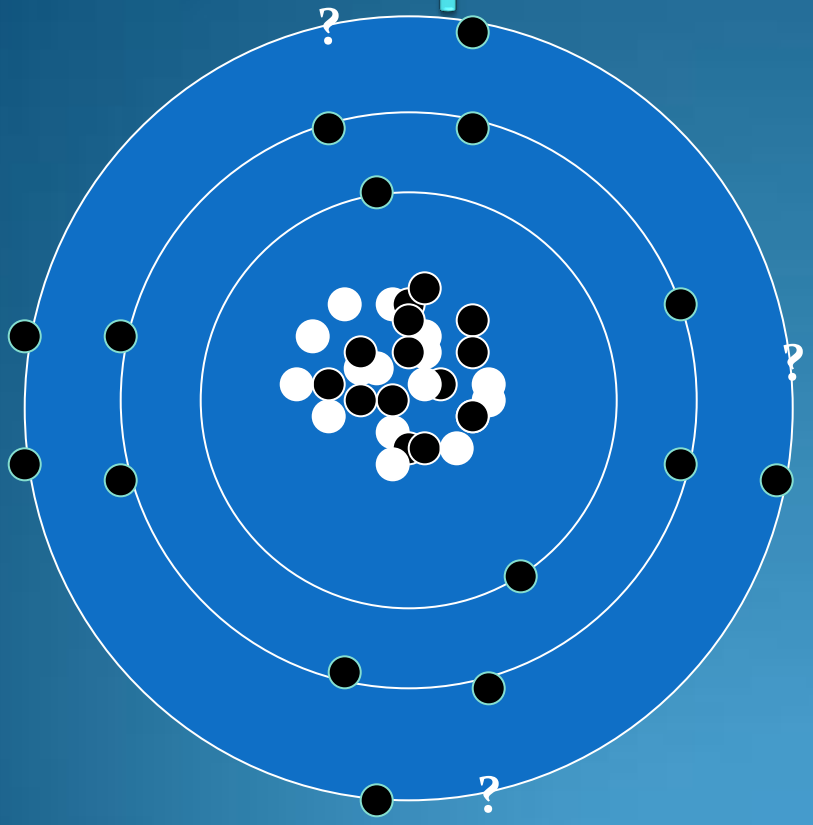
Phosphorus and Phosphate



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Assoc. Prof. Kozet YAPSAKLI

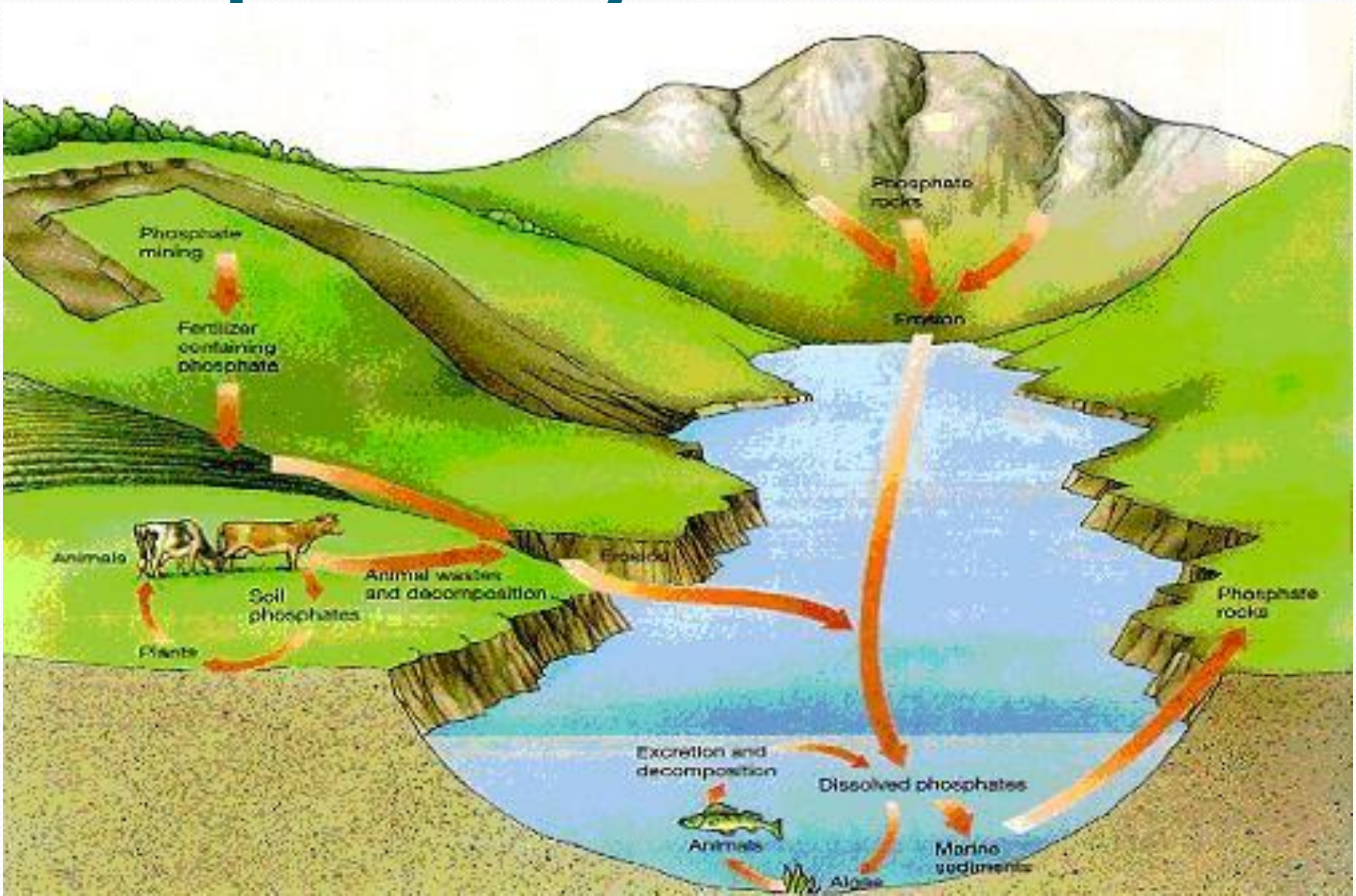
Phosphorus

- Phosphorus is a vital nutrient necessary for plants and animals in the form of PO_4^{3-} and HPO_4^{2-}.
- Phosphorus is the building block of important parts of the body such as bones and teeth.
- Component in DNA
- About 80% of the world's phosphorus is used in fertilizers and soft drinks.

