabongs.

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – natural & artificial

1. Natural wetlands - formed naturally e.g.

- **e)** *Palustrine wetlands* – e.g. bogs, fens, swamps, & marshes that are non-saline & not lakes or rivers.
- It is what people traditionally think of as wetlands (vegetated wetlands).
- Have > 30 % emergent vegetation.

UNIT 2: SOME FRESHWATER SYSTEMS

<u>Wetlands</u> – natural & artificial

- **2. <u>Artificial wetlands</u>:** they're formed by the activities of man.

- Examples include;
  - Aquaculture/mariculture
  - Agriculture
  - Salt exploitation
  - Urban/industrial
  - Water storage areas

UNIT 2: SOME FRESHWATER SYSTEMS

Wetlands – Importance

1. Improve water quality;
2. Reduce flood damage;
3. Reduce erosion;
4. Act as groundwater discharge/recharge;
5. Provide habitat;
6. Help moderate global warming;
7. Used for recreation & tourism;
8. Provision of sustainable products,

UNIT 2: SOME FRESHWATER SYSTEMS

Recap

- Wetland:...
  - Definition & Basic features
  - Characterization
    - **Structural**
    - **Functional**
    - **Natural or anthropogenic**
  - Importance ..

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries –

- Place where inland freshwaters & ocean waters meet.
- The resulting mixture is called brackish water i.e. have salinity between **0.5 ppt** & that of full strength ocean water, **35 ppt**.
- They form a transition zone or **ecotone** between river & marine environments.

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries –

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Hydrology

- This depends on:
  - tidal currents,
  - estuarine circulation,
  - river discharge, &
  - inflow from ground water, etc

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Hydrology

- The **extent** of these movements depends on the morphology of the estuary.
- River current & salinity shape the life in an estuary.
- **Current** is important for a number of reasons:
  - the mixing of fresh & saltwater systems,

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Hydrology

- **productivity** within the estuarine system,

- & **eutrophication** of surrounding coastal areas

- Current flow varies with season – wet & dry season, & with the oscillating ocean tides, & wind.

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries salinity

- Estuarine **salinity** varies vertically & horizontally:

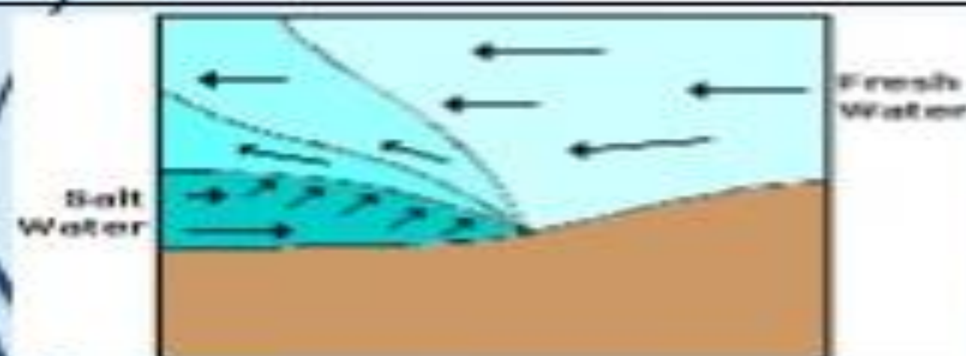
- **Vertical salinity** may be uniform or stratified depending on:
  - the strength of the **currents**,
  - periodicity of **tides**, &
  - **winds**, which tend to mix the salt & fresh waters in estuaries

UNIT 2: SOME FRESHWATER SYSTEMS

Levels of estuarine stratification –

Highly stratified

- The water flow of river is strongly dominant over tidal action. So freshwater tends to overflow the heavier salt water forming a wedge.
- Characterized by the sharp change in salinity from top to bottom (Fig. 6).
- eg.-The Amazon river estuary ,the Nile river estuary

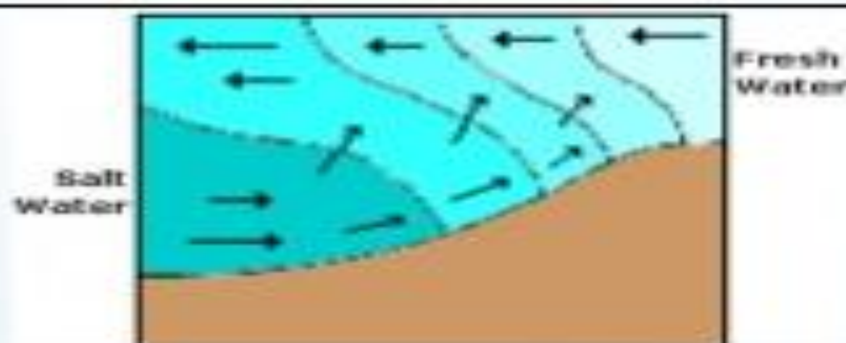


UNIT 2: SOME FRESHWATER SYSTEMS

Levels of estuarine stratification

Moderately stratified

- River output is less than the marine input
- Turbulence causes mixing of the whole water column, such that salt content varies both horizontally and vertically with moderate density stratification.
- eg.--Chesapeake Bay

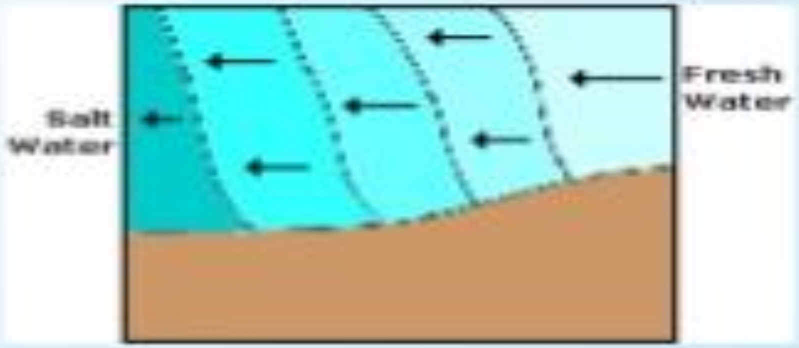


UNIT 2: SOME FRESHWATER SYSTEMS

Levels of estuarine stratification

Vertically/Completely mixed

- The tidal action is strongly dominant.
- The water tends to be well mixed from top to bottom and the salinity is relatively high.
- eg- Bar-built estuaries.



UNIT 2: SOME FRESHWATER SYSTEMS

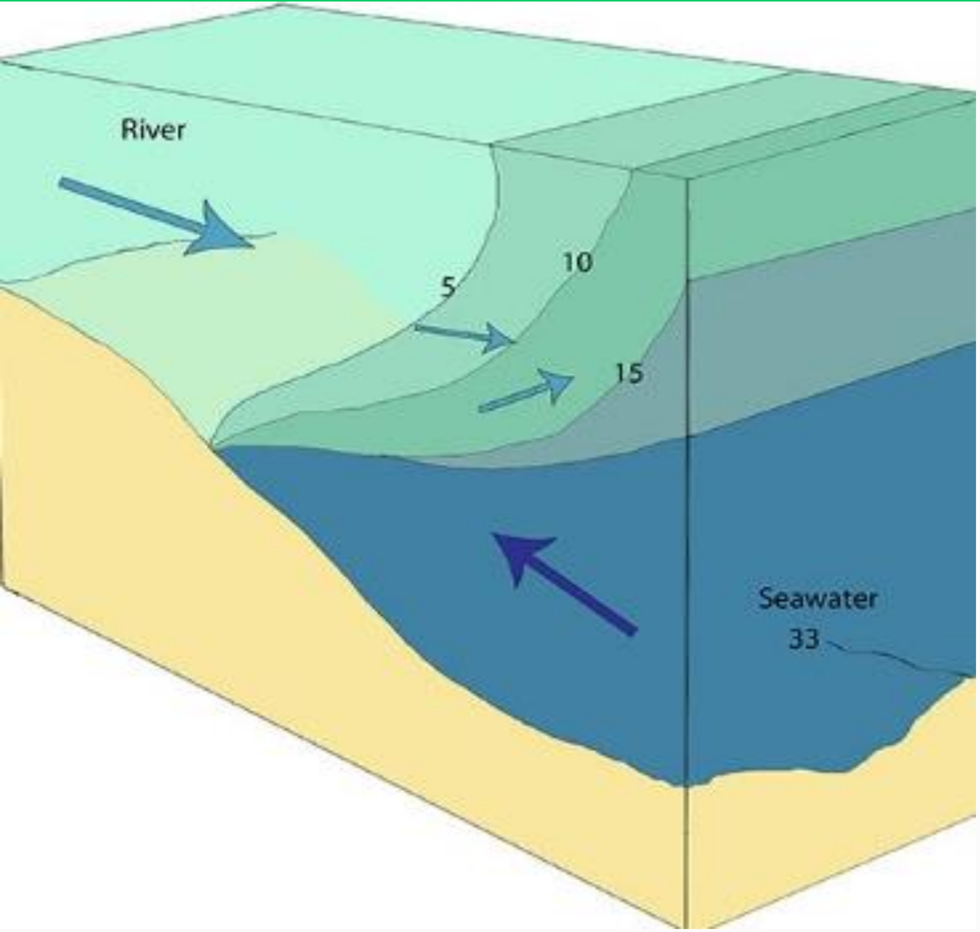
Estuaries salinity

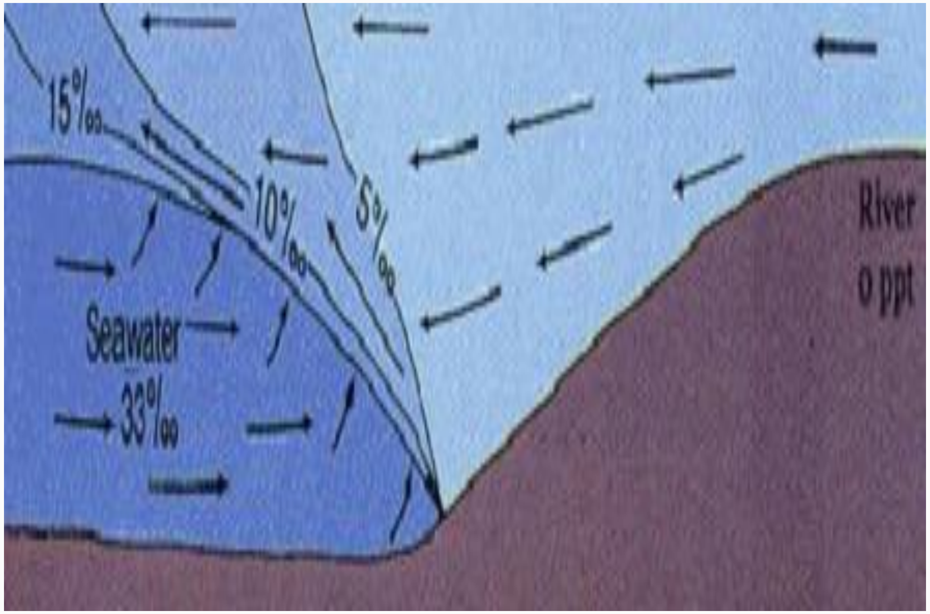
- Estuaries can also show **horizontal salinity** variations.

- Horizontally, the least saline waters are at the river entrance, & the most saline at the mouth of the estuary….

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Hydrology





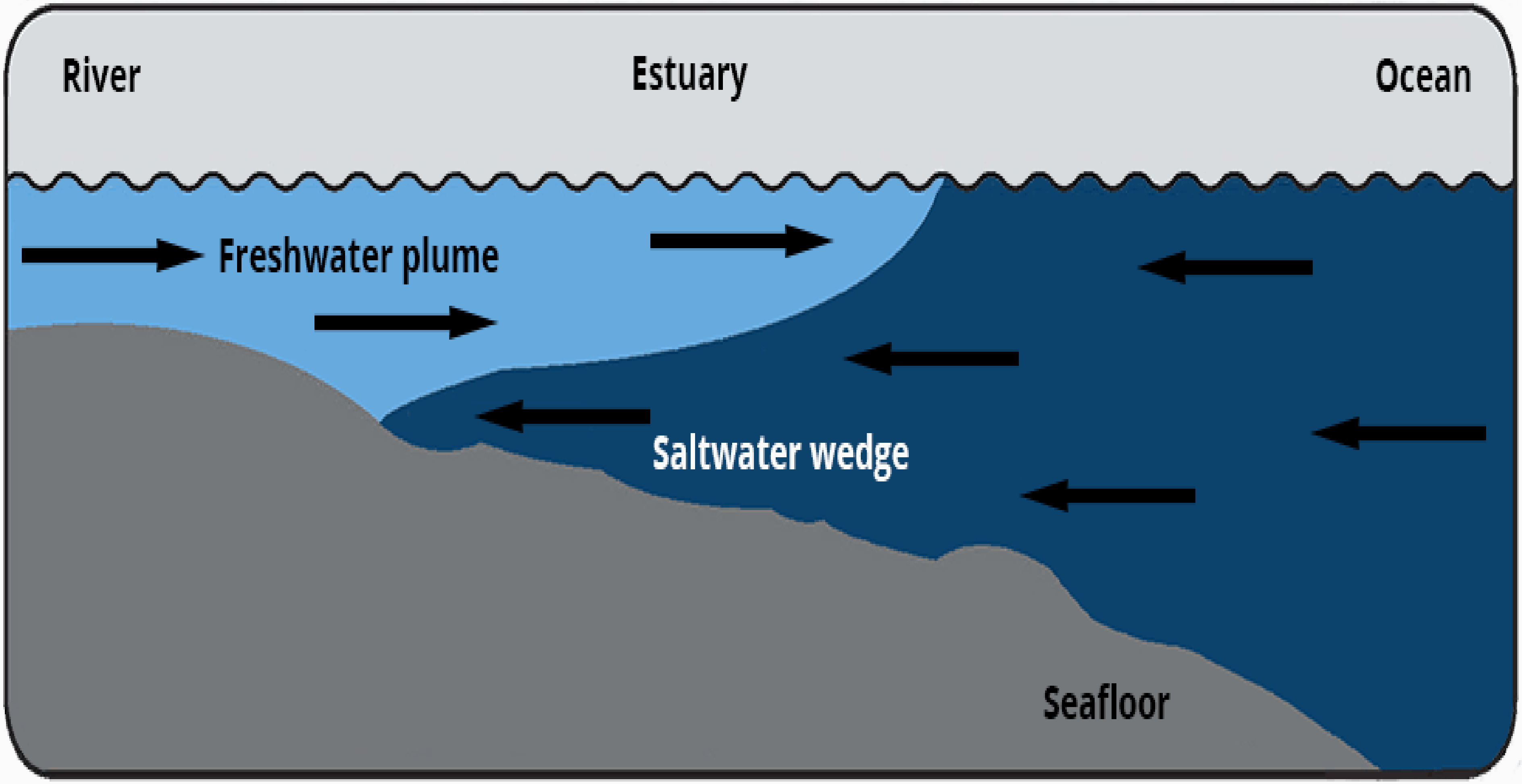
UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries salinity

- Mixing of high density salt water & low density fresh water results in a region of brackish water, the ‘*salt wedge....*’
- The salt wedge tends to underlie the freshwater & gives a layered structure to the estuarine waters.. ...

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Hydrology



UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Biological communities

- Estuarine environments are characterized by variable salinities.
- Hence, to survive, organisms must be **euryhaline**.
- They must also have special physiological adaptations for eliminating salt.

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Biological communities

- Osmotic regulation is needed since body fluids of organisms are similar in chemical composition & thus in ionic pressure.

- Problem of exosmosis & endosmosis in **marine** & **freshwater** organisms.

- Varying salinity of estuaries requires both osmotic regulation in the same organism.

UNIT 2: SOME FRESHWATER SYSTEMS

<u>Estuaries</u> – Biological communities

- Such physiological & anatomical flexibility is unusual.

- Hence, most species avoid osmotic changes or periodically switch systems as needed.

- For example;

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Biological communities

- Anadromous salmon & catadromous eels convert their osmoregulation from hypotonic to hypertonic, or vice versa as they migrate between salt & freshwater.

- But, most estuarine organisms cannot osmoregulate very well.

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Biological communities

- So they survive either by avoiding salinity changes or their cells tolerate changes in internal salinity that would kill most other organisms.

- Few species of organisms can live in estuaries because of this challenge.

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Biological communities

- E.g.s of such organisms include; bacteria, fungi, algae (e.g. *Pfiesteria piscida.*), higher plants, invertebrates, or fish.

- Hence, the flora & fauna of estuaries tend to be poor in species relative to the adjacent habitats of the river & the ocean.

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Biological communities

- In particular insects are virtually absent as they are in the ocean.
- Estuarine organisms are mostly of marine origin.
- Also, many common forms can survive in the coastal ocean.

UNIT 2: SOME FRESHWATER SYSTEMS

<u>Estuaries</u> – Biological communities

- This is important over geological time scales....
- ....because estuaries are not deemed to be very permanent limnological features.

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Biological communities

- But, estuaries are still regions of high productivity due to;
  - inflow of soluble & particulate materials of rivers & also
  - nutrients brought from the ocean during high tides

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Tropical ~

- In tropical areas, typical grass/reed-dominated salt marsh of the temperate zones is replaced by low trees called **mangroves** (tide forest).

- Typical species include *Rhizophora, Avicennia, & Bruguiera*, *Acrostichum*, *Conarcarpus*, *Laguncularia*, etc

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Tropical ~

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Tropical ~

- Mangrove swamps cover huge areas of the lowland tropics since they can tolerate salinities typical of oceans to freshwater & also zero dissolved oxygen (anoxia).

- Can be found on saltwater coasts of 118 tropical & subtropical countries, totalling more than 137,000 sq. km (85,000 sq. mi).

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Tropical ~

- Indonesia tops the worldwide list with over 23,000 sq. km (~ 14,000 sq. mi.)

- They grow rapidly & support large growths of attached animals & plants on their root system.

UNIT 2: SOME FRESHWATER SYSTEMS

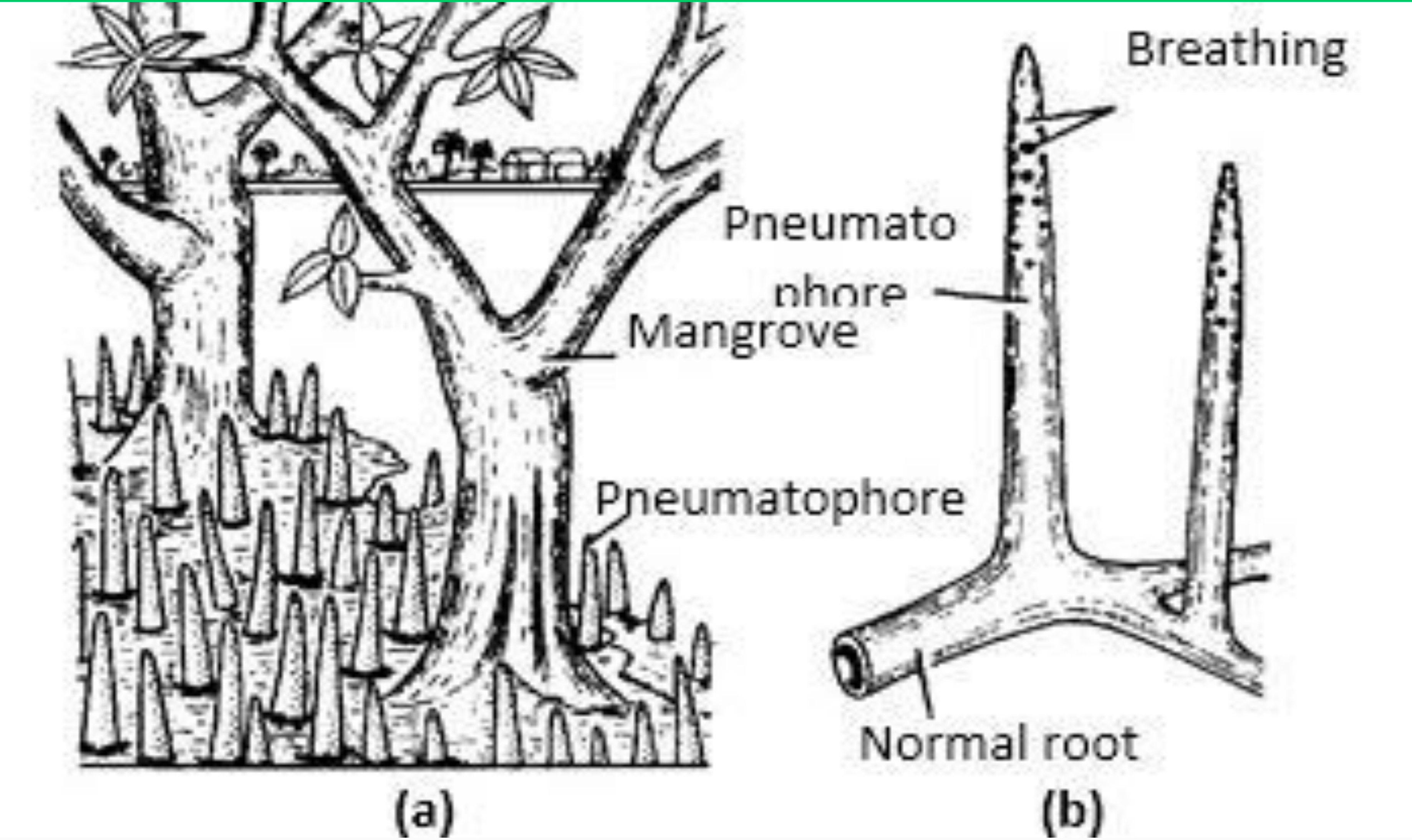
Estuaries – Tropical ~

- Roots form of stilt-like branches that grow away from the main trunk & can penetrate anoxic mud to obtain water & nutrients.

- The upper part of the roots supply O_2 for the respiring root hairs below....

UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Tropical ~



UNIT 2: SOME FRESHWATER SYSTEMS

Estuaries – Tropical ~

- These are **pneumatophores** or root branches that grow upwards & assist in root respiration or oxygenation….

- Examples of mangrove plants with pneumatophores include:
  - *Avicennia*
  - *Laguncularia*

UNIT 3

FACTORS IMPORTANT IN THE STUDY OF AQUATIC ECOSYSTEMS

UNIT 3: IMPORTANT FACTORS ILOs –

- **know** some of the key physical & chemical factors that give structure to aquatic systems & affect the conditions of existence of aquatic organisms;

- **understand** how these key factors act to affect the life activities of aquatic organisms;

-

UNIT 3: IMPORTANT FACTORS
ILOs –

- In particular, **understand** how light, temperature, current flow, pH, Eh, DO, BOD, COD, conductivity (TDS), nutrients, etc are measured & their effects on aquatic organisms;

UNIT 3: IMPORTANT FACTORS
Physical factors – Introd

- Aquatic organism deal with both ideal & bad conditions/**factors** in their env't.

- **Physical factors** are one such key factors.
  - **<u>temperature</u>** (time & space, limits, DO, etc)
  - **<u>light</u>** (intensity, duration, quality, turbidity)
  - <u>wind</u> (water movt/**current** – lotic & lentic systems, physico-chemical, biology)
  - **Interaction** of temperature, light, wind, etc

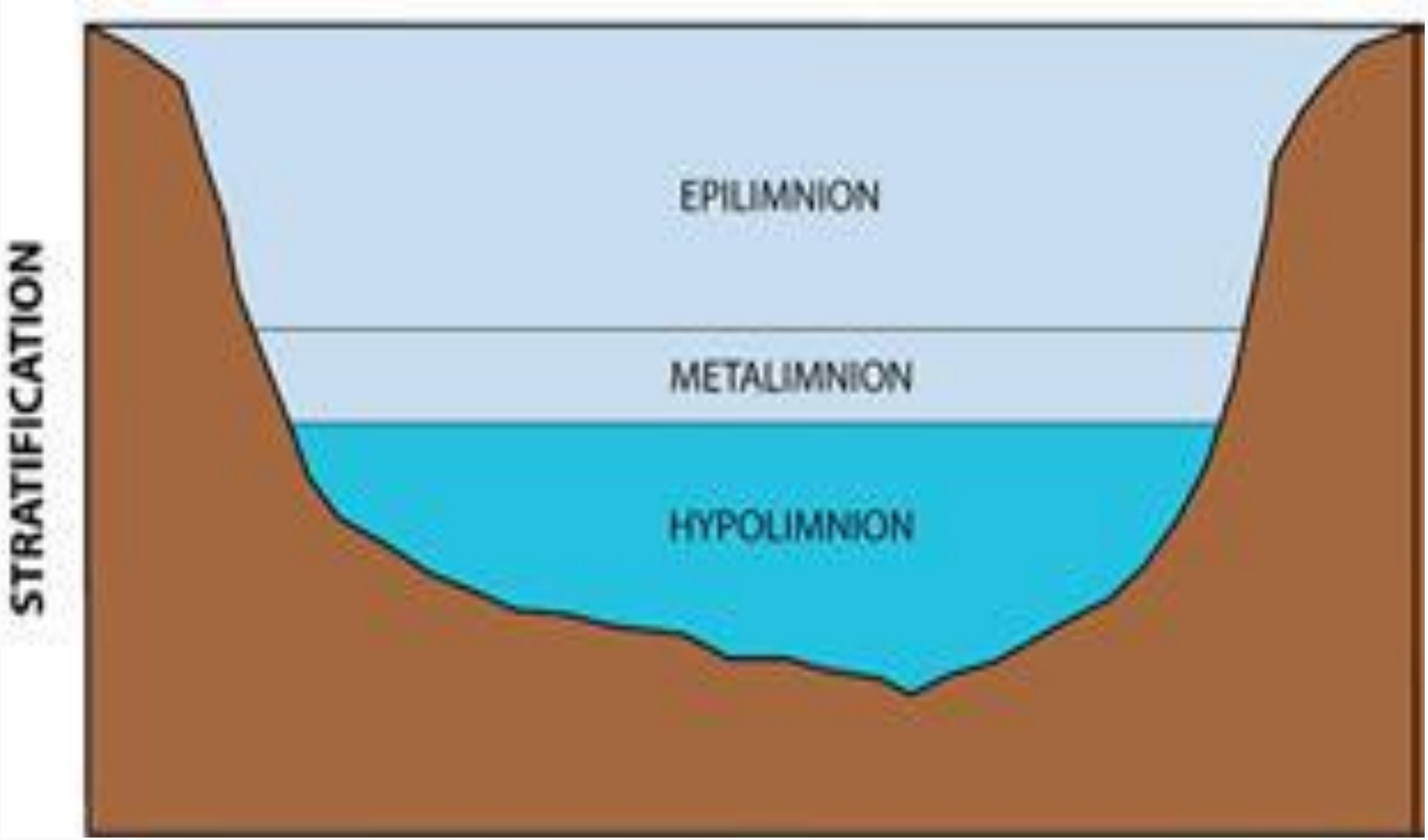
UNIT 3: IMPORTANT FACTORS
Physical factors – (a) Temperature

- Temperature affects speed & intensity of **biochemical reactions**.

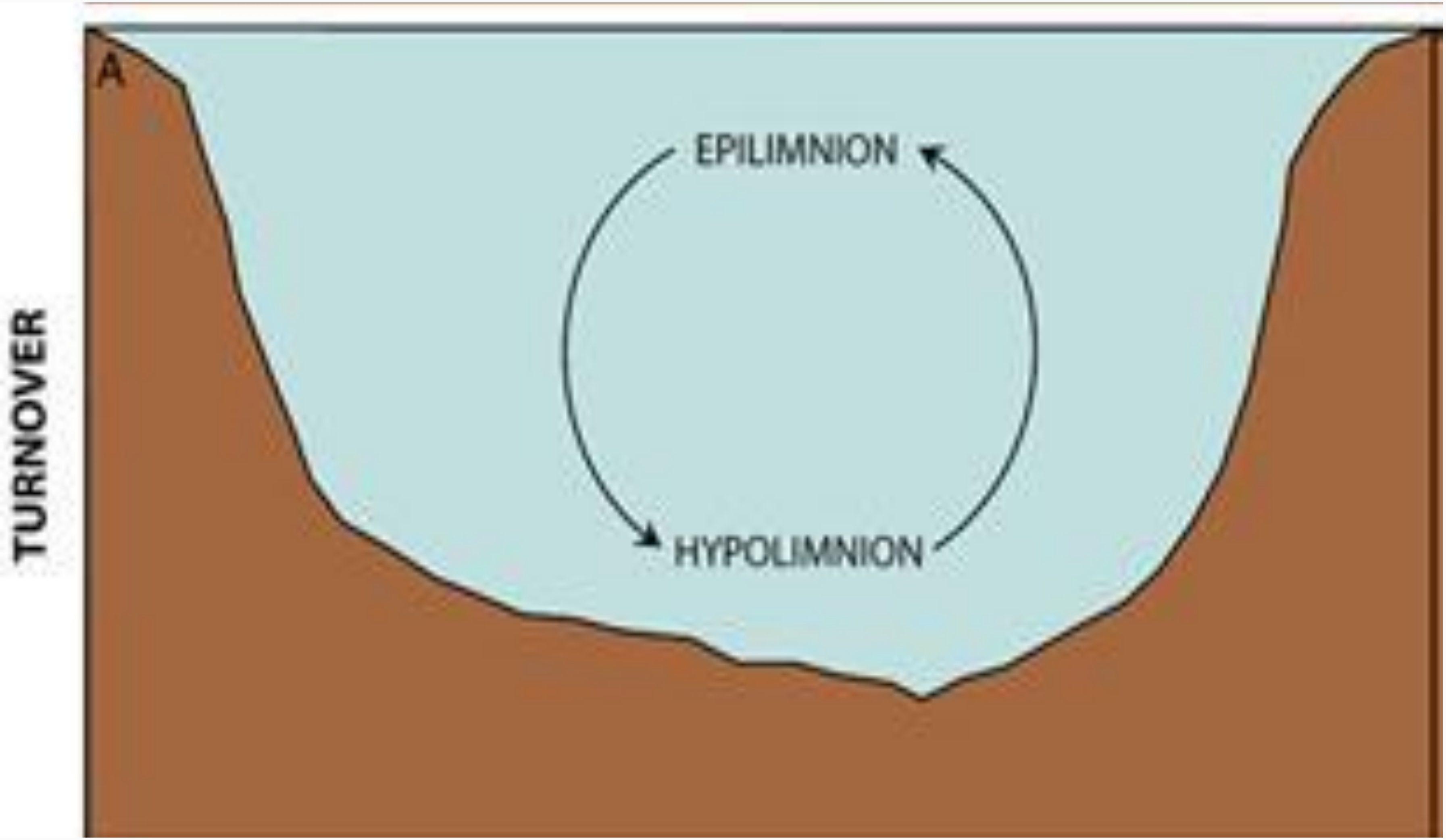
- Organisms are restricted to temperature range conducive for growth & reproduction.

- Temperature effects on dissolved gases, biodegradation rate, stratification/mixing with implications for **plankton** & **nutrients**.

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (a) <u>Temp & Lake mixing</u>



UNIT 3: IMPORTANT FACTORS
Phys. Fact: (a) Temp & Lake mixing



UNIT 3: IMPORTANT FACTORS
Phys. Fact: (a) Temp & Lake mixing

- Lakes aren’t permanently static but undergo rhythms of stagnation & circulation.
- Density is the principle behind lake mixing (same density) & stagnation (different densities) is based.
- Less dense sits on top of the more dense water when densities are different.

UNIT 3: IMPORTANT FACTORS

Phys. Fact: (a) Temp & Lake mixing

- Two **main** factors affect water density – temperature & salinity (dissolved substances)

- In most cases, **both factors** contribute to some differing extent.

- When lake water receives heat from sun, the surface become heated & less dense.

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (a) Temp & Lake mixing

- Separation of water into 2 vertical layers – **epilimnion** & **hypolimnion** separated by a **metalimnion**…

- Metalimnion & the **thermocline**.

- Lakes are not able to mix when densities of epilimnion & hypolimnion are different..

