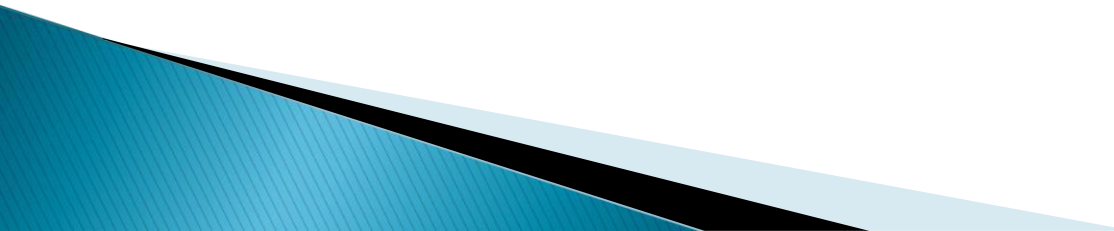


# Algal bloom and Eutrophication.

# Introduction :

- ▶ An algal bloom is a rapid increase or accumulation in the population of **algae** in freshwater or marine water systems, and is recognized by the discoloration in the water from their pigments.

- ▶ **Cyanobacteria** were mistaken for algae in the past, so Cyanobacterial blooms are sometimes also called algal blooms
- ▶ Blooms which can injure animals or the ecology are called "**Harmful algal blooms**" (HAB),
- ▶ Harmful algal blooms (HABs) represent a natural phenomena caused by a mass proliferation of phytoplankton (**Cyanobacteria, diatoms dinoflagellates**) in waterbodies).

- ▶ Even if exact causes of HABs are still unclear human impacts combined with climate changes have contributed to the recent increase in HABs incidence.
  - ▶ A distinction must be made between two different types of HABs—those that involve toxins or harmful metabolites, such as toxins and those which are nontoxic but cause harm in other ways.
- 

3 billion years ago

temporal scale

# Cyanobacteria



*Microcystis*



*Oscillatoria spp.*



*Anabaena spp.*



*Cylindrospermopsis spp.*



*Aphanizomenon spp.*

400 million years ago

135 million years ago

## Dinoflagellates

## Diatom

*Pyrodinium* spp.

*Karenia brevis*

*Gambierdiscus toxicus*

*Protoperidinium* spp.

*Prorocentrum lima*

*Gonyaulax* spp.

*Pseudo-nitzschia* spp.





Fig: Discoloration of water caused by a red tide

Fig: Cyanobacterial scum during a bloom in Lake Varese



(Italy)



- ▶ Algal blooms may occur in freshwater as well as marine environments.
- ▶ Harmful algal blooms is an algal bloom that causes negative impacts to aquatic organisms via production of natural toxins, mechanical damage to aquatic organism.
- ▶ HABs are often associated with large-scale marine mortality events and have been associated with various types of shellfish poisonings and also fin fishes and other aquatic organisms .
- ▶ The most well known HAB toxins are generically referred to as Ciguatera fish poisoning (CFP), Neurotoxic shellfish poisoning (NSP), Paralytic

shellfish poisoning (PSP), Diarrheic shellfish poisoning (DSP), Amnesic shellfish poisoning (ASP), and Azaspiracid Shellfish Poisoning (AZP)

Poisoning	Main toxins	MOST common organisms producing toxin	Effects	Main targets	Primary vector
PSP*	Saxitoxins	<i>Alexandrium</i> spp., <i>Gymnodinium</i> spp., <i>Pyrodinium</i> spp.	Muscle twitching, burning, numbness, drowsiness, headache, vertigo, respiratory paralysis leading to death	Sodium channels	Shellfish
NSP*	Brevetoxins	<i>Kerenia brevis</i> , <i>Chattonella marina</i> , <i>C. antiqua</i> , <i>Fibrocapsa japonica</i> , <i>Heterosigma akashiwo</i>	Tingling, numbness, nausea, muscular pain, neurologic symptoms	Sodium channels	Shellfish
CFP*	Ciguatoxins	<i>Gambierdiscus toxicus</i>	Tingling, itching, hypotension, bradycardia, vomiting, diarrhoea, nausea	Sodium channels	Coral reef fish
AZP*	Azaspiracids	<i>Protooperidinium crassipes</i> , <i>Azadinium spinosum</i>	Diarrhoea, nausea, vomiting, stomach cramps	Calcium channel	Shellfish
DSP*	Okadaic acid, Dinophysis toxins	<i>Dinophysis</i> spp., <i>Prorocentrum</i> spp.	Diarrhoea, nausea, vomiting, abdominal cramps	Serine/threonine protein phosphatases	Shellfish

diatoms: their effects, primary targets and vectors

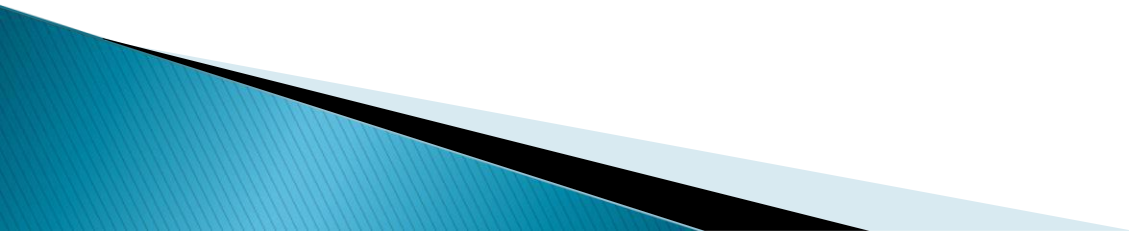




Fig: Fish kill caused by a bloom episode



Taken in October 2011, the worst algae bloom that **Lake Erie** has experienced in decades. Record torrential spring rains washed fertilizer into the lake, promoting the growth of **microcystin** producing cyanobacteria blooms