Phosphorus

- Unlike other cycles of matter compounds, phosphorus cannot be found in atmosphere as a gas.
- It usually cycles through water, soil, and sediments.
- The phosphorus cycle may also be referred to as the *mineral cycle*.

Phosphorus Cycle

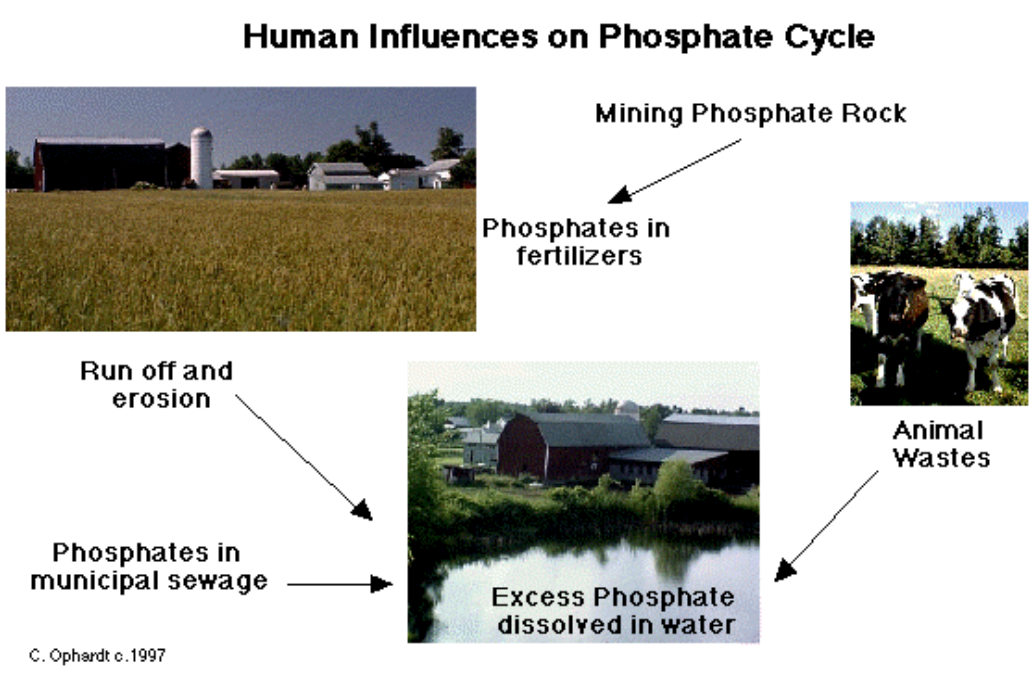


Phosphorus Cycle

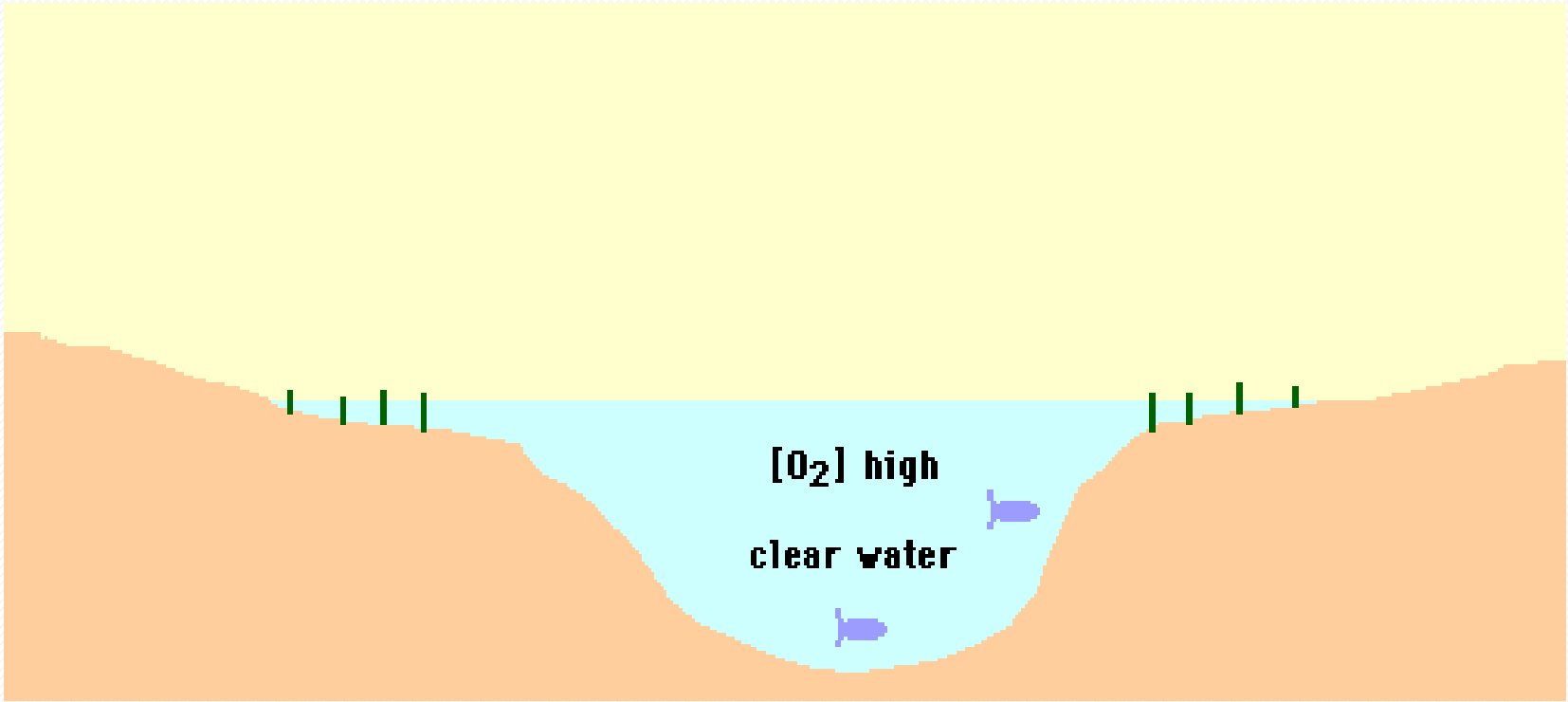
- The phosphorus cycle is the SLOWEST cycle.
- Phosphate salts that are released from rocks through weathering usually dissolve in soil water and will be absorbed by plants.
- Animals absorb phosphates by eating plants or plant-eating animals.
- When animals and plants die, phosphates will return to the soils or oceans again during decomposition.
- After that, phosphorus will end up in sediments or rock formations again, remaining there for millions of years. Eventually, phosphorus is released again through weathering and the cycle starts over.

