Ecosystem

Ecosystem

- Terminologies related to ecosystems
- Human influence on ecosystems
- Energy and mass flow
- Bioaccumulation of hazardous chemicals
- Nutrient cycle: C, N, P
- Ecosystem example - lake ecosystem

Some terminologies

- **Ecosystem**: community of organisms that interact with one another and with their physical environment

- **Habitat**: the place where a population of organisms lives

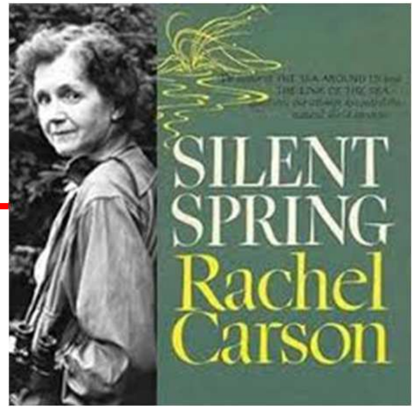
- **Population**: a group of organisms of the same species living in the same place at the same time

Human influence on ecosystems

- Destruction of the habitat
  - deforestration, dam construction, road construction, etc.

- Changes in species population
  - can result in local and global extinction
  - release of toxic chemicals (ex: DDT, petroleum compounds, heavy metals)
  - shifting living conditions: acid rain, global warming, eutrophication, etc.
  - introduction of nonnative (exotic) species
  - excessive hunting

DDT and Silent Spring



1874: DDT first synthesized by O. Zeidler

1939: P. H. Müller discovered the insect killing ability and won Nobel Prize (1948)

1940s: Widely used as an insecticide (especially for lice-Typhus and mosquito-malaria)

1962: Rachel Carson published “Silent Spring” - described how DDT accumulates in organisms and affect wildlife

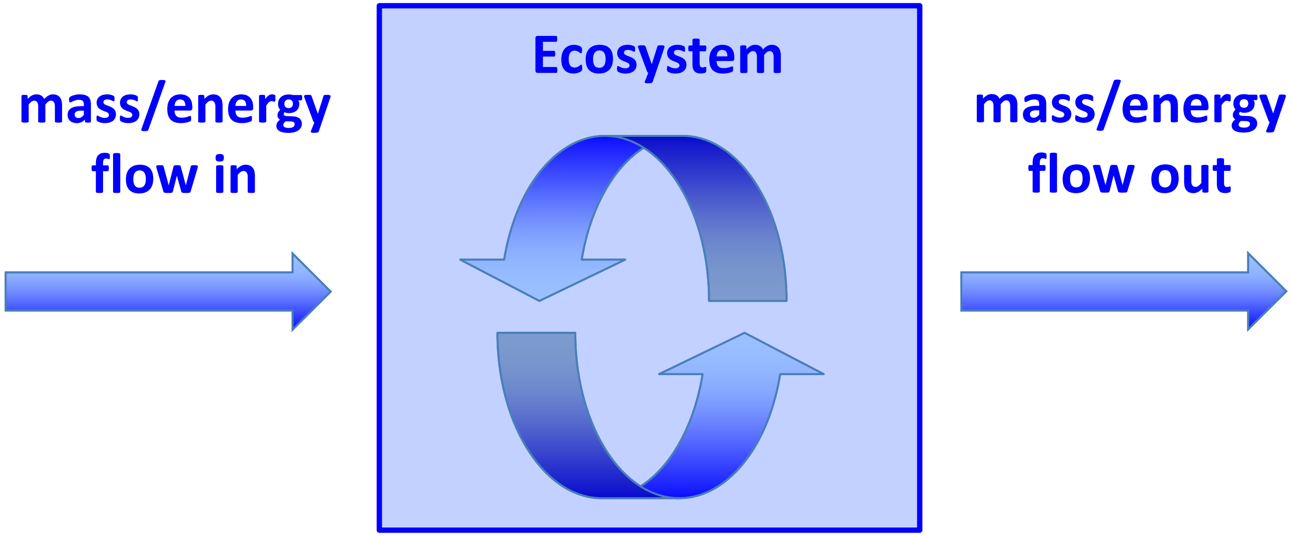
1960s: Environmental scientists published researches to support R. Carson’s argument (egg shell thinning by DDT)

1972: DDT banned in the U.S.

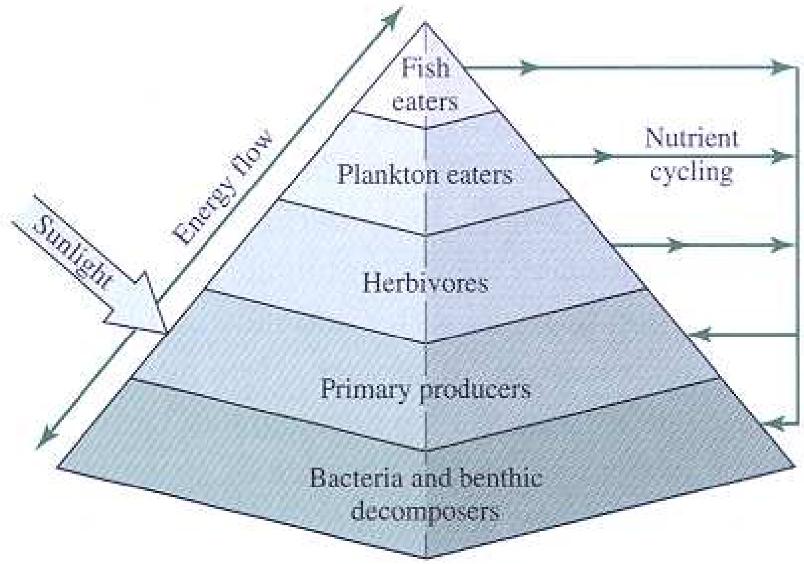
Energy and mass flow

- Important feature of an ecosystem:
  - Flow of matter into, out of, and within the system
  - Magnitude of internal cycling ↑, flow in & out ↓