# In India

- ▶ Researchers have found toxic bloom has increased around 15 percent over the 12 years in Indian seas.
- ▶ There was 80 harmful bloom recorded between the 1998–2010 in Indian water. Research data was generated by– K.B. Padmakumar & V.N. Sanjeevan (Centre for Marine Living Resources & Ecology, Kochi).

- ▶ 1st recorded observation on algal bloom in India was in 1908





A Noctiluca algae bloom that was observed in the sea off Kochi during the 2008 monsoon.



This deep red harmful algae, called **Lingulodinium polyedrum**, is a type of HAB that often

# Types of algal blooms

produces brightly colored water discoloration. It has been associated with fish and shellfish mortality events.

† Algal blooms occur when environmental conditions allow explosive growth of phytoplankton that create very dense clouds of these organisms (blooms) which can change the color of ocean water.

† These blooms are often called 'red tides.' However, red tides are not always "red," and furthermore, they really



have nothing to do with the tides.

† There are three kinds of red tides: **red**, **brown**, and **green**.

† Red tides are caused by phytoplankton that have a reddish pigment called peridinin.

† Most dinoflagellates, such as *Alexandrium catenella*, have this pigment.



† Green tides can be caused by *Phaeocystis*, which is a unicellular, photosynthetic algae found throughout the world.

† Green tides can also be caused by macroalgae such as *Enteromorpha* spp. and *Codium* spp., which have caused serious damage to many coastal regions when in bloom.



‡ Brown tides are caused by the pelagophytes (another type of microalgae) such as *Aureococcus anophagefferens*.

‡ *Aureococcus* is a spherical, non-motile species that has caused noticeable damage to the coastal ecosystems in which it occurs.

✦ Brown tides are commonly seen in the northeast and mid-Atlantic US estuaries

## *Worldwide Effects of HAB's*

- ▶ Light penetration levels in water decrease altering photosynthesis rate.
- ▶ Algal blooms may be harmful to seagrass and coral reef ecosystems and the connected food webs.
- ▶ Shellfish may accumulate algal



toxins by feeding on the toxic phytoplankton resulting in fish kills, marine mammal distress, human illness and possible death.

oEcologic Concerns :

Low dissolved oxygen Food-web disruption

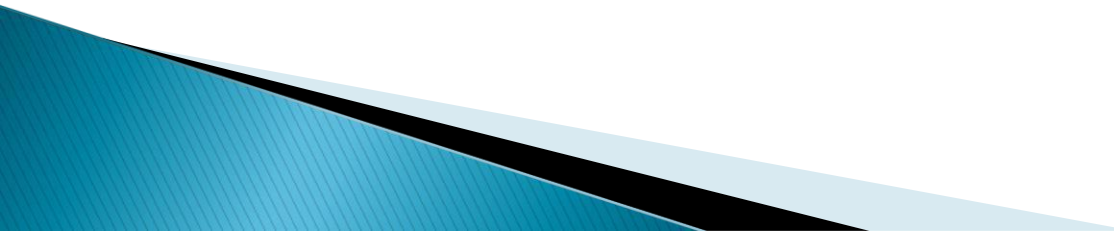
oEconomic Concerns:

Loss of recreational revenue

Taste and odor

Added drinking

water treatment costs ○Public Health  
Concerns : Allergic reactions  
Toxicity (Cyanobacteria only)



**Table 2: Toxins produced by cyanobacteria: their effects and primary targets**

Toxin classification	Toxins	Most common cyanobacteria genera producing toxins	Main organ affected	Effects	Main targets
Hepatotoxins	Microcystins	<i>Microcystis</i> , <i>Anabaena</i> , <i>Anabaenopsis</i> , <i>Aphanizomenon</i> , <i>Planktothrix</i> , <i>Oscillatoria</i> , <i>Phormidium</i>	Liver	Diarrhea, vomiting, weakness liver inflammation, liver hemorrhage, pneumonia, dermatitis	Serine/ threonine protein phosphatases
	Nodularin	<i>Nodularia</i> , <i>Nostoc</i>	Liver	Diarrhea, vomiting, weakness liver inflammation, liver hemorrhage, pneumonia, dermatitis	Serine/ threonine protein phosphatases
Cytotoxins	Cylindrospermopsin	<i>Cylindrospermopsis</i> , <i>Anabaena</i> , <i>Aphanizomenon</i> , <i>Raphidiopsis</i> , <i>Oscillatoria</i> , <i>Lyngbya</i> , <i>Umezakia</i>	Liver	Gastroenteritis, liver inflammation, liver hemorrhage, pneumonia, dermatitis	Protein synthesis