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (a) Temp & Lake mixing

- Separation of into epilimnion & hypolimnion due to temperature is called **thermal stratification**.

- A reduction in ambient temperature results in decline of epilimnion temperature & may become isothermal with of the hypolimnion.

- This result in mixing due to same densities.

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (a) <u>Temp & Lotic systems</u>

- **<u>NB</u>**: In **lotic** systems, there is continuous unidirectional flow of water.
- Hence, **vertical stratification** usually does not occur or are not pronounced if they do.
- Other effects of temperature in lotic waters
  - Small **vs** large lotic systems
  - Exposed **vs** shaded lotic sections

UNIT 3: IMPORTANT FACTORS

Phys. Fact: (a) Lake classes by mixing

- Frequency of mixing
  - **amictic** - permanently covered with ice.
  - **monomictic**, **dimictic**
  - **polymictic**

- Degree of mixing
  - **holomictic**
  - **meromictic**

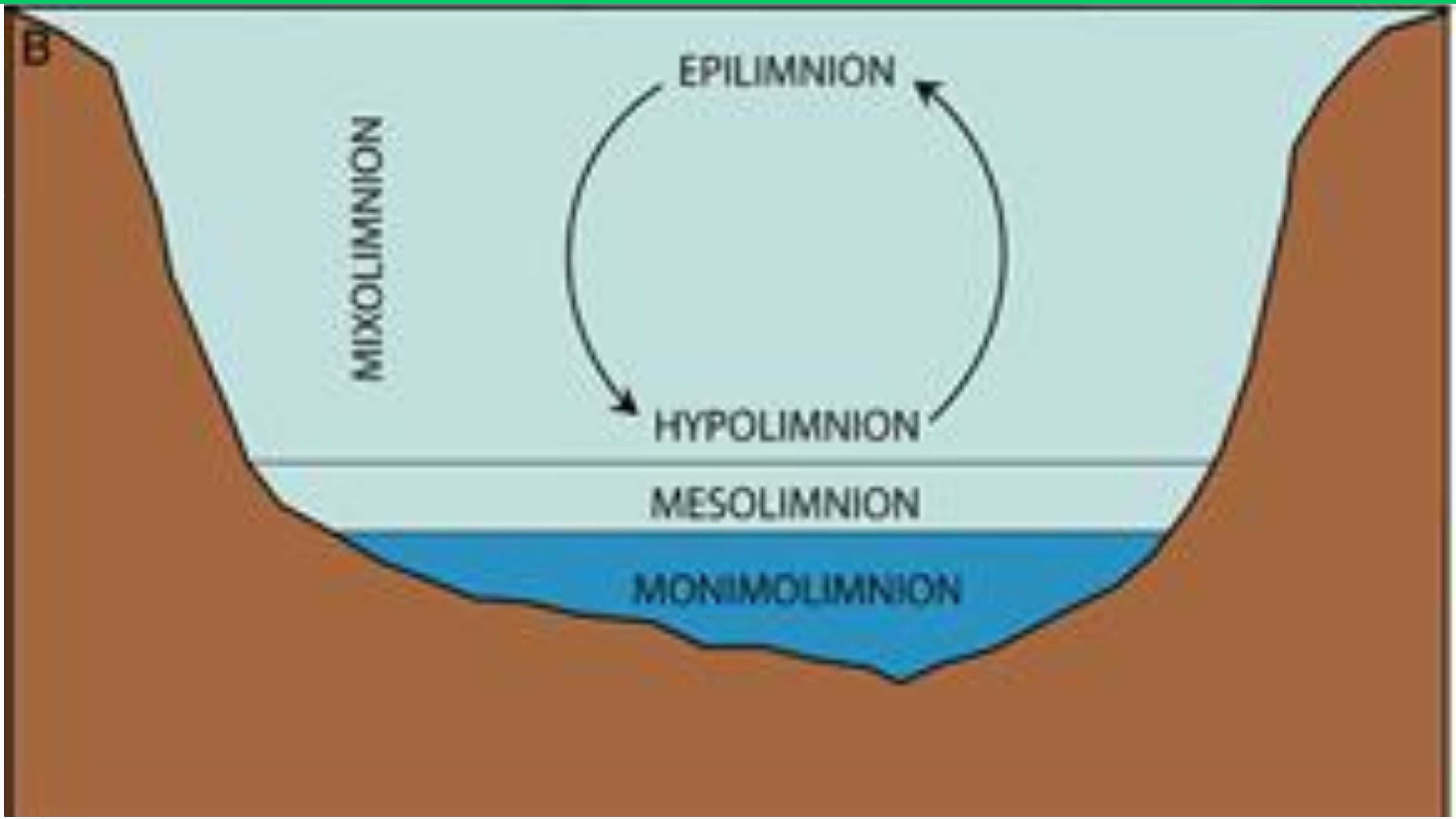
UNIT 3: IMPORTANT FACTORS

Phys. Fact: (a) Lake classes by mixing

- Region of lake that mixes at a particular time is the **mixed layer/**depth.

- **Meromictic** lakes consist of two layers in annual cycle:
  - **mixolimnion**, &
  - **monimolimnion...**

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (a) <u>Temp & Lake mixing</u>



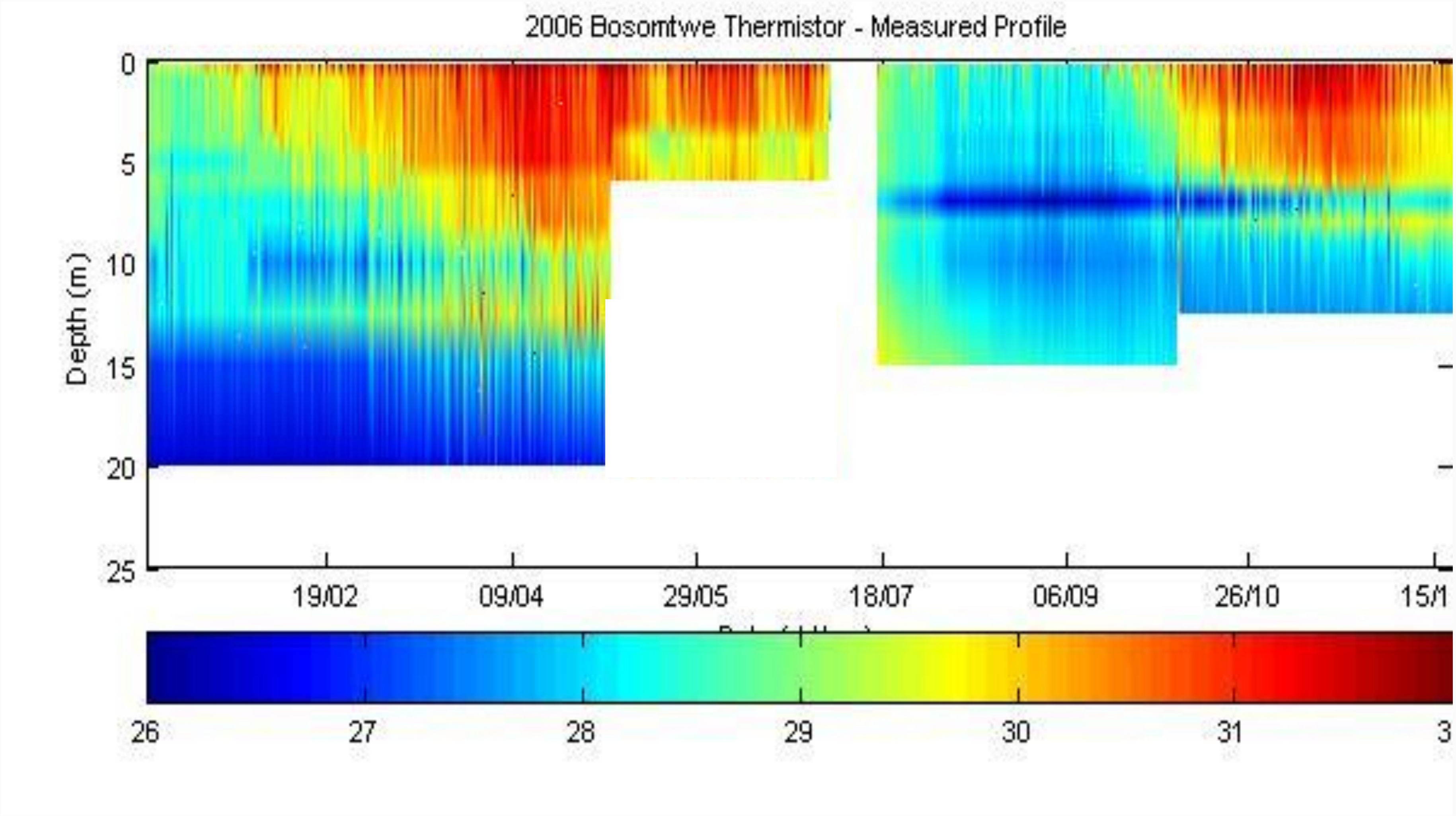
UNIT 3: IMPORTANT FACTORS

Phys. Fact: (a) Temperature measurement

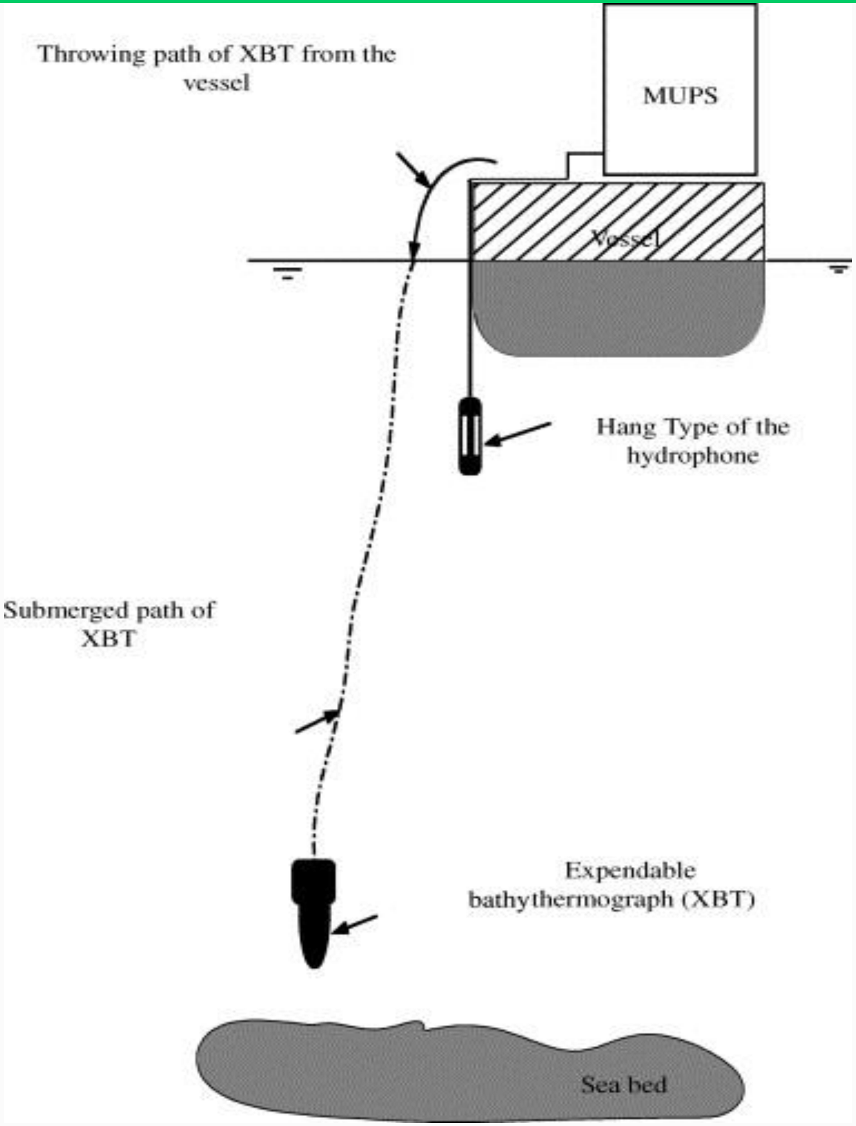
- a) Direct measurement with a **fluid thermometer** e.g, Hg thermometer…
- b) **thermister electrical thermometers** are based on electrical resistance…
- c) **bathythermograph** takes continuous vertical profiles of temperature with depth..

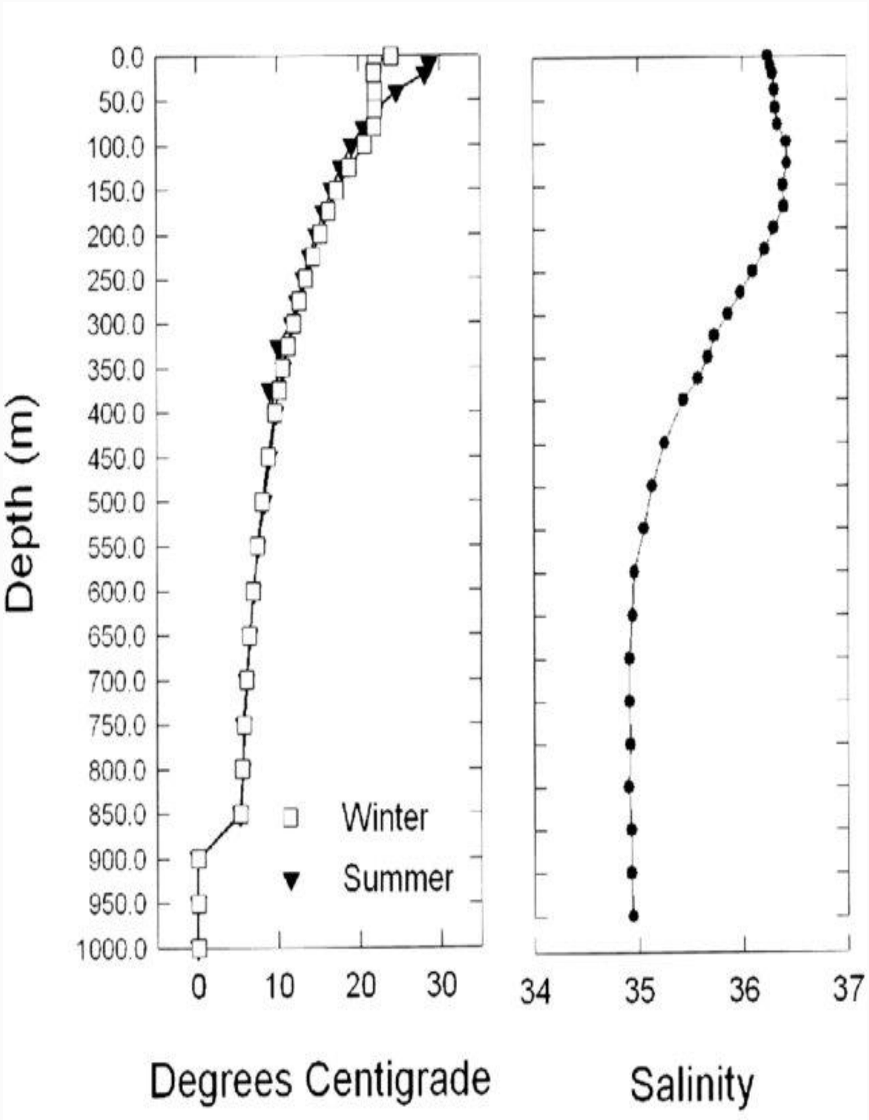
UNIT 3: IMPORTANT FACTORS
Phys. Fact: (a) <u>Temperature measurement</u>

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (a) Temperature measurement

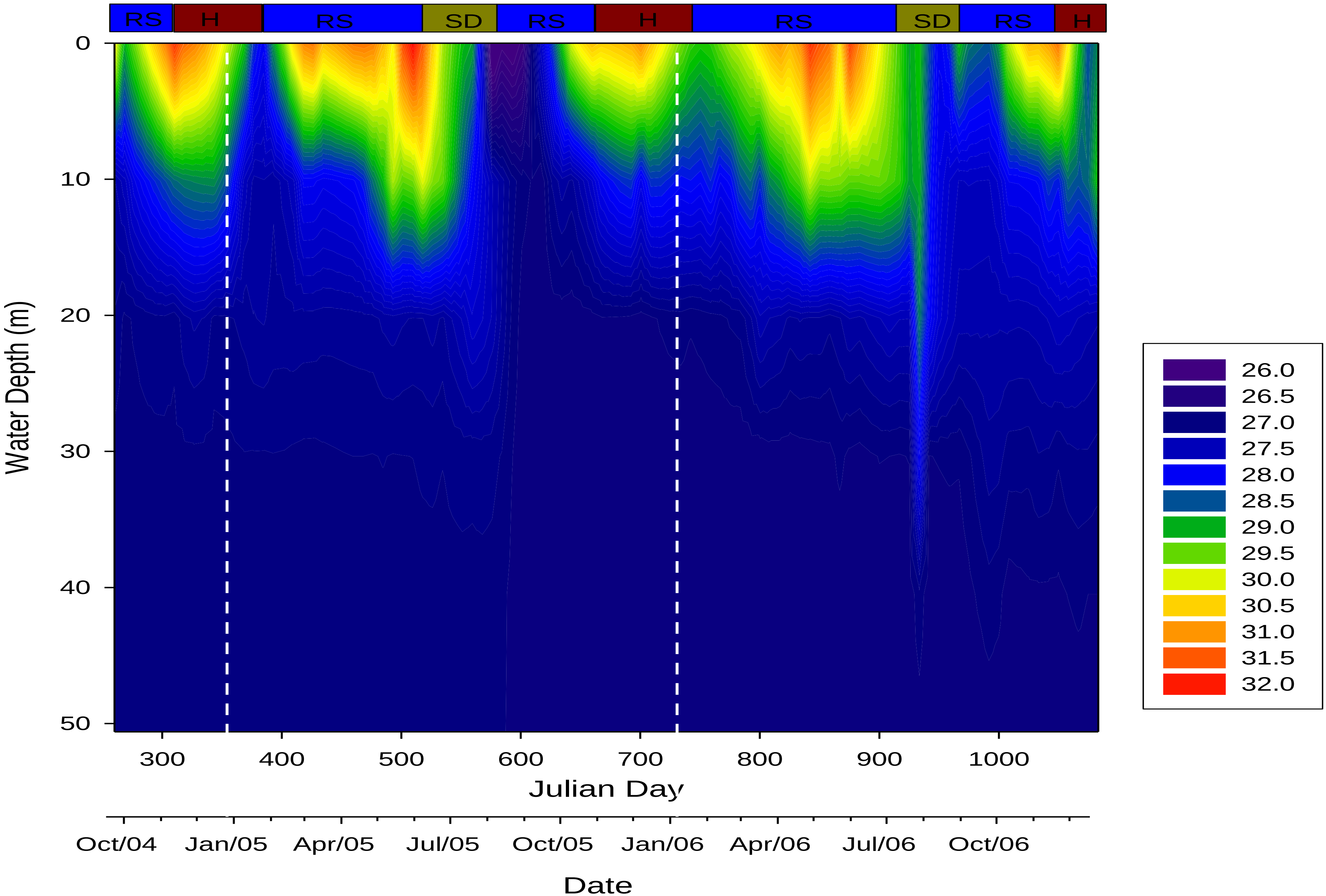


UNIT 3: IMPORTANT FACTORS
Phys. Fact: (a) Temperature measurement





Temperature Profiles of Lake Bosomtwe 2004-2006 (degrees Celsius)



UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) <u>Light</u>

- **Importance** of light;
  - primary production
  - distribution of various aquatic organisms
  - for <u>moving</u> about, <u>detecting prey</u>, & <u>spotting predators</u>

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) Light

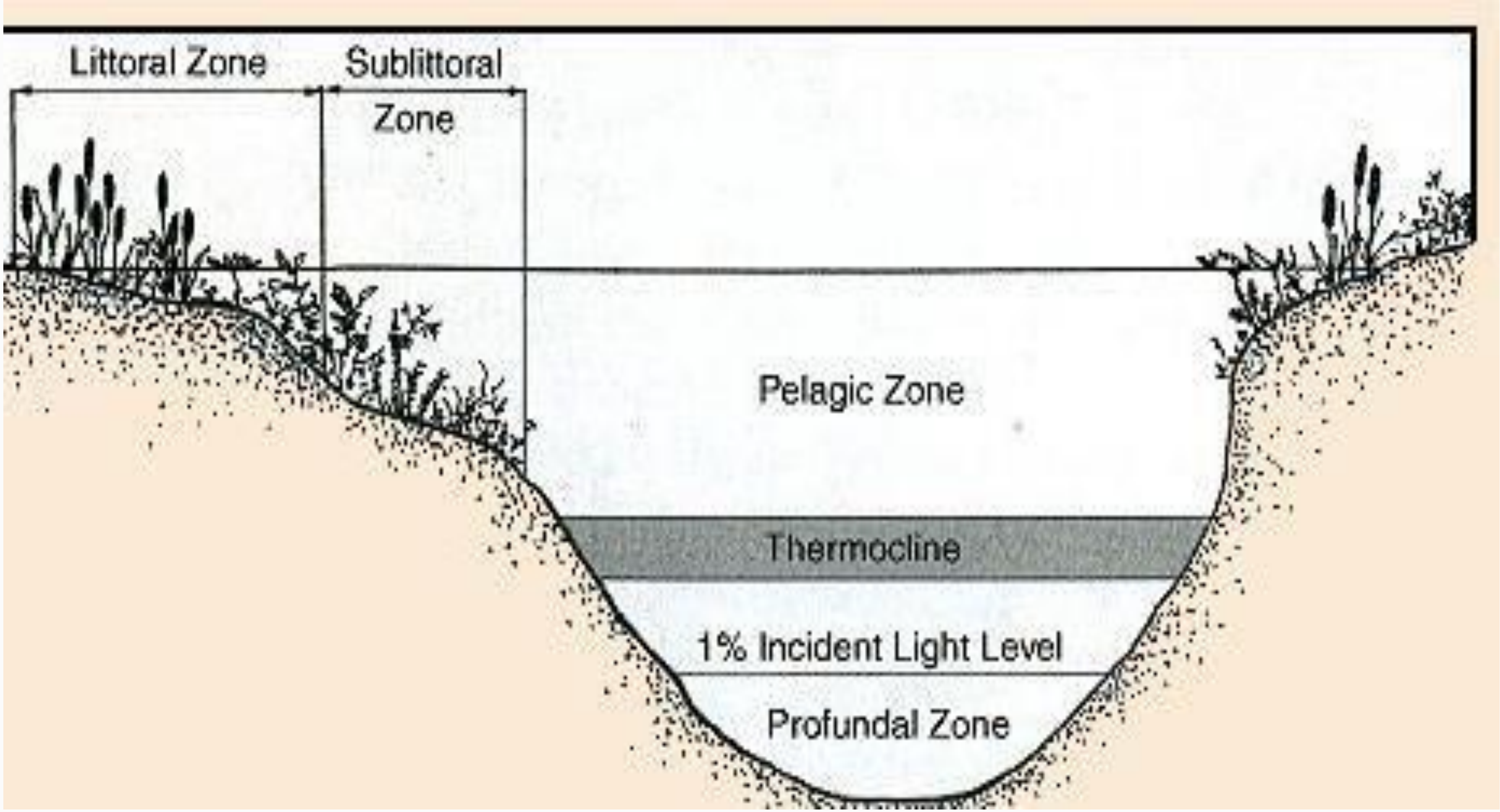
- But high intensities can depress primary productivity in surface waters.

- Also, **UV** part is damaging to different kinds of aquatic organisms.

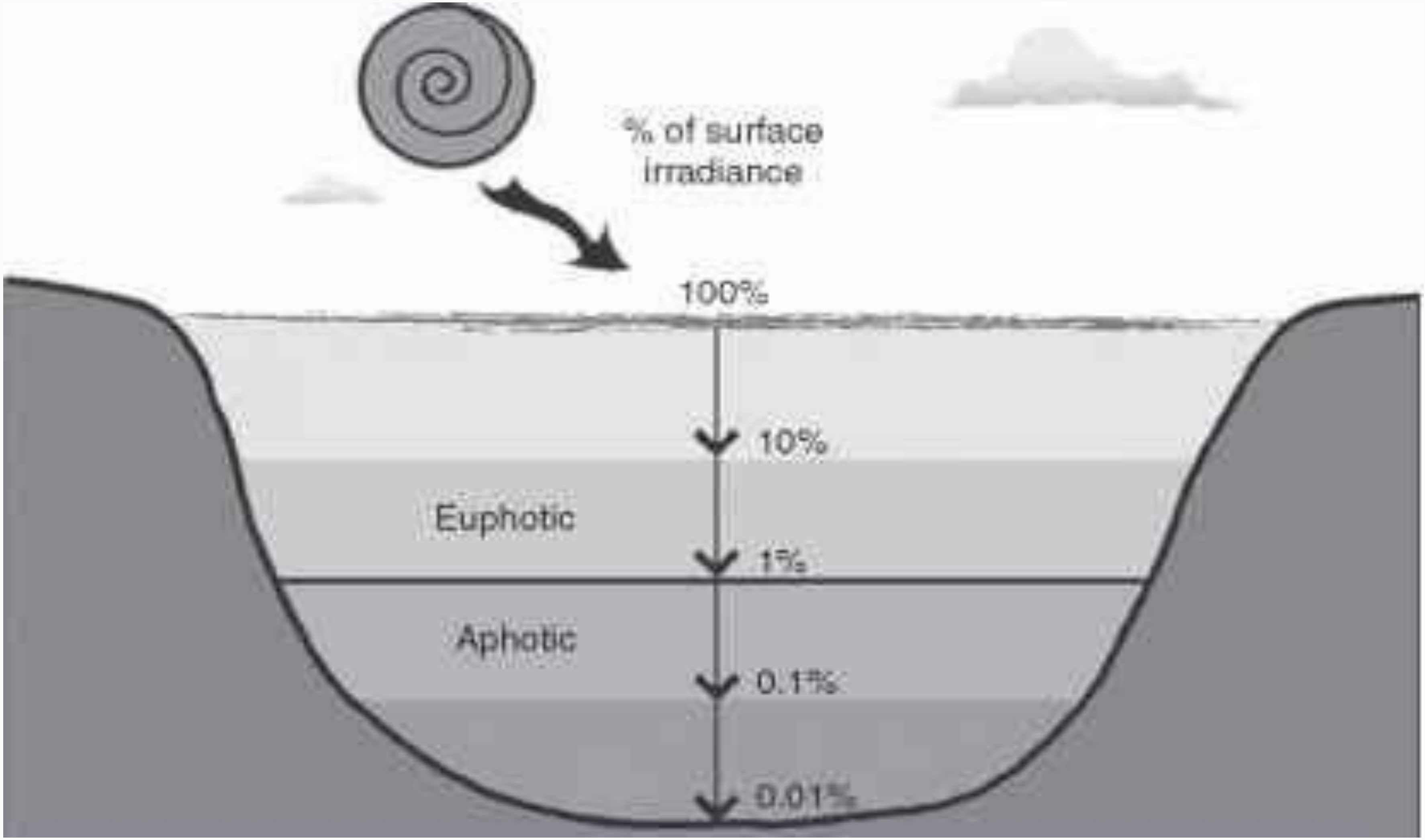
UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) Light zones in lakes

- These include:
  - **Photic zone** (Z_{eu}) – photosynthesis is **>** respiration.
  - **Aphotic zone** – photosynthesis is **<** respiration.
  - **Compensation depth**?

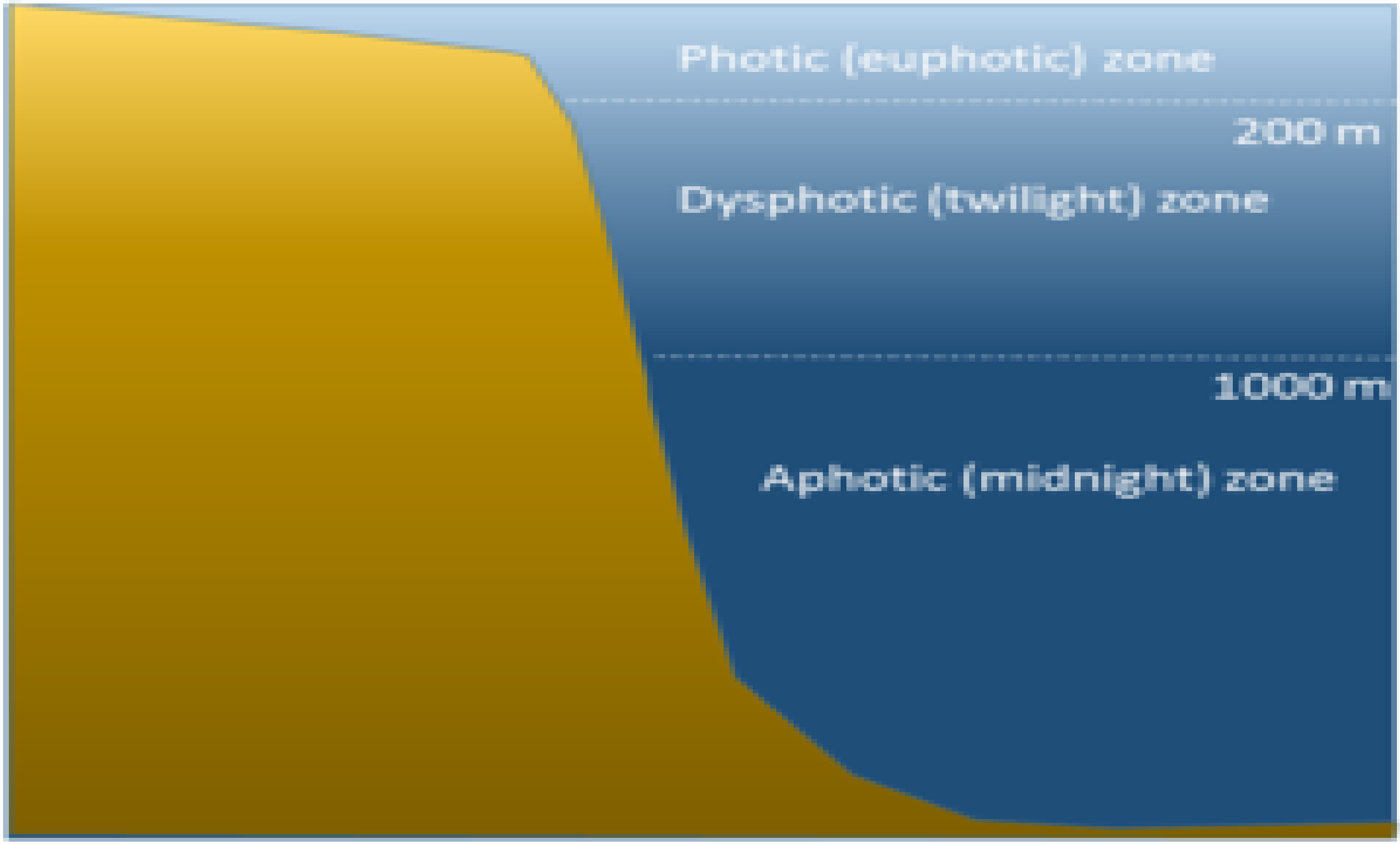
UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) <u>Light zones in lakes</u>



UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) Light zones in lakes



UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) <u>Light zones in oceans*</u>



UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) Light zones in lakes

- Thickness of $\mathbf{Z_{eu}}$ can be expressed as:

  $\mathbf{Z_{eu} = \ln 100/k}$ or

  $\mathbf{Z_{eu} = 4.6/k}$, ***k*** is extinction coefficient

- About ½ insolation is absorbed & scattered in **atmospheric** layers i.e. only **50 %** of is received at water surfaces.