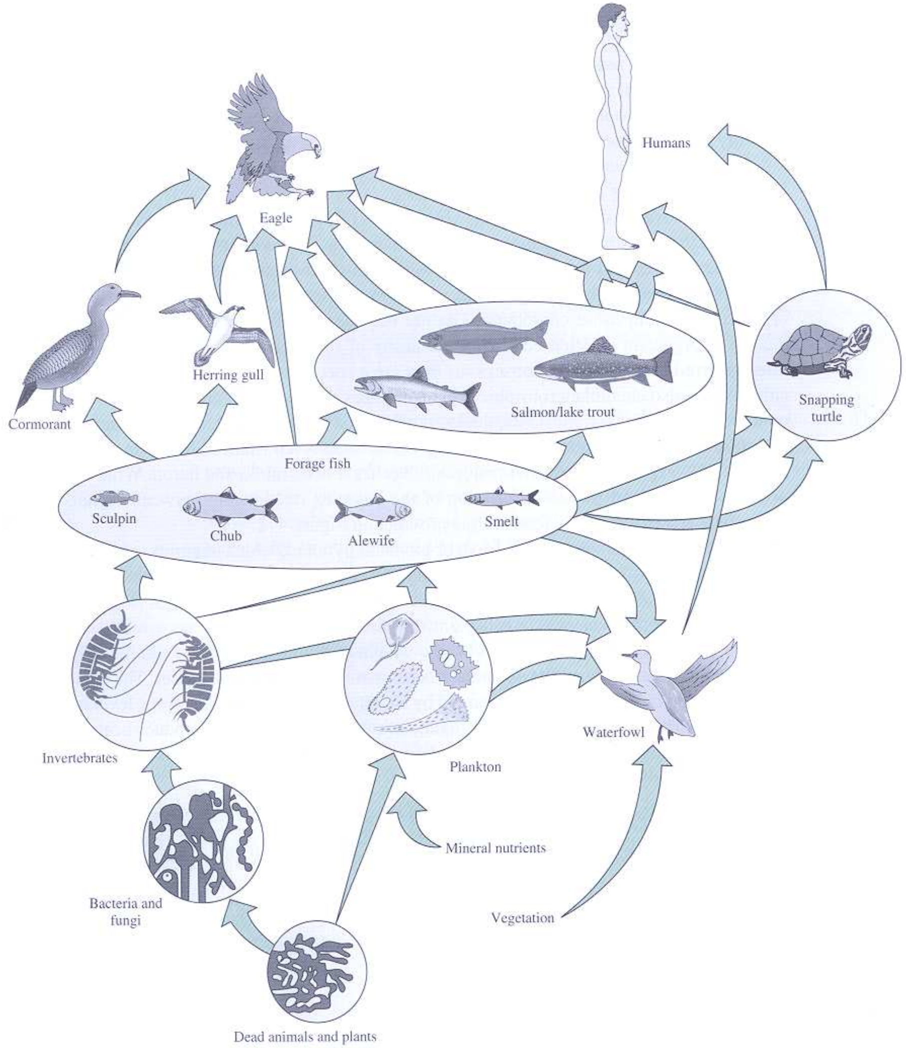
    cf) man-made systems: internal cycling ↓, flow in & out ↑



Energy and mass flow



<Ecological pyramid example>



<Food web example>

Energy and mass flow

- Primary producers
  - Major source of energy for an ecosystem: sunlight
  - Major source of carbon (essential element for organic matter) for an ecosystem: CO_2
  - Primary producers can use sunlight and CO_2 (or HCO_3^-) to produce organic matter that contains energy in a chemical form:

    <Photosynthesis>

    $$6CO_2 + 6H_2O + \text{sunlight (2800 kJ)} \xrightarrow{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2$$

  - Organisms that obtain carbon from inorganic sources and use sunlight as an energy source is called "*photoautotrophic*"

Energy and mass flow

- Classification of organisms based on energy / carbon source
  - Based on energy source
    - Phototrophs: light
    - Chemotrophs: organic or inorganic compounds
      - Chemolithotrophs: inorganic
      - Chemoorganotrophs: organic
  - Based on carbon source
    - Autotrophs: inorganic C (CO_2 or HCO_3^-)
    - Heterotrophs: organic C

Energy and mass flow

- Respiration
  - A process of oxidizing organic compounds so that the chemical energy stored can be released
  - The energy released is used to derive other reactions (ex: cell metabolism and growth)