Human Impacts on the Phosphorus Cycle

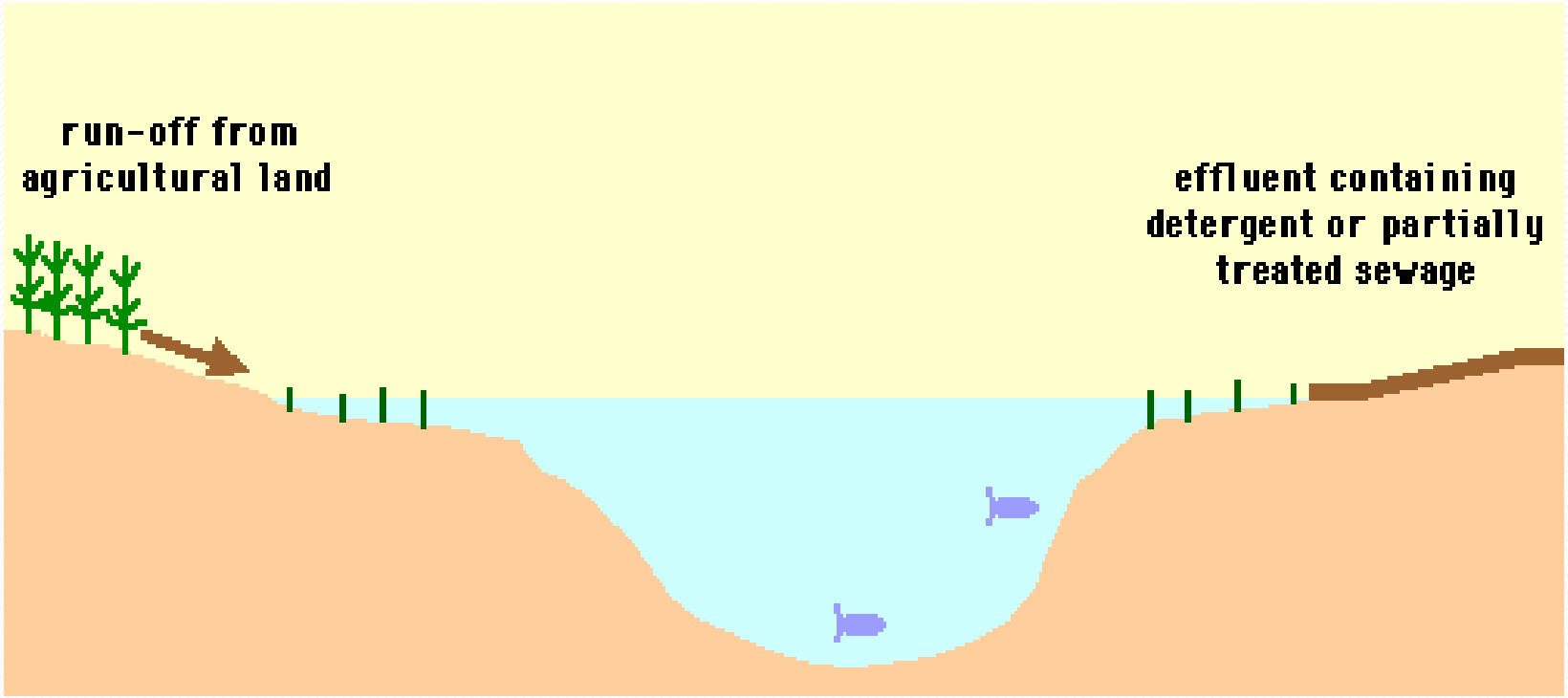
- Like nitrogen, increased use of fertilizers increases phosphorus runoff into our waterways and contributes to eutrophication.