Neurotoxins	Anatoxins	<i>Anabaena, Aphanizomenon, Planktothrix, Cylindrospermopsis, Oscillatoria</i>	Nervous system	Muscle twitching, burning, numbness, drowsiness, salivation, respiratory paralysis leading to death	Nicotinic receptors or acetylcholinesterase
	Saxitoxins	<i>Anabaena, Aphanizomenon, Cylindrospermopsis, Lyngbya, Planktothrix, Rhabdidiopsis</i>	Nervous system	Muscle twitching, burning, numbness, drowsiness, headache, vertigo, respiratory paralysis leading to death	Sodium channels
	BMAA*	<i>Nostoc, Microcystis, Anabaena, Aphanizomenon, Nodularia</i>	Nervous system	No specific clinical symptoms, ALS/PDC with long-term consistent exposure	NMDA* excitotoxicity, ROS production
Dermatoxins	Lypopolysaccharide	<i>Synechococcus, Microcystis, Anacystis, Oscillatoria, Schizothrix, Anabaena</i>	Skin	Skin irritation, eye irritation, headache, allergy, asthma, fever	Toll-like receptors
	Lyngbyatoxins	<i>Lyngbya</i>	Skin	Skin and eye irritation, respiratory problems	Protein kinase C
	Aplysiatoxin	<i>Lyngbya, Schizothrix, Oscillatoria</i>	Skin	Skin irritation, asthma	Protein kinase C

\* (**BMAA** stands for  $\beta$ -Methylamino-L-Alanine; **NMDA** stands for N-Methyl-D-Aspartate)

# What Types of Algae Cause Blooms?

All types of algae can cause harmful algal blooms under the right conditions.



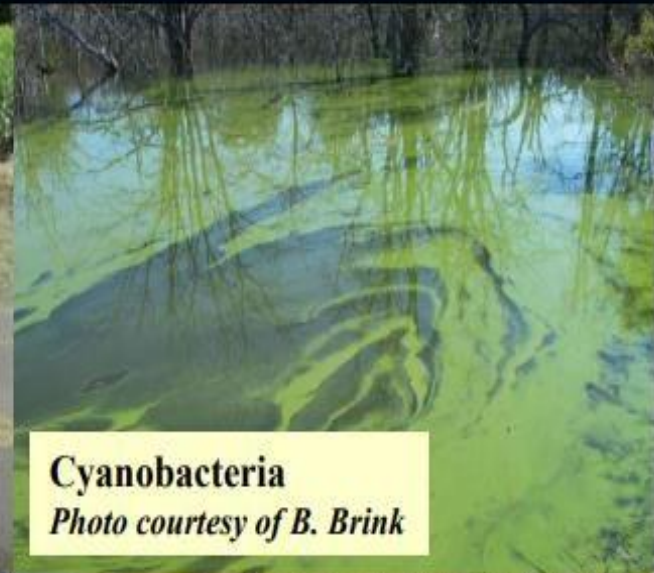
**Euglena**

*Photo courtesy of T. Bennett*



**Diatoms**

*Photo courtesy of N. Clercin*



**Cyanobacteria**

*Photo courtesy of B. Brink*



**Golden Algae**

*Photo courtesy of TDWP*



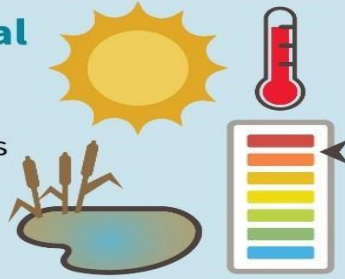
**Green Algae**

*Photo courtesy of N. Clercin*

# Causes of Algae Blooms

## Environmental Conditions

- Abundant light
- High temperatures
- High pH levels
- Stagnant water
- Excess nutrients



## TOXIC ALGAE BLOOM

## Sources of Excess Nutrients

### Agriculture:

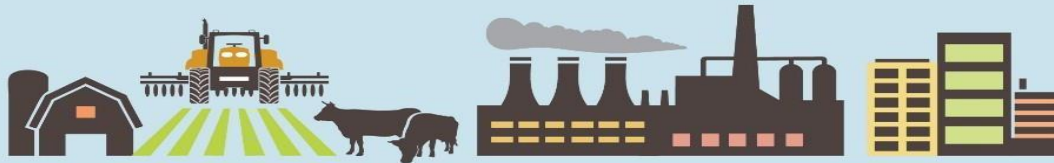
Fertilizer runoff (nitrogen & phosphorus) and animal waste