<Aerobic respiration>

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

  - Requires an oxidizing agent to oxidize an organic compound by the redox reaction: called "electron acceptors"
  - Some organisms can use electron acceptors other than O_2

Energy and mass flow

- Other electron acceptors: nitrate (NO_3^-), nitrite (NO_2^-), sulfate (SO_4^{2-}), ferric ion (Fe^{3+}), CO_2, organic compounds

- Classification of organisms based on living in the presence/absence of O_2

  : Aerobes / Anaerobes

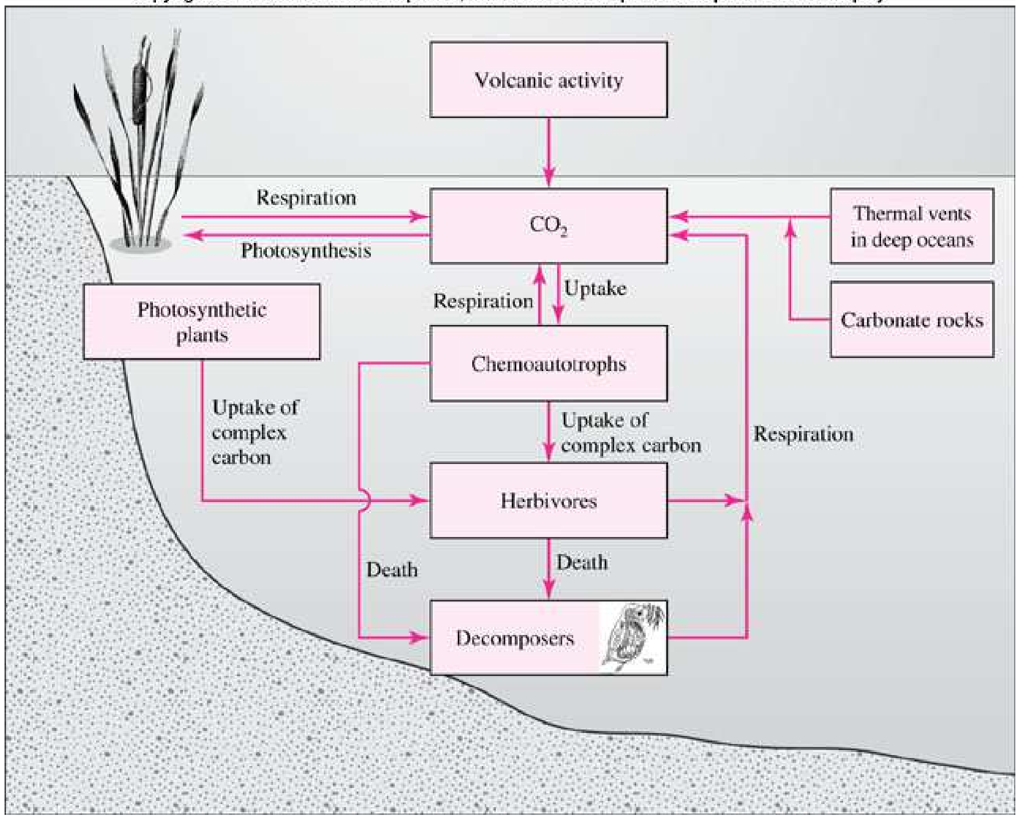
  – Obligate aerobes: can survive only in the presence of O_2
  – Facultative (an)aerobes: can use O_2 and other electron acceptor(s)
  – Aerotolerant anaerobes: cannot use O_2, but can survive in the presence of O_2
  – Obligate anaerobes: cannot survive in the presence of O_2

Energy and mass flow

Q: How would you classify yourself (i.e., a human being) based on i) the energy source, ii) the carbon source, and iii) living in the presence or absence of oxygen?

Nutrient cycle: C cycle

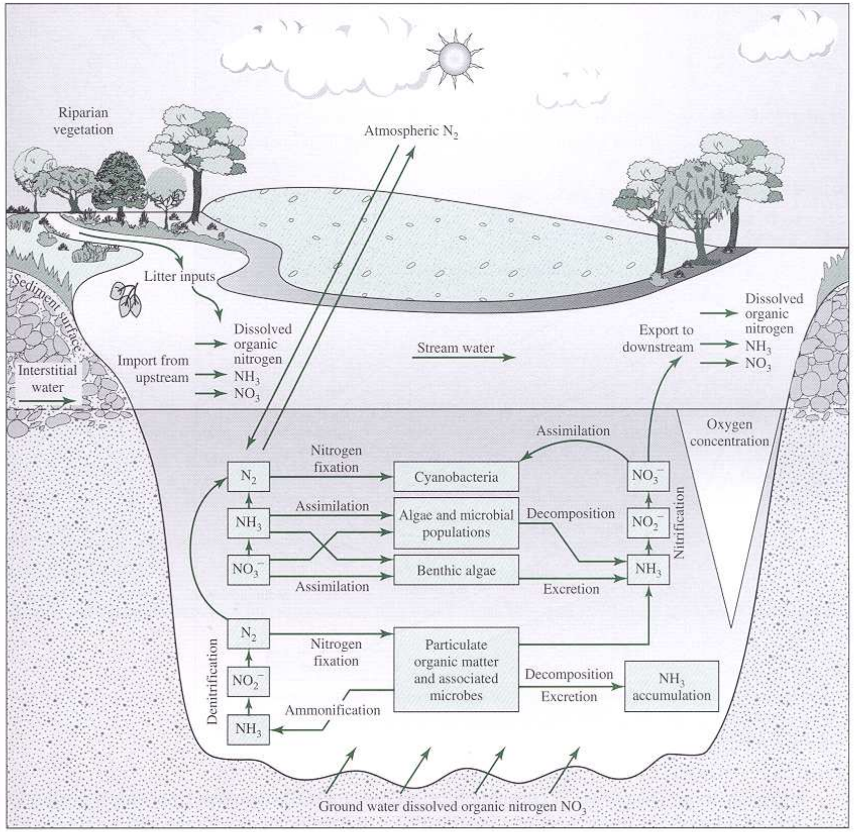
- Essential element: building block of life & life-sustaining chemicals



