1. Introduction

Ecology: The study of the interrelationships between plants and animals that lives in a particular physical environment

Ecosystems:

(1) Ecological system

(2) Communities of organisms and the physical environment

(3) can vary great in size (e.g., couple meter diameter of a tidal pool, Biosphere = Atmosphere (대기권) + Hydroshpere (수권) + Lithosphere (암석권)

(4) Materials flow into and leave the ecosystem. However, materials into and out of the ecosystem < materials that cycle within in the ecosystem.

(5) can change with time (extreme environmental condition change – flooding, droughts, temperature change, volcanic activity, forest fire, etc.) – 1925 년 을축대홍수로 인한 한강 변화 1970 년 공유수면 매립으로 석촌호수 탄생

부리도(浮里島)

 산불 (Yellow Stone National Park)

(6) natural or artifical (e.g., constructed wet lands, agricultural lands, etc.)

Habitats (서식지): the place where a population of organisms lives

2. Human Influences on Ecosystems

Although ecosystems change naturally, human activities can speed up natural processes by several orders of magnitude in terms of time. (e.g., large-scale agricultural operations, stock-breedings, dams, etc.)

Human activities can change ecosystem through the destruction of species by loss of habitat (global extinction vs. local extinction).

Release of toxic chemicals (예, 살충제 (DDT), 비료, PCBs, etc.)

Excessive hunting – (예, 오스트리아의 날지 못하는 대형 조류들). 특정 종의 멸종은 먹이 사슬 상의 아래 위 다른 종에게 직접적인 영향

Nonnative (exotic) species (e.g., zebra mussel, 황소개구리, 솔잎혹파리, 재선충, 블루길, 배스 등의 담수어)

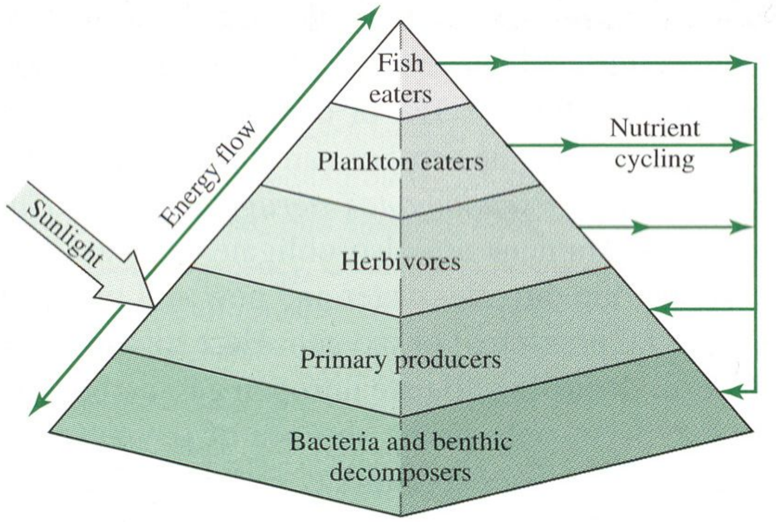
침묵의 봄 - 미국 느릅나무병의 사례: 1930 년대 유럽에서 미국으로 수입된 느릅나무 목재로 인해 전염. 나무의 수액을 통해 이동하는 균류 형태의 병원균이 독성물질을 분비하여 나무를 고사시킴. 느릅나무에 사는 딱정벌레가 매개체. 딱정벌레 방재를 위한 살충제 (DDT) 살포로 오염된 느릅나무 잎을 먹은 지렁이가 오염되고, 이 지렁이를 먹는 울새 절멸

3. Energy and Mass Flow in Ecosystem

Ecological pyramid: Quantitative relationships of energy flow by plotting the mass of biomass (all organisms) with trophical level

FIGURE 4–3

A simplified illustration of the relationship between organisms in an ecosystem is the biomass, or ecological pyramid. This diagram shows both mass and energy flow.



Primary producer: sunlight-using organisms. Autotrophic (독립영양), e.g., photosynthesis

Primary consumers (초식): eat plant material. Obtain energy from chemicals formed by other organisms. Chemoheterotrophic (종속영양)

Secondary consumers (육식): eat the flesh of animals, Chemoheterotrophic (종속영양)

Decomposers: consume the materials were excreted by the living organisms or released during the decay of the dead organisms.