### Industry:

Chemical discharge and waste

### Urban Life:

Sewage and waste runoff



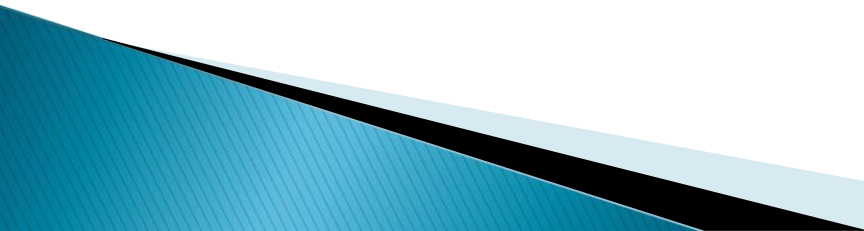
## Climate Change

*Climate change is increasing the frequency and severity of blooms due to:*

- Increases in water and air temperature
- Increases in droughts and flooding
- Changes in salinity
- Increased amount of CO<sub>2</sub>
- Sea level rise and coastal upswelling



# Reasons for HAB's

- ▶ Global climate changes producing wider ranges for some species.
  - ▶ Human contributions of increased nutrients and pollution in coastal waters and also fresh waters.
  - ▶ Changes in local ecosystems that may allow exotic species to thrive if introduced.
  - ▶ Upwelling.
  - ▶ Formation of mud banks.
- 

- ▶ Nutrients discharge on sea or fresh water through river.

## Occurrence:

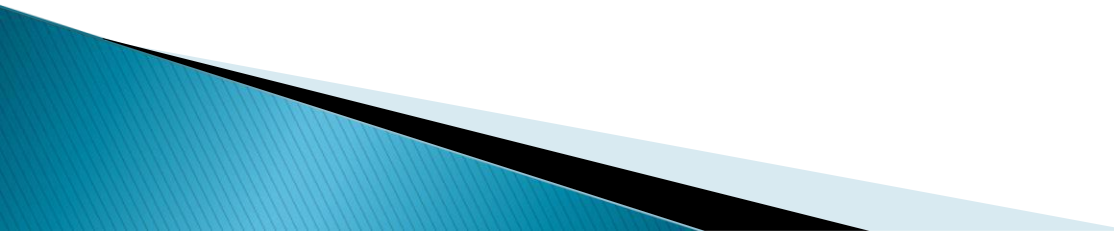
- ▶ Algal blooms can occur any time of the year:
- ▶ Green algae and diatom blooms are common in the spring.
- ▶ Cyanobacterial blooms are common during summer and early fall.
- ▶ Golden algae blooms are common in the winter.



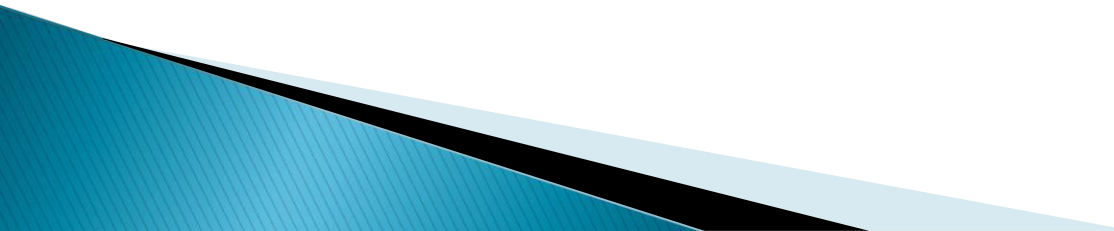
# Algae growth conditions..

- ▶ In all water bodies, a basic level of algae is present.
- ▶ However, when a specific **algal type starts growing exponentially**, it can suffocate other organisms within the water that are important for a balanced lake ecology, causing a deterioration of the water quality, and eventually massive deaths of fish and other

aquatic organisms, creating an imbalance in the lake that may result in reduced levels of dissolved oxygen, reduced plant growth and altered pH levels.

- ▶ Favourable conditions for blue-green algae are stagnant water in combination with high temperature and high concentration of nutrients (**Nitrogen** and **phosphorus** )in the water.
  - ▶ Especially in the summer months, when the water temperature increases, the concentration of algae
- 

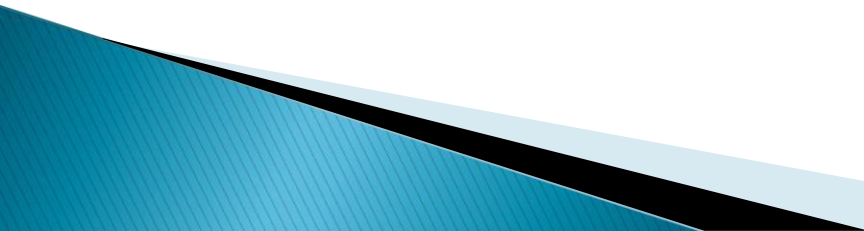
can grow exponentially.

- ▶ Water in raw water reservoir is often stagnant, the lack of circulation of the water can cause the algae to over-compete other organisms in the ecosystem and thus create massive algae blooms.
  - ▶ Even if new nutrients cease to be introduced into the water body, the biochemistry of a pond or lake is such that, due to the laws of growth, decay and gravity, eutrophication will not be stopped.
- 

- ▶ This is because of an internal phosphorus cycling; the plant food never leaves. Further introduction of nutrients related to human activity, such as agriculture, will increase the level of eutrophication

## What causes algae to grow....

- ▶ A preventive measurement that can be taken is the real time monitoring of essential water quality parameters and algal indicators.