- Relevant processes
  - carbon cycling in the biosphere: photosynthesis, respiration, predation
  - ocean as a major carbon sink: solubility pump and biological pump
  - fossil fuel combustion: significant input of CO_2 by humans
  - dissolution of carbonate rocks

Nutrient cycle: N cycle

- Critical element for all life (protein)
- N_2 in the air: abundant, but not easily available to organisms



- Relevant processes

  - nitrification

    $NH_4^+ + 2O_2 = NO_3^- + 2H^+ + H_2O$

  - denitrification

    $2NO_3^- + \text{organic C} = N_2 + CO_2 + H_2O$

  - nitrogen fixation

    $N_2 + 8e^- + 8H^+ + ATP \rightarrow$

    $2NH_3 + H_2 + ADP + \text{inorganic P}$

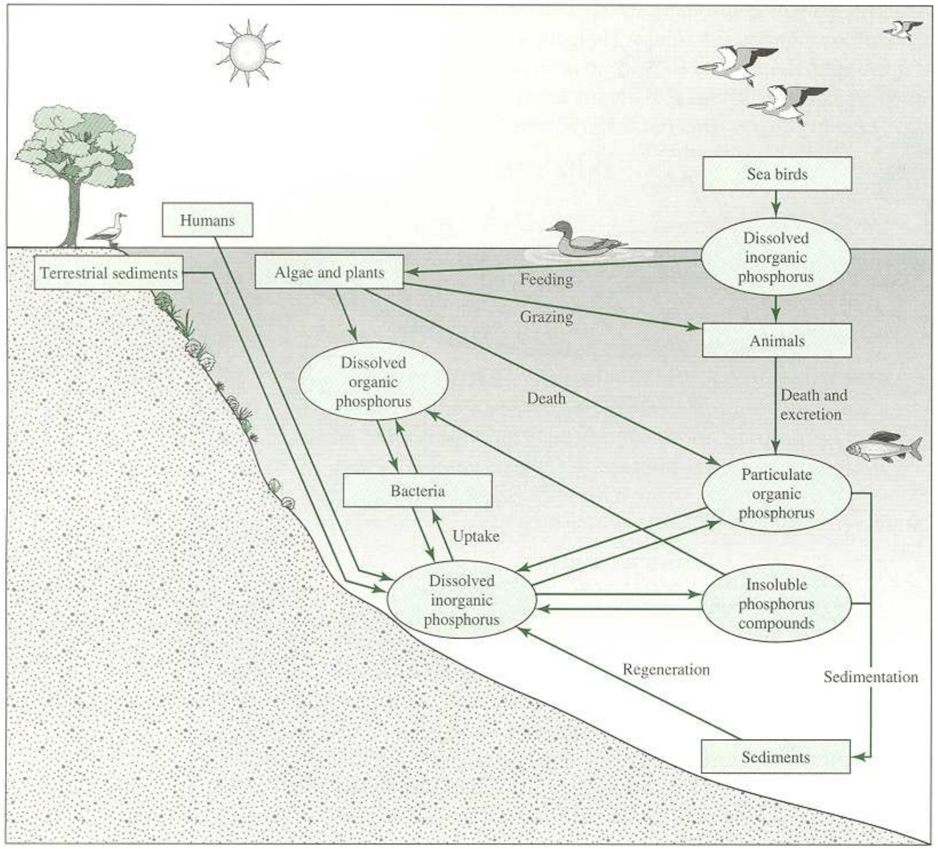
  - significant human contribution:

    Haber-Bosch process

    $N_2 + 3H_2 \rightarrow 2NH_3$

Nutrient cycle: P cycle

- Another essential nutrient (DNA, RNA, ATP)
- Very slow cycling: moves slowly through the soil and ocean



- Relevant processes
  - natural source: input from mineral weathering
  - human contribution can be significant (fertilizer, detergent, etc.)
  - uptake by plants and algae in a soluble inorganic form (HPO_4^{2-}, PO_4^{3-}, etc.)
  - loss by sediment burial

Bioaccumulation

- Some chemicals have significantly higher affinity to some part of organisms than to the environment (water, air, soil, etc.)