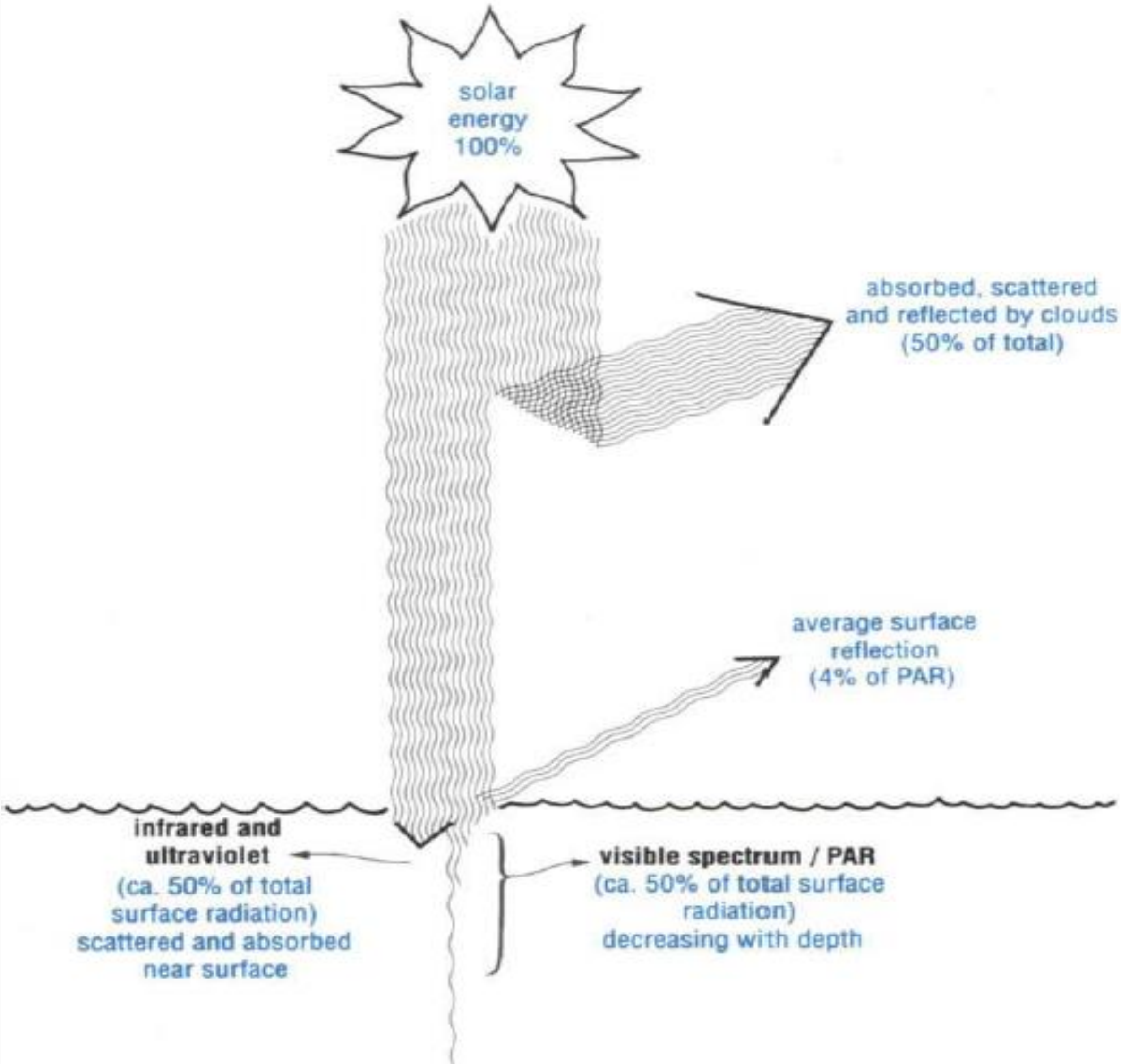
UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) Light

- Some (**4 %**) reflected back into the atmosphere with only about **46%** left…

- Visible light (i.e. **380-780 nm**) is part of the insolation (**EMR**) striking aquatic surfaces.

- Each visible light colour has its own wavelength & associated energy.

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) Light measurement



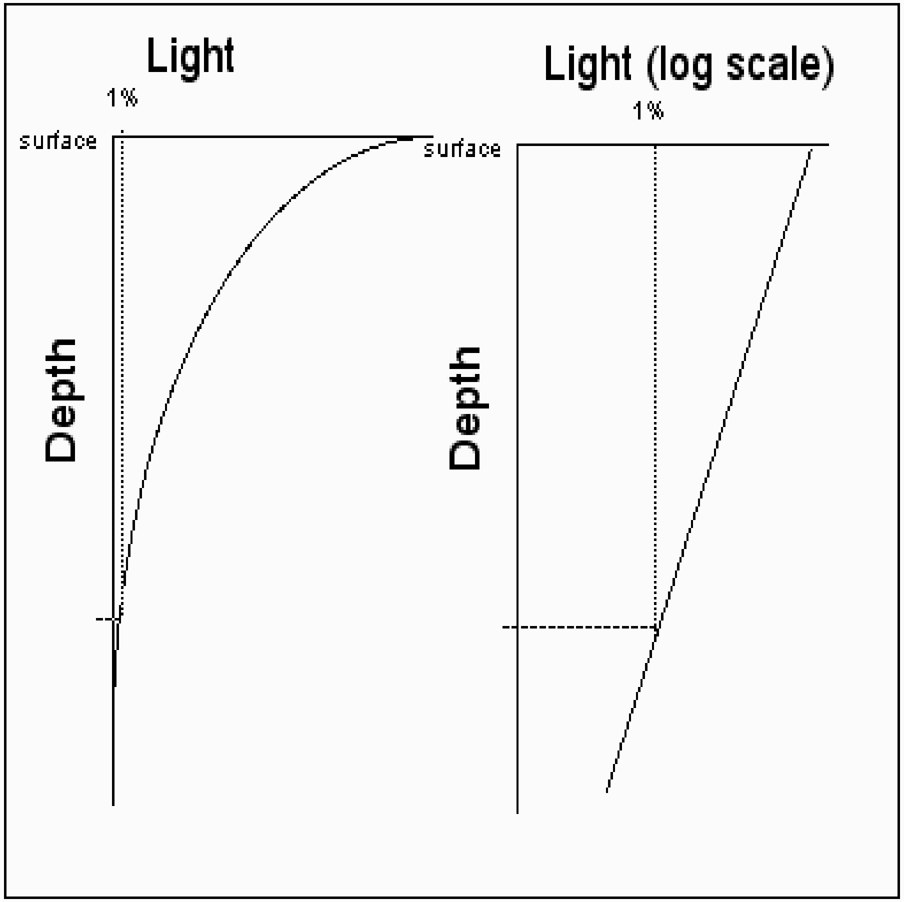
UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) Light

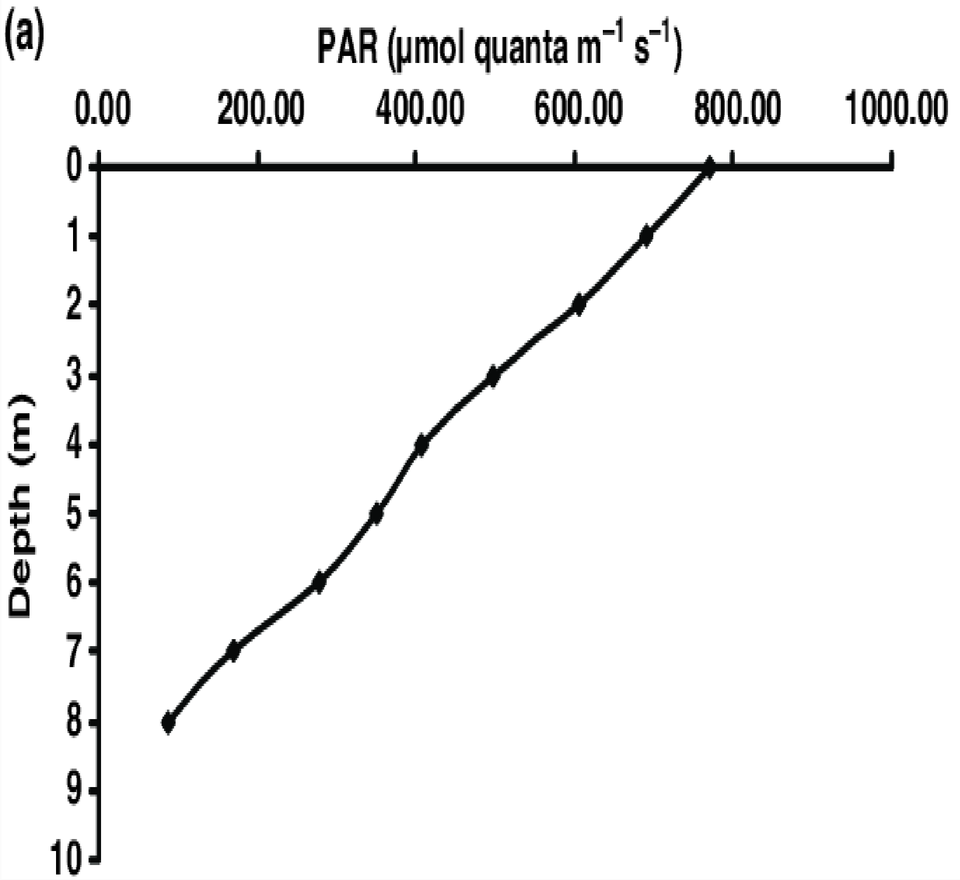
- Aquatic systems **transmit** visible portion of EM spectrum that declines exponentially.
  - **60** % absorbed in **1st metre**
  - **80** % in **10 m**, etc.

- But, water has low light absorption coefficient in **visible region** (380 – 780 nm) compared to **IR** (>780 nm) & **UV** regions (< 380 nm).

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) Light

- Thus, there is exponential decline in light intensity with depth expressed by an extinction coefficient, ***k***…

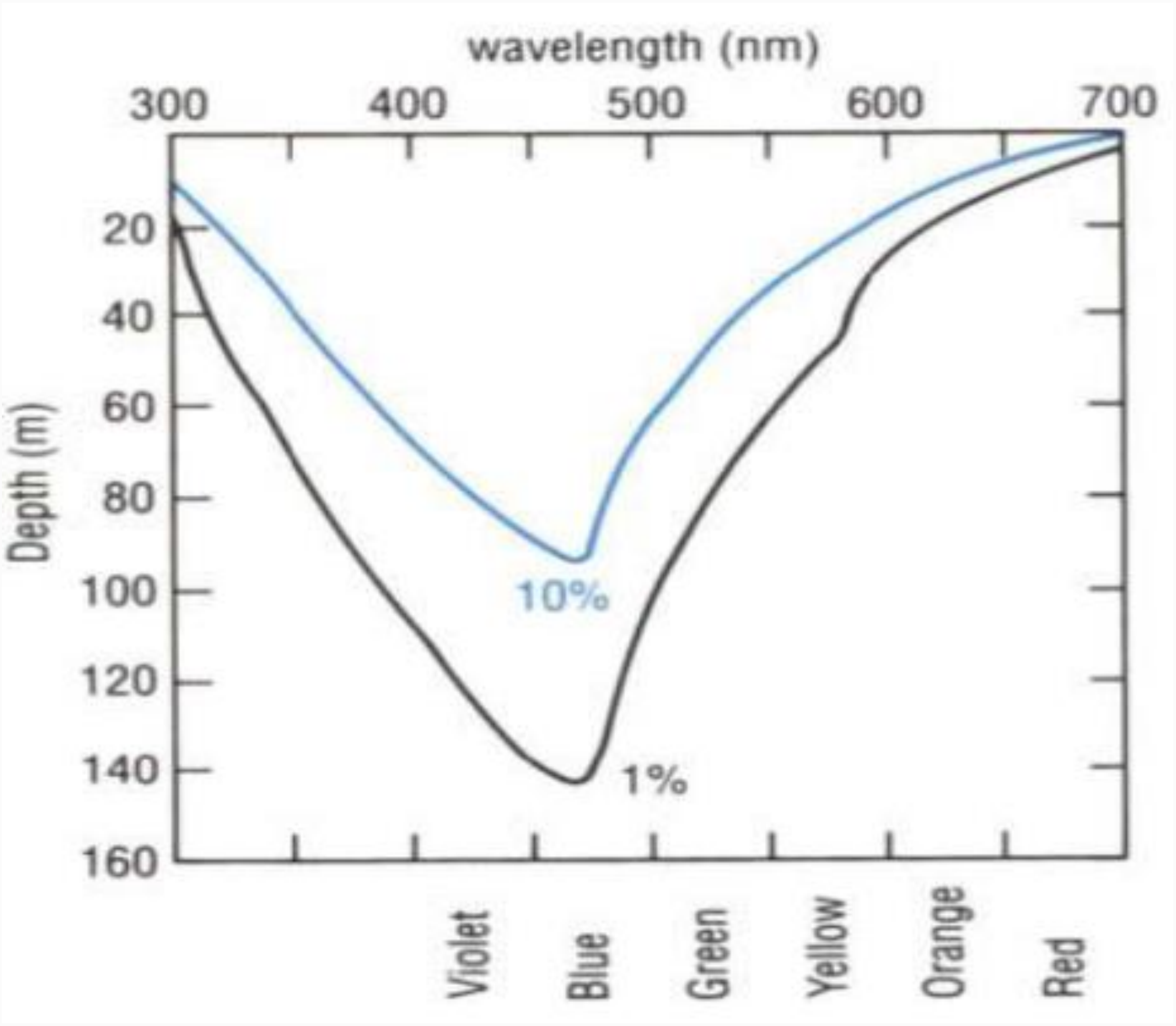

Light
1%
surface
Depth
Light (log scale)
1%
surface
Depth


(a)
PAR (µmol quanta m⁻¹ s⁻¹)
0.00
200.00
400.00
600.00
800.00
1000.00
Depth (m)
0
1
2
3
4
5
6
7
8
9
10

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) Light

- Differential **transmission** of wavelengths...
  - Longer wavelengths with high ***k*** (e.g. **red -** 650 nm) are lost very rapidly in first 10 m.
  - Shorter wavelengths with low ***k*** (e.g. **blue-green** - 450 nm) are deeply transmitted...

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) Light



UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) <u>Underwater light</u>

- Fate of light underwater;
  - reflected & **refracted**
  - **absorbed**
  - **scattered**

- These happened due to:
  - **suspended particles** (silt, plankton, etc),
  - **water** itself
  - **salt** molecules

UNIT 3: IMPORTANT FACTORS

Phys. Fact: (b) Underwater light

- But water have low light scattering coefficient.

- Hence ***k*** is a composite value ($\mathbf{k_t}$) due to these processes & is expressed as:

$$\mathbf{k_t = k_w + k_p + k_c}$$

$\mathbf{k_w}$ = water, $\mathbf{k_p}$ = suspended particles, & $\mathbf{k_c}$ = dissolved compounds/salts

UNIT 3: IMPORTANT FACTORS

Phys. Fact: (b) Underwater light

- Underwater light measurement methods:

1. **% absorption** = **100(I_o - I_z)/I_o …**

2. Use of ***k*** from exponential **curve** & derived **equation**…

   $$I_z = I_o e^{-kz} \text{ or } (\ln I_o - \ln I_z)/z = k \; (k = 2.303(\log_{10} I_o - \log_{10} I_z)/z) \ldots$$

3. **% transmissivity** = **100*e^{-k}**

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) <u>Underwater light</u>

- **<u>NB</u>**: *k* can be used to derive the depth at which a particular % of light is found using:

Depth (*x*) % light = ln (100/*x*)/*k*

where ***x*** is % of light at that depth

UNIT 3: IMPORTANT FACTORS

Phys. Fact: (b) Underwater light

- E.g. if **k** is **0.8/m** in a lake, then the depth where 10 % of light will be found is:

  Depth (10) % light = ln (100/10)/0.8

  = ln (10)/0.8

  = 2.30/0.8

  = 2.9 m

- This can be done for find other depths e.g. 100%, 75%, 50%, 25%, 10%, 5%, **1%**, etc

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (b) Underwater light

- Effect of particle density on water colour

  - Higher # of particles implies **blue** light is scattered more than **red** making **green** penetrate the deepest & vice versa.

UNIT 3: IMPORTANT FACTORS

Phys. Fact: (b) Underwater light measurement

- **Light metres** used to measure intensity & **quantum metres** measure total available light.

- **Filters** can be used to measure only specific wavelengths.

- Popular units in aquatic studies are einstein (E) & watt (W) – (**1 W m^{-2}** = **4.16 μE m^{-2}s^{-1}**)

UNIT 3: IMPORTANT FACTORS

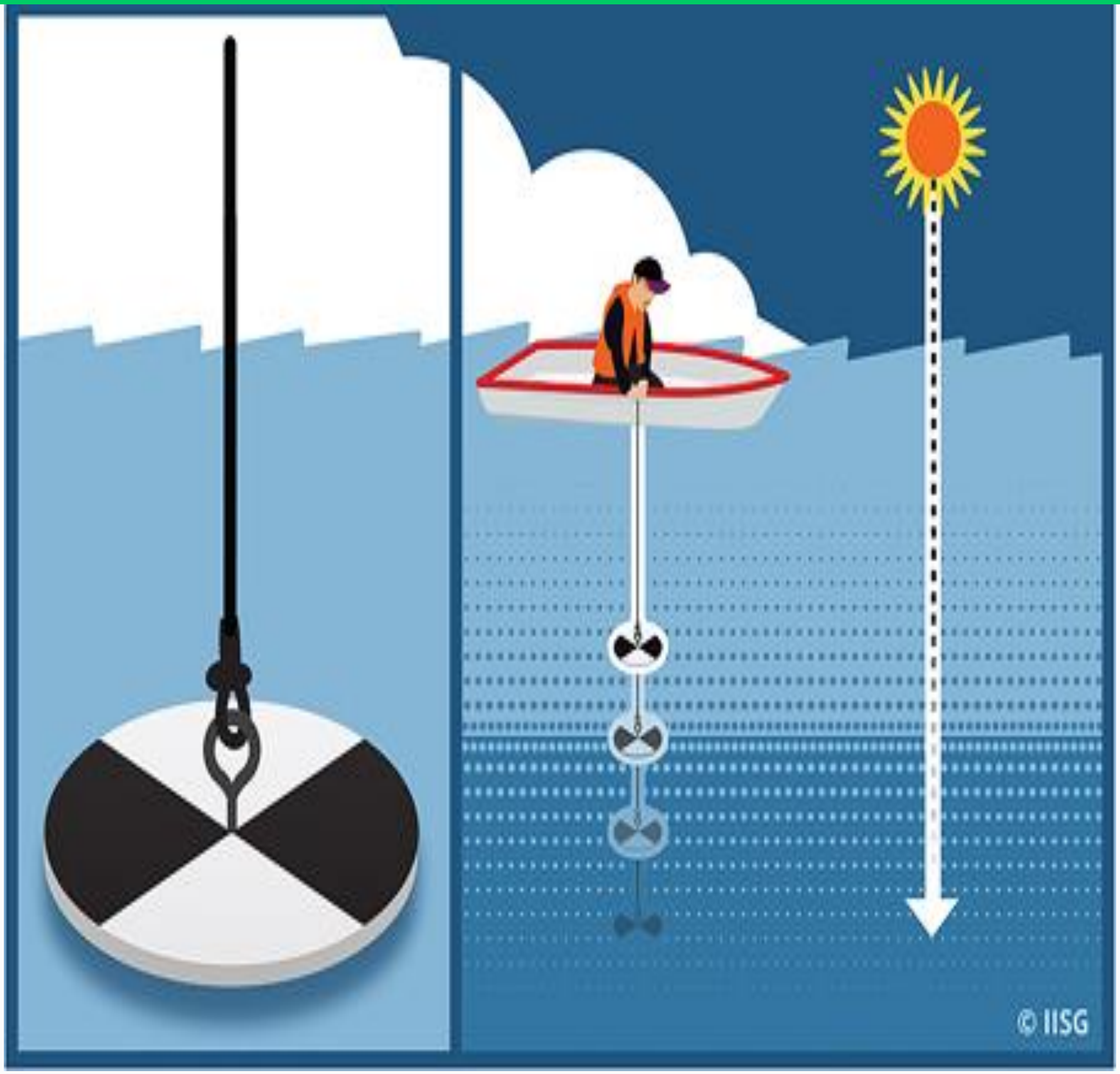
Phys. Fact: (b) <u>Underwater light measurement</u>

<u>Secchi Disc (SD)</u>

- SD & SD depth (**Z_{SD}**)

- Measurement of ***k*** using SD depth (**Z_{SD}**):

$$\mathbf{k = 1.7/Z_{SD}}$$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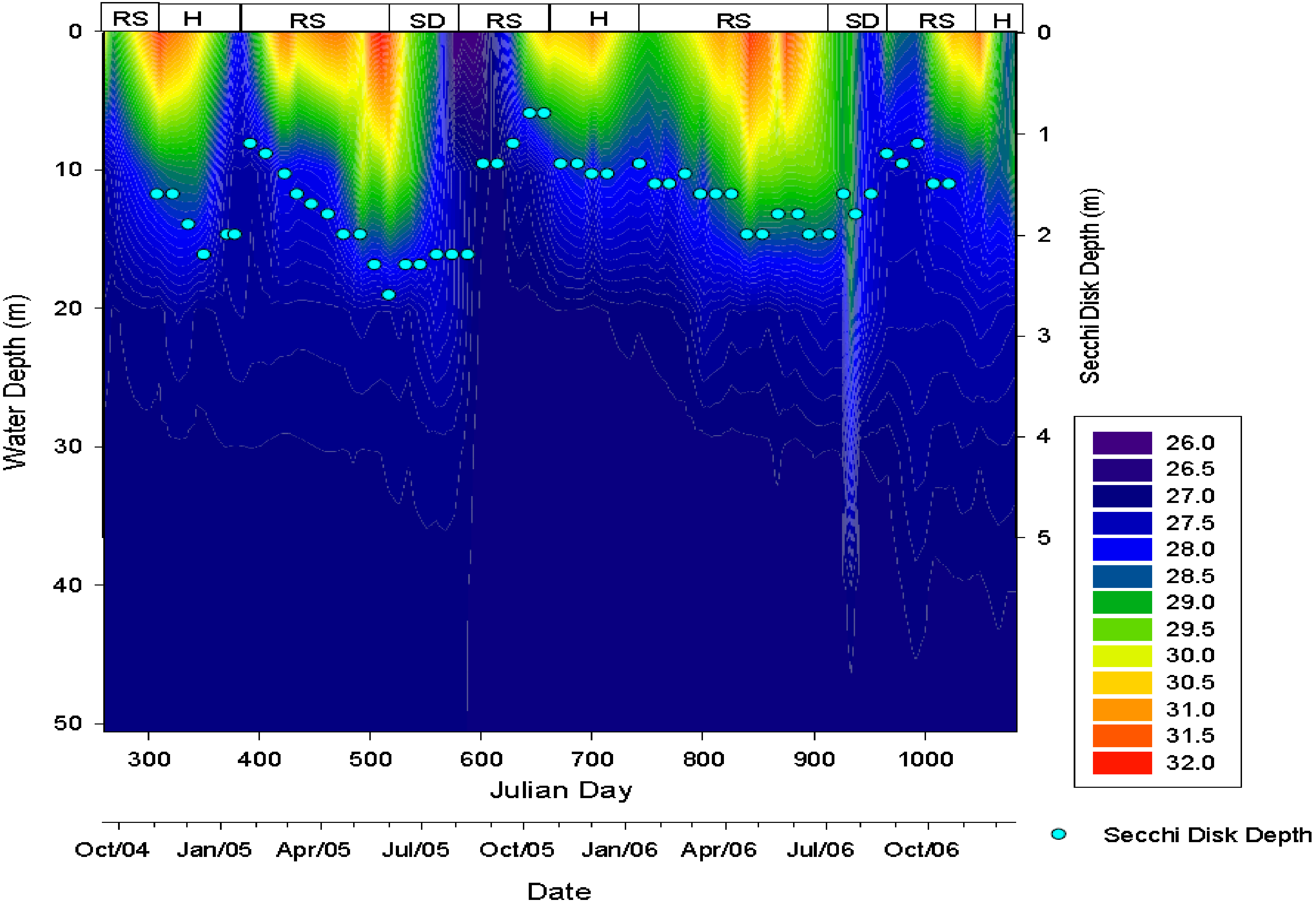


RS
H
RS
SD
RS
H
RS
SD
RS
H
0
10
20
30
40
50
Water Depth (m)
0
1
2
3
4
5
Secchi Disk Depth (m)
26.0
26.5
27.0
27.5
28.0
28.5
29.0
29.5
30.0
30.5
31.0
31.5
32.0
300
400
500
600
700
800
900
1000
Julian Day
Oct/04
Jan/05
Apr/05
Jul/05
Oct/05
Jan/06
Apr/06
Jul/06
Oct/06
Date
Secchi Disk Depth

UNIT 3: IMPORTANT FACTORS

Phys. Fact: (b) Underwater light measurement

Secchi Disc (SD)…

- The *advantages* of SD:
  - it does not need adjustment,
  - It is low costs,
  - it does not have leaking problems, &
  - it does not need replacement of electronic components

UNIT 3: IMPORTANT FACTORS

Phys. Fact: (c) Turbidity

- The level of **opaqueness** of a water body.
- High turbidity causes light to be absorbed & scattered rather than transmitted.
- Largely caused by **suspended** inorganic & organic matter.

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (c) Turbidity

- The **sources** of turbidity include:
  - a) soil erosion
  - b) water discharge
  - c) urban runoff
  - d) **phytoplankton/algal** abundance
  - e) **bioturbation** (disturbance by organisms) usually bottom-feeders
  - f) re-suspended sediments from wave action

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (c) Turbidity

- **Challenges** of high turbidity:
  1. Impairs water quality for **domestic** & **industrial** users.
  2. Creates problems of **water treatment**.
  3. Decreases visual appeal for **recreation**.
  4. Causes decline in the DO-holding capacity & can potentially kill fish from asphyxiation.
  5. Reduces light for photoautotrophs.
  6. Leads to low DO from low photosynthesis.

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (c) Turbidity

7. Clogs fish gills & leading to asphyxiation & death.

8. Visual feeding is impaired in some fishes.

9. Burial of fish eggs & larvae due to increased sedimentation at the bottom.

10. Macroinvertebrates, a fish food source is adversely affected by decline in DO.

UNIT 3: IMPORTANT FACTORS
Phys. Fact: (c) <u>Turbidity</u>

- <u>Turbidimeters</u> are used to measure the turbidity of water.

UNIT 3: IMPORTANT FACTORS

Phys. Fact: (d) Water currents

- **Current** velocity is a key factor affecting organisms in lotic systems.

- **Discharge** - volume of water through a cross-sectional area of a lotic system per unit time i.e.

$$\mathbf{Q = Av}$$

Q = discharge (m^3s^{-1}), **A** = cross sectional area (m^2), & **v** = mean velocity (ms^{-1})

UNIT 3: IMPORTANT FACTORS

Phys. Fact: (d) Water currents: measure?

1. **Colour** method using a strong **dye**.
2. **Drift** method using a **float**.

- **NB**: The principle is that an object floating on a lotic surface is carried along at a speed of the water current.

UNIT 3: IMPORTANT FACTORS
Chemical. Factors:

- Role of **major** (Na, Cl) & **minor** (e.g. NH_4^+, NO_3^-, PO_4^{3-}, etc) inorganic substances.

- Levels of occurrence - separately or interactively & link to salinity & conductivity.

- Included also are **gases** like O_2 & CO_2 & their impacts on alkalinity, acid rain, redox potential, etc

UNIT 3: IMPORTANT FACTORS
Chemical. Factors:

- Important chemical factors in aquatic systems include;
  - **Hydrogen ion concentration (pH),**
  - **Redox potential (Eh)**
  - **Dissolved Oxygen (DO)**
  - **Biological Oxygen Demand (BOD)**
  - **Chemical Oxygen Demand (COD)**
  - **Nutrients (organic & inorganic compounds e.g. N, P, Si, etc),**
  - **Conductivity, TDS, etc**

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (a) pH

- Definition and range.

- pH values from **6** $\rightarrow$ **0** indicate increasing **acidity** & values from **8-14** indicate increasing **alkalinity**.

- Most naturally- occurring waters vary around a pH of **7**.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (a) pH - NB

- **[H^+]** & **[OH^-]** relationship in pH measurement.

- Log scale for pH & implication for changes in water bodies.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (a) pH Measurement

- This is done either by:
  - **Colorimetric methods** (e.g. pH paper, etc) or
  - **electrometric methods** using pH meters
- Utility of the pH meter.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (a) pH & Acid Rain

- Relation between pH of rain water & acid rain.

- Major anthropogenic sources of a**cid rain (N & S)**.

- pH & **alkalinity** - measure of water's <u>ability to resist changes in pH caused by addition of acids</u>.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (a) pH & Alkalinity

- Components of alkalinity in natural waters - HCO_3^-, CO_3^{2-}, & borates, silicates, & PO_4^{3-}.
- Other terms used to describe alkalinity are <u>alkaline reserve</u>, <u>total alkalinity</u>, & <u>ANC</u>.
- Units are in mg/L of $CaCO_3$ or μeq/L (20 μeq/L = 1 mg/L).

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (b) Redox Potential (E_h)

- It's same as <u>oxidation-reduction potential</u>.

- It's related to presence of O_2 or reduced compounds e.g. HS^-, Fe^{2+}, & S^- groups.

- Positive & negative values & implications.

- The Eh values of natural waters usually lie between +**400** & +**435** mV at pH 7.6 to 8.3.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (b) E_h, pH, & temperature

- Control of E_h -photosynthesis & respiration.
- Photosynthesis utilizes CO_2 & HCO_3^- & releases O_2, or removes H_2.
- So, photosynthesis tends to raise both the **E_h** & **pH** & respiration has reverse effect.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (c) Dissolved oxygen (DO)

- Provides valuable information on biological & biochemical reactions in water bodies;

- It’s a key factor affecting aquatic organisms

- It’s also a gauge water’s capacity to accept organic matter without causing nuisance.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (c) Dissolved oxygen (DO)

- Sources of O_2
  - **atmosphere**
  - **photosynthesis** of aquatic plants e.g.?

- Use in demarcating zones in waterbodies:
  - **oxic** e.g. surface waters
  - **anoxic** e.g. monimolimnia, rivers sediments
  - **hypoxic**

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (c) Dissolved oxygen (DO)

- Use of to characterize occurrence of fishes – salmonid & non-salmonids.

Table 3.1 DO requirements of salmonid fishes

a. Embryo and larval stages	mg/L
No production impairment	11
Slight production impairment	9
Moderate production impairment	8
Severe production impairment	7
Limit to acute mortality	6
b. other life stages	
No production impairment	8
Slight production impairment	6
Moderate production impairment	5
Severe production impairment	4
Limit to acute mortality	3

Table 3.2 DO requirements of non-salmonid fishes

a. Embryo and larval stages	**mg/L**
No production impairment	6.5
Slight production impairment	5.5
Moderate production impairment	5
Severe production impairment	4.5
Limit to acute mortality	4
b. Other life stages	
No production impairment	6
Slight production impairment	5
Moderate production impairment	4
Severe production impairment	3.5
Limit to acute mortality	3

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (c) Dissolved oxygen (DO)

Table 3.3 DO requirements of invertebrates

Embryo and larval stages	mg/L
No production impairment	8
Moderate production impairment	5
Limit to acute mortality	4

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (c) Dissolved oxygen (DO)

- On average, fish require at least **5 mg/l** of oxygen.
- Below about **3 mg/l**, many aerobic aquatic organisms cannot survive.
- **Hypoxia** (2 mg/l) **anoxia** (0 mg/l) & these often result in fish kills.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (c) DO Measurements

- **Chemical methods**: most frequently used chemical method.

- **Oxygen-sensitive electrodes**: provide a rapid & sensitive measurement of DO.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (d) Biological O_2 Demand

- Definition of BOD.

- Relation between BOD, levels of organic matter, & O_2 levels, in water bodies.

- Measurement of **BOD_5** at **20 ºC**.

$$\mathbf{BOD_5}\ (\mathrm{mgl^{-1}}) = [\mathbf{DO}]_{\text{initial bottle}} - [\mathbf{DO}]_{\text{dark bottle}}$$

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (e) Chemical O_2 Demand

- Definition of COD.