- ▶ Real-time monitoring of water quality parameters related to phytoplankton dynamics such as Chlorophyll-a, phycocyanin, Temperature, DO, pH, Turbidity, and Redox is essential for shortterm forecasting of potentially harmful algal blooms.
  - ▶ These parameters provide direct and indirect information about the concentration of algal biomass in a waterbody. Once a bloom is predicted, it is easier to anticipate an algae bloom and take preventative measures.
- 

# Algae control methods

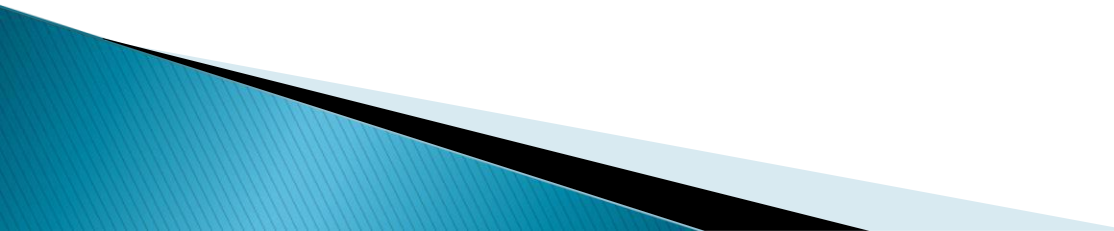
- ▶ The presence of **cyanobacteria** is a severe and global problem. When it comes to lakes or bigger ponds.
- ▶ While some methods are environmentally unfriendly (Algaecides), other methods are expensive (Aeration). To treat and control the growth of algae, the following four main methods.
- ▶ Chemicals
- ▶ Aeration ▶ Mixing
- ▶ Ultrasound

# Chemicals :

- ▶ Chemical intervention involves treating the water with a variety of additives, such as alum, lanthanum, or any other products that precipitate or sequester the ionized orthophosphates.
- ▶ Algaecides., herbicide for algae can also be used.

Aeration:



- ▶ Aeration is an environmentally friendly technique to maintain and rejuvenate water bodies.
  - ▶ To eliminate chemical use and create a healthy ecosystem, aeration systems can be used.
  - ▶ The oxygen aids in the breakdown of decaying vegetation and other nutrients that find their way into the water.
- 



- ▶ The disadvantages of this technology are the high costs for maintenance (labor costs) and energy use.

## Mixing:

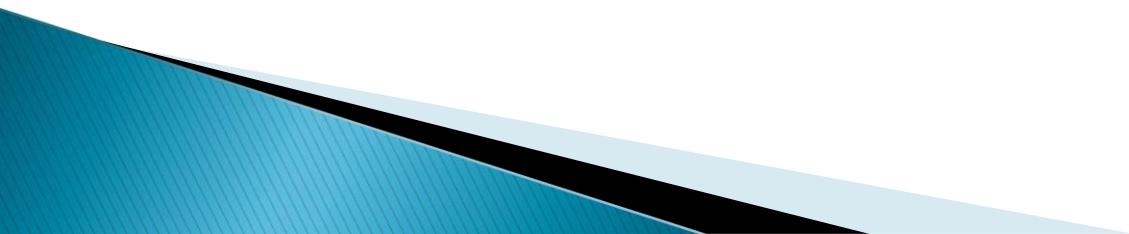
- ▶ The main function of mixers in a reservoir is destratification, which is a process in which the water is mixed to eliminate stratified layers (Epilimnion, Metalimnion, Hypolimnion) and make it less favorable for algae growth in certain layers.

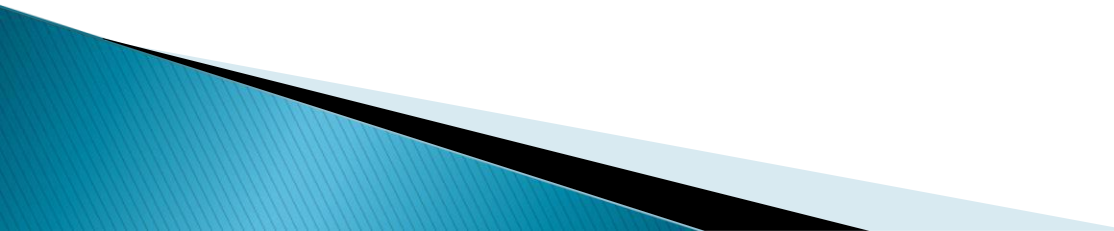
- ▶ The disadvantage of the mixing or circulation of water is often the high maintenance

## Ultrasound

- ▶ Ultrasound waves create a sound layer in the top layer of the water. The sound layer has a direct impact on the buoyancy of the algae. The algae cells will sink to the bottom and are unable to photosynthesize and eventually die due to a lack of light.