  ex) hydrophobic compounds have very high affinity to lipids than to water

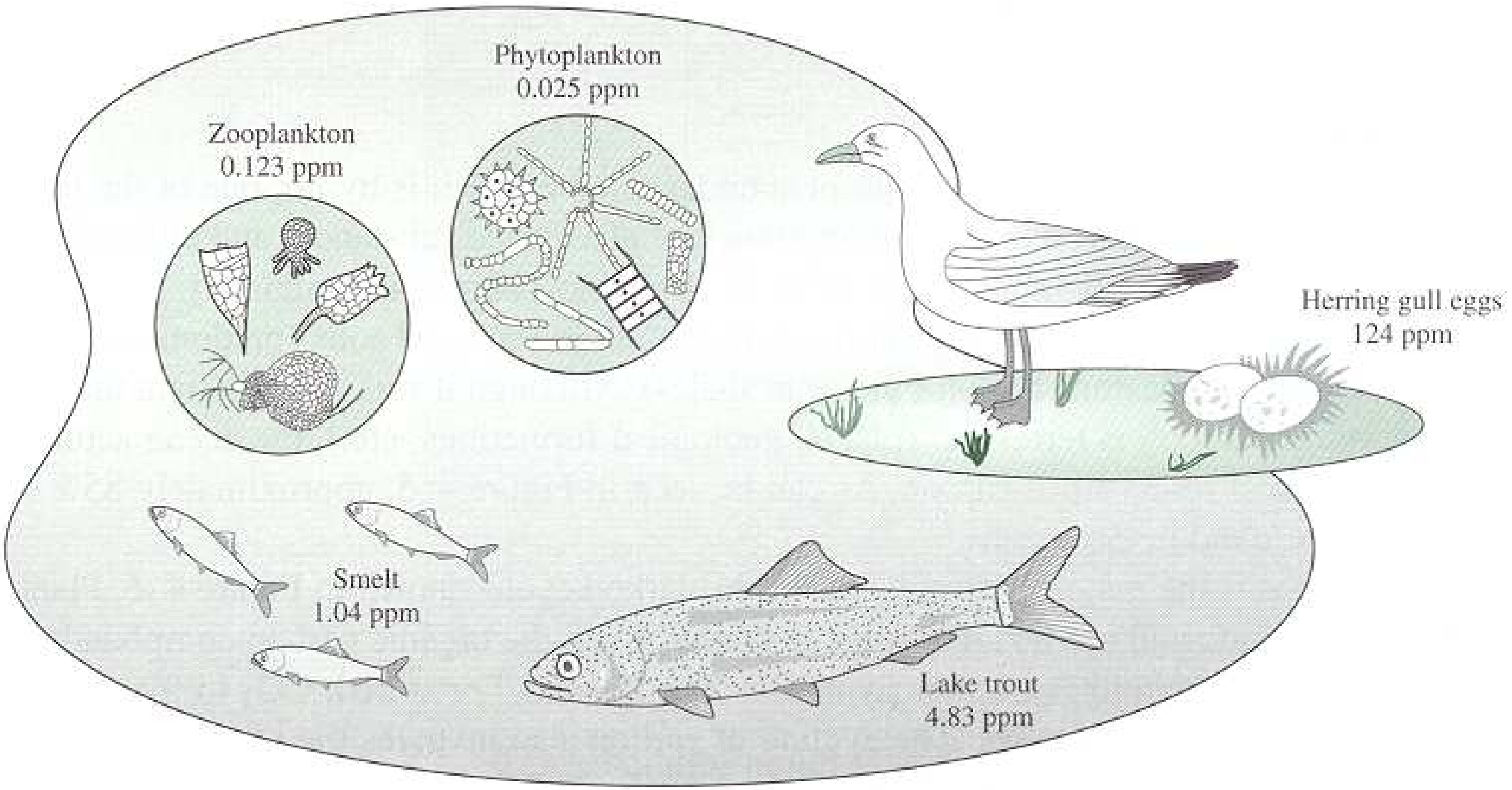
- If chemical gain > loss for an organism, then the chemical may be accumulated within the body
- The chemical accumulation may occur more significantly for higher trophic level organisms

Terminologies related to bioaccumulation

- **Bioaccumulation**: total uptake of chemicals by an organism from either water or food
- **Biomagnification**: a process that results in accumulation of a chemical in an organism at higher levels than are found in its own food
- **Bioconcentration**: the uptake of chemicals from the dissolved phase