- It measures O_2 demand by chemical means using $K_2Cr_2O_7$ as oxidizing agent.

- Differences between COD & BOD.
  - Both organic & inorganic compounds
  - Requires shorter time (2 hours)

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (e) Chemical O_2 Demand

- The utility of the BOD:COD ratio.

- COD is measured by adding H_2SO_4 & Cr to a sample & determining the maximum O_2 consumption of the sample.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (f) Conductivity

- Estimate of the amount of **TDS** (total dissolved ions or solids) in a water body.

- This can be done using the relationship:

  TDS (mg/L) = 0.5*1000Conductivity (µS/cm)

- It's unit of measurement is **microsiemens per centimeter** (uS/cm)

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (f) Conductivity

- It is measured on a scale from **0** to **50,000** uS/cm (good mixed fisheries = 150 - 500).

- **Freshwater** = **0 & 1,500** uS/cm & typical **sea water** = about **50,000 uS/cm.**

- But **industrial waters** = <u>10 000</u> µScm^{-1}.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (f) Conductivity

Applications related to **water quality** e.g.;

- a) Mineralization/TDS used as an index of the **ionic effect** of a water source.
- b) Noting changes in natural & waste waters quickly;
- c) Estimating sample size needed for other chemical analysis;

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (f) Conductivity

- d) Determining amount of treatment chemicals to be added to a water sample,

- e) Determining the salinity of waters.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (f) Conductivity & salinity

- Quantity of **Cl^- ions** in a water sample is used to estimate its salinity.

- Known mount of **$AgNO_3$** is added to sample to react with all the Cl^- ions.

- Knowing the amount of $AgNO_3$ that reacted with all the Cl^- ions implies that the amount of Cl^- is also known.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (f) Conductivity & salinity

- The [Cl^-] measured in this way is termed **<u>chlorinity</u>** (ppt).

- Relation of chlorinity & salinity:

  Salinity (ppt) =1.80655 x Chlorinity (ppt)

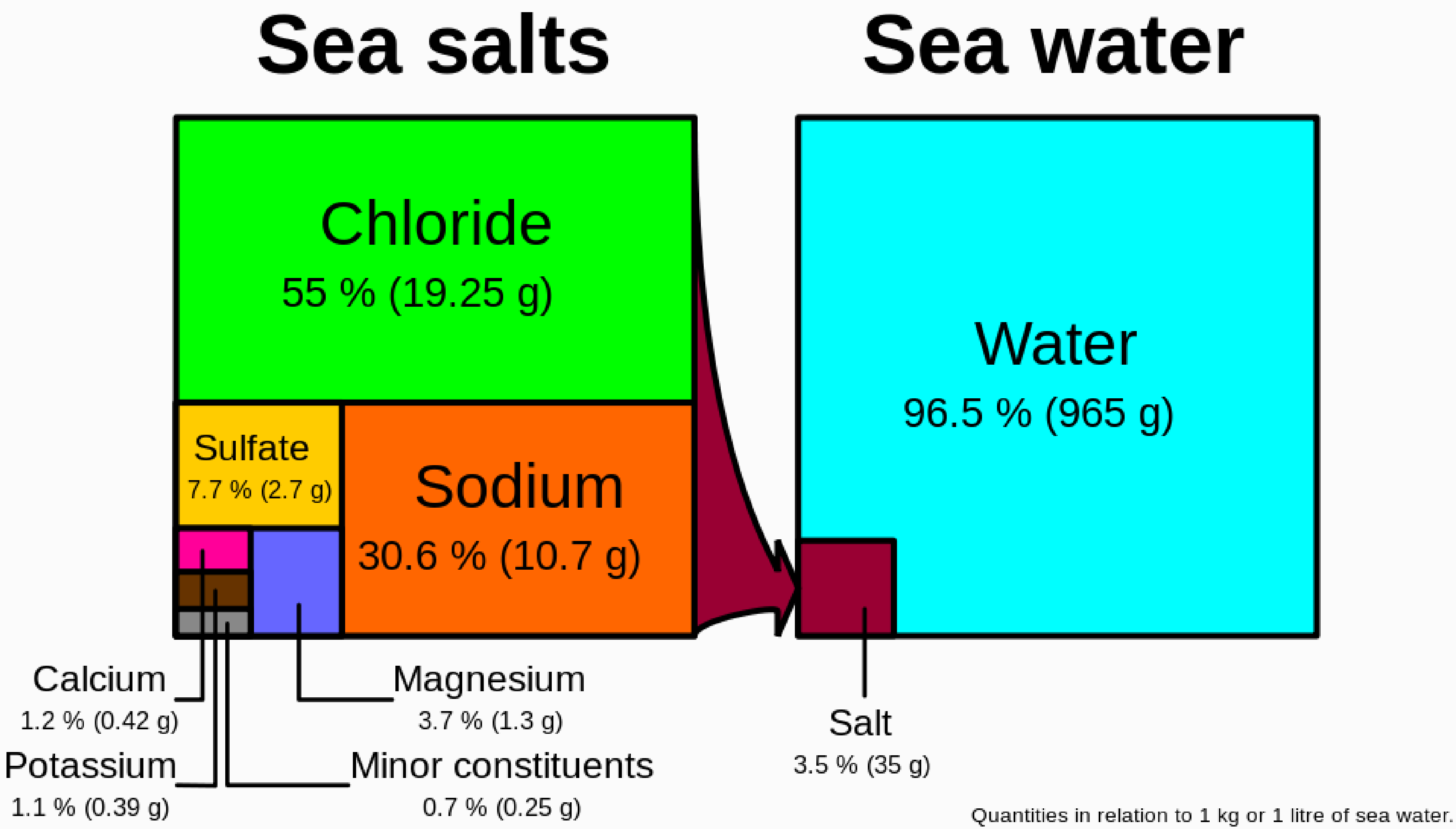
- From the chlorinity, concentrations of other major constituent can be found using the rule or **principle of constant proportions**.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (f) Conductivity & salinity

- The **rule of constant proportions** states “absolute salinity of ocean water might differ in different places, but the relative *proportions* of 6 *major ions* in it are always constant’’

- E.g., no matter the total salinity of a seawater sample, 55% = chloride, 30.6% = Na, SO_4^{2-} = 7.7, etc. ..

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (f) Conductivity & salinity



UNIT 3: IMPORTANT FACTORS
Chem. Fact: (f) Conductivity & salinity

- Since the proportion of major ions doesn't change, they're called **conservative ions**.
- Ions with proportions that are not constant are referred to as **non-conservative ions**.
- **NB: <u>Salinometers</u>** are the instruments for measuring electrical conductivity of a water body or sample.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (g) Nutrients

- Ions & chemicals required by organisms for maintenance, growth, development, & reproduction are called **nutrients**.
- As on land, plants require **P** & **N** but utilize them mostly as $\mathbf{PO_4^{2-}}$ & $\mathbf{NO_3^-}$ ions.
- Silicon (silicate ion - $\mathbf{SiO_4^-}$) needed by diatoms & some protozoans.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (g) Nutrients

- P, N, & enter water bodies by runoff from cities, crop & animal farms, factories, etc.
- Despite their importance, their levels in natural waters are usually very small.
- They are <u>removed</u> as plant grow & reproduce & <u>returned</u> as they die & decay.
-

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (g) Nutrients

- That’s why they are described as **bio-limiting** nutrients.

- They’re cycled into animals as the animals feed on the plants (trophic cascades).

- Animals are eaten by others, & gradually nutrients returned through death & decay & are reused by a new generation of plants.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (g) Nutrients - phosphorus

- **P** is a key metabolic nutrient & its supply regulates productivity of natural waters

- E.g. natural sources of P – **rainfall***, & phosphates from **weathering minerals**.

- E.g. human sources - quarrying, agric, tillage, & sewage treatment, etc.

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (g) Nutrients - phosphorus

- P - scarcest element the in earth's crust of those elements absolutely required for autotrophs & hence for other trophic levels.

- **Limitation** in water bodies results from;

  - Rock breakdown in watersheds release little available P to water bodies;

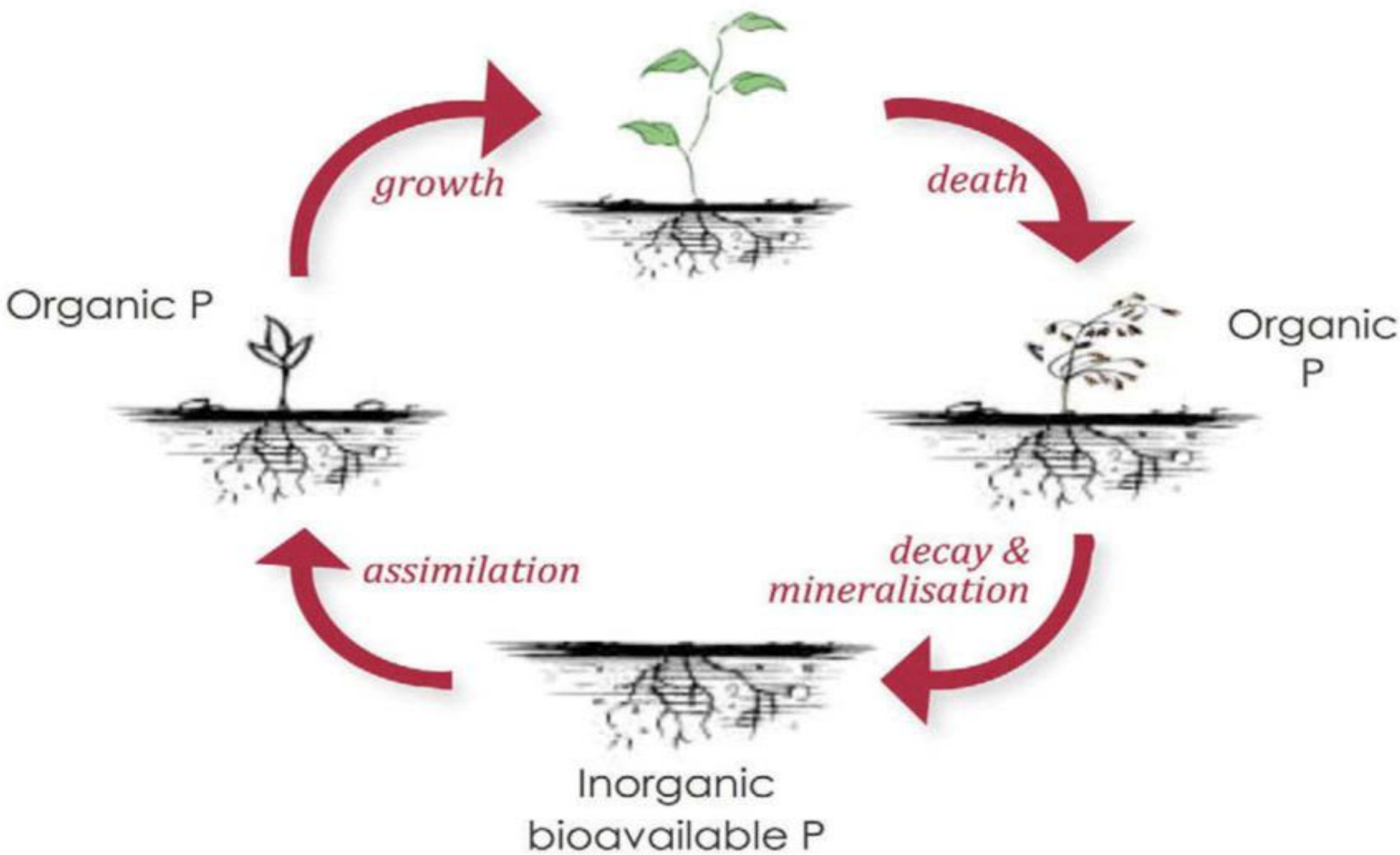
UNIT 3: IMPORTANT FACTORS
Chem. Fact: (g) Nutrients - phosphorus

- The root zone on land intercepts & retains most soluble phosphorus compounds
- No gaseous phase in the P-cycle.
- It is relatively insoluble.
- Rapid adsorption of soluble P onto particle making it unavailable to primary producers

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (g) Nutrients - phosphorus

- P is needed for <u>proteins</u> & <u>nucleic acids</u> synthesis

- The P-cycle is largely <u>abiotic/sedimentary</u> compared to the N-cycle & other gaseous cycles...

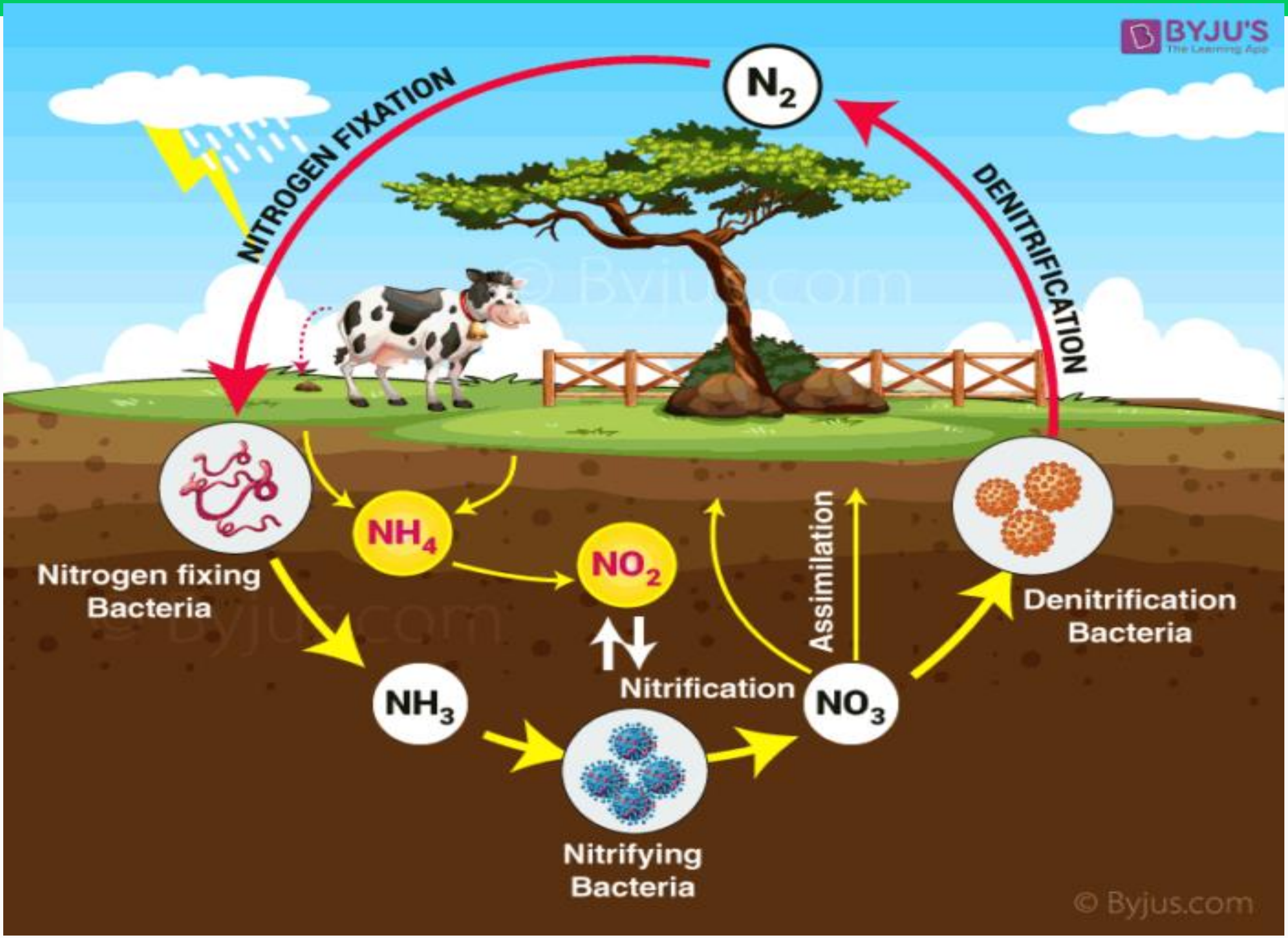


growth
death
Organic P
Organic P
assimilation
decay & mineralisation
Inorganic bioavailable P

UNIT 3: IMPORTANT FACTORS
Chem. Fact: (g) Nutrients - nitrogen

- Despite **N**'s huge atmospheric reserve, it is relatively unreactive & available to only a few **N-fixers** all of them prokaryotes.

- N_2 is converted to available compounds by
  - **atmospheric lightening,**
  - **UV-radiation,** & by
  - **nitrogen fixers**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N_2
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NH_3
Nitrification
NO_3
Nitrifying
Bacteria
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UNIT 3: IMPORTANT FACTORS
Chem. Fact: (g) Nutrients - nitrogen

- N is also needed in formation of **proteins** & **nucleic acids**.

- Fixation of N_2 by biological, meteorological, or industrial processes are the primary sources of **inorganic N** for ecosystems.

- But most N in **organic** matter exists as <u>amino groups</u> in protein.

UNIT 4

INLAND WATER PLANTS AND ANIMALS

UNIT 4: INLAND WATER PLANTS & ANIMALS
ILOs –

- To **appreciate** the diversity of life forms found within water bodies;
- In particular, to briefly **survey** this diversity from bacteria to mammals;
- To refresh our **knowledge** on aquatic macrophytes – types, benefits, adaptations, & zonations in littoral zones;

UNIT 4: INLAND WATER PLANTS & ANIMALS
ILOs –

- To **know** the basic classes of fishes in water bodies & to **understand** the terminologies associated with the movement from one location to another in relation to breeding & other life activities.

UNIT 4: INLAND WATER PLANTS & ANIMALS – Biological diversity

- Aquatic organisms are found in all the 3 domains of life namely;
  - **Bacteria** which are widely represented in all freshwaters e.g.
    - blue-green algae or cyanobacteria, &
    - other true bacteria

UNIT 4: INLAND WATER PLANTS & ANIMALS – Biological diversity

- **Arhaea** – restricted in to extreme paces
  - Methanogens that produce methane as a waste product from respiration,
  - extreme halophiles that live in extremely salty environments,
  - extreme thermophiles that live in extremely hot waters

UNIT 4: INLAND WATER PLANTS & ANIMALS – Biological diversity

- **<u>Eukarya</u>** e.g.
  - algae,
  - fungi,
  - fishes,
  - invertebrates,
  - aquatic plants, etc

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (a) Bacteria

- On the basis of **energy source** bacteria are designated as:
  - **Phototrophs** able to utilize light as an energy source or gain energy from light.
  - **Chemotrophs** gain energy from chemical compounds & can't photosynthesize.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (a) Bacteria

- Based on **electron source** bacteria are designated as:
  - **Lithotrophs** that can use reduced inorganic compounds as electron donors.
  - They can be Chemo- or photolithotrophs

  - **Organotrophs** that can use organic compounds as electron donors.
  - They can be chemo- or photoorganotrophs.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (a) Bacteria

- Thus, bacteria may be either:
  - **Photolithotrops** which gain energy from light & use reduced inorganic compounds such as H_2S as a source of electrons. eg: *Chromatium okeinii*.
  - **Photo-organotrophs** which gain energy from light & use organic compounds such as Succinate as electron source e.g.; *Rhodospirillum*.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (a) Bacteria

- **Chemo-lithotrophs** which gain energy from reduced inorganic compounds such as NH_3 as a source of electron eg; *Nitrosomonas*

- **Chemo-organotrophs:** which gain energy from organic compounds such as glucose & ammino acids as a source of electrons.eg; *Pseudomonas pseudoflora*.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biological diversity – (a) Bacteria

- Some bacteria can live either chemo-lithotrophs or chemoorganotrophs like *Pseudomonas pseudoflora* as they can use either glucose or H_2S as electron source.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (a) Bacteria

- Bacteria can also be classified based on **carbon source**:
  - All organisms need C in some form for use in synthesizing cell components.
  - All organisms require at least a small amount of CO_2.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biological diversity – (a) Bacteria

- But, some can use CO_2 as their major or even sole source of C & are called autotrophic bacteria.

- Others require organic compounds as their C source & are called heterotrophic bacteria.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (a) Bacteria

- Most bacteria of inland waters don't have chlorophyll or carry out photosynthesis.
- But, special group of anoxic photosynthetic ones are found in some lakes & estuaries.
- Like most unicellular algae, many bacteria can swim by using hair-like flagella.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (a) Bacteria

- Collectively, bacteria can mediate more chemical transformation than any other group of organisms.

- These include:
  - nitrogen transformation such as – nitrogen fixation, denitrification, nitrification,

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biological diversity – (a) Bacteria

- cellulose breakdown,
- degradation of oil,
- carbon & sulphur mineralization,
- food spoilage,
- disease production in plants & animals, etc.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (a) Bacteria

- Oxygen plays an important role in the classification of bacteria.

- For instance, there are obligate forms that absolutely requires & others that cannot tolerate it while the facultative forms can grow with or without it.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biological diversity – (a) Bacteria

- Main role of bacteria in nature is in the recycling of organic & inorganic materials.

- Heterotrophic bacteria can cause decay & provide a nutritious layer for detritivorous animals feeding on decaying organic particles in lentic & lotic systems.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (a) Bacteria

- They can also cause diseases in fish & other aquatic organisms.

- Chemolithotrophic bacteria found in sediments or on particles in natural waters are responsible for oxidations of NH_3 to nitrite & nitrate [nitrification], H_2S oxidation to SO_4^{2-}, & oxidation of Fe^{2+} to Fe^{3+}.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biological diversity – (a) Bacteria

- Layers of photosynthetic chemolithotrophic purple bacteria are often found in anoxic conditions in lakes.

- Rod-shaped coliform bacteria associated with sewage well-known & always present in natural waters but high levels indicate water pollution from sewage.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (a) Bacteria

- **NB**: Cyanobacteria (blue greens) are true bacteria but since they have chlorophyll a like algae are often classified with them.

- They are responsible for many water quality problems in surface waters of lakes, rivers, & water treatment ponds.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (a) Bacteria

- They affect the colour, taste, odour, etc of water bodies & produce a variety of toxins called **cyanotoxins**.

- These toxins cause several human health problems like gastroenteritis, dermatitis, body organ effects (primary liver cancer, etc), & sometimes death.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (b) Fungi

- These are heterotrophic organisms which lack chlorophyll & play a major saprophytic role in aquatic environments.

- They & bacteria are important breakdown & recycling plant & animal matter.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (b) Fungi

- Three major groups are common in aquatic environments –
  - actinomycetes,
  - oomycetes, &
  - true fungi

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (b) Fungi

- But they've also established themselves as major parasites of important groups in fresh water environments.

- E.g., *Saprolegnia* sp is well-known to fisheries biologists as a frequent parasite on dying or injured fish.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (b) Fungi

- Others e.g. chytrids (true fungi) common in lakes can alter the species composition of algal blooms.
- Fungi are either saprophytic or parasitic.
- Thin films of bacteria & fungi present on submerged organic detritus is a major food source for river & lake invertebrates.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (b) Fungi

- Although most bacteria can use detrital cellulose, only fungi & a few bacteria possess the special enzymes that can break down lignin, which is the skeletal material of leaves.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (c) Algae

- Simple mostly microscopic "plants" lacking roots, stems, & leaves but have chlorophyll a primary photosynthetic pigment & lack a sterile covering of cells around their reproductive cells.

- They dominate primary production in most aquatic systems where they're present as free-floating phytoplankton or attached algae (periphyton).

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (c) Algae

- Periphytic algae dominate the shallow areas of clear water lakes & streams whilst phytoplanktons dominate in larger lakes & the slowest reaches of rivers.

- Primary classification of algae into different divisions is on based on <u>pigment content</u>, type of <u>energy reserves</u>, <u>locomotory organs</u>, & <u>general structure</u>…

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biological diversity – (c) Algae

Name & typical colour	**Most common aquatic habitat**	**Examples**
Diatoms (golden-brown) Bacillariophyta	Lakes, rivers, estuaries, attached or planktonic	*Asterionella*, *Melosira*, *Nitzschia*, etc
Green algae (grass green) Chlorophyta	Lakes, rivers, estuaries; plantonic or attached	*Cladophora*, *Oocystis*, *Ulva*
Dinoflagellates (red-brown) Pyrrophyta	Lakes and estuaries; planktonic	*Peridinium*, *Ceratium*, *Gymnodinium*
Blue-greens (blue-green) Cyanophyta	Lakes; planktonic or attached	*Anabaena*, *Nostoc*, *Oscillatoria*, *Aphanezomenon*

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biological diversity – (c) Algae

Name & typical colour	Most common aquatic	Examples
Chrysophyta (yellow- or brown-green) Chrysophyta	Lakes, streams; planktonic	*Mallomonas*, *Dinobryon*, *Tribonema*
Cryptomonads (various colours) Cryptophyta	Lakes; planktonic	*Rhodomonas*, *Cryptomonas*
Euglenoids (various colours) Euglenophyta	Ponds, lakes; Planktonic	*Euglena*, *Phacus*, *Trachelomonas*,
Red algae Rhodophyta	Estuaries, lakes, streams; attached	*Gigartina*, *Batrachospermum*
Brown algae Phaeophyta	Estuaries; attached, free floating	*Gracilaria*, *Sargassum*

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (c) Algae

- They contain 2 main groups of pigments –
  - chlorophylls, &
  - carotenoids
- **Chlorophyll** is a complex molecule made up of 4 C-N rings around Mg atom.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (c) Algae

- The loss of the Mg atom produces the common degradation product – <u>phaeophyton</u>.

- **<u>Carotenoids</u>** are composed of linear unsaturated hydrocarbons called <u>carotenes</u> which give the red colour of some zooplankton, some salmon, & trout, etc.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biological diversity – (d) Macrophytes

- These are aquatic photosynthetic organisms, large enough to be seen with the naked eye.

- They grow permanently or periodically submerged below, floating on, or growing up through the water surface.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (d) Macrophytes

- In other words, they are the macroscopic forms of plants found in water bodies, & include
  - flowering vascular plants,
  - mosses,
  - ferns,
  - macroalgae, etc

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (d) Macrophytes

- Most aquatic plant research is focused on controlling nuisance/invasive macrophytes.

- Many of these nusisance or invasive species exist but 5 of these are quite problematic in Africa.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biological diversity – (d) Macrophytes

- These are:
  - **water hyacinth** (*Eichhornia crassipes*),
  - **water lettuce** (*Pistia stratiotes*),
  - **salvinia** (*Salvinia molesta*),
  - **red water fern** (*Azolla filiculoides*), &
  - **parrot feather** (*Myriophyllum aquaticum*).

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Macrophytes benefits

- 1. Provide habitat & protection for water organisms e.g. fish, frogs, insects, etc
- 2. Act as food sources for mammals, birds, fish, turtles, invertebrates (e.g. insects), etc
- 3. Help recycle O_2 & CO_2.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Macrophytes benefits

- 4. Prevent shoreline erosion – those that float on surface of water, or emerge from water near shore, act to buffer destructive waves that could lead to erosion.

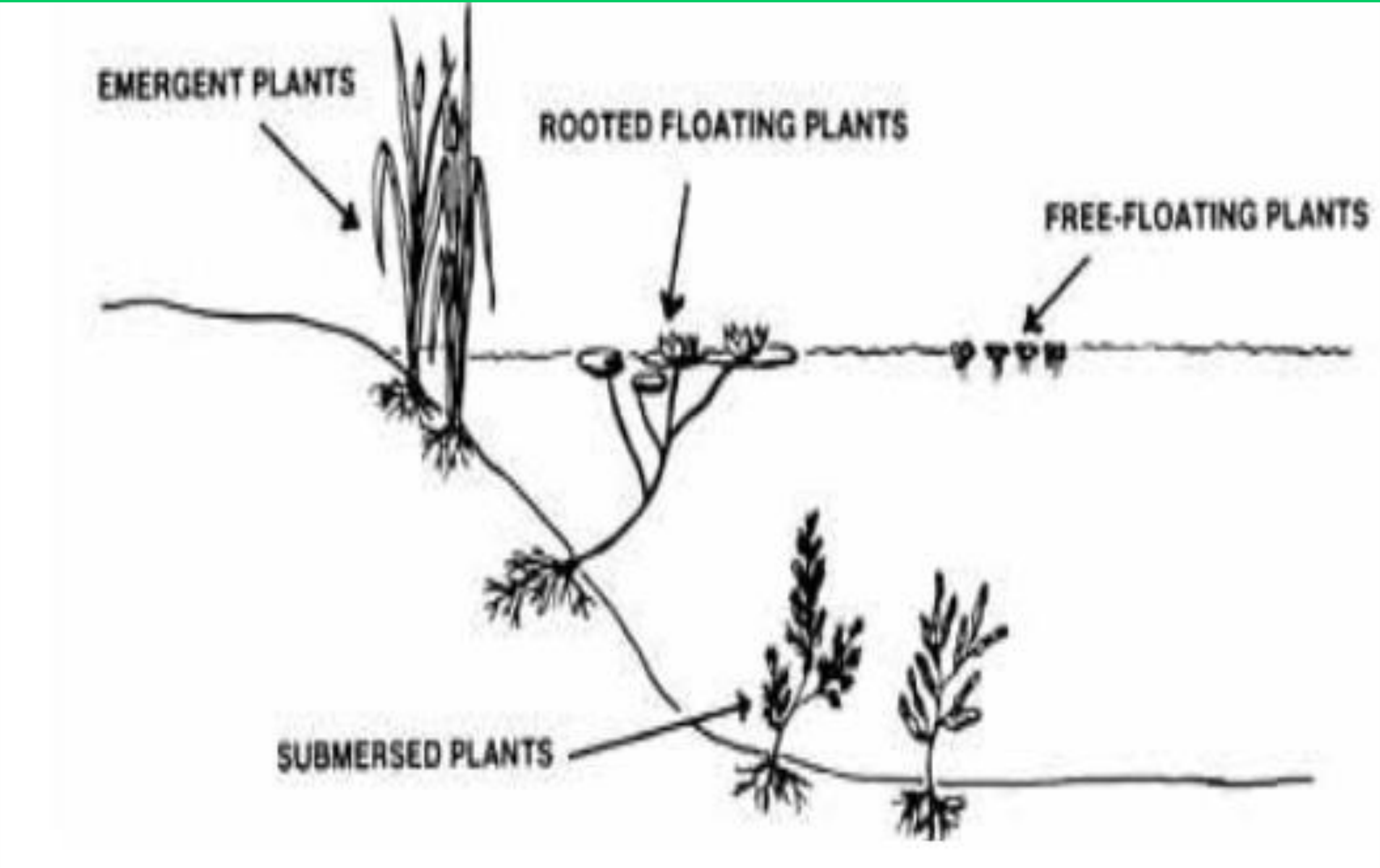
- 5. Help improve water clarity – aquatic plants may act as filters to trap particles & absorb the organic particles in tea-colored (tannic or humic) water.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (d) Types of Macrophytes

- Aquatic & wetland plants (macrophytes) can be classified into 4 groups:
  - emergent,
  - floating-leaved,
  - submersed, &
  - free-floating….

UNIT 4: SOME FRESHWATER SYSTEMS – Lentic Systems: b) shoreline



UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Types of Macrophytes

- a) **Emergent macrophytes** - are rooted in the water bottom with their base portions submersed in the water & their tops out;
- They grow on periodically inundated or submersed soils.

- Most emergents are perennials & common examples:
  - **bulrushes** (*Scirpus* sp.)

Biodiversity – (d) Types of Macrophytes

a) **Emergent macrophytes** -

- **cattails** (**Typha** sp.),
- **reeds** (*Phragmites* sp.),
- **spikerushes** (*Eleocharis* sp.)
- **maidencane** (*Panicum hemitomon*),
- **pickerelweed** (*Pontederia cordata*),
- **duck potato** (*Sagittaria lancifolia*), etc…

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Types of Macrophytes

Figure 4.2. Emergent plant: Bulrush (*Scirpus* spp.)