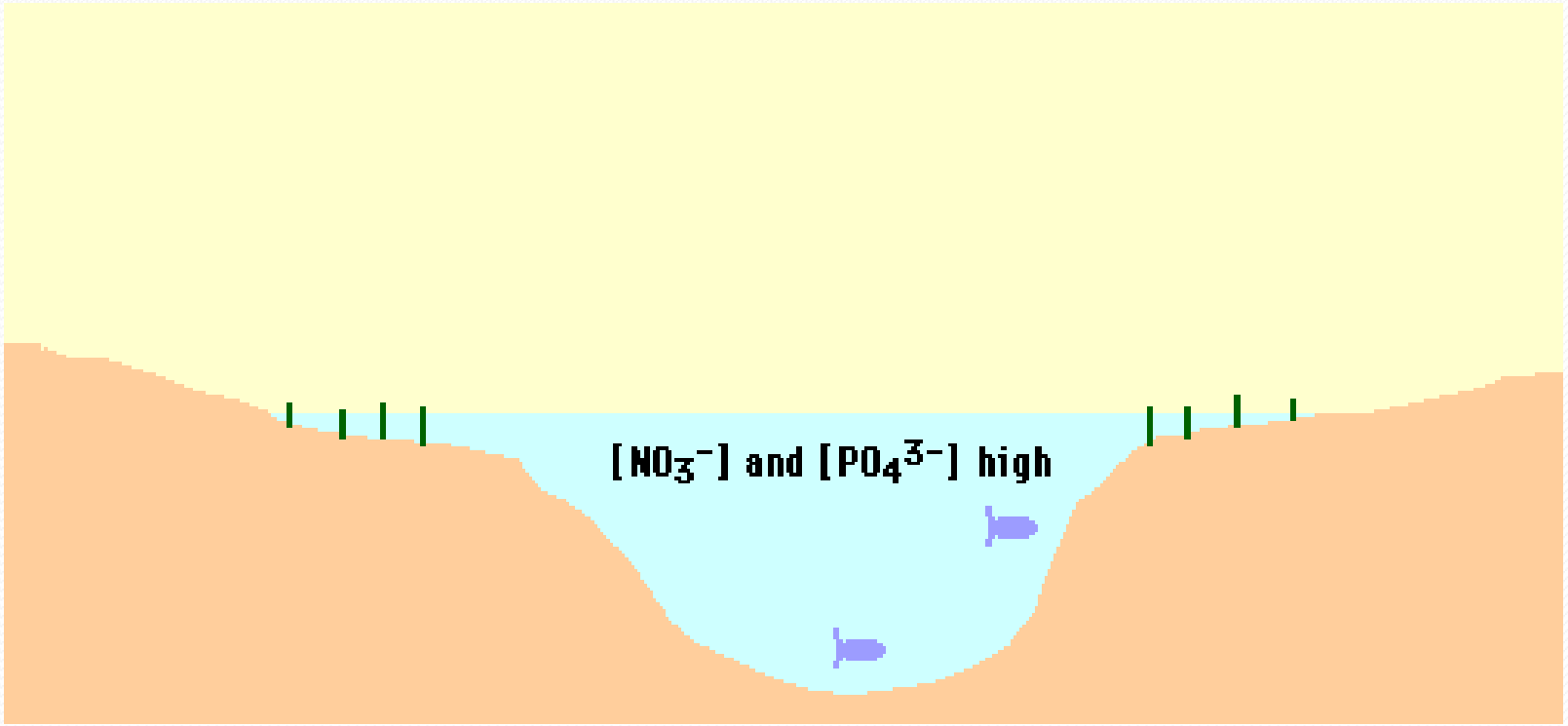
Step by step eutrophication process



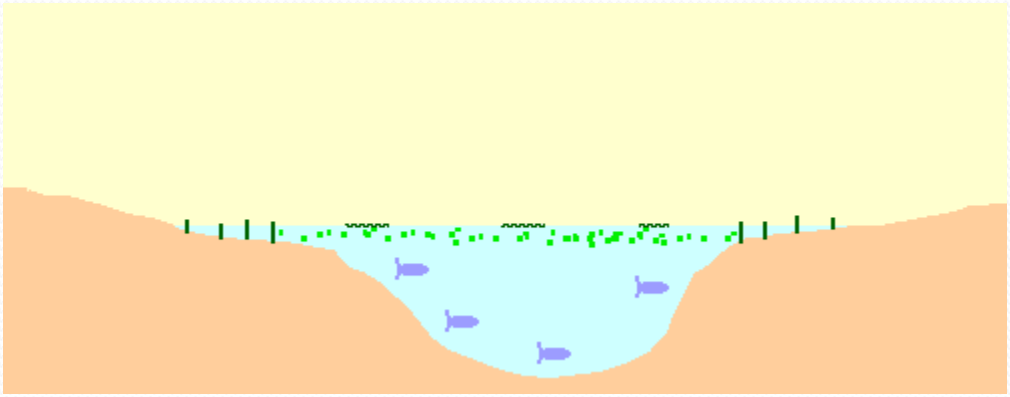
Oligotrophic lake with a low level of nutrients.



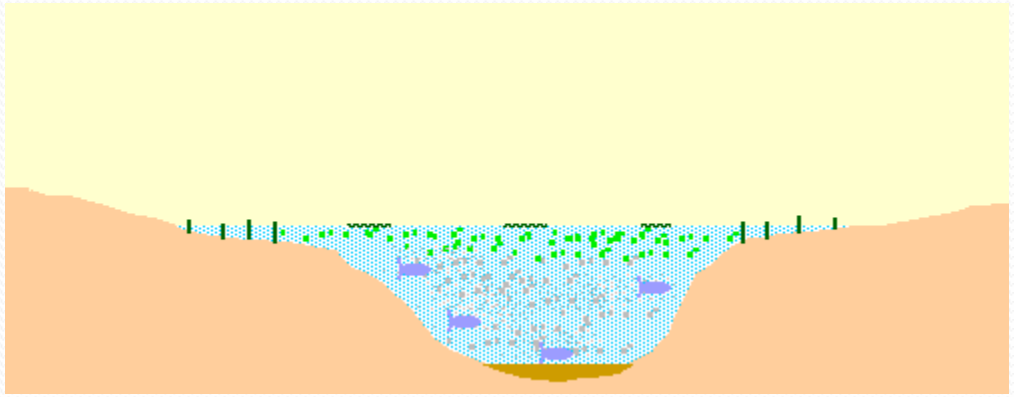
Artificial input of nutrients from run-off and discharge of effluent.



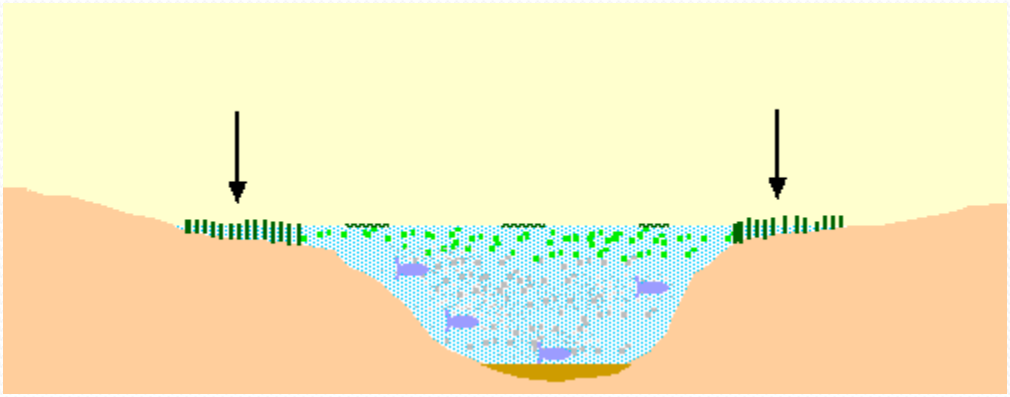
Eutrophic lake with a high level of nutrients. Phosphorus is usually the bio-limiting element in freshwater lakes.