# Eutrophication



- ▶ “Eutrophication” can be defined as the process by which increasing nutrients.
  - ▶ Cause a change of the nutritional status of a given body of water mainly arises from the oversupply of **phosphate** and **nitrate** nutrients.
  - ▶ Excessive richness of nutrients in a lake or other body of water, frequently due to run-off from the land, which causes a dense growth of plant life.
- 

## Point sources (can locate the cause)

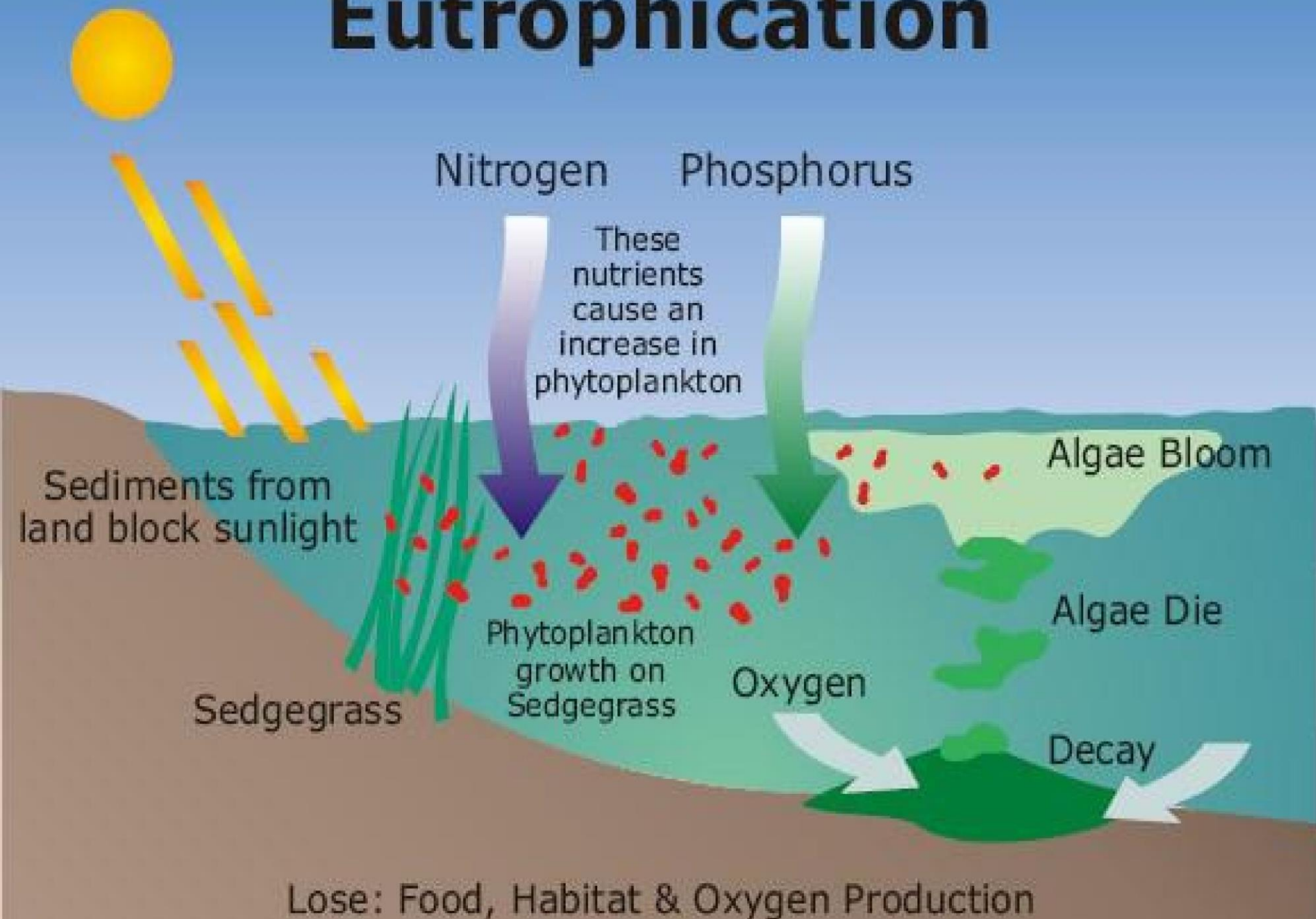
- ▶ Sewage treatment plant discharges
- ▶ Storm sewer discharges
- ▶ Industrial discharges

Non-point sources (can't locate the cause,

it's everywhere)

- ▶ Atmospheric deposition
- ▶ Agricultural runoff (fertilizer, soil erosion)
- ▶ Septic systems