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Types of Macrophytes

- b) **Floating-leaved macrophytes** are rooted to lake bottom, with leaves that float on the surface of the water…..

- Common examples include:
  - **waterlilies** (*Nymphaea* sp.),
  - **parrot feather** (*Myriophylum* sp),
  - **spatterdock** (*Nuphar advena*. – yellow water lily),

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Types of Macrophytes

Figure 4.3. Free floating plant: ***Trapa natans* & *Lemna minor***

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Types of Macrophytes

b) **Floating-leaved macrophytes**

- **watershield** (Brasenia schreberi),
- *Trapa natans*,
- *Lemma minor*, etc

- Floating leaves are attached to roots or rhizomes with a flexible, tough stem (actually in many cases a leaf stalk).

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Types of Macrophytes

- c) **Submersed macrophytes** grow completely under the water…..

- They're a diverse group & includes:
  - **coontail** (*Ceratophyllum demersum*),
  - **quillworts** (*Isoetes* sp.),
  - **mosses** (*Fontinalis* sp.),
  - **muskgrasses** (*Chara* sp.),
  - **stoneworts** (*Nitella* sp.), etc

c) **Submersed macrophytes**

- Some e.g widgeon-grass, pondweeds, tape-grass, & *Hydrilla* sp cause serious aquatic weed problems.

- Grow rapidly to water surface, & form dense canopies in the upper water column which interfere with use & aesthetics.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Types of Macrophytes

Figure 4.4. Submersed plant: Coontail (*Ceratophyllum demersum*).

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Types of Macrophytes

- d) **Free-floating macrophytes** typically float on or just under water surface with roots in the water & not in the sediment…

- Small ones include:
  - **duckweeds** (*Lemma* spp.),
  - **mosquito** fern (*Azolla* caroliniana),
  - **water meal** (*Wolffia* columbiana), &
  - **water fern** (*Salvinia* spp.).

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (d) Types of Macrophytes

Figure 4.5 Free floating plant: Water hyacinth (*Eichhornia crassipes*)

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Types of Macrophytes

d) **<u>Free-floating macrophytes</u>**

- Larger ones include:
  - **water hyacinth** (*Eichhornia crassipes*..
  - **water lettuce** (*Pistia stratiotes*),
- They're the <u>number one targets for aquatic plant management</u> in several places around the world.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Types of Macrophytes

Figure 4.5 Free floating plant: Water hyacinth (*Eichhornia crassipes*)

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (d) Types of Macrophytes

d) **Free-floating macrophytes**

- They’re are entirely dependent on the water for their nutrient supply.

- Some e.g., water hyacinth have been used in wastewater treatment to remove excess nutrients.

d) **Free-floating macrophytes**

- If nutrient limitation will work for macrophyte management, this is the group for which it will work most.

- They're are also the only aquatic plants not constrained by water depth.

d) **Free-floating macrophytes**

- The location of these plants is at the whim of wind, waves, & current.

- They grow & multiply extremely quickly.
- Others include fragrant waterlily (*Nymphaea odorata*), yellow waterlily (*Nymphaea mexicana*) & American lotus (*Nelumbo lutea*).

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (d) Macrophytes & littoral zone

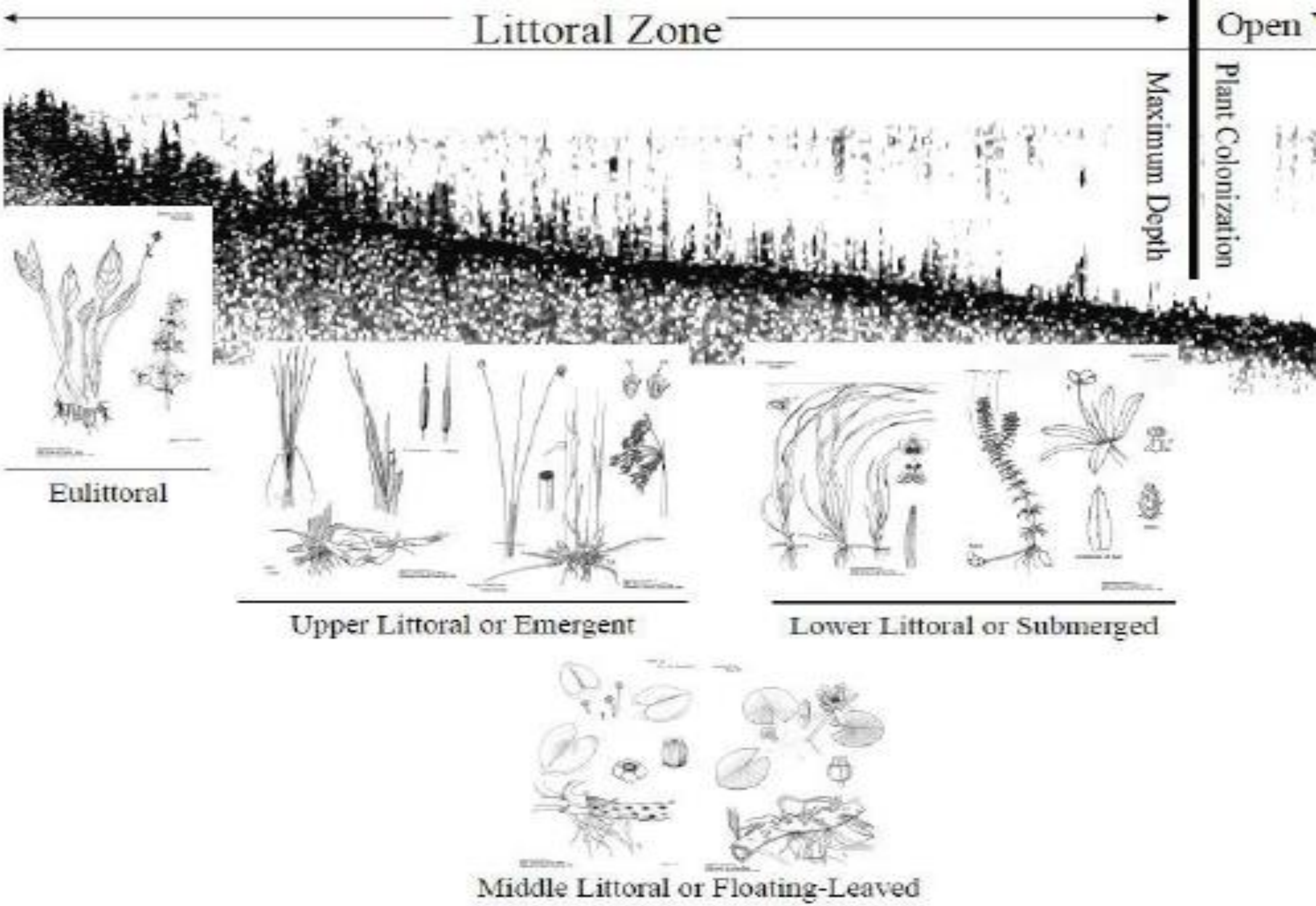
- Rooted aquatic plants inhabit the littoral zone, the interface between dry land & open water of lakes & reservoirs.

- The littoral area can also be defined as the area from the lake’s edge to the maximum water depth where rooted plant growth occurs.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (d) Macrophytes & littoral zone

- The littoral zone has traditionally been divided into 4 distinct transitional zones:
  - **eulittoral zone,**
  - **upper littoral zone,**
  - **middle littoral zone, &**
  - **lower littoral zone**
-



Littoral Zone
Open
Maximum Depth
Plant Colonization
Eulittoral
Upper Littoral or Emergent
Lower Littoral or Submerged
Middle Littoral or Floating-Leaved

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (d) Macrophytes & littoral zone

- iii) The **middle littoral zone** is deeper & is generally dominated by floating-leaved plants & extends lake-ward from the upper littoral zone to water depths of 1 to 3 m.

- iv) The **lower littoral zone** is the deepest zone where most submersed plants are found & extends from floating-leaved plant zone down to the limits of the photic zone.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (e) Protozoans

- Are single-celled heterotrophic eukaryotes found in almost all aquatic habitats.
- Tend to be abundant in waters where organic matter, bacteria, or algae are abundant.
- They are classified based on how they move.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (e) Protozoans

- They feed on detritus, free-living bacteria, fungi, yeasts, algae, & other protozoans in lentic & lotic systems.

- But strictly forms parasitic exist…e.g.;
  - *Ichthyophthirius..*, which causes white pustules on freshwater fish,
  - *Vampyrella..*, which feeds on algae, &
  - *Plasmodium*, causes malaria in humans

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (e) Protozoans

- Some such as the flagellated *Ceratium* & *Peridinium*, can photosynthesize & are often classified with the algae.
- Protozoans that parasitize freshwater phytoplankton & zooplankton may modify their species composition which may eventually affect fish communities. How?

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (f) Rotifers

- Microscopic invertebrates with a wheel-shaped projecting cilia at their anterior end.
- They inhabit a wide range of aquatic habitats but mostly found in freshwaters.
- They form an important part of the zooplankton community of lakes & usually dominate the zooplankton in rivers.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (f) Rotifers

- They are suspension feeders that feed on bacteria & single-celled algae.

- They're preyed on heavily by invertebrates but vertebrate predation is low.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (g) Crustaceans

- Invertebrates with several pairs of jointed legs, a hard protective outer shell, 2 pairs of antennae, & eyes at the ends of stalks.
- Most large zooplankton are crustaceans.
- They also include benthic species like shrimps, crabs, & crayfish.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (g) Crustaceans

- Two groups – cladocerans & copepods are well known because of their abundance, larger size, & ease of preservation compared to the rotifers.

- The **cladocerans** e.g. *Daphnia* (water flea) & *Bosmina* are mostly filter-feeders & feed on single-celled & colonial algae.

UNIT 4: INLAND WATER PLANTS & ANIMALS
Biodiversity – (g) Crustaceans

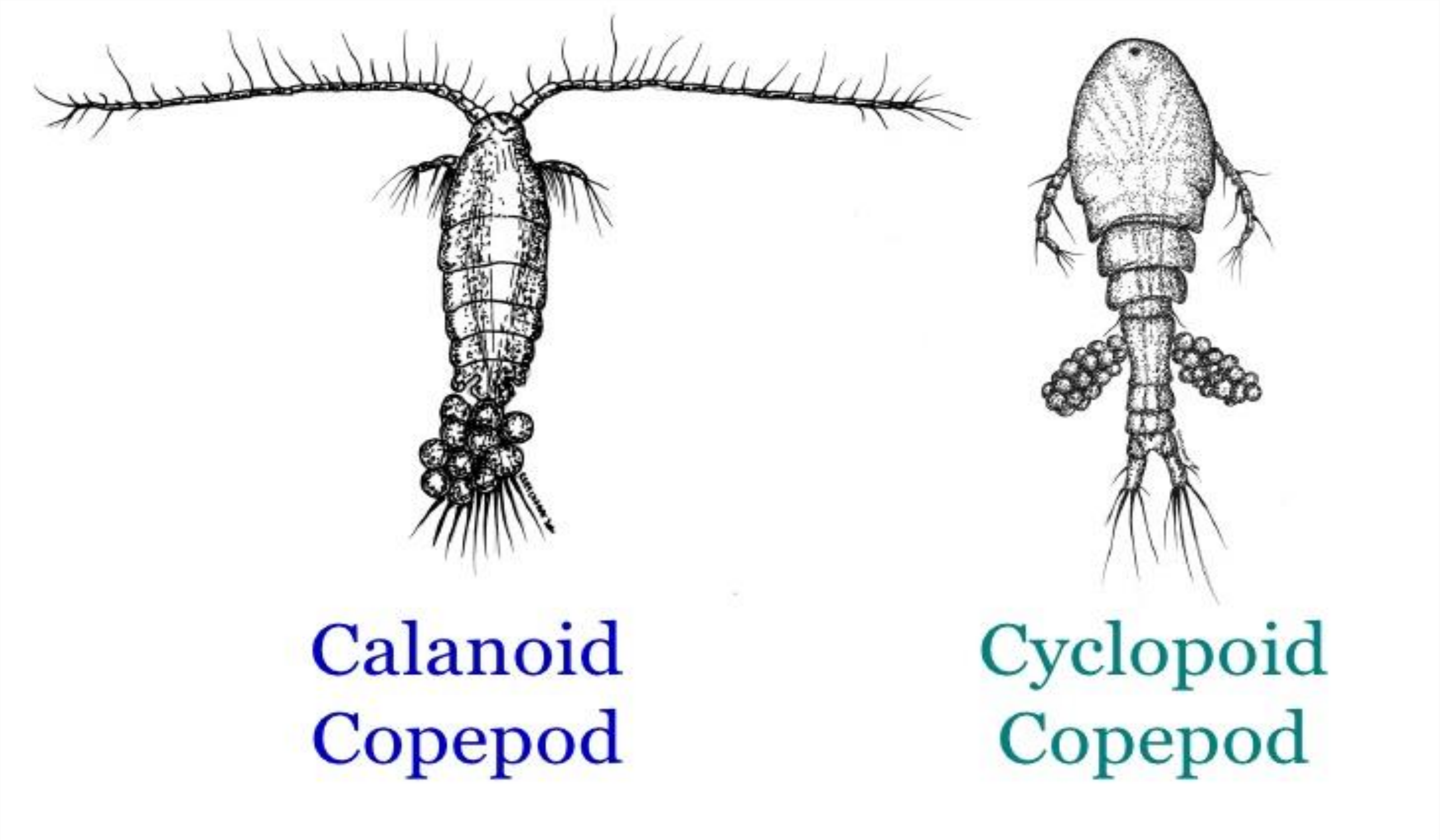
- Invertebrate predation is moderate but vertebrate predation is high.

- The **copepods** consist of the filter-feeding calanoids & the cyclopoids with raptorial feeding but can occasionally filter-feed.

- They also feed on single-celled & colonial algae.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (g) Crustaceans



UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (g) Crustaceans

- Predation by invertebrates is moderate on adults but high on juveniles but vertebrate production is generally low.

- The <u>cladocerans</u>, <u>copepods</u>, <u>rotifers</u>, & <u>protozoans</u> dominate the **zooplankton** of freshwaters.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (h) Aquatic insects

- An arthropod group, are very successful in invading almost all regions of the earth's surface except the marine environment.

- In rivers & streams, aquatic insects dominate the trophic level between primary producers & fish but adults are short-lived aerial forms.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (h) Aquatic insects

- Though most aquatic insect larvae are predaceous, many filter drifting particles or graze detritus, & attached algae.

- Common e.gs include the:
  - mayflies (Empheroptera),
  - stoneflies (Plecoptera),
  - caddis flies (Trichoptera), & the
  - dragonflies (Odonata)

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (h) Aquatic insects

- They're an important part of lake benthos, & emergence of the adults often triggers a frenzy of surface feeding by fish.
- Giant water bugs (Belostomatidae) are large enough to capture small fish, etc.….
- Chironomid larvae with tolerate low O_2 are most widespread of lake benthic insects.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (h) Aquatic insects

Biodiversity – (h) Aquatic insects

- This tolerance means that they may even be found in the anoxic hypolimnion of some mesotrophic & eutrophic lakes.

- In Arctic, **blackfly** (*Aphis*) larvae coat the surfaces of rocks in swift streams but in fast-flowing tropical water, They’re carriers of river blindness, onchocerciasis.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (h) Aquatic insects

- The predatory *Chaoborus* or phantom midge, with its ghostly transparent larvae, is the only major insect member of the plankton.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (i) Worms & Mollusks

- These, like aquatic insects, convert detritus & living plant materials to food for each other or for fish.
- Some e.g. <u>leeches</u> may be predators on large animals or fish.
- Nematode worms are common internal parasites of many aquatic animals.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (i) Worms & Mollusks

- The huge masses of snails found around pond edges can decimate attached algal crops in the same manner as stream insect larvae do.

- Snails serve as hosts for parasitic **schistosomes** responsible for the tropical disease bilharzias & the swimmers itch of temperate climates.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (j) Aquatic insects

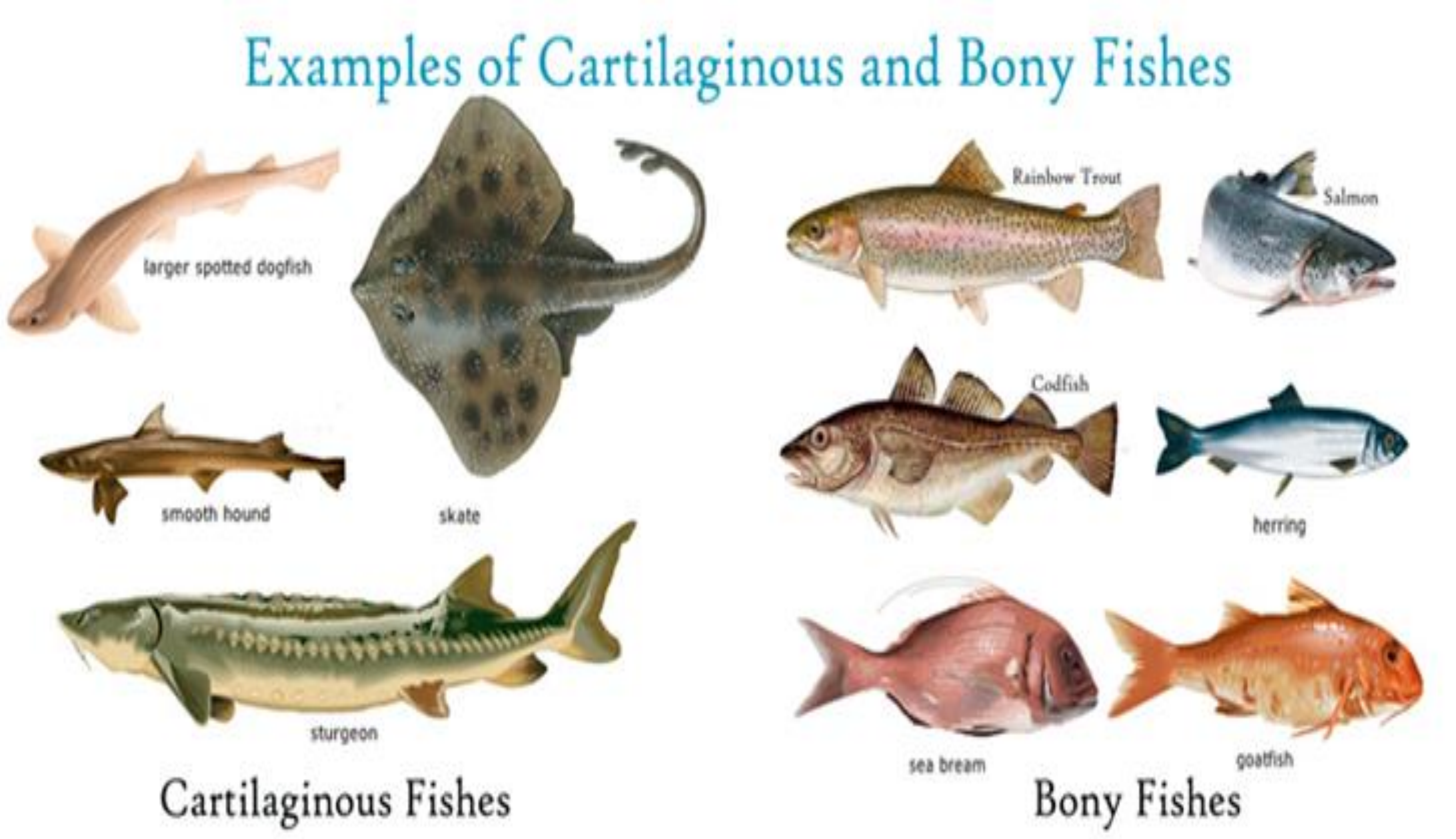
UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (j) Fishes

- Fishes are very diverse & taxonomically divided into 3 major extant classes:
  - Agnatha (cyclostomes, or **jawless** fishes);
  - Chondrichthyes (**cartilaginous** fishes); &
  - Osteichthyes (**bony** fishes)

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (j) Aquatic insects



UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (j) Fishes

- The cyclostomes are jawless & the most primitive & e.gs are lampreys & hagfishes.
- Freshwater & marine lampreys lack biting jaws & are adapted to life as parasites or scavengers.
- Adult sea lamprey lives in sea but return to freshwater to spawn (<u>anadromous</u>).

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (j) Fishes

- Chondrichthyes includes sharks & their relatives & there few freshwater examples.

- Osteichthyes are the most advanced fishes

- Most have gas bladders that make them less dense than water so that they spend less energy in swimming compared to heavy fishes like the sharks.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (j) Fishes

- An important family of Osteichthyes is the Cichlidae, which includes many species of *Tilapia* an important source of protein in Africa, South, & Central America, & India.

- In oceans, Pacific & Atlantic salmons – shad & smelt – are anadromous & feed in fertile ocean areas & grow to large adults, & then return to freshwaters to spawn

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (j) Fishes

- In doing so, the Pacific salmon which die after spawning, carry nutrients in their bodies from ocean to unproductive lakes & streams where their progeny will hatch.

- On the other hand, fish that live in freshwater but must go to the ocean to spawn are catadromous.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (j) Fishes

- Some fishes undertake regular migrations in large lakes & are called potamodromous equivalent to oceanodromous fishes who undertake regular migrations in the ocean.

- Amphidromous fishes do migrations from freshwater to ocean water & vice versa for purposes other than breeding at some stage of their life cycle.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (j) Fishes

- Anadromous & catadromous fish which move between fresh & ocean waters, are equipped metabolically to adjust their salt balance or osmoregulate.

- Estuaries usually provide the transitional zone for a more gradual adjustment to salinity changes.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (j) Fishes

- Freshwater fish entering salt water must be able to eliminate salts effectively & efficiently to remain hypotonic to their environment.,

- But saltwater fish entering freshwater must conserve the salts in their body fluids to remain hypertonic to their new less saline habitat.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Biodiversity – (j) Fishes

- Except for the sharks & their allies, which maintain a high urea concentration in the blood, the bony fish balance salt uptake & loss with their gills & kidneys.

- Some additional salt loss occurs in marine fish through their faeces.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Bio – (k) Amphibians, reptiles, birds, mammals

- **Amphibians** need water in their early life stages & must return to water to reproduce..

- **Reptiles** are able to leave water since their amniotic eggs do not need external water & their impervious skin retains body fluids in terrestrial & even desert environments.

- But many reptiles remain closely associated with water.
- Small snakes are common predators of fish & amphibians in weedy ponds & streams.
- Among more dramatic examples of aquatic snakes is the Amazonian giant anaconda.

- E.gs of major carnivorous reptiles in tropical rivers & lakes are:
  - the caimans of South America,
  - crocodiles, &
  - alligators

- Though they feed mainly on fish, large ones also take small to moderate-sized mammals, including an occasional human.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Bio – (k) Amphibians, reptiles, birds, mammals

- Wetlands are traditional nesting & feeding grounds for **waterfowl**.

- They show a great variety of feeding activities & adaptations, since they feed at every level of the aquatic food chain.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Bio – (k) Amphibians, reptiles, birds, mammals

- Herons & egrets for e.g., stalk their prey on long legs while the tropical fish eagle, fish hawk, & osprey take living fish when they venture near the surface.

- Among the most interesting avian fish predators are the kingfishers & the Arctic tern (*Sterna paradisaea*) that hover over the water & dive to capture their prey.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Bio – (k) Amphibians, reptiles, birds, mammals

- Some birds e.g. flamingos strain algae out of water while other birds peck along the shore in search of snails & small crustaceans.

- Perhaps the most truly aquatic birds are the **grebes** & **cormorants** which obtain food by directly pursuing & capturing fish under water.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Bio – (k) Amphibians, reptiles, birds, <u>mammals</u>

- The cormorants literally fly through the water.

- There are many **mammals** groups in inland waters e.g. <u>beavers</u>, <u>muskrats</u>, <u>otters</u>, etc.

- Beavers are limnologically important as they create their own aquatic environment.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Bio – (k) Amphibians, reptiles, birds, mammals

- Their small ponds often provide the only relatively still water in upland areas.

- Though seals are usually considered marine, endemic populations of the freshwater seal – *Phoca sibirica* – exist in Lake Baikal.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Bio – (k) Amphibians, reptiles, birds, mammals

- For larger mammals, hippopotamus (*Hippopotamus amphibius*) play a role in freshwaters of African lakes & marshes

- They consume high quantities of terrestrial grasses around the lake, fertilize the nearshore waters with their faeces, & keep the waterways open in the shallow portions of their habitat.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Bio – (k) Amphibians, reptiles, birds, <u>mammals</u>

- During periods of drought/overpopulation they may devegetate the shore zones & accelerate erosion.

- They are sometimes to be even more dangerous than the crocodiles in terms of their aggressiveness towards humans.

UNIT 4: INLAND WATER PLANTS & ANIMALS

Bio – (k) Amphibians, reptiles, birds, mammals

- Elephants, Cape buffalo, & bison make a great deal use of water, & in some places some ponds owe their origins to their wallowing.

UNIT 5

COMMUNITY STRUCTURE & DYNAMICS IN AQUATIC ECOSYSTEMS

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS IN AQUATIC ECOSYSTEMS: ILOs –

To **review**:

- **Knowledge** about community structure & organization in natural aquatic ecosystems;

- **Knowledge** about energy & material flows in aquatic ecosystems;

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS IN AQUATIC ECOSYSTEMS: ILOs –

To **review**:

- **Concepts** of trophic levels & pyramids in aquatic ecosystems;
- **Knowledge** about population growth dynamics in aquatic ecosystems;
- **Knowledge** & **understanding** about the various ways aquatic communities interact.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS IN AQUATIC ECOSYSTEMS: introduction –

- Key factors affecting organisms in aquatic ecosystems
  - Physical
  - Chemical
  - **Biological**

- Concept of ecology – action, **reaction**, **coaction**

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS IN AQUATIC ECOSYSTEMS: introduction –

- Concept of **ecological hierarchies**
  - species,
  - populations,
  - communities,
  - ecosystems

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Energy & material flow –

- Ecosystems have a source(s) of **energy** & **nutrients** & maintains a <u>relationship</u> with its **abiotic** & **biotic** parts that enable efficient energy & nutrient cycling.

- A balance in these processes lead to a **sustainable ecosystem**.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Energy & material flow –

- ..i.e. able to maintain its basic **structure** & **function** even in when disturbances occur

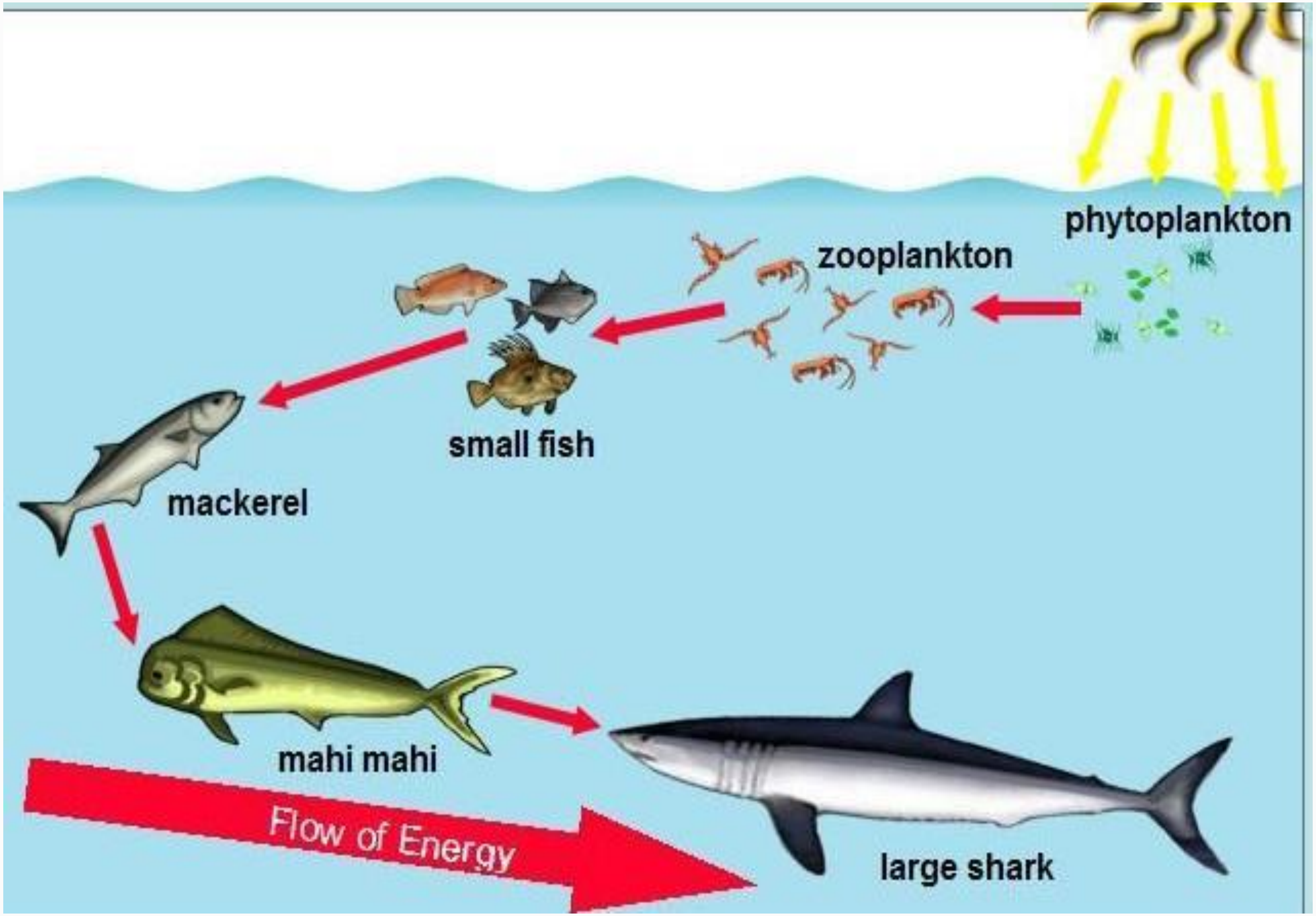
- Energy **acquisition**, **transformation** & **use**
  - Autotrophs & heterotrophs (consumers).
  - Energy & material transfer between **abiotic** & **biotic** environment.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure –

- Concept of **trophic structure** & **trophic levels**.
- Flow of energy & matter in aquatic system can be traced by observing who makes food & who eats it i.e. trophic relationships.
- Concept of **food chains** & **food webs**.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

:Trophic structure –



UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Trophic structure – challenges of trophic level

- **Limitations** of food chain concept:
  - Most ecosystems have a number of <u>different autotrophs</u>.
  - <u>Many animals eat more than just one kind of food</u>.
  - <u>Many change their diet</u> as they get older & larger.