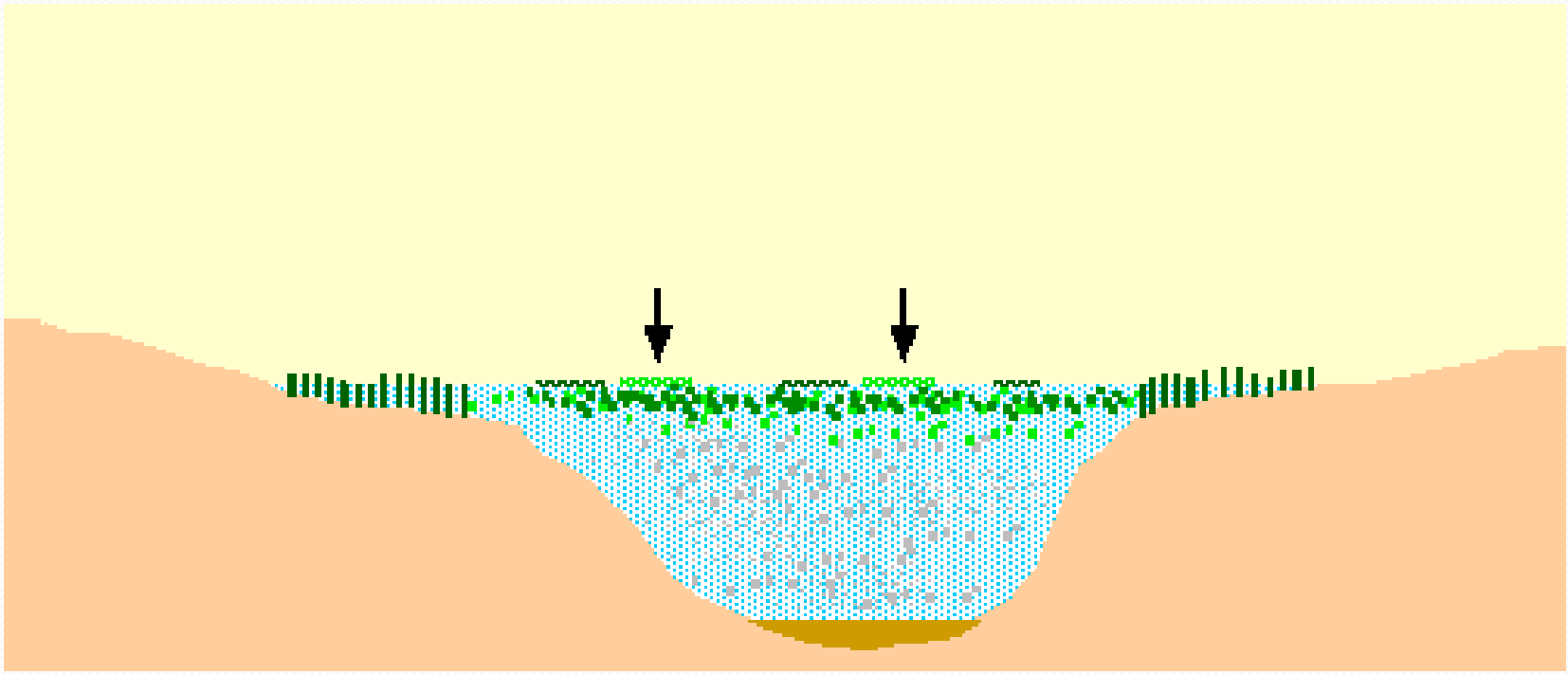
Rapid growth of algae and other biomass resulting in a decrease in the concentration of dissolved oxygen.



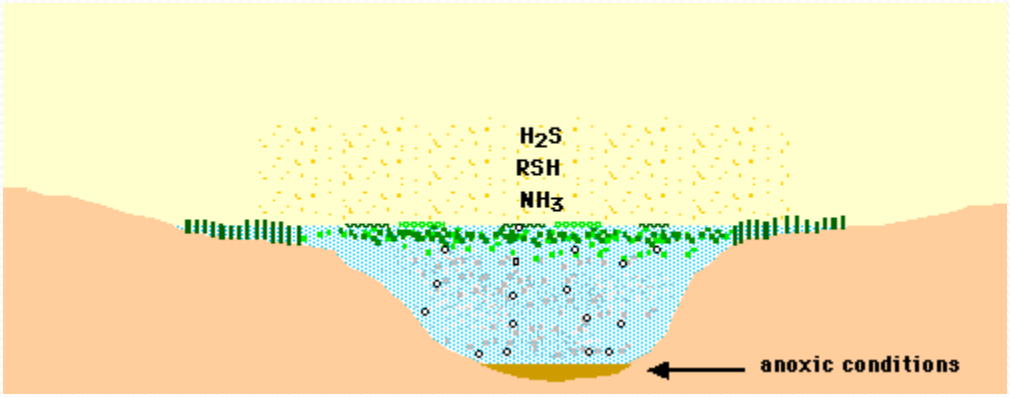
Turbidity (cloudiness) of water increases as does rate of sedimentation.



Increased growth of rooted plants such as reeds.