Biomagnification in aquatic food web

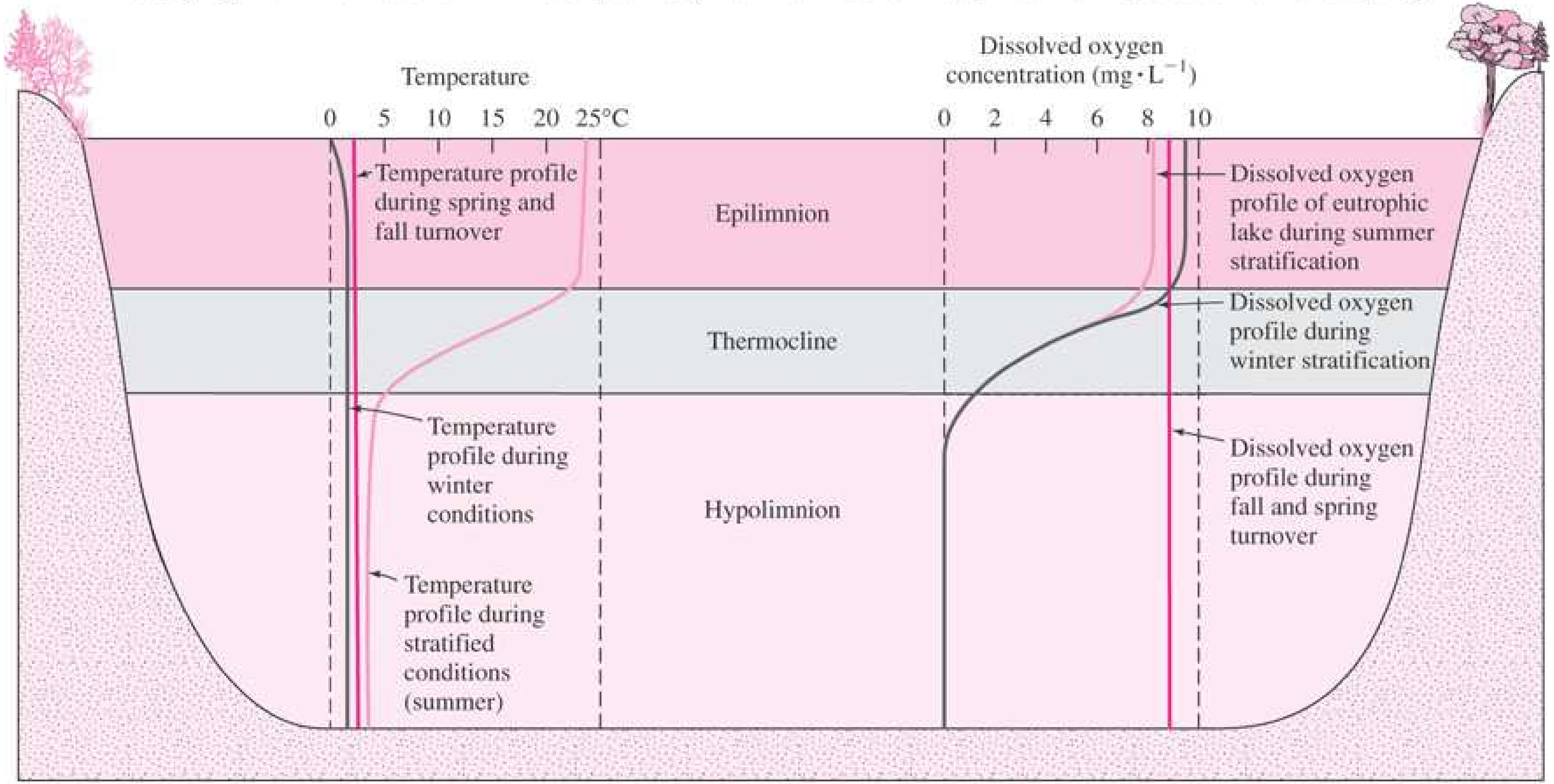
<PCBs in Great Lakes aquatic food web>



Bioaccumulation

Q: A fish species "ticto barb" has been reported to show a bioconcentration factor (BCF) of 89,010 L water/kg liver for DDT (Sgatyanarayan & Ramakant, 2004). Using this value, estimate the concentration of DDT in the liver of ticto barb living in a pond with an aqueous DDT concentration of 5 µg/L.

Lakes: seasonal changes in stratification



(a) Temperature profile (b) Dissolved oxygen profile

Lake productivity

- A measure of a lake's ability to support aquatic life (a more productive lake has a higher biomass concentration)

- Controlled by the limiting factor
  – Recall "Liebig's law of the minimum"