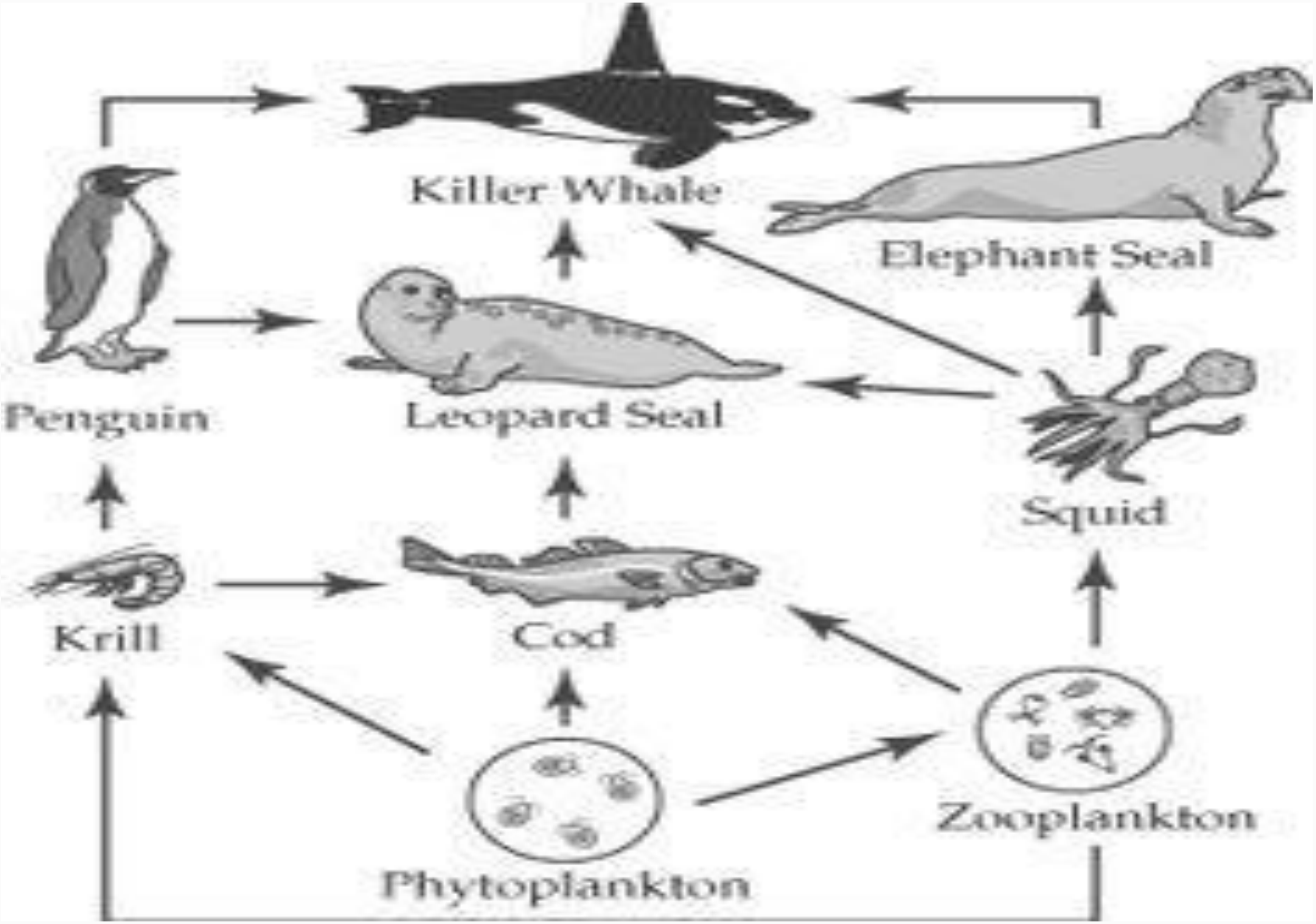
UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Trophic structure –aquatic trophic level

- The concept of **food webs**:
  - complex of interwoven food chains & not a simple linear one of food chains…

- E.g.s of biotic energy transmission pools:
  - Primary producers?
  - Primary consumers?
  - Secondary consumers?
  - Tertiary consumers?

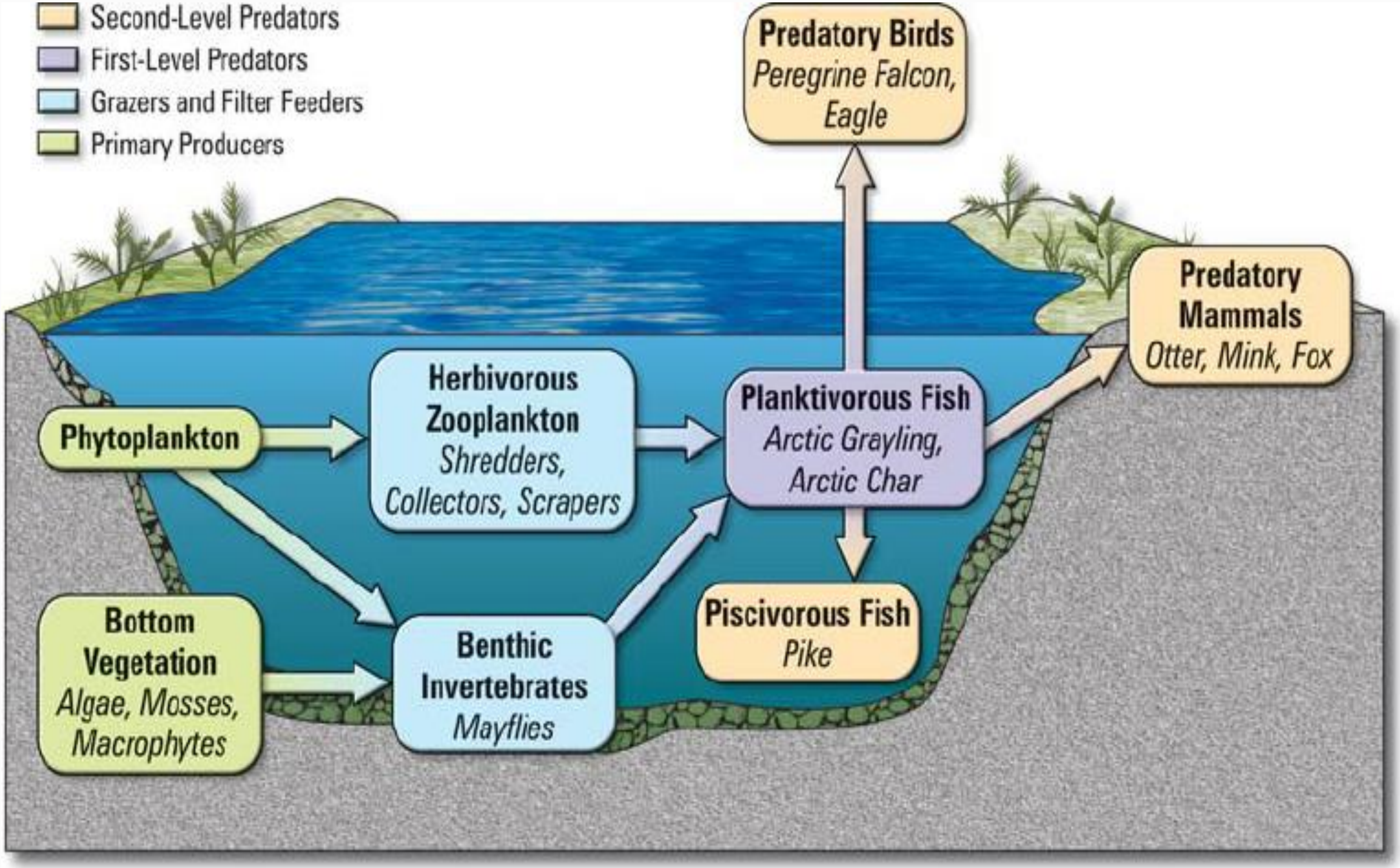
UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

:Trophic structure –



UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

:Trophic structure –



UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – aquatic trophic pyramids

- The concept of **ecological pyramids**.

- Types of ecological pyramids:
  - Numbers
  - Biomass
  - Energy

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Trophic structure – aquatic trophic pyramids

- The concept of trophic levels connotes that whatever is produced at a particular trophic level is passed on to the next level.

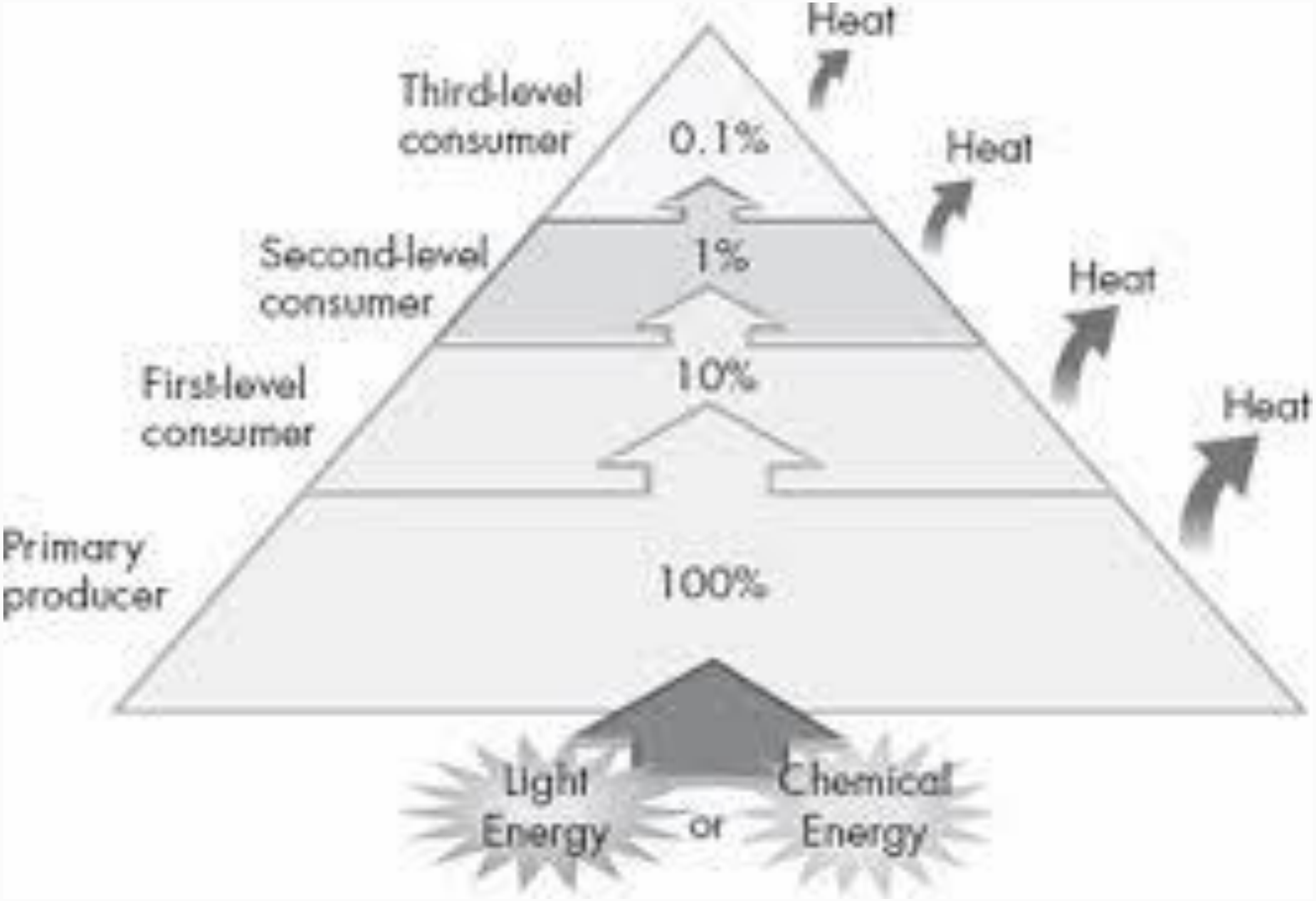
- But, that is not so e.g.
  - most of what is produced in a trophic level is used up by the activities of the organisms at that trophic level (**?**).

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – aquatic trophic pyramids

- some energy & organic matter are lost as waste.

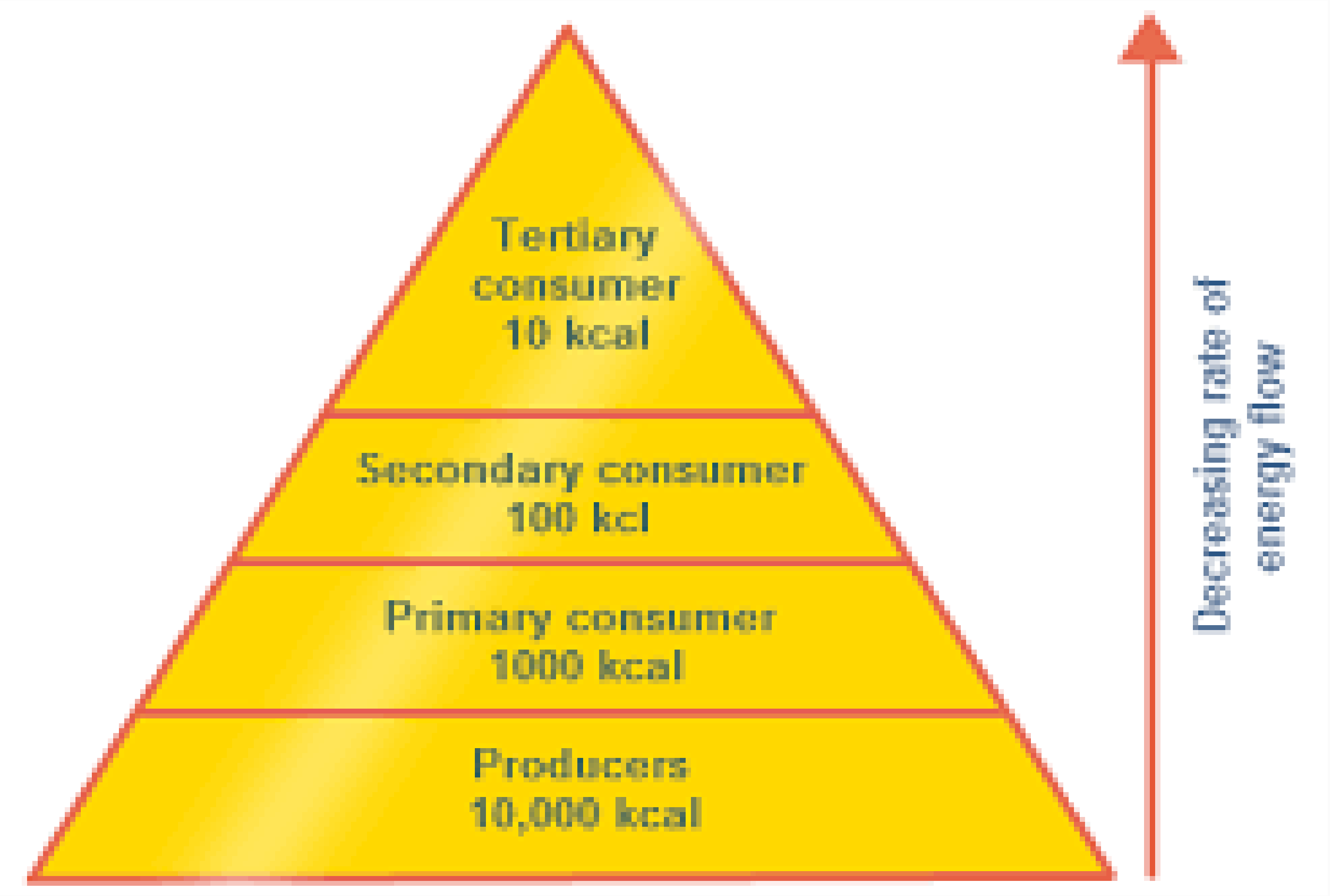
- …only about 10 % of what is produced, on average, is passed from a lower trophic level to the next higher level.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – aquatic trophic pyramids



UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

:Trophic structure – aquatic trophic pyramids



UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – aquatic trophic pyramids

- Hence, there are fewer primary consumers than producers, & fewer secondary than primary consumers.

- E.g., to support a given biomass of primary consumers, primary producers must make about 10 times as much living tissue.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Trophic structure – aquatic trophic pyramids

- For instance, to support **1000 g** zooplanktons, about **10,000 g** of phytoplankton is needed for consumption.

- In turn, only about **1/10th** of the primary consumer's biomass (i.e. **100 g**) will make it to the secondary consumers….

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – aquatic trophic <u>pyramids</u>

- Hence, decreasing energy at each level limits how many levels there can be.

- This is because eventually, the system just <u>runs out of energy</u>.

- Hence, most aquatic food webs have 3-4 trophic levels.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

:Trophic structure – aquatic trophic pyramids

NB: Inverted pyramids –

- Some aquatic systems have inverted pyramids of biomass.

- E.g. in a planktonic system dominated by small organisms, turnover of phytoplankton at the primary level is very rapid.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

:Trophic structure – aquatic trophic pyramids

NB: Inverted pyramids –

- But there is rapid consumption of these by zooplankton so quickly that they are not able to develop large population sizes.

- Hence, rapidly-reproducing phytoplankton can support **heterotrophs** much larger in biomass & more numerous than them.

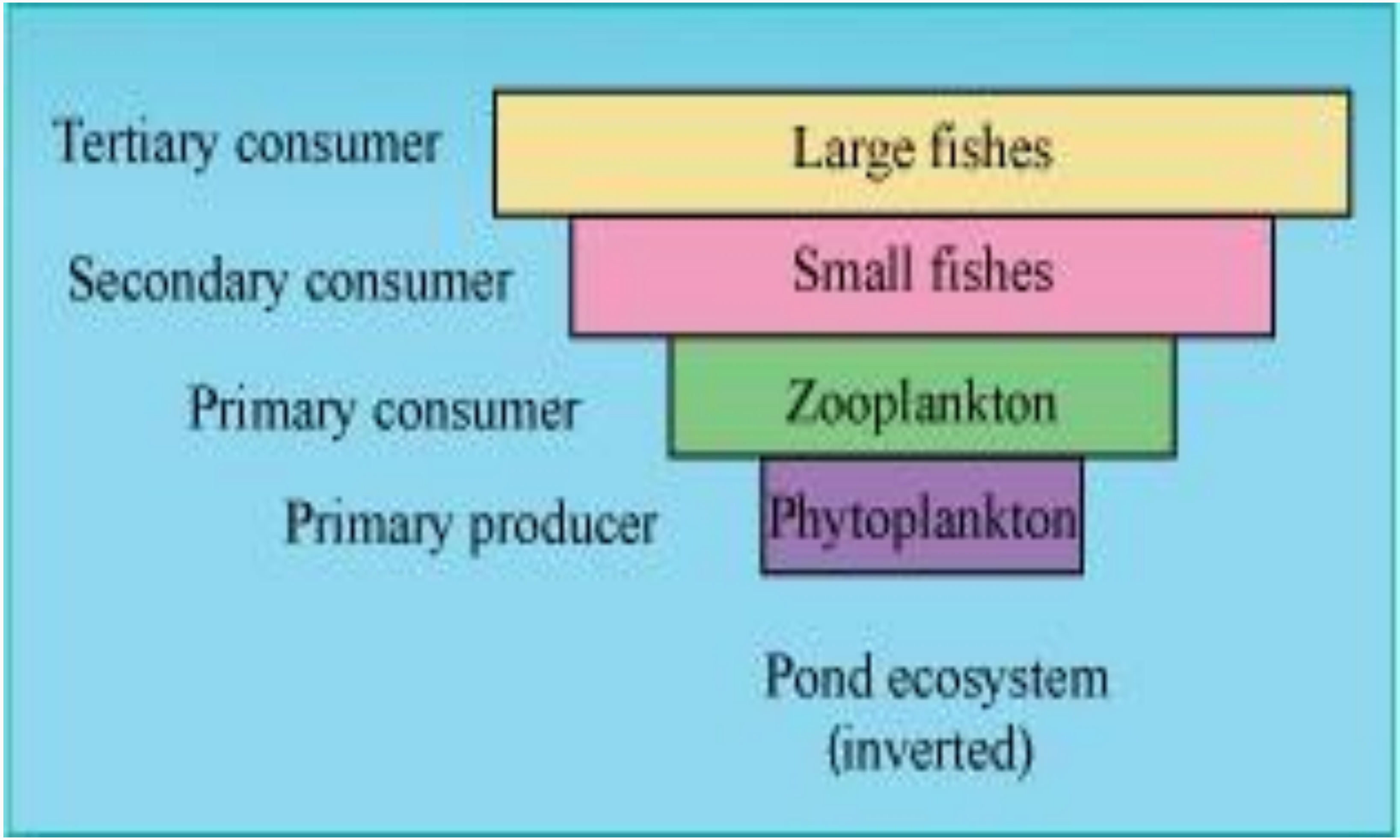
UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – aquatic trophic pyramids

NB: Inverted pyramids –

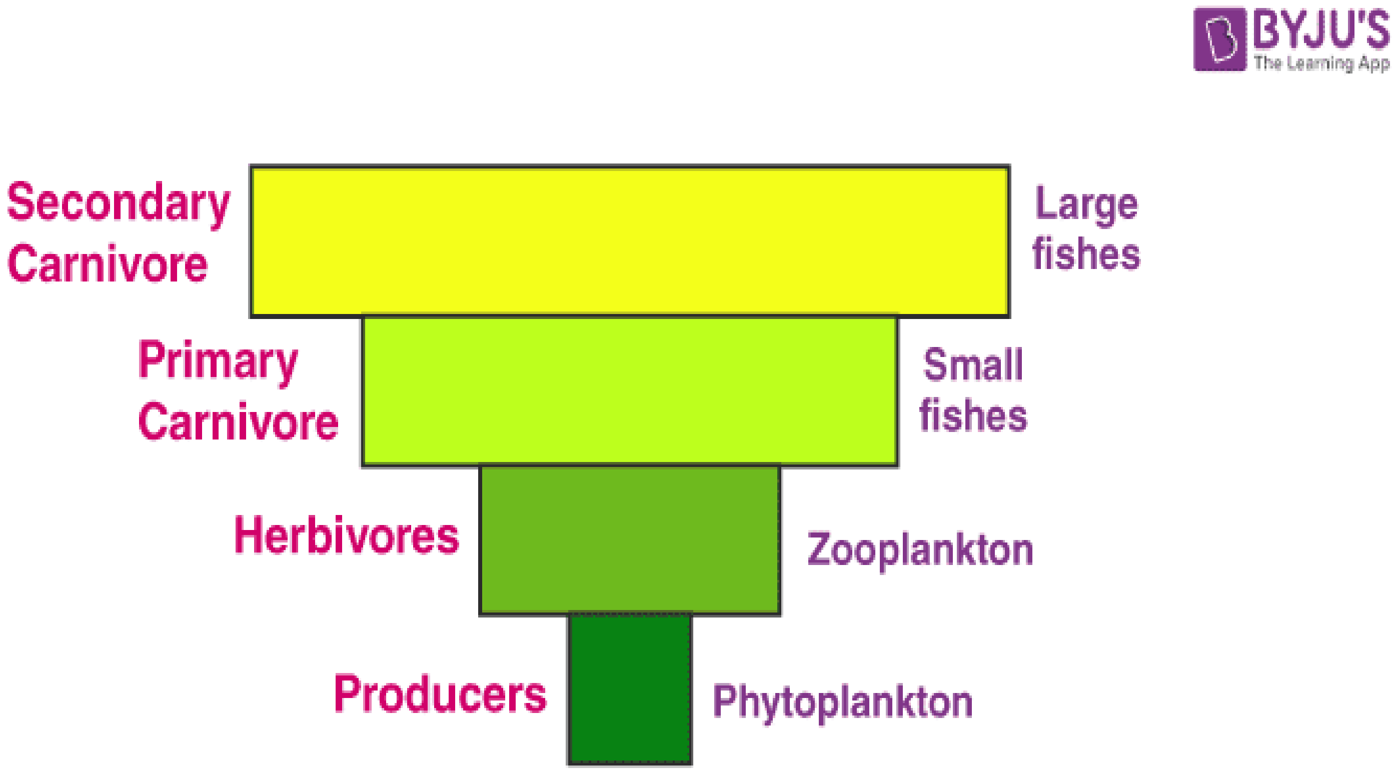
- This results in an inverted pyramid where phytoplankton biomass is less than that of the zooplankton at any particular time.....

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

:Trophic structure – aquatic trophic pyramids



UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – aquatic trophic pyramids



Inverted pyramid of biomass for marine ecosystem

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – aquatic trophic pyramids

- As noted, some organic matter is lost as waste instead of moving through a food web of herbivores & predators.
- But this material isn't lost to the ecosystem.
- Bacteria, fungi & other decomposers break them into their original parts – CO_2, H_2O, & nutrients – a process = **mineralization**.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

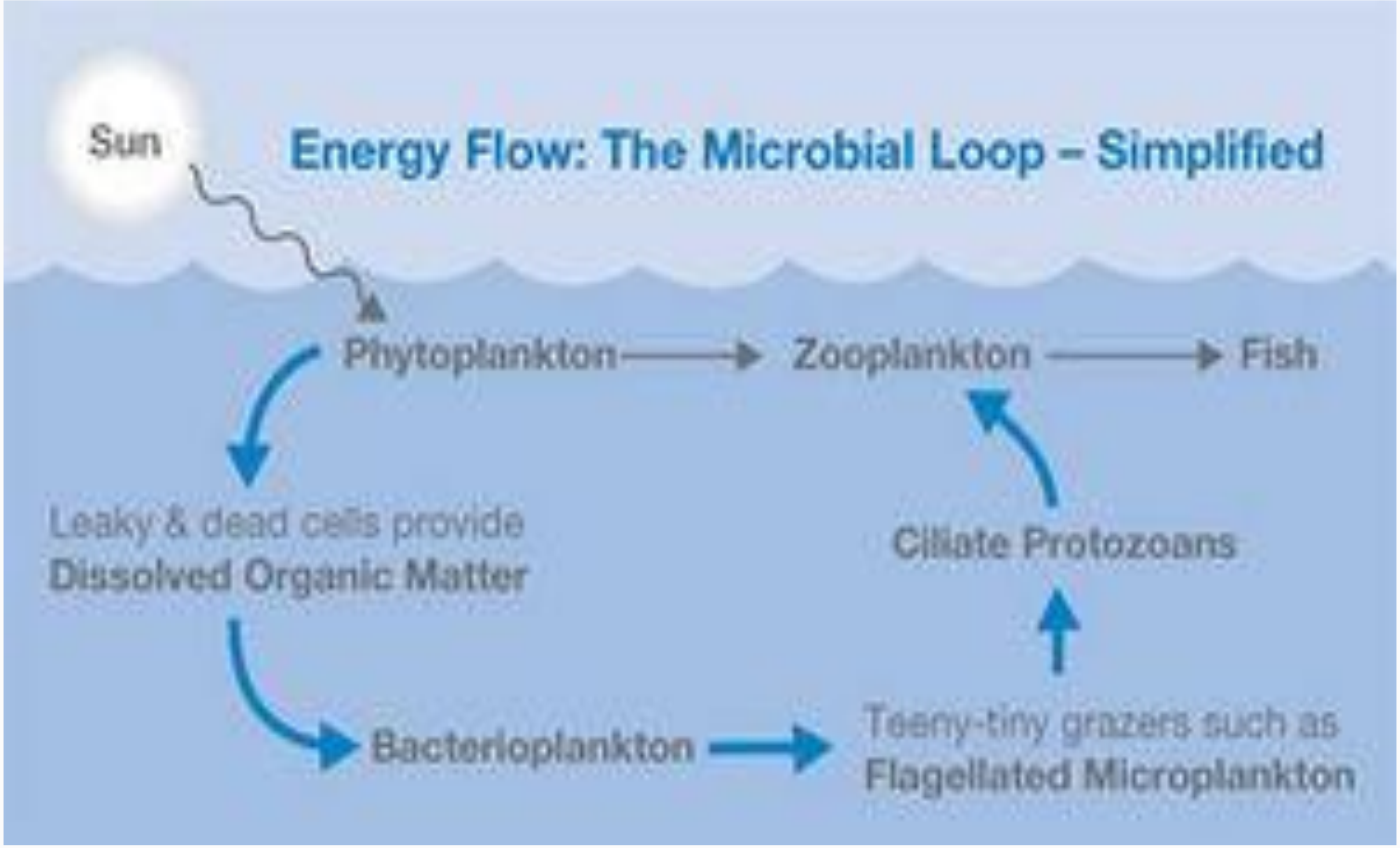
:Trophic structure – aquatic trophic pyramids

- Together, decomposers & dead organic matter are called **detritus**…
- …an important energy pathway in aquatic ecosystems as food for many organisms.
- This channels the organic matter back into the food web.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – aquatic trophic pyramids

- **NB**: The **microbial loop** describes a trophic pathway, in aquatic systems…
- ..where DOC is returned to higher trophic levels by incorporation into bacterial biomass, & then linked with classic food chain of phytoplankton-zooplankton-nekton.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – aquatic trophic pyramids



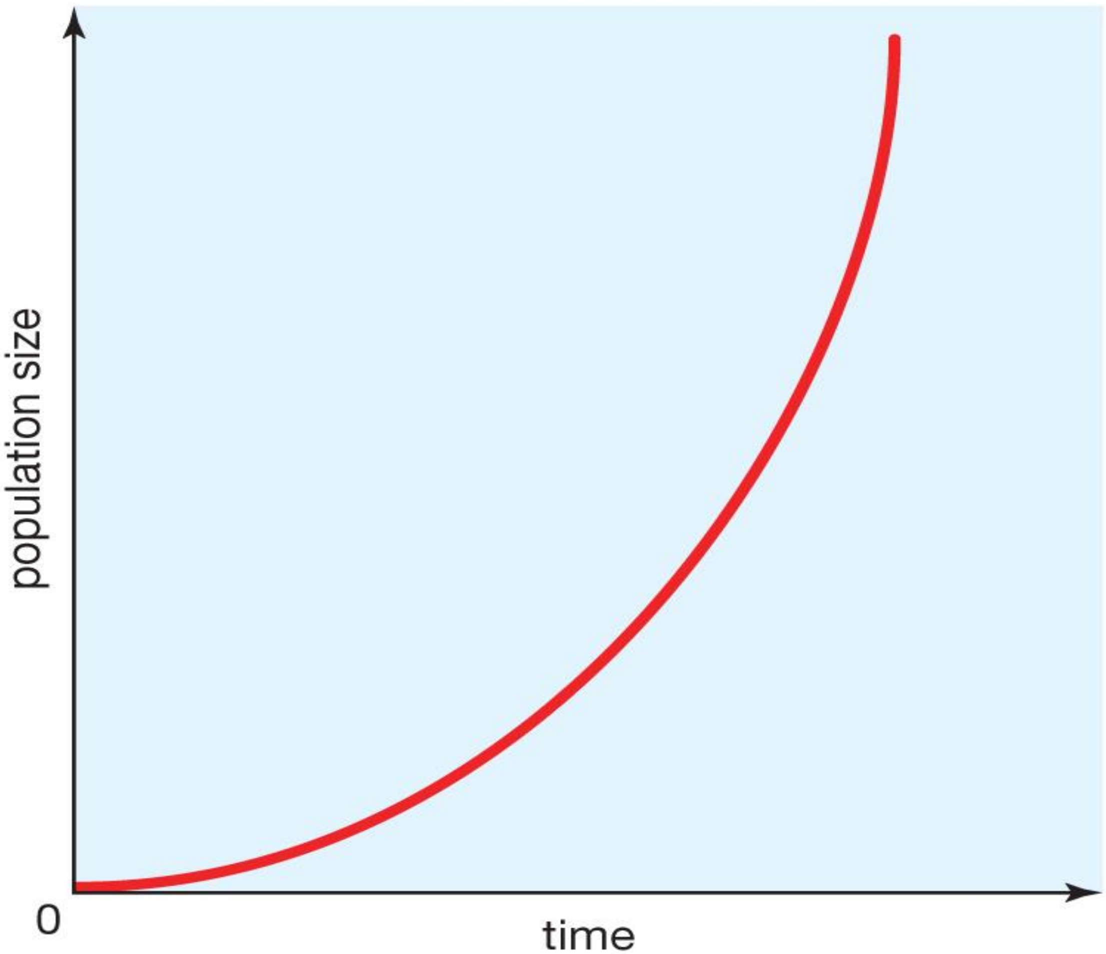
Recap

- Ecology
- Ecological hierarchies
- Energy & material flow in aquatic ecosystems
  - Abiotic & biotic components
- Trophic structure, food chains & food webs
- Ecological pyramids - #s, biomass, energy
- Nutrient regeneration through mineralization
- Concept of microbial loop

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – how populations grow

- When conditions of existence are right, organisms can produce more than it takes to replace themselves.
- This may result in population explosion as population may increase every generation.
- If unchecked any species can grow to cover the earth in a relatively short time…

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – how populations grow



UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Trophic structure – how populations grow

- But, both <u>predictable</u> & <u>unpredictable</u> factors often act to regulate such growth.
- Also some mechanisms limit population growth even if abiotic env’t doesn’t change:
- E.g. overcrowding induces <u>slow growth rate</u> in some aquatic animals or <u>stop reproduction</u>.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Trophic structure – how populations grow

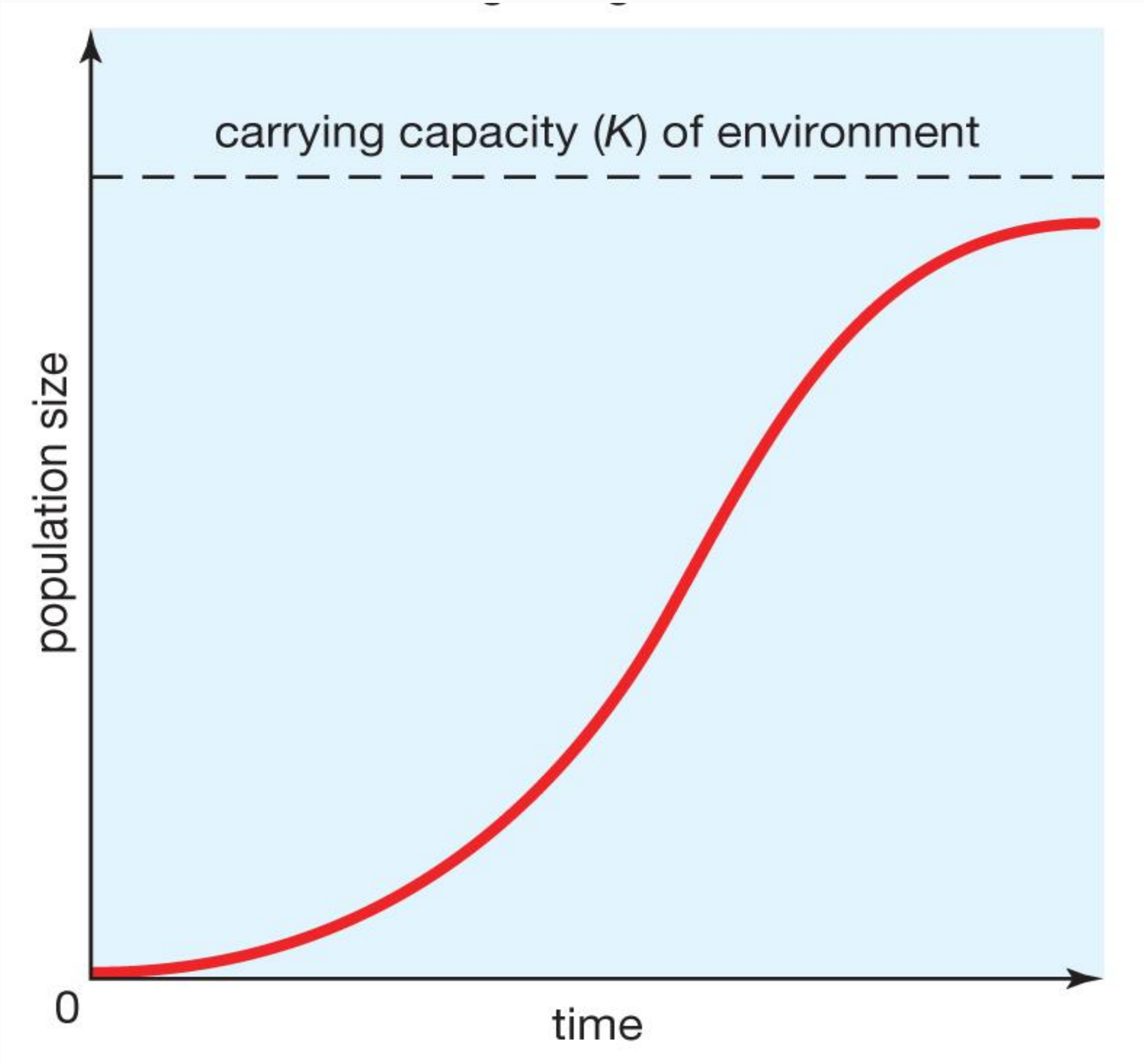
- Fighting & <u>cannibalism</u>.
- Attraction of <u>natural enemies</u>.
- Fast <u>disease</u> spread in crowded conditions.
- Pollution of env’t with <u>waste</u> that limit growth.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Trophic structure – how populations grow

- Thus, as populations increase, **resources** (e.g. space, food, etc) are used up.