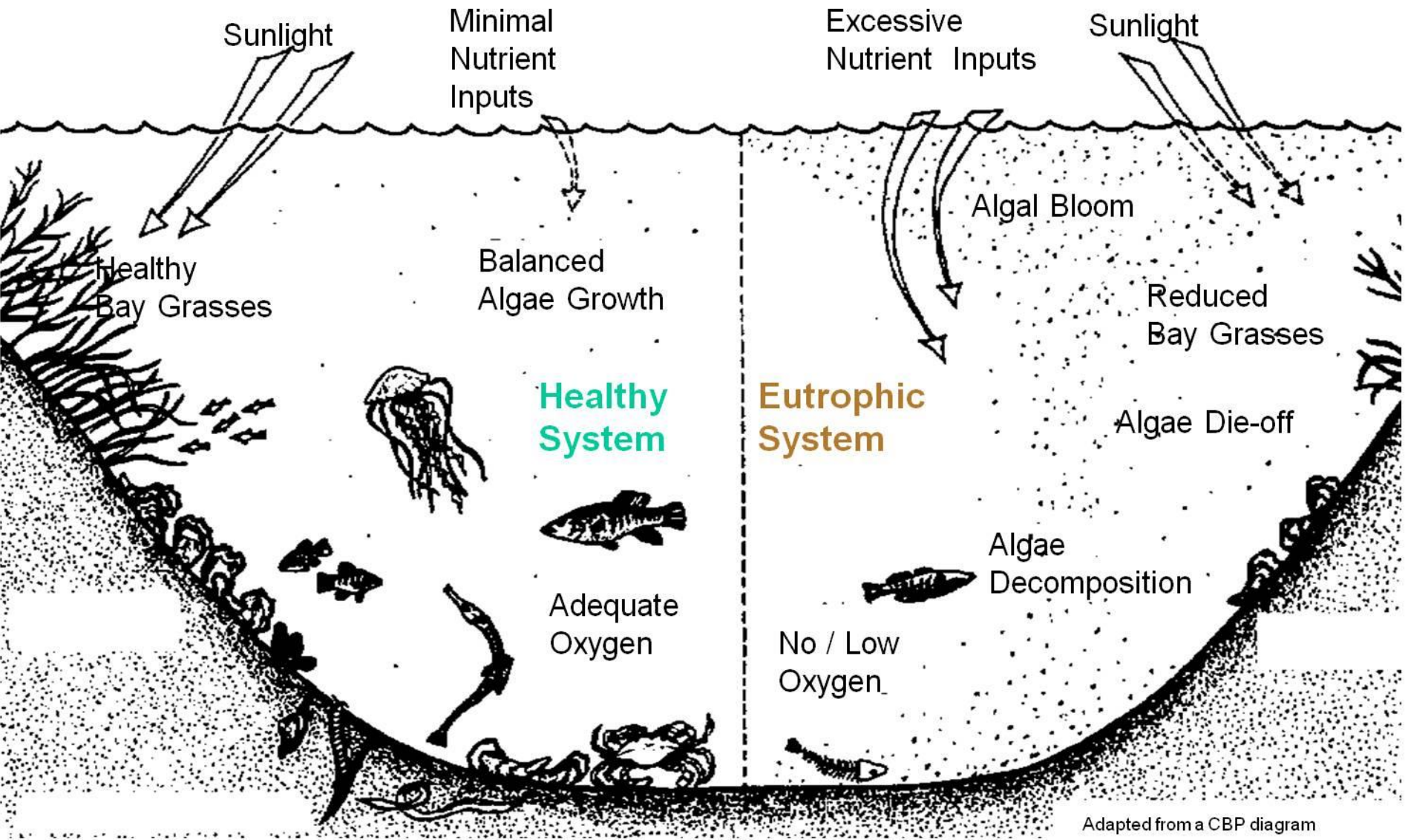


Algal blooms during the Summer months. Note that dissolved oxygen levels are at their lowest at night when plants respire rather than photosynthesis.



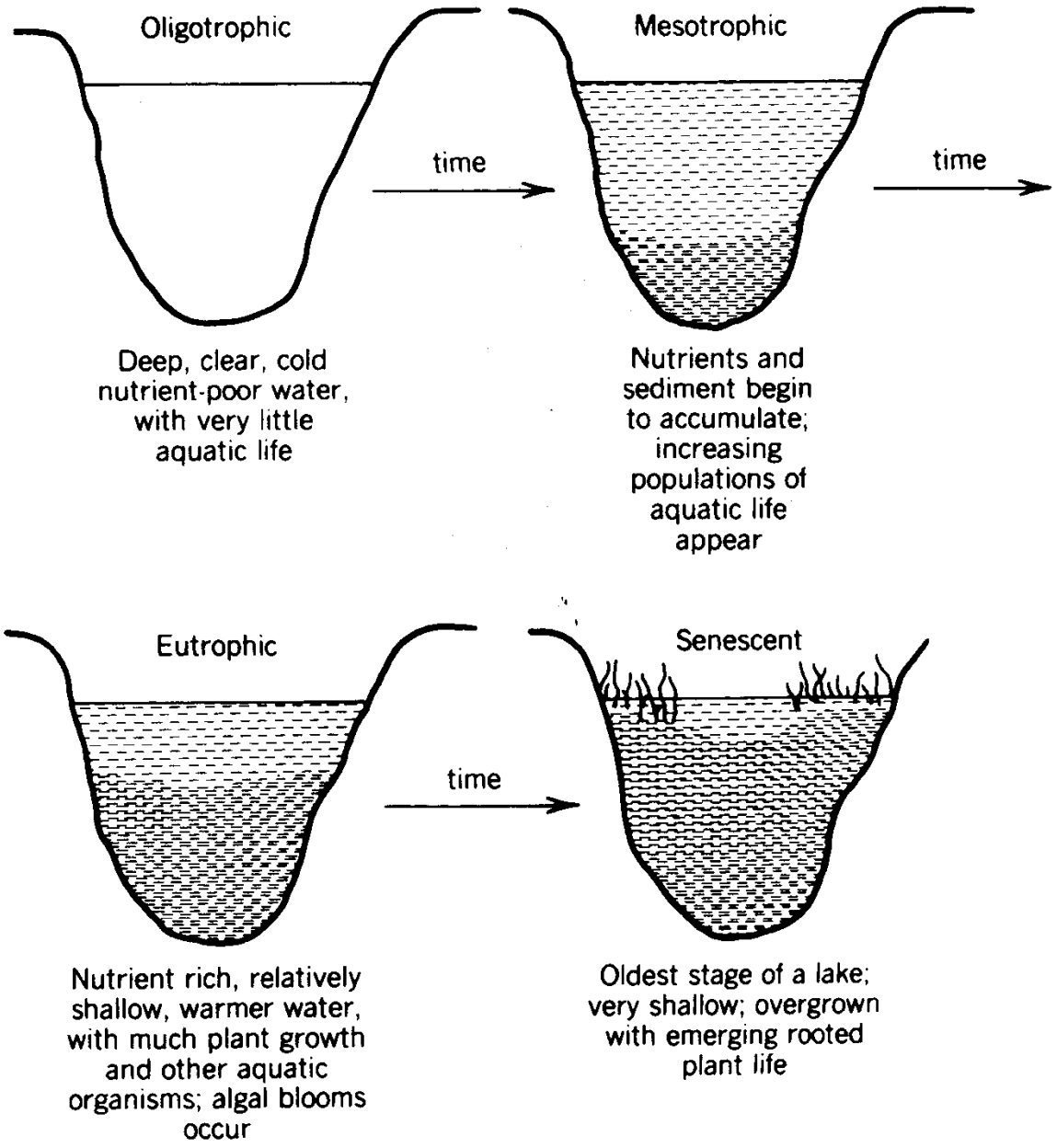
Development of anoxic conditions and release of noxious gases such as hydrogen sulphide, thioalcohols and ammonia.