# Eutrophication

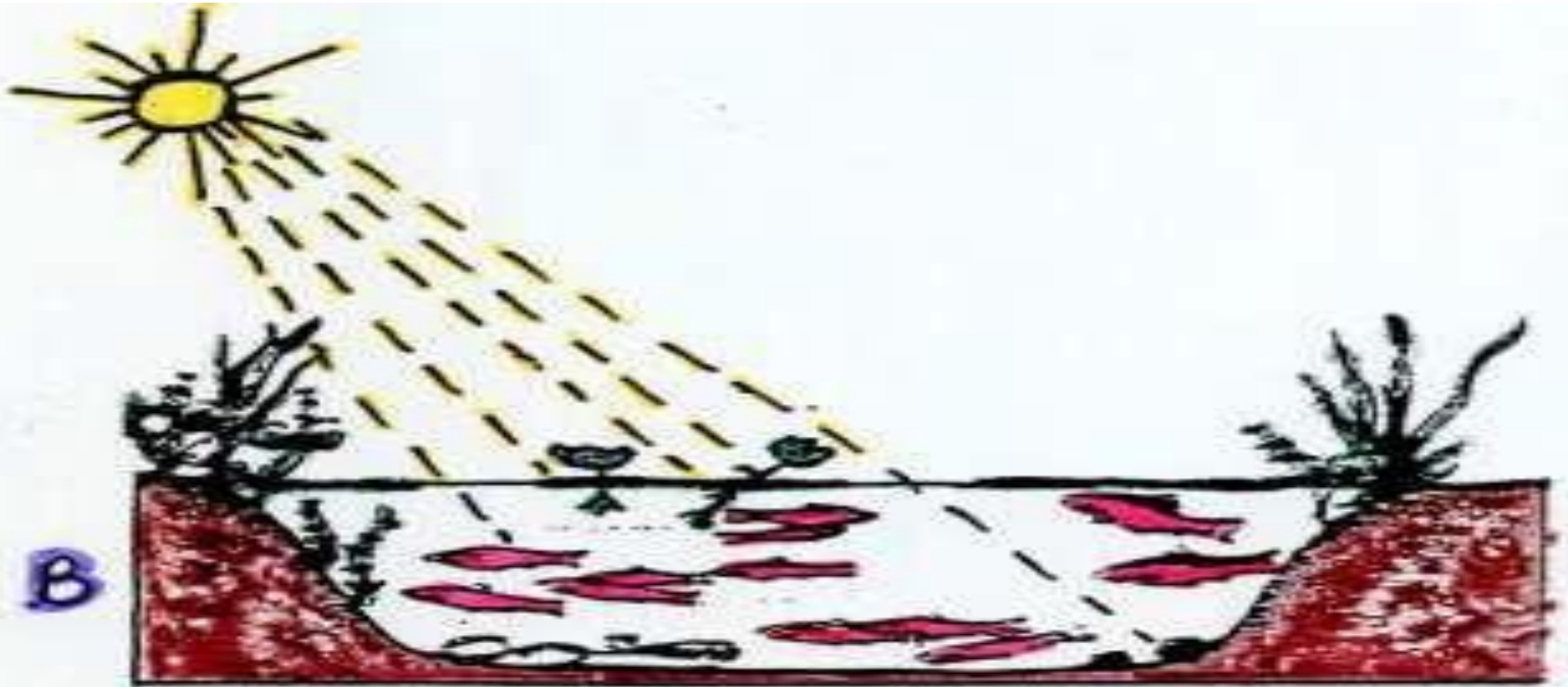


# STEPS OF EUTROPHICATION

Fertilizer flows into water causing....