- Eventually, there are just not enough resources to support any more individuals & the population levels off …..

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – how populations grow



UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Trophic structure – how populations grow

- Organisms use many different resources & a lack of any adversely affects them.
- A **limiting resource** is one whose short supply prevents the optimal growth.
- Because of the **drain of resources** or other effects of **crowding**, populations do not grow forever.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Trophic structure – how populations grow

- As the size of the population increases, its growth rate slows down.
- So, the population is **self-regulating** i.e. its growth rate depends on its own numbers.
- Whiles **abiotic factors** e.g. weather affects populations of all sizes, self-regulation only acts when population is large.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Trophic structure – how populations grow

- As resources run out, there are not enough to go around.
- Individuals vie for resources left resulting in **competition** where one organism uses resource at the expense of another.
- Those who compete successfully survive to replace themselves by reproducing.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS.. :Trophic structure – how populations grow

- Unsuccessful competitors don’t reproduce successfully & eventually disappear.
- Nature favours those best suited to env’t & due to this **natural selection**, populations are a little better adapted each generation.
- In other words, it **evolves**.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
:Trophic structure – ways species interact

- Aquatic organisms may have strong effects on each other & such interactions affect community organization.

- They compete for resources with members of their own species (**intra-specific**) & members of other species (**inter-specific**).

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – ways species interact: competition

- This is a major organising force in aquatic ecosystems e.g. dolphins, sharks, & seabirds all eat same type of ocean fish.
- Competition can be direct or indirect.
- When 2 species use the same **scarce** resource, the 2 must compete as if they were members of the same population.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – ways species interact: competition

- One of the 2 spp almost always tends to be a little better at the competition.

- If the 2 species eat exactly the same type of food for then one of the 2 will be a little better at obtaining it.

- Unless something interferes, the inferior competitor loses out.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – ways species interact: <u>competition</u>

- When this happens, the losing species have to **emigrate**, or **die** & competitively superior species takes over.

- When one species eliminates another by out-competing it in this "head to head" way, **competitive exclusion** is said to occur.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – ways species interact: <u>competition</u>

- Sometimes a superior competitor is prevented from excluding poorer one for e.g., by changing env't.

- Thus, when conditions are <u>variable</u>, neither species is able to exclude the other (e.g. **contemporaneous disequilibrium hypothesis** – paradox of the plankton).

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – ways species interact: competition

- Species also avoid exclusion if they share limiting resource, by specializing on just part it (**character displacement**).

- E.g., 2 species of fish that eat seaweeds can divide the resource by specializing on different types of seaweeds/different parts of it.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
Trophic stx – ways species interact: competition

- Also, organisms that use same resources develop spatial & temporal separation staying out of each others way.

- This sharing of the same resources at different places & times is called **resource partitioning**.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – ways species interact: competition

- In other words, species that might others competitively exclude each other coexist by resource partitioning.
- But resource partitioning & character displacement have their **price**.
- By specializing, each species gives up some of the resource.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – ways species interact: competition

- With fewer resources available, the size of the population tends to be smaller.
- But, the species might be able to use the resource more efficiently by been a **specialist** than if it were a **generalist**.
- So it must find the right balance between specialization & generalization.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: eating each other

- Species do not always compete for resources but sometimes they use each other as the resource.
- i.e., they eat one another – animals that eat other living organisms are **predators** & the one that gets eaten are called the **prey**.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
Trophic stx – species interact: eating each other

- Predator is reserve for **carnivores** – animals that eat animals, a special case of which is herbivory, where animals eat plants (**herbivores**).

- Predation obviously affects the individual eaten & the prey population by reducing their number.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: eating each other

- The relationship between the prey & the predator is **not unidirectional**, however.
- E.g. if bad weather or disease wipes out the prey, the predators will suffer.
- Prey #s may also decline if there are too many predators or predators eat too much.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: eating each other

- In this case the predator population starts to decline, having used up its food supply.
- The more successful an individual predator is at catching its prey the better its chances are of surviving to reproduce.
- So natural selection favours the most efficient predators in the population.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: eating each other

- In the aquatic env't, some of the ways predators get prey include;
  - **being swift** & **powerful** -e.g. tunas, whales
  - **being sneaky,**
  - **using lures (anglerfishes),**
  - **drilling through shells (snails), &**
  - **eating prey from inside (slime eels)**
  - **climbing inside**, etc.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: <u>eating each other</u>

- Natural selection also favours prey that are more successful at getting away with adaptations such as;
  - **been fast** & **elusive,**
  - **use of camouflage** (cryptic, disruptive)**,**
  - **possession of defensive structures,**
  - **been distasteful**,
  - **production of toxins**,
  - **mimicry** (mullerian or batesian) etc.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
Trophic stx – species interact: <u>eating each other</u>

- Thus, there is a continual interaction between predators & preys with each trying to overcome each others defences.

- This interplay of predator & prey evolving in response to each other is called **coevolution**.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
Trophic stx – species interact: living together

- Coevolution becomes even more important when species interact more intimately.
- Members of different species may live in very close association, even with one inside another.
- Such close relationships are called **symbiosis**, meaning "living together".

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
Trophic stx – species interact: <u>living together</u>

- It refers to any type of a close & long-term interaction between 2 different biological organisms.

- It may be
  - **Mutualistic** (obligate or facultative),
  - **commensalistic**, or
  - **parasitic**

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

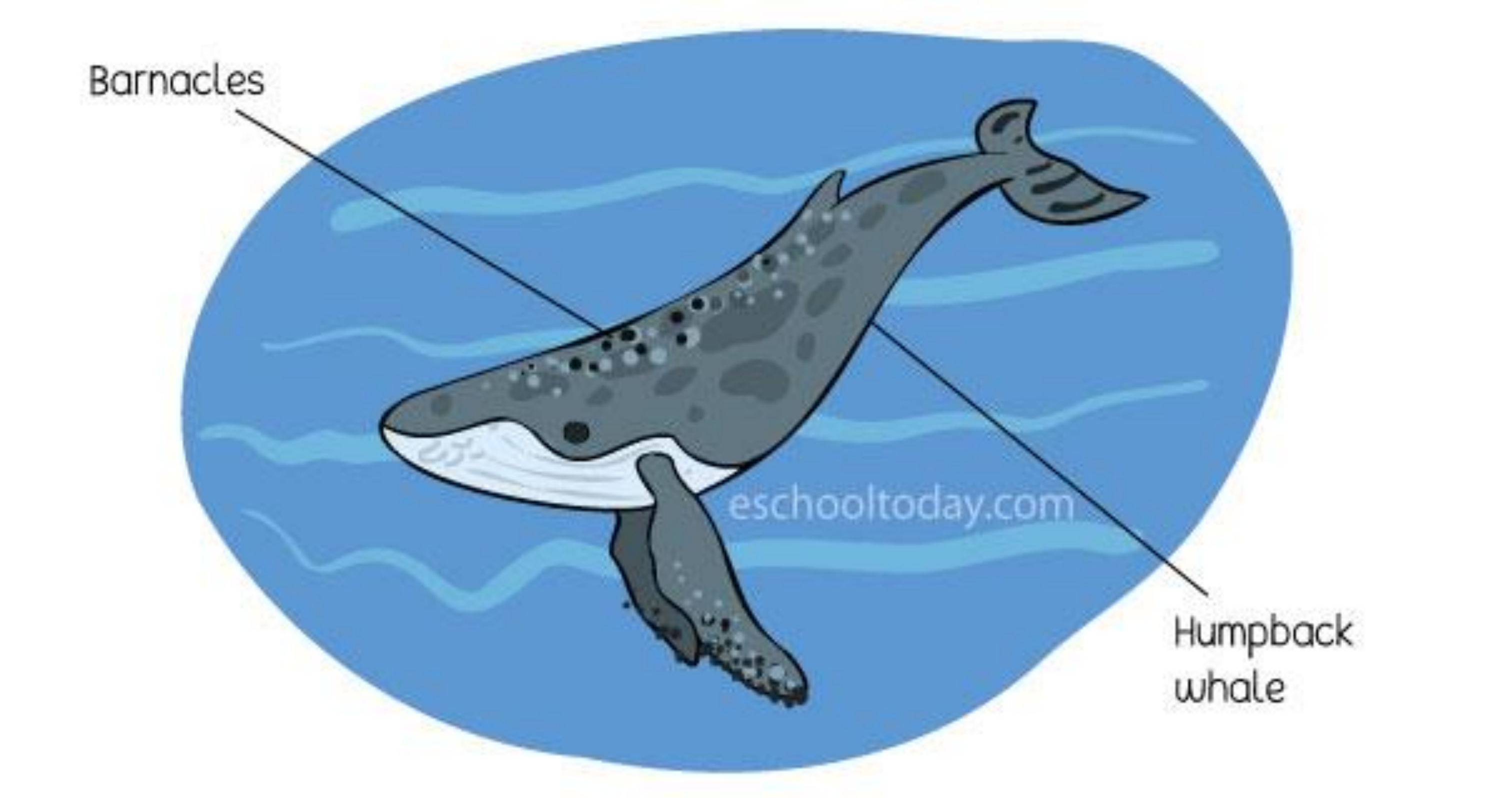
Trophic stx – species interact: living together

- In a symbiotic relationship, the smaller partner is referred to as the **symbiont** & the larger one the **host**.

- In **commensalism**, one species some benefits without affecting the other species one way or the other.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
Trophic stx – species interact: living together

- E.g., certain barnacles live only on whales where they get a place to live & a free ride.



UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: living together

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: <u>living together</u>

- They feed by filtering water, & the whale is neither harmed nor helped by them.

- A 2nd e.g. is the association between the **pilot fish** (*Naucrates ductor*) & **shark** where the pilot fish <u>dines on the scraps</u> coming from the shark's meal, etc….

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: <u>living together</u>

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: living together

- But, sometimes symbionts benefit at the expense the host & this is **parasitism**.
- E.g. the giant tapeworm that lives in the guts of whales is considered a parasite since it gets food & shelter from the host.
- In the process, they may weaken their whale hosts.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: living together

- Parasitism is the most common type of symbiotic association.

- But not all symbiotic relationships are one-sided.

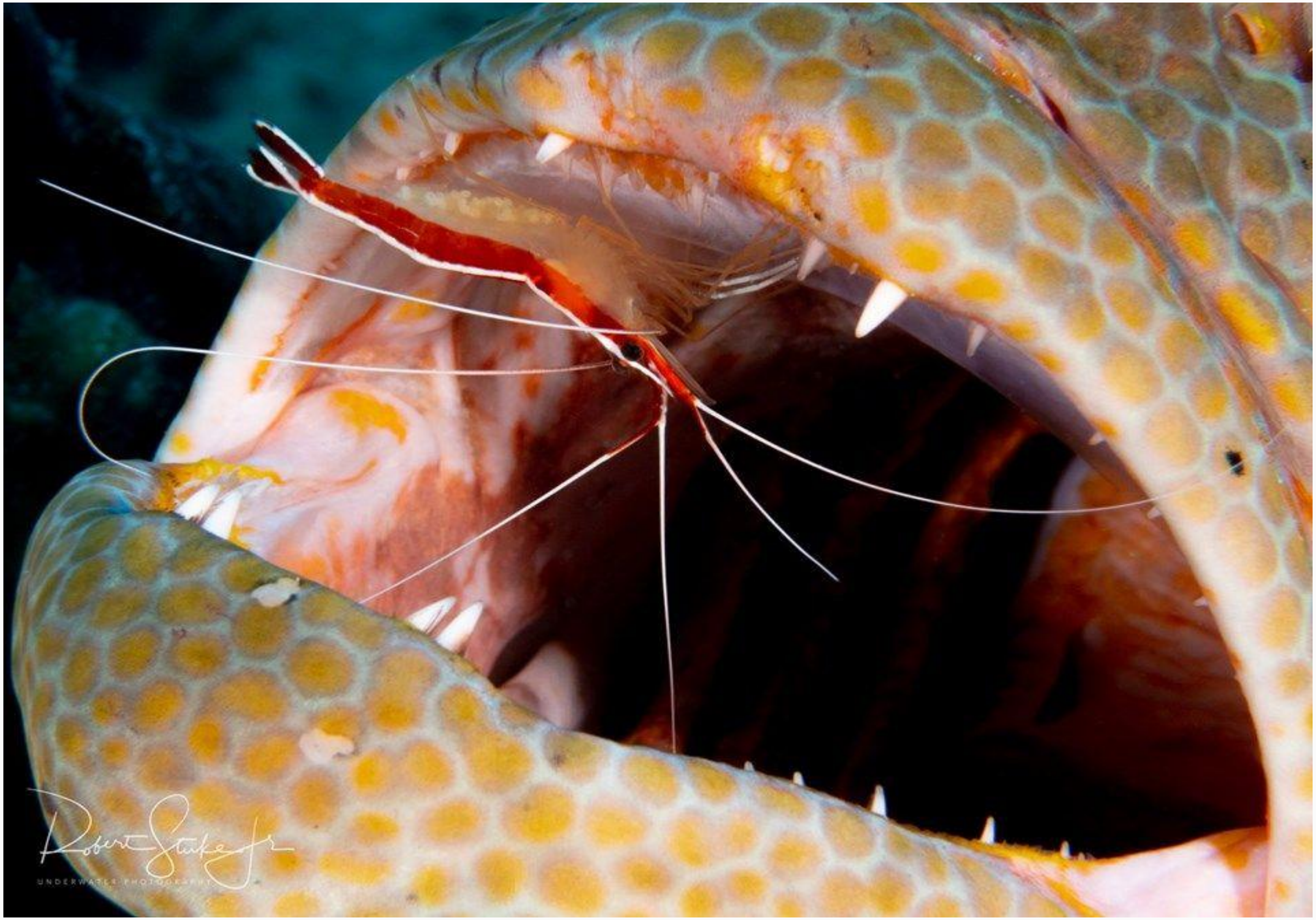
UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: living together

- In **mutualism**, both partners benefit from the relationship.
- E.g., small cleaner fishes & shrimps have mutualistic relationships with larger fishes..
- They remove harmful parasite & dead tissues for the fish & these serve as their meal for them…

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: living together



UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..
Trophic stx – species interact: <u>living together</u>

Trophic stx – species interact: living together

- The fish which could easily eat the cleaners allow them to poke & prod over their bodies & even inside their mouths.

- This type of symbiosis is called cleaning symbiosis – **protocooperation**.

- Here, both partners can get by without the other if they have to.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: living together

- A 2nd e.g. anemone fish & sea anemone.
- Here brightly coloured anemone fishes nestle in the stinging tentacles of the sea anemone & is protected from predators…..
- In return, the anemone fish feeds the sea anemone with scraps of food & often lure prey into its reach.

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: living together

Trophic stx – species interact: living together

- 3rdly, sometimes the partners depend on each other e.g., **crab**, *Trapezia* sp, is found nowhere else but on its host **coral**…
- The coral supplies not only shelter & food, by producing the mucus that the crab eats.
- The crabs in turn drives away predators like sea stars, etc.…

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: <u>living together</u>

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: living together

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

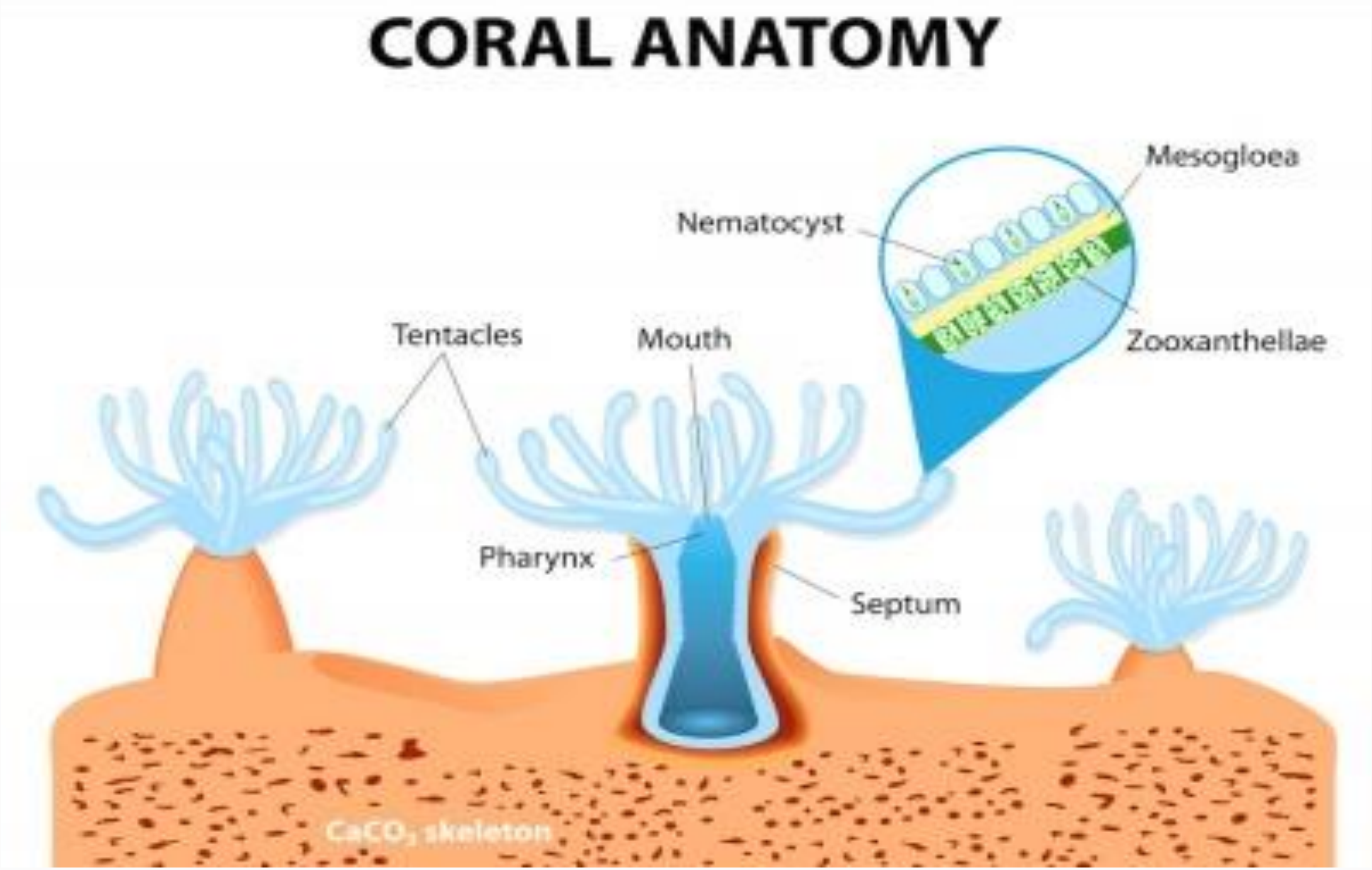
Trophic stx – species interact: living together

- 4thly, corals provide an e.g. of **obligate mutualism**, one in which neither partner can live without the other.

- The tiny zooxanthellae (i.e. photosynthetic dinoflagellates) that live in its tissues helps the coral makes its **$CaCO_3$ skeleton**….

UNIT 5: COMMUNITY STRUCTURE & DYNAMICS..

Trophic stx – species interact: <u>living together</u>



Trophic stx – species interact: living together

- The zooxanthellae also make food for the coral by photosynthesis.

- The zooxanthellae, in turn, get both nutrients & a place to live from the deal.

- So, without resident dinoflagellates, corals won't be able to deposit $CaCO_3$ & these rich tropical reef communities won't exist.

UNIT 6

PRODUCTIVITY, NUTRIENT CYCLING, & EUTROPHICATION OF AQUATIC ECOSYSTEMS

UNIT 6: PRODUCTIVITY, NUTRIENT CYCLING, & EUTROPHICATION: ILOs –

To **know**:

- and **understand** the concept of primary production & how it is measured in pelagic communities of phytoplankters;

- and **understand** various **indices** for assessing primary production in aquatic ecosystems & some limitations associated with them;

UNIT 6: PRODUCTIVITY, NUTRIENT CYCLING, & EUTROPHICATION: ILOs –

To **know**:

- and **understand** the concept of secondary & other productions & in aquatic ecosystems;

- and **understand** the concepts of food chain & growth efficiencies & how they can be used to assess potential fish production at the top of a food chain.

UNIT 6: PRODUCTIVITY:

primary production –

- Definition of **primary production**.

- Energy source for primary production in aquatic ecosystems.
  - Sunlight (main source)

  - Energy from inorganic molecules

UNIT 6: PRODUCTIVITY :

primary production –

- Why the **need** for primary production measurement in water bodies?
  - Capacity for potential energy formation.
  - Conversion of potential energy to other forms usable by other aquatic organisms.
  - Estimation of energy transfer efficiency.

UNIT 6: PRODUCTIVITY:

primary production – –

- Photosynthate **usage** by photoautotrophs in aquatic ecosystems:
  - 1st, is satisfaction of **respiratory** needs (a minimum of about 10 %);
  - 2nd, reservation of a portion for maintenance of their **community structure**.

UNIT 6: PRODUCTIVITY:
primary production of phytoplankton

- Primary production **measurement** is based on the photosynthetic equation;

$$\mathbf{(CO_2)n} + H_2O \longrightarrow \mathbf{C(H_2O)n} + \mathbf{O_2}$$

- **Based on equation what can be measured to represent rate of photosynthesis?**

UNIT 6: PRODUCTIVITY:
primary production of phytoplankton

- Primary production **measurement** is based on the photosynthetic equation;

$$\mathbf{(CO_2)n} + H_2O \rightarrow \mathbf{C(H_2O)n} + \mathbf{O_2}$$

- Measurement factors include:
  - rate of **carbohydrates accumulation** (i.e. $C[H2O]_n$) or the **dry weight***,
  - Rate of **O_2 production**, or
  - Rate of **CO_2 decline**

UNIT 6: PRODUCTIVITY:

primary production of phytoplankton

- **Limitations** of dry weight measurement in aquatic ecosystems -
  - 1st, dry weight increases too small to be measured over short measurements times.
  - 2ndly, it may include varying non-autotroph biomass e.g. detritus & sediments from the bottom or transported into a lake by rivers.

UNIT 6: PRODUCTIVITY:
primary production of phytoplankton

- So, O_2 production is often used to get an estimate of the rate of dry weight production based on similar stoichiometry.
- In other words, **1 carbohydrate** molecule is produced for **1 O_2** released.
- O_2 measurement is done using bottles called Winkler or BOD bottles.

UNIT 6: PRODUCTIVITY:
primary production of phytoplankton

- **Three (3) pairs** of these bottles are often used…..
- 1st lake water is taken using a water sampler e.g. van Dorn sampler.. & water collected used to fill the 3 BOD bottles.
- The 1st bottle designated **A** gives the initial O_2 concentration.

UNIT 6: PRODUCTIVITY..:
primary production of phytoplankton

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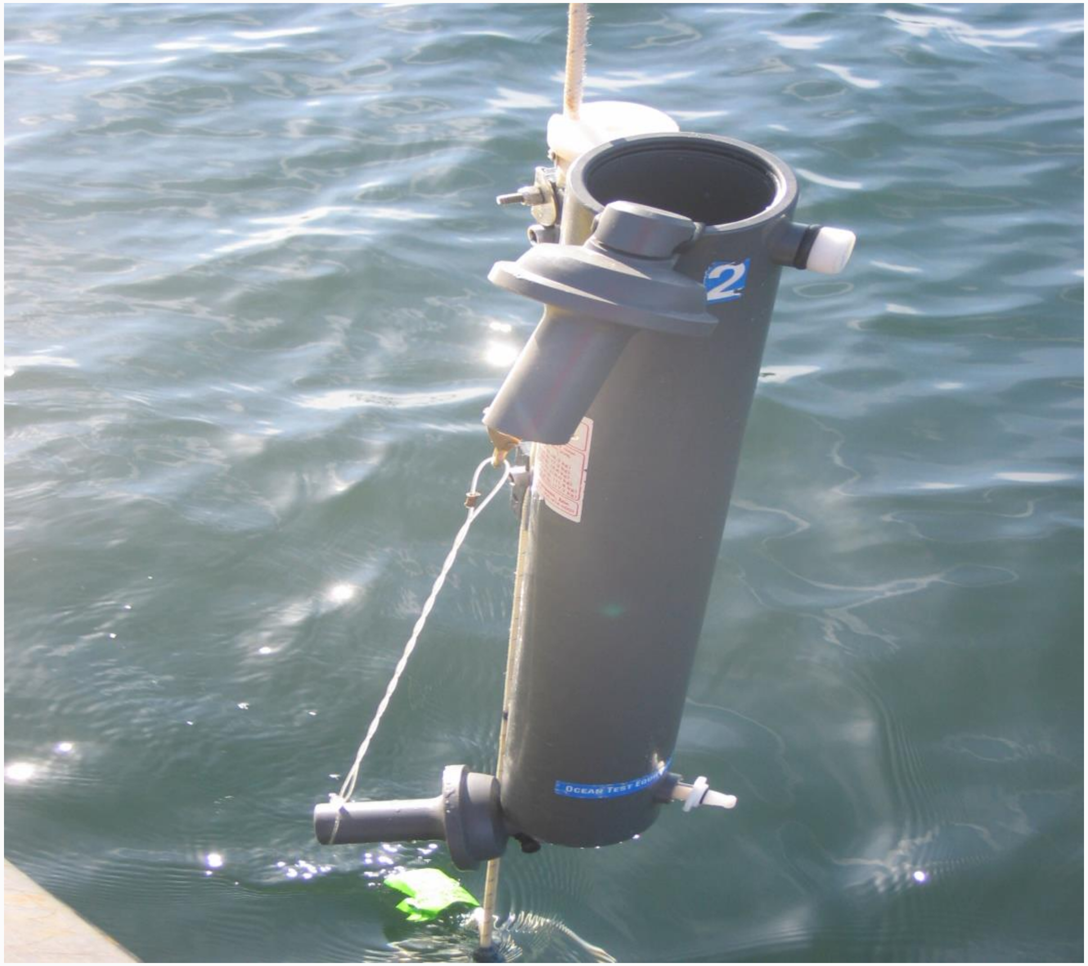
UNIT 6: PRODUCTIVITY..:
primary production of phytoplankton

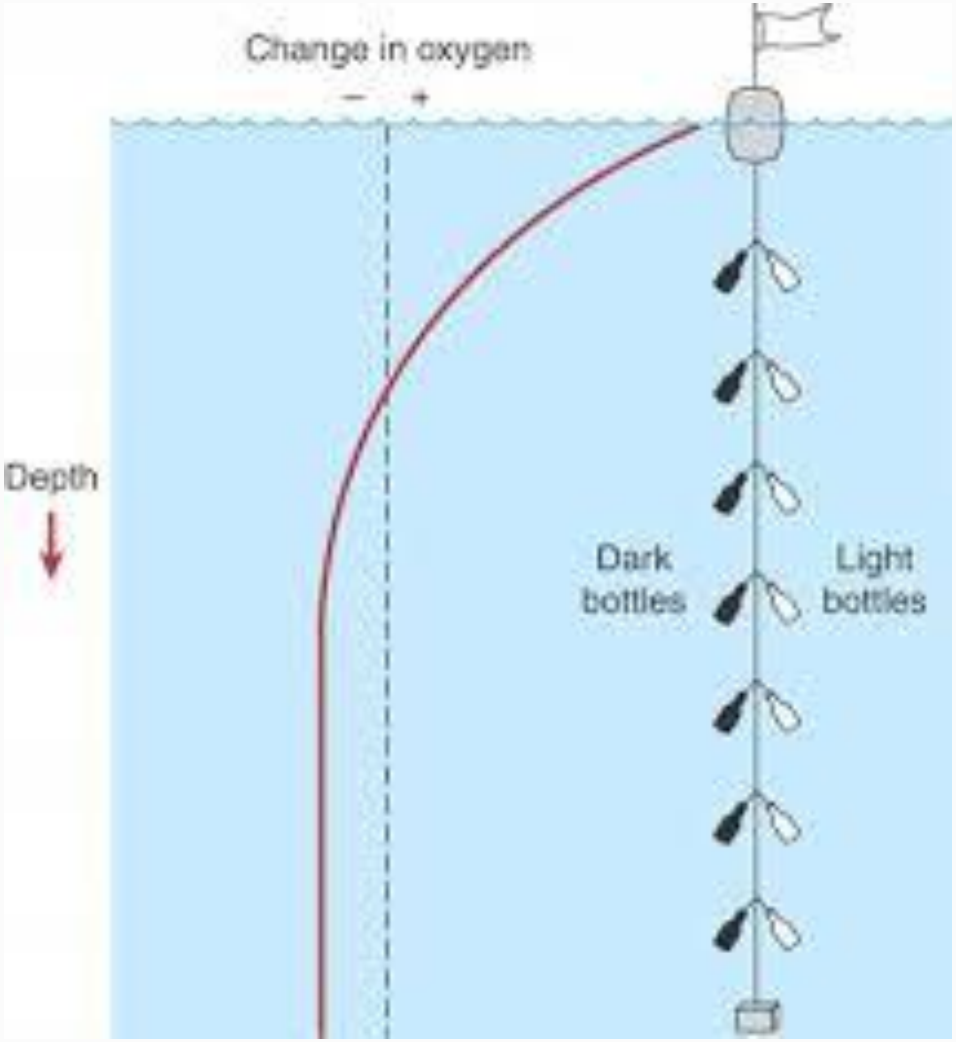


UNIT 6: PRODUCTIVITY..:

primary production of phytoplankton

- A 2nd bottle (**L**) is placed in the light while the 3rd bottle **D** is placed in total darkness..
- Bottles **L** & **D** are then incubated for a period of time either ***in situ*** or ***ex situ***….
- O_2 levels in both bottles are then determined using the Winkler method….