The Big Picture



Effects on water quality

- **Bad taste and odor :** some of the algal species that "bloom" produce toxins (geosmin, MIB), water taste and odor deteriorates.
- **Oxygen depletion**: penetration of light into the water is diminished. This occurs because the algae forms mats as a result of being produced faster than they are consumed. Diminished light penetration decreases the productivity of plants living in the deeper waters and hence their production of oxygen.
- As the water becomes depleted in oxygen, the abundant algae and fish die and decompose, further oxygen is consumed by this process.
- Under anoxic conditions **iron, manganese, ammonia and phosphorous** are released into the water column, anaerobic bacteria flourish, producing **hydrogen sulfide**.



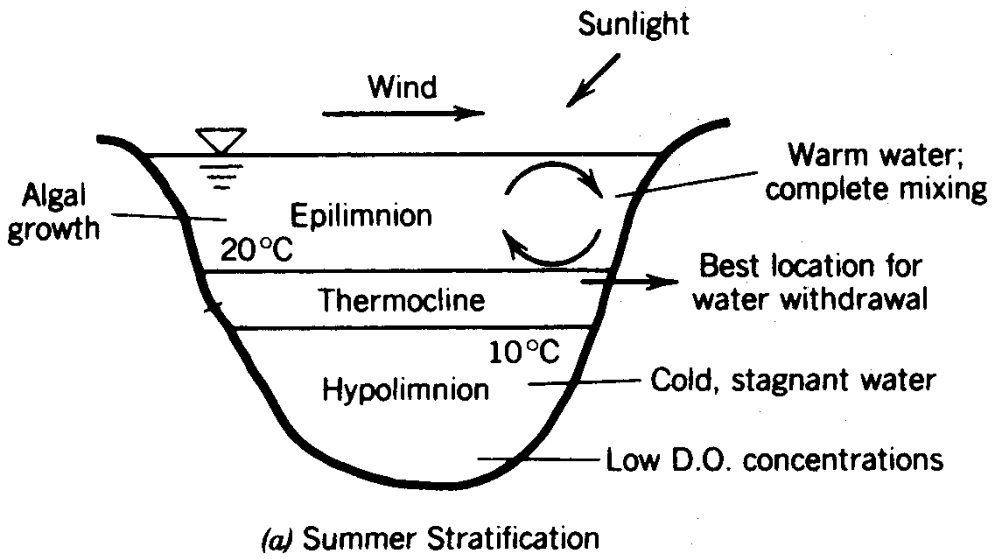
Primary ***productivity***

- rate of photosynthesis (carbon-fixing)

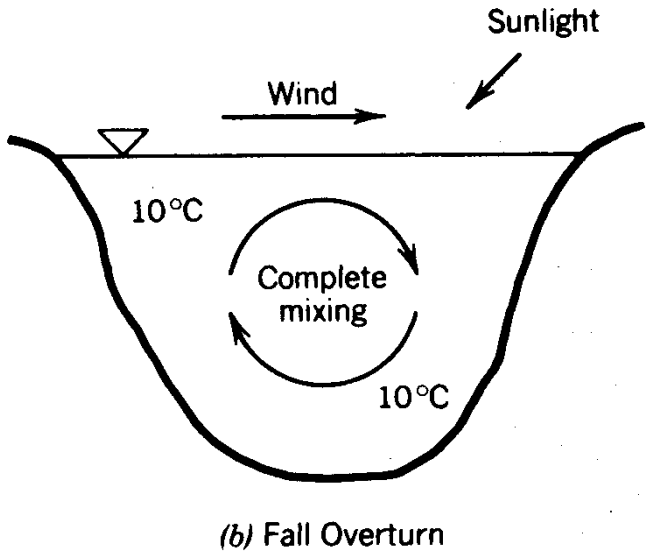
Three common productivity levels are indicated in the figure:

- oligotrophic
- mesotrophic
- eutrophic

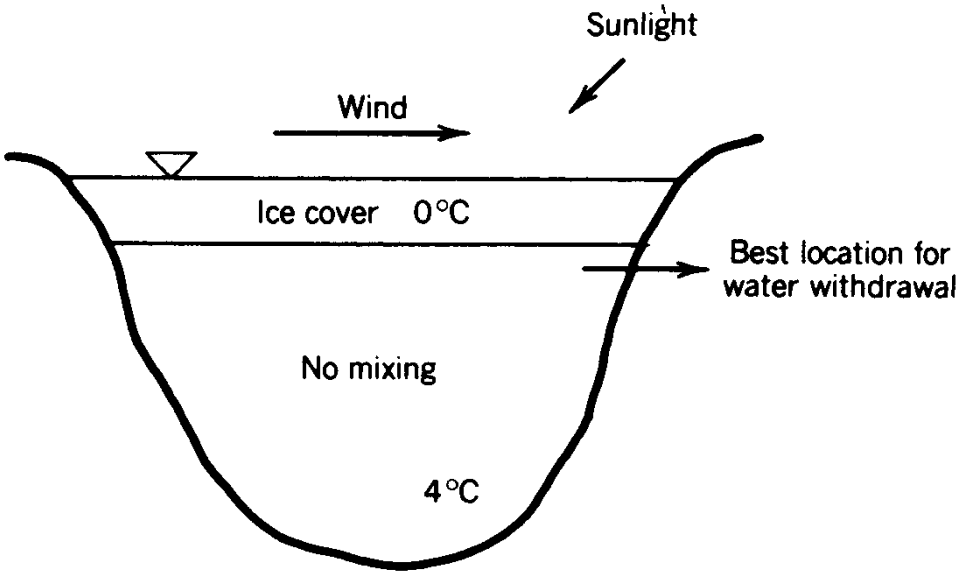
Ideal Development of Stratification in a Lake