Eutrophication of lakes

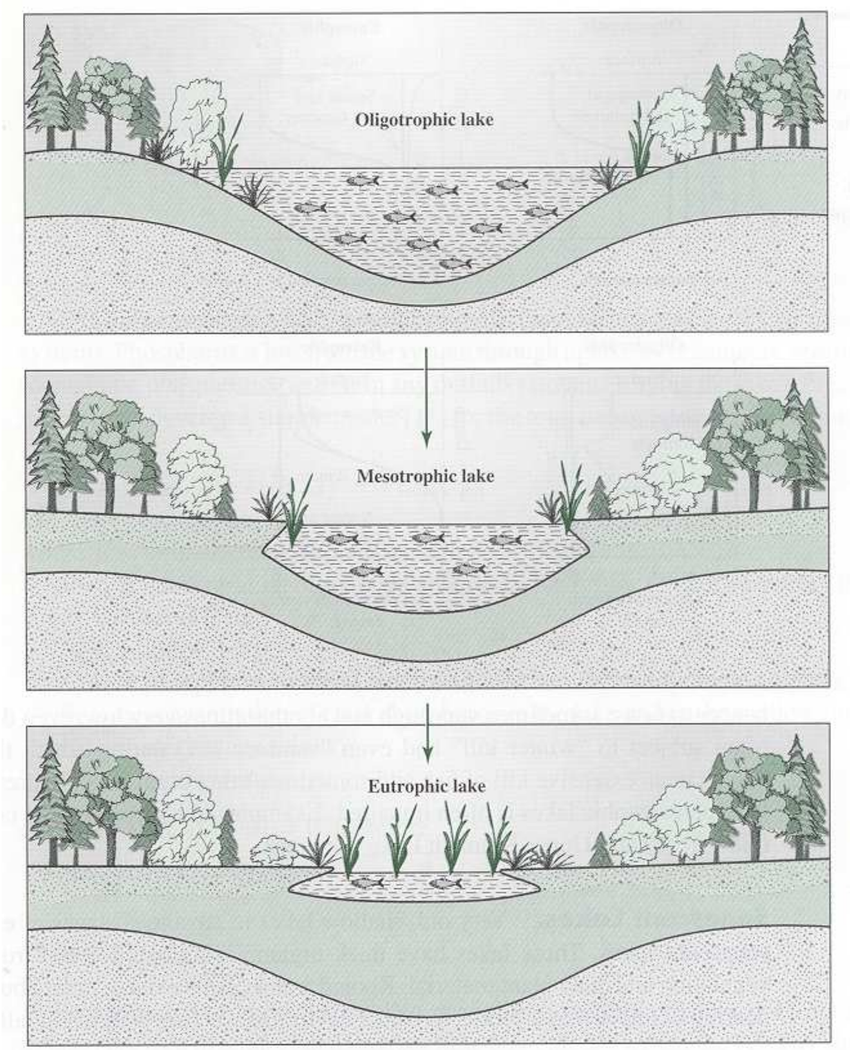
- **Natural eutrophication**: A natural aging process of a lake; may take over thousands of years (an unpolluted lake)

- **Cultural eutrophication**: accelerated eutrophication through the introduction of high levels of nutrients (a polluted lake)

Natural eutrophication

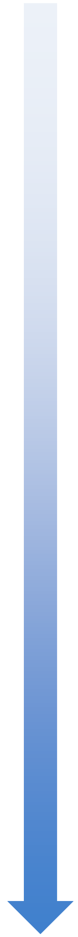
Oligotrophic lake

low productivity,
clear water



Eutrophic lake

high productivity,
turbid water



lake productivity increases over time

Cultural eutrophication

- Caused by the introduction of high levels of N and P (usually P for lakes and N for coastal waters)
- Sources of nutrients
  - human waste (sewage)
  - animal waste
  - agricultural sites

Effect of cultural eutrophication

- Algal bloom
  - high algae biomass: taste and odor problems, aesthetic problem
  - deposition of dead algae: oxygen depletion in the bottom
  - harmful algal bloom: some algal species produce toxic materials (ex: microcystin by cyanobacteria)
  - fish kills by O_2 depletion and toxic compounds, and clogging by algae

Suggested readings

[ENG] pp. 199 – 213, 224 – 233

[KOR] pp. 193 – 208, 220 – 230

Next class

Risk perception and assessment

- The concept of risk
- Risk: public concern and quantitative evaluation
- Assessing the risk from exposure to hazardous chemicals

Slide#13 solution

i) Based on the energy source: chemoorganotroph

ii) Based on the carbon source: heterotroph

iii) Based on living in the presence/absence of oxygen: strict aerobe

Slide#20 solution

From the definition of "bioconcentration" and the unit given, we can deduce that BCF is obtained by the concentration of a chemical in a tissue of an organism (liver in this case) relative to the aqueous concentration of the chemical.

$$BCF\ (L\ water/kg\ liver) = \frac{concentration\ in\ the\ liver\ (\mu g\ DDT/kg\ liver)}{aqueous\ concentration(\mu g\ DDT/L\ water)}$$

$$concentration\ in\ the\ liver = aqueous\ concentration \times BCF$$

$$= 5\ \mu g\ DDT/L\ water \times 89{,}010\ L\ water/kg\ liver$$

$$= 445{,}050\ \mu g\ DDT/kg\ liver$$

$$\approx \mathbf{445\ mg\ DDT/kg\ liver}$$

Risk Perception, Assessment, and Management I

Today's lecture

- Hazard, exposure, and risk
- Thinking about risk
- Risk assessment processes - general

Hazard, exposure, and risk

- **Hazard**: the inherent properties of a substance, object, or activity with a potential for adverse or harmful effects to occur

- **Exposure**: a quantitative measurement to the extent to which a given hazard is present

- **Risk**: the probability that an adverse effect will occur to someone

Hazard, exposure, and risk - example

- Hazard: arsenic (As) is a human carcinogen
- Exposure: a 60-kg person in Bangladesh drinks 2 L water containing 90 µg/L As everyday
- Risk: using the carcinogenicity data for As and the given exposure, the person has 0.2% possibility of cancer development caused by As ingestion in his entire life

P&G, 2012

Thoughts about risk: public risk perception

Orders of perceived risk for 30 activities or technologies

Activity or technology	College students	Experts	Activity or technology	College students	Experts
Nuclear power	1	20	Contraceptives	9	11
Handguns	2	4	Fire fighting	10	18
Smoking	3	2	Surgery	11	5
Pesticides	4	8	Food preservatives	12	14
Motor vehicles	5	1	Spray cans	13	26
Motorcycles	6	6	Large construction	14	13
Alcoholic beverages	7	3	Private aviation	15	12
Police work	8	17	Commercial aviation	16	16

Slovic (1987), Science

Thoughts about risk: public risk perception

Attributes that elevate the perception of risk	Attributes that lower perception
Involuntary	Voluntary
Exotic	Familiar
Uncontrollable	Controllable
Controlled by others	Controlled by self
Dread	Accept
Catastrophic	Chronic
Caused by humans	Natural
Inequitable	Equitable
Permanent effect	Temporary effect
No apparent benefits	Visible benefits
Unknown	Known
Uncertain	Certain
Untrusted source	Trusted source

Masters (1998) Introduction in Environmental Engineering and Science, 2nd ed.