UNIT 6: PRODUCTIVITY..:
primary production of phytoplankton



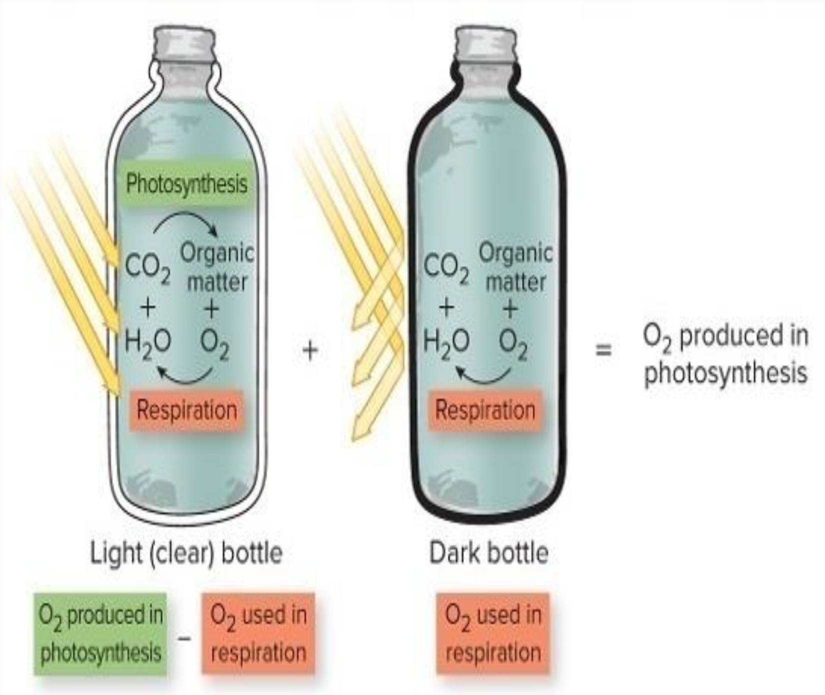
UNIT 6: PRODUCTIVITY…:
primary production of phytoplankton

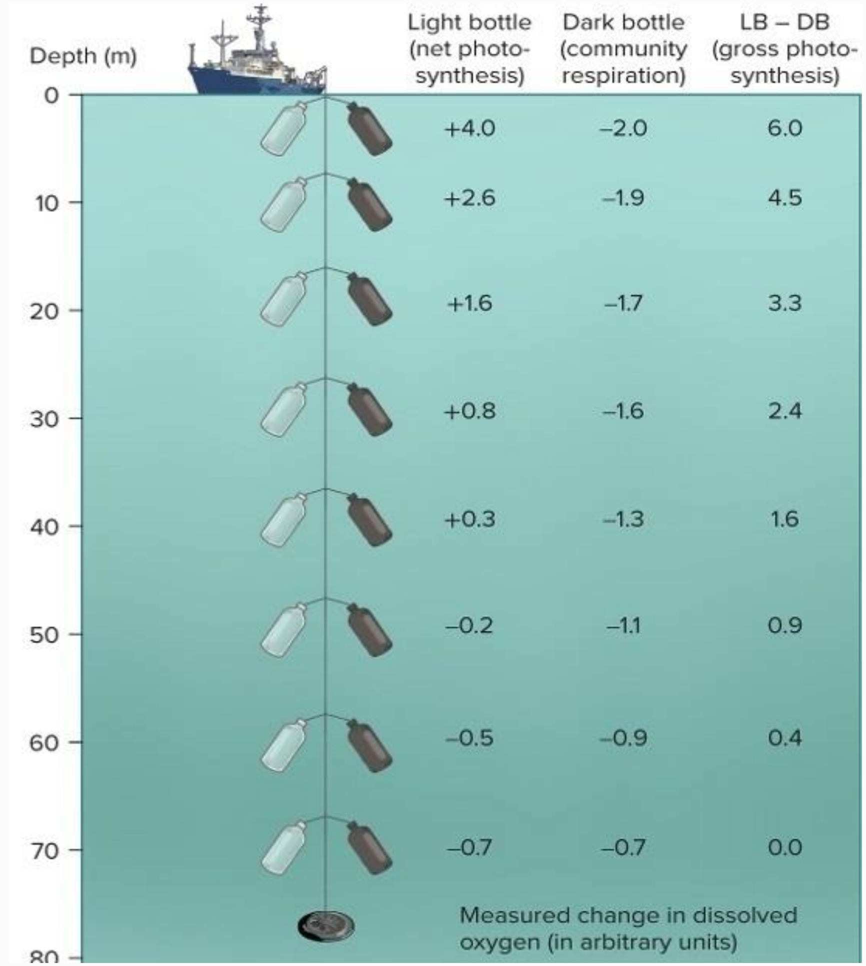
- During incubation, O_2 in initial bottle **A** will reduce to a lower value in the dark bottle **D** & to a higher value in the light bottle **L**.

- The difference between bottle **A** & **D** O_2 levels is phytoplankton **respiration** per unit volume over the incubation time period i.e.

Respiratory loss = $[O]_A - [O]_D$

UNIT 6: PRODUCTIVITY…:
primary production of phytoplankton





UNIT 6: PRODUCTIVITY….:
primary production of phytoplankton

- The difference between bottles **L** & **A** is **net photosynthesis** i.e.

  Net photosynthesis = $[O]_L - [O]_A$

- The difference between **L** & **D** bottles is **gross photosynthesis** i.e.

  GPP = NPP + Respiration

UNIT 6: PRODUCTIVITY…:

primary production of phytoplankton

Gross photosynthesis $= \mathbf{([O]_L\text{-}[O]_A) + ([O]_A\text{-}[O]_D)}$

$= \mathbf{[O]_L\text{-}[O]_A + [O]_A\text{-}[O]_D}$

$= \mathbf{[O]_L\text{-}[O]_D}$ …..

NB:

- 1. Gross primary production (**GPP**) is the total photosynthesized material before it is consumed & dissipated by both primary producers themselves & other organisms.

UNIT 6: PRODUCTIVITY…:
primary production of phytoplankton

- 2. Net primary production (**NPP**) is the amount of photosynthate left after it is consumed in respiratory & other maintenance activities of the primary producers.

- 3. Hence, **GPP**, **NPP**, & **respiration** are related by the equation

GPP = NPP + Respiration, or

UNIT 6: PRODUCTIVITY….:
methods of evaluating primary production

- a) **Standing Crop** – part of primary production physically present in the system & doesn't include respiratory losses.

- It represents the result of a continual **loss** & **replacement** process.

UNIT 6: PRODUCTIVITY…:

methods of evaluating primary production

a) **Standing Crop** –

- Losses due to
  - **death**,
  - **consumption** by grazers as food,
  - **removal** by out-flowing waters, etc

- ..must be offset more or less by normal **growth** & **reproduction**.

UNIT 6: PRODUCTIVITY…:

methods of evaluating primary production

a) **Standing Crop** –

- **Increases/decreases** are due to excess of production over losses & vice versa.

- It is a measure of the biomass of the system at a single point in time measured as calories or grams per m^2.

UNIT 6: PRODUCTIVITY….:

methods of evaluating primary production

- b) **Productivity** is the rate at which biological production occurs.
- Limitation of using standing crop as a measure of productivity.
- E.g., standing crop may be greatly reduced by grazing & water mov’t but rates of photosyntheis may remain high.

UNIT 6: PRODUCTIVITY…:

methods of evaluating primary production

- Primary productivity expression
  - per unit area, per unit of time e.g., **calories**/m^2/year (energy) or **grams**/m^2/year (weight).

UNIT 6: PRODUCTIVITY…:
limitations of standing crop measures

Cells	Wet weight	Dry weight	Chlorophyll *a*
1). No differentiation between small & big cells;	2). Underestimate of net & other small plankton if correct net size is not used;	1. Differentiating phytoplankton **seston** is difficult;	1. Subject to a physiological state of cell;
2). Requires taxonomic finesse	2). Requires taxonomic finesse	2). Obtaining the dry weight require very sensitive equipment for drying & weighing measurement	2). Affected by degree of light exposure; 3). Different groups of phytoplankton have different chlorophyll contents.

UNIT 6: PRODUCTIVITY….:
limitations of standing crop measures

NB:

- The ratio of the standing crop to the production is equal to the **turnover** of the system.

- By dividing standing crop (**g/m^2**) by productivity (**g/m^2/yr**), the turnover is in **units** of **time**.

UNIT 6: PRODUCTIVITY…:

limitations of standing crop measures (NB)

- It is important to consider the time element when thinking about almost any aspect of an organism or an ecosystem.

- Questions of "how much" & "how fast" in an organism or ecosystem is important in making decisions about them;

UNIT 6: PRODUCTIVITY….:
limitations of standing crop measures (NB)

- E.g., normal decisions of a fisherman may be driven by economic concerns or by conservation concerns.

- But the "**best**" choice for either of those choices depends understanding productivity, standing crop, & turnover of the aquatic system of interest.

UNIT 6: PRODUCTIVITY…:

Ecological efficiency of aquatic primary producers

- This can be measured as production of new tissues.

- All the tissues of plants formed at a particular time & place can be collected & their energy contents determined.

- This is usually expressed in **kJ/g** or **kcal/g**.

UNIT 6: PRODUCTIVITY…:

Ecological efficiency of aquatic primary producers

- The sunlight energy used by primary producers in photosynthesis in the area & time concerned can also be determined.

- These values enable us to estimate the **ecological efficiency** of the primary producers found in a water body.

UNIT 6: PRODUCTIVITY…:

Ecological efficiency of aquatic primary producers

- This can be expressed by the ratio:

$$\frac{\textbf{kJ(kcal) in newly formed material}}{\textbf{kJ(kcal) in incident sunlight}}$$

- Ecological efficiency of primary producers turn out to be quite **low** for land plants (**1%**) & for aquatic plants far less e.g. Lake Bosomtwe = **0.28%**).

UNIT 6: PRODUCTIVITY….:
Secondary & other productions

- **Secondary production** is the fixation or production of energy by heterotrophs (consumers).

- It's driven by transfer of organic material between trophic levels, & represents the quantity of new tissue formed through assimilated food.

-

UNIT 6: PRODUCTIVITY…:
Secondary & other productions

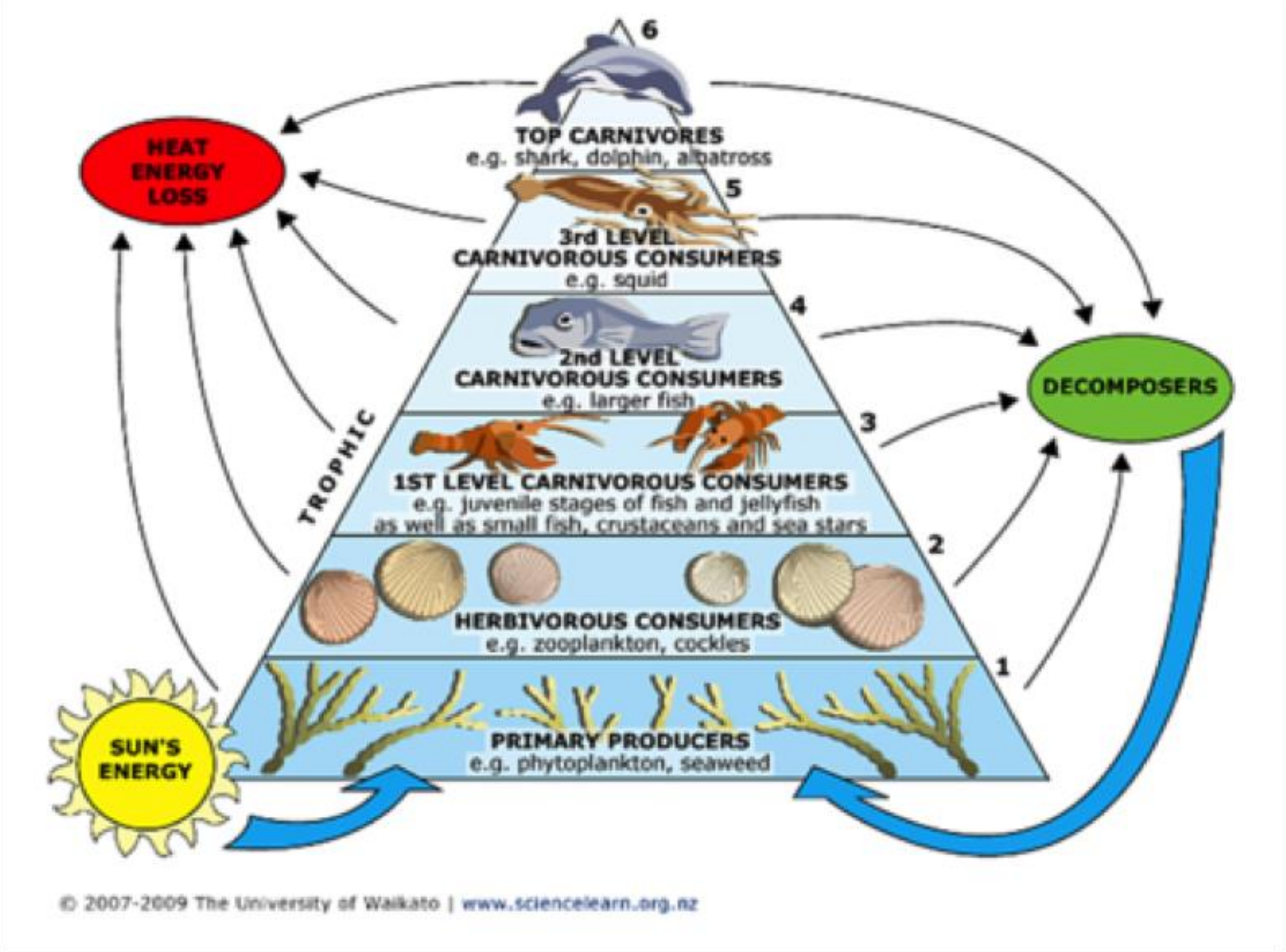
- **Secondary productivity** is the rate at which the consumers convert the chemical energy of their food into their own biomass.

- **NB: Tertiary production** is the amount of new biomass (weight) that is produced by meat-eating animals (carnivores).

- Tertiary productivity?

UNIT 6: PRODUCTIVITY…:

Secondary production components



UNIT 6: PRODUCTIVITY…:

Secondary production components

- Not all food eaten by aquatic heterotrophs is converted into new animal mass.

- E.g. for a stream **snail** grazing on **algae** .., only a fraction of the material <u>ingested</u> (I) is <u>assimilated</u> (A) from the digestive tract; the remainder passes out as <u>faeces</u> (F).

UNIT 6: PRODUCTIVITY…:

Secondary production components

- Only a fraction of assimilated material contributes to growth of the snail's mass or to reproduction i.e. its production (P).

- The rest is used for respiration (R) & a small portion is lost in excretion (E), which is often ignored in such energy budgets.

UNIT 6: PRODUCTIVITY...:
Secondary production components

- Thus, the fate of ingested energy can be described by this equation:

$$\mathbf{I} = R + P + F + E \text{ i.e.}$$

$$\mathbf{P} = I - (F + R + E) \text{ \underline{\textbf{or}}}$$

$$\mathbf{P} = I - F - R - E$$

$$\mathbf{P} = I - F - R$$

- All these (ingestion, assimilation, faeces, respiration, production, mortality) have units of **mg dry mass m^{-2} day^{-1}**.

UNIT 6: PRODUCTIVITY…:

Secondary production components

NB:

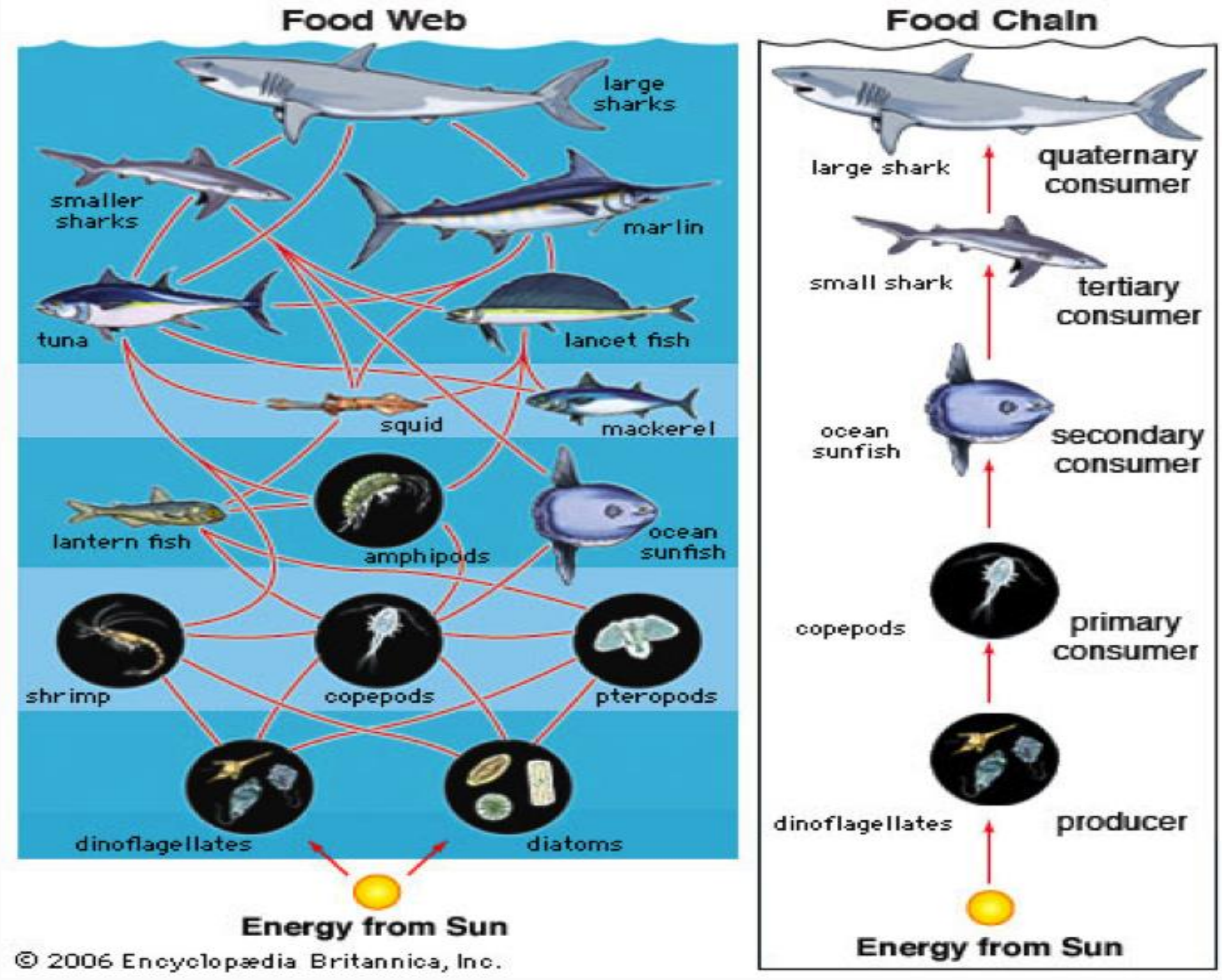
- **Production** adds to biomass & **mortality** subtracts from biomass simultaneously.
- If production **exceeds** biomass lost to mortality, **biomass will increase**.
- If biomass lost to mortality **exceeds** production, **biomass will decline**.

UNIT 6: PRODUCTIVITY….:
Food chain efficiency in aquatic ecosystems

- Species in a trophic level are consumed by species in a higher trophic level.
- Note that some species may change levels in the food chain at different life stages.
- Consumers may also feed at several levels in the food chain resulting in a **foodweb**.

UNIT 6: PRODUCTIVITY…:

Food chain efficiency in aquatic ecosystems



UNIT 6: PRODUCTIVITY…:

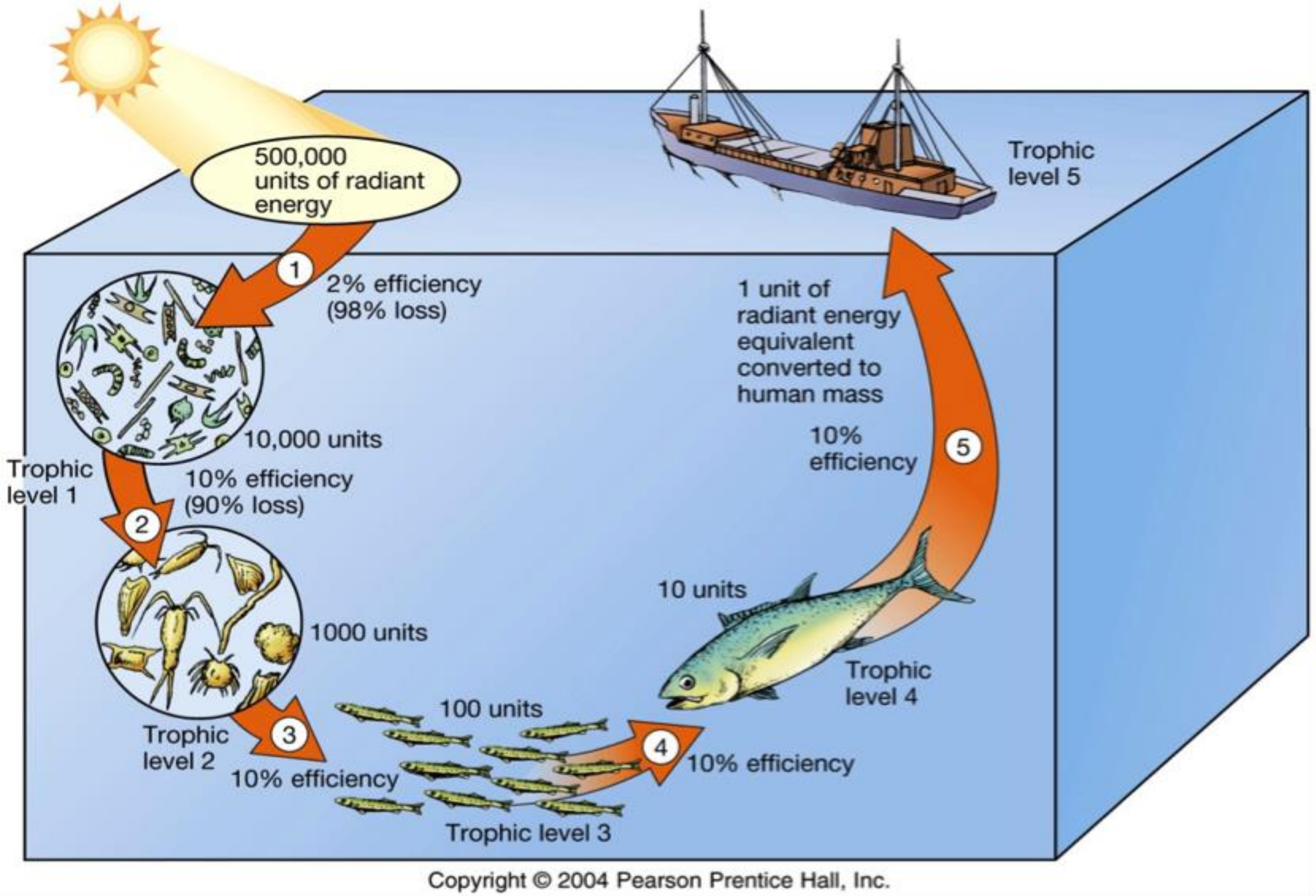
Food chain efficiency – transfer between trophic levels

- Transfer of production/energy from one trophic level to another is not complete.

- i.e. not all the production from one trophic level is transferred perfectly to the next as noted earlier.

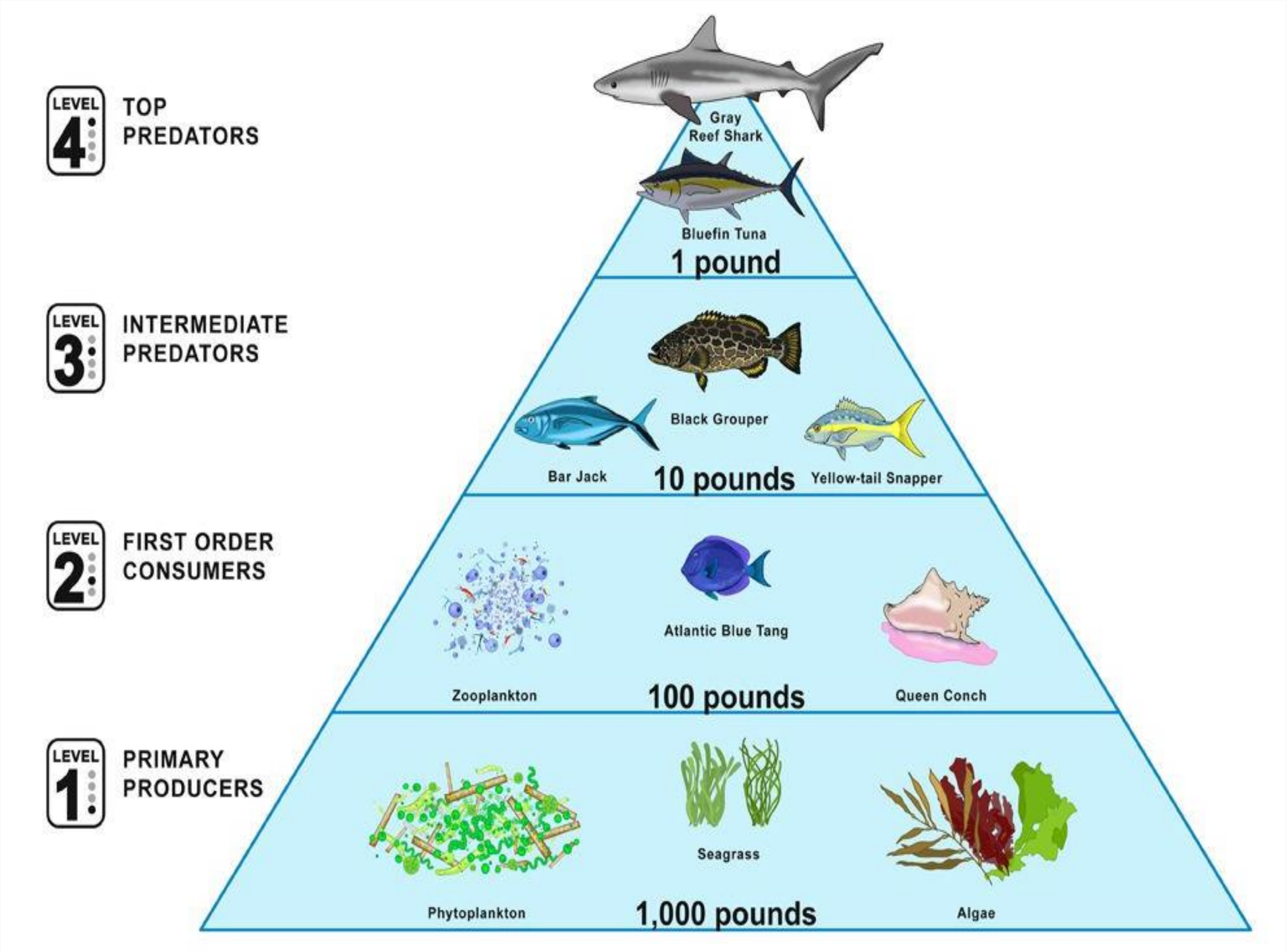
UNIT 6: PRODUCTIVITY…:

Food chain efficiency – transfer between trophic levels



UNIT 6: PRODUCTIVITY…:

Food chain efficiency – transfer between trophic levels



UNIT 6: PRODUCTIVITY…:

Food chain efficiency – transfer between trophic levels

- To estimate potential production at top of the food chain e.g. fish production, losses of production along the food chain must be taken be considered.

- Losses result from essentially 2 factors:
  - **Evasion** of consumption
  - **Inefficient** conversion

UNIT 6: PRODUCTIVITY…:

Food chain efficiency – transfer between trophic levels

- 1. **Evasion of consumption** – some proportion of a given trophic level evades consumption through:
  - **escape**,
  - **unpalatability**,
  - **Unavailability** e.g. spiny or toxic planktons are avoided
  - Phytoplankton **cell size** may be too small or too large to allow for ingestion.

UNIT 6: PRODUCTIVITY…:

Food chain efficiency – transfer between trophic levels

- 2. **Inefficient conversion** – some part of food ingested is not converted into growth.

- Thus, an ingested food budget can be constructed like this:

$$I = E + R + G$$

where **I** = amount ingested; **E** = amount egested; **R** = amount used in respiration; **G** = amount used in growth

UNIT 6: PRODUCTIVITY….:

Food chain efficiency – transfer between trophic levels

- **Growth** is usually partitioned between somatic (body) growth & reproduction.
- It's usually a minority of ingested budget.
- Not all food can be digested & assimilated & some therefore are egested.

UNIT 6: PRODUCTIVITY…:

Food chain efficiency – transfer between trophic levels

- Some of the energy obtained in food is lost as respiration, hence is not available to the next trophic level.

- The incompleteness of transfer up a food chain can be estimated in terms of **food chain efficiency (E)**.

UNIT 6: PRODUCTIVITY…:

Food chain efficiency – transfer between trophic levels

- This is the amount of energy extracted from a trophic level **divided** by the amount of energy supplied to that trophic level.

- **Growth efficiency** - portion of assimilated food used in growth

- Range from 30 – 45 %, but **food chain efficiency** is far lower, often about 10 %.

UNIT 6: PRODUCTIVITY…:

Food chain efficiency – transfer between trophic levels

- Food chain efficiency can be used to calculate the **potential fish production** at the top of a food chain using the formula:

$$\mathbf{P = B * E^{n}}$$

where **B** = phytoplankton biomass; **E** = efficiency; **n** = number of links between trophic levels; & **P** = fish production

UNIT 6: PRODUCTIVITY…:

Food chain efficiency – transfer between trophic levels

- E.g. a change in **E** from 0.1 to 0.2 would magnify by **32 times**, the estimate of **fish production** at the 5th trophic level.