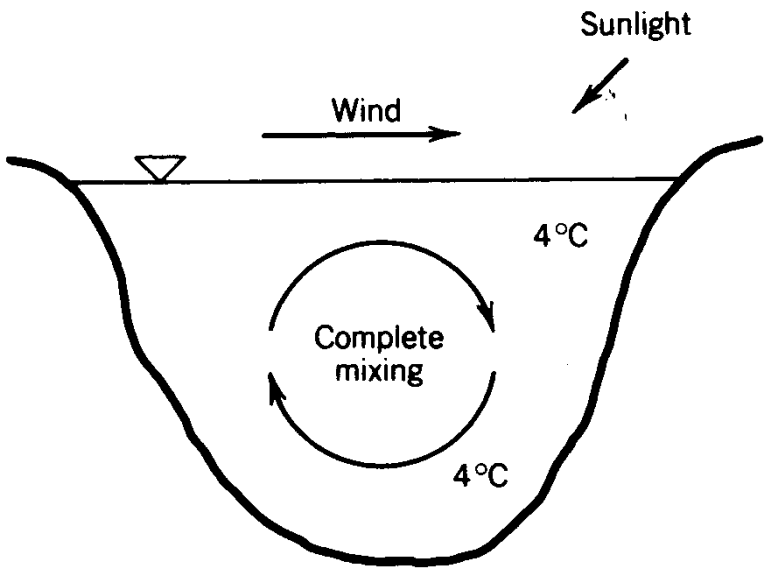
(a) Summer Stratification



(b) Fall Overturn



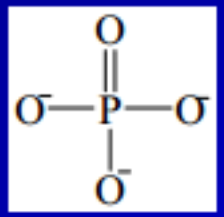
(c) Winter Stagnation



(d) Spring Overturn

Phosphorus in Wastewater

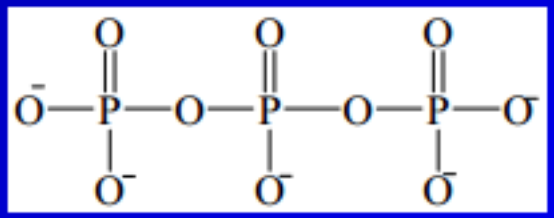
orthophosphate



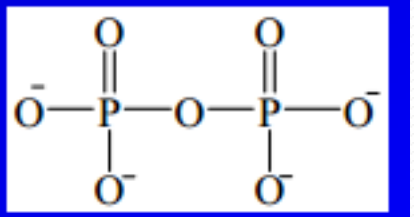
condensed phosphates

polyphosphates (linear)

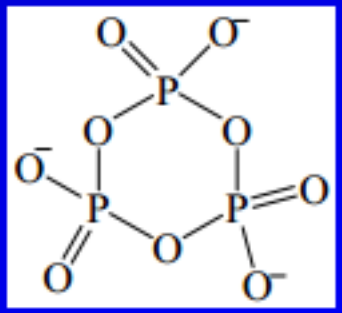
tripolyphosphate



pyrophosphate



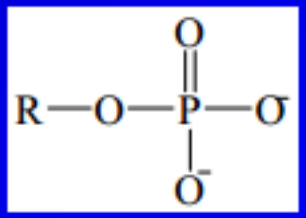
metaphosphates (cyclic)



trimetaphosphate

organic phosphates

R = organic



e.g., nucleotides, phospholipids, sugar phosphates

Forms of phosphorus found in aqueous solutions

Orthophosphate

PO_4^{3-}, HPO_4^{2-} , $H_2PO_4^-$, H_3PO_4

Polyphosphate

2 or more P atoms + O_2 atoms + (H) combined in a complex molecule

Organic Phosphate

Minor

Phosphorus in wastewater

- Average person releases 1.5 g/day
- Prior to the development of detergents:
  - Inorganic 2-3 mg/L
  - Organic 0.5 – 1 mg/L
- EPA:
  - Sewage effluent should not contain > 1 mg/L
  - Unpolluted waters usually < 0.1 mg/L

Human Impacts

- Heavy-duty synthetic detergents
  - Contain polyphosphates
  - 12-13% phosphorus
- Domestic wastewater
  - 2-3x inorganic P due to detergents
- Municipal wastewater contain 4-16 mg/L phosphorus as P

Polyphosphorus is a builder

- Laundry detergents are formulated from six groups of substances :
- . surfactants
- . builders
- . bleaching-agents
- . enzymes
- . fillers
- . other minor additive

Builders

Builders are key detergent components which remove the calcium and magnesium ions presents in hard water and in soils, thus lowering the concentration of surfactants necessary to perform the detersive action. Some builders also prevent the deposition of calcium and magnesium salts on fabrics and washing-machines.

* Orthophosphates are available for biological metabolism without further breakdown

Polyphosphate $\longrightarrow$ Orthophosphate

Hydrolysis (slow)

* Organic Phosphate : minor in domestic ww

Methods

- Methods:
  - Gravimetric→applicable when concentration is high
  - volumetric → when conc.>50 mg/L
  - colorimetric

- Organic and polyphosphates have to be converted to orthophosphate for measurement

* Orthophosphate determined colorimetrically

* Ammonium molybdate

↓

Colored complex with phosphate at low pH

Polyphosphate analysis→ boil the sample (that have been acidified with H_2SO_4) for at least 90 min

Total inorganic phosphate-ortophosphate=poly-P

Phosphorus Determination is important

- Corrosion prevention, control of boiler's scale
- Assessing the potential biological productivity of surface waters
- Eutrophication control
- WWTP effluents
- Operation of WWTP
- Stream Pollution Control