Thoughts about risk: cost-effectiveness

Life-saving interventions and their cost-effectiveness

Interventions	$/life-year saved*
Chlorination of drinking water	$3,100
Radon remediation in homes with levels ≥ 21.6 pCi/L	$6,100
Radon remediation in homes with levels ≥ 8.11 pCi/L	$35,000
Radon remediation in homes with levels ≥ 4 pCi/L	$140,000
Mandatory seat belt use law	$69
Improve educational curriculum for beginning drivers	$84,000

*in 1993 dollars

Tengs et al. (1995), Society for Risk Analysis

Thoughts about risk: “How clean is clean?”

You applied a soil remediation technology to reduce Cu concentration in a contaminated soil down to 200 mg/kg. This is still above the regulation level of 150 mg/kg. You searched nearby areas which are not influenced by humans and found that the Cu concentration there (i.e., background Cu concentration) is 50-300 mg/kg.

Is the soil clean?

You tested the soil to find that there is no possibility for Cu to be released out from the soil.

Is the soil clean?

How clean is clean???

Thoughts about risk: implications

Environmental problems need to be managed based on ***risk*** that is properly estimated in order to protect the human health in a cost-effective manner and to persuade the general public

- (Quantitative) risk assessment: quantification of risk at a certain situation
- Risk management: the use of the results of risk assessment to make policy decisions

US EPA's risk assessment process

For human risk assessment:

- Data collection and evaluation
- Toxicity assessment
- Exposure assessment
- Risk characterization

* Risk assessment is considered to be *site-specific*: the whole steps of a risk assessment is conducted for every contaminated site

토양오염물질 위해성평가 지침

[시행 2014. 10. 10.] [환경부고시 제2014-181호, 2014. 10. 10., 폐지제정]

환경부(토양지하수과), 044-201-7178

제1장 총칙

1. 목적

이 지침은 토양환경보전법 (이하 "법"이라 한다) 제15조의5 규정에 따른 토양오염 위해성평가(이하 "위해성평가"라 한다)를 실시함에 있어 위해성평가계획서의 작성 및 제출, 위해성평가 방법, 위해성평가서의 작성방법, 위해성평가서의 공고·공람 및 주민의견 제출 방법, 위해성평가 검증 및 위해성평가 대상지역의 사후관리에 관한 구체적인 사항을 정함을 목적으로 한다.

2. 적용 범위

가. 본 지침은 법 제15조의5의 제2항에 따라 위해성평가를 하고자 할 때 적용한다.

나. 토양환경보전법에서 별도의 규정이 없는 한 위해성평가를 위한 오염도 조사방법은 본 지침에 의하여 실시한다.

3. 용어의 정의

이 지침에서 사용하는 용어의 정의는 [별표 1]과 같다.

4. 평가대상지역

가. 법 제6조의3에 따라, 다음 각 호의 어느 하나에 해당하는 경우로 환경부장관이 토양오염의 확산을 방지하기 위하여 토양정밀조사를 한 후 토양정화를 하는 지역

(1) 「국유재산법」 제2조제1호에 따른 국유재산으로 인하여 우려기준을 넘는 토양오염이 발생하여 토양정화가 필요한 경우로서 국가가 법 제10조의4에 따른 오염원인자인 경우

(2) 법 제15조제3항 단서에 따라 토양정화를 하는 경우로서 긴급한 토양정화가 필요하다고 시·도지사 또는 시장·군수·구청장이 요청하는 경우

(3) 법 제19조제3항에 따라 오염토양 개선사업을 하는 경우로서 긴급한 토양정화가 필요하다고 특별자치도지사·시장·군수·구청장이 요청하는 경우

나. 법 제15조제3항 단서에 따라 오염원인자를 알 수 없거나 오염원인자에 의한 토양정화가 곤란하다고 인정하는 경우로 시·도지사 또는 시장·군수·구청장이 오염토양의 정화를 실시하려는 지역

다. 법 제19조제3항에 따라 대책지역의 오염토양 개선사업을 하려는 경우로 오염원인자가 존재하지 아니하거나 오염원인자에 의한 오염토양 개선사업의 실시가 곤란하다고 인정하여 특별자치도지사·시장·군수·구청장이 오염토양 개선사업을 하는 지역

Suggested readings

[ENG] pp. 244-246

[KOR] pp. 236-238

Next class

Risk assessment and management

- Data collection and management
- Toxicity assessment
- Exposure assessment
- Risk characterization
- Managing the risk from exposure to hazardous chemicals