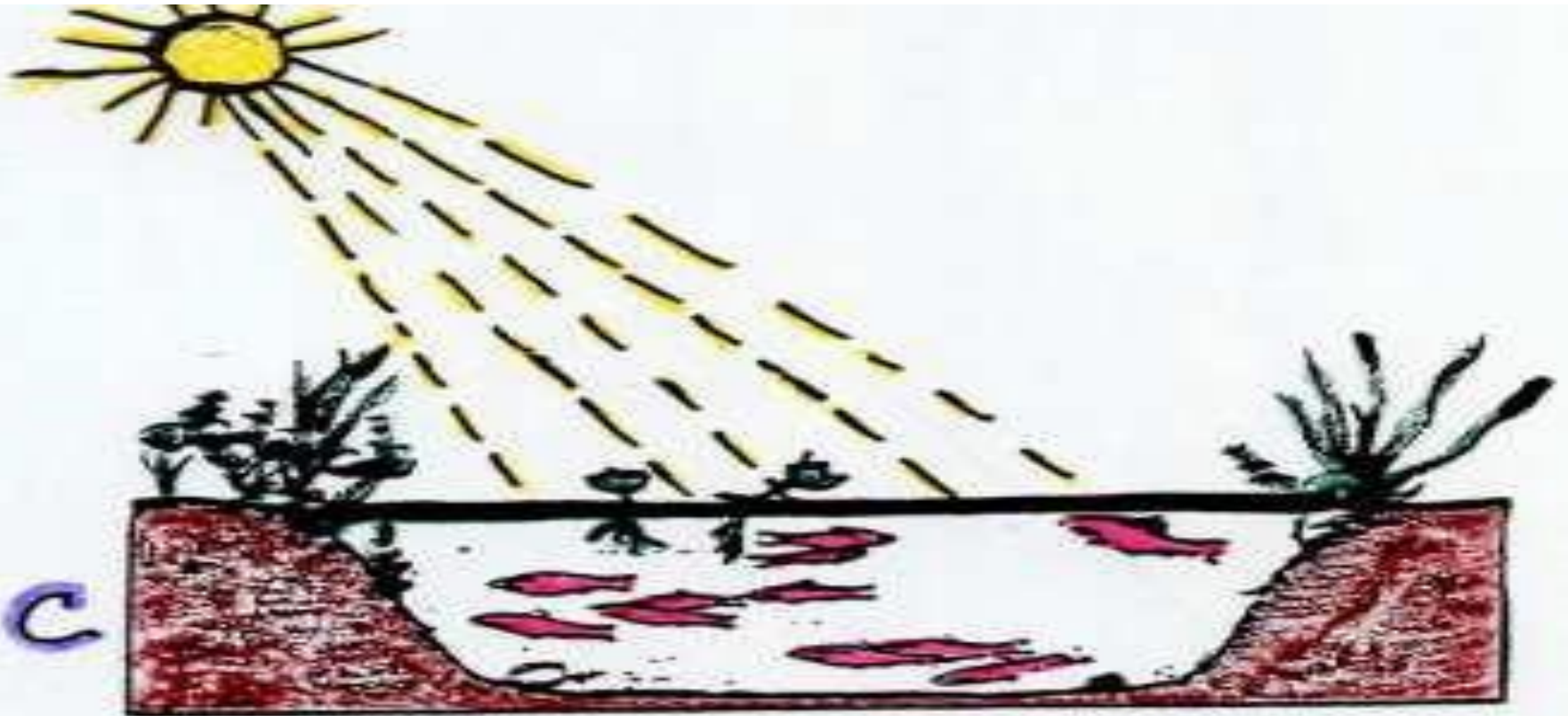






→ Increased plant growth on the surface of water, causing.

→ Decreased light in lower levels of water, causing.



→ Plants in lower levels of water to die, causing....

→ Decay using up O<sub>2</sub> and increasing  
CO<sub>2</sub>, causing.....



Death of fish and other animals

# Eutrophication process in 6 stages

ADDITION OF NITRATES



GROWTH OF PLANTS



DEATH OF PLANTS



GROWTH OF BACTERIA

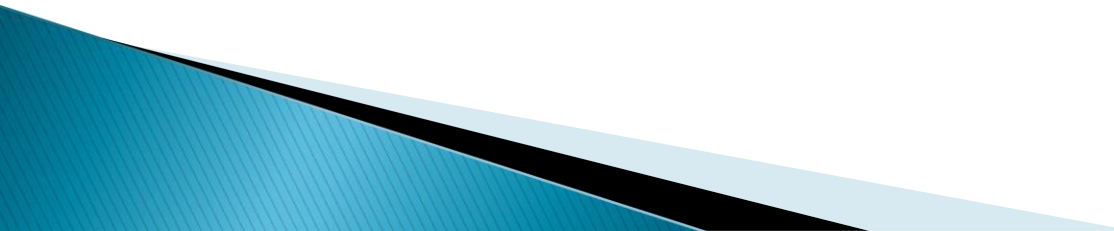


LACK OF OXYGEN



# CAUSES

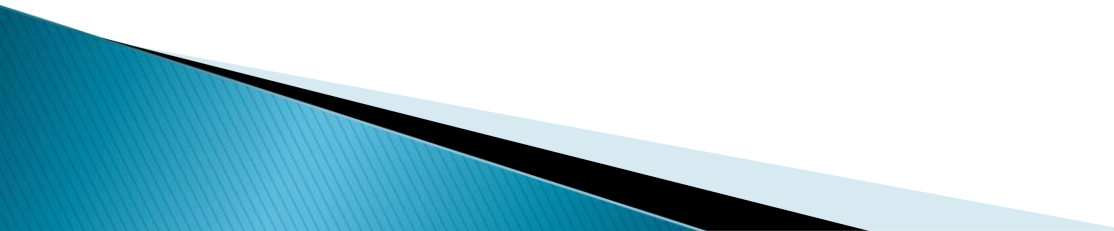
## SUFFOCATION

- † Run-off of inorganic fertiliser (containing nitrates and phosphates)
  - † Run-off of manure from farms (containing nitrates, phosphates and ammonia)
  - † Run-off from erosion (following mining, construction work or poor land use)
  - † Discharge of detergents (containing phosphates)
- 

# Effects of Eutrophication on water quality

- † Discharge of partially treated or untreated sewage (containing nitrates and phosphates)
- † Deterioration of water quality.
- † Decline in the availability of clean drinking water

# Ecological Effects of Eutrophication:

- ▶ Phytoplankton grows much faster in such situations.
  - ▶ These phytoplankton species are toxic and are inedible.
  - ▶ Gelatinous zooplankton blooms fast in these waters.
  - ▶ Increased biomass of benthic and epiphytic algae.
  - ▶ Changes in macrophyte species composition and biomass.
- 



- ▶ Decreases in water transparency.
- ▶ Colour, smell, and water treatment problems.
- ▶ Dissolved oxygen depletion.
- ▶ Increased incidences of a fish kill.
- ▶ Loss of desirable fish species.
- ▶ Reductions in harvestable fish and shellfish.
- ▶ Decreases in the perceived aesthetic value of the water body.
- ▶ P Assmy, 2009. Environmental Microbiology and Ecology, Algal blooms

# Reference

- ▶ Eugene P.Odum,Ph.D and Gary W.Barrett,Ph.D,2005.Fundamentals of Ecology(5<sup>th</sup> edition),Eutrophication :causes and control

THANK YOU