TABLE 4–1 Characteristic Terms for Biological Organisms Based on Energy and Carbon Sources

Type	Energy Source	Electron Donor[a]	Carbon Source
Phototrophs	Light		
Chemotrophs	Organic or inorganic compounds		
Lithotrophs (subgroup of chemotrophs)		Reduced inorganic compounds	
Organotrophs (subgroup of chemotrophs)		Organic compounds	
Autotrophs			Inorganic compounds (e.g., CO_2)
Heterotrophs			Organic carbon

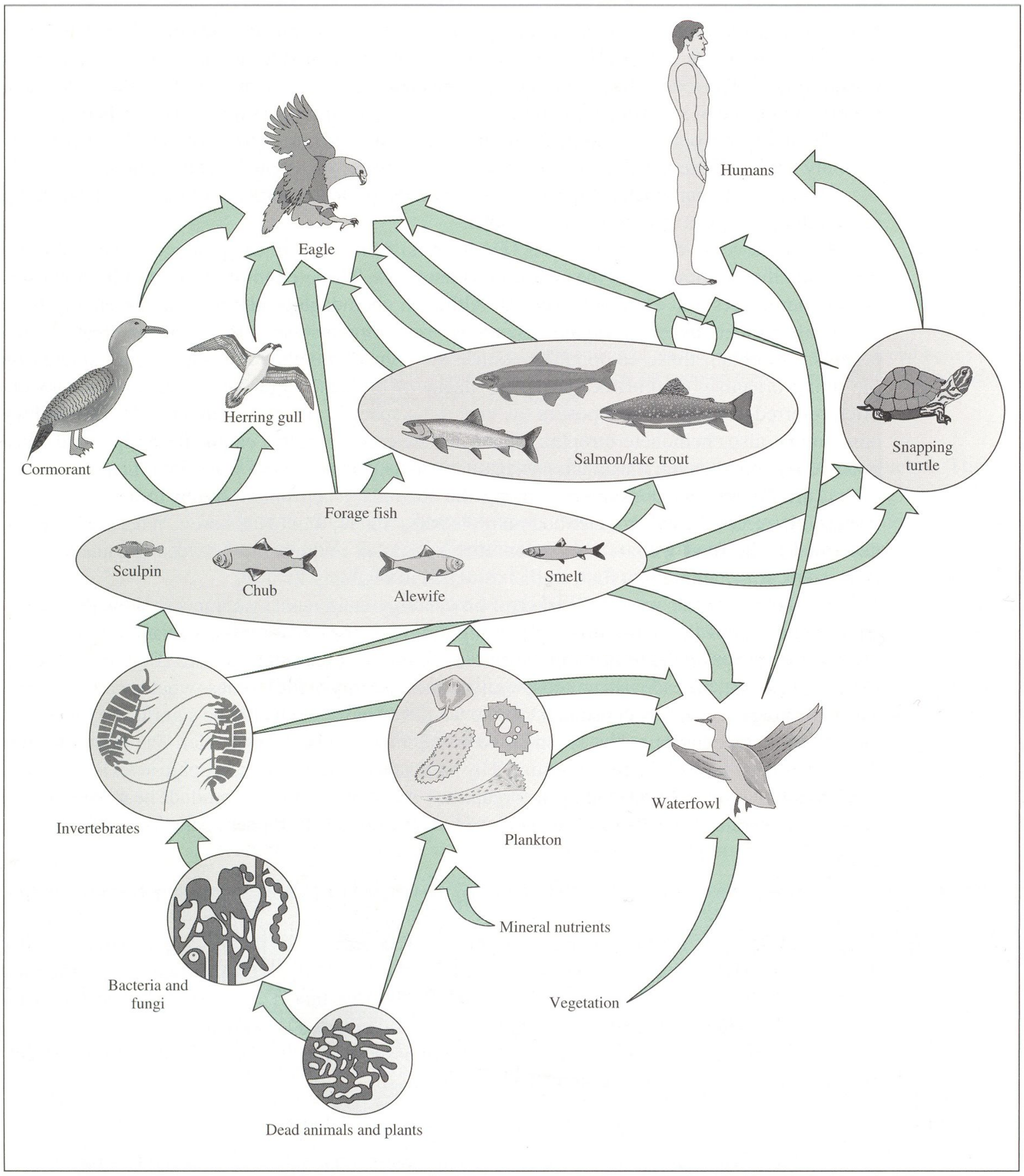
[a]Electron donors (reducing agents) are the source of electrons that come from reduced bonds (i.e., C—H bonds). The breaking of these reduced bonds may be coupled directly or indirectly to the production of adenosine triphosphate (ATP) within the cell.

Electron acceptor (respiration): aerobic, anaerobic, and anoxic

Food web (or Food chain): Relationship between organisms in an ecosystem

FIGURE 4–2 Simplified Representation of a Food Web, Showing the Main Pathways

Food (energy) moves in the direction of the arrows. The driving force is sunlight. Depictions of the various organisms are not drawn to scale. (*Source:* http://www.epa.gov/glnpo/atlas/images/big05.gif)



3.1 Bioaccumulation

Bioaccumulation: The total uptake of chemicals by an organisms from food items as well as via mass transport of dissolved chemicals through the gills and epithelium (상피)

Biomagnification: The process that results in the accumulation of a chemical in an organism at higher levels than are found in its own food. Chemicals may become more and more concentrated as it move up through a food chain. For example, DDT 10 ppm in soil, 141 ppm in earthworms, 444 ppm in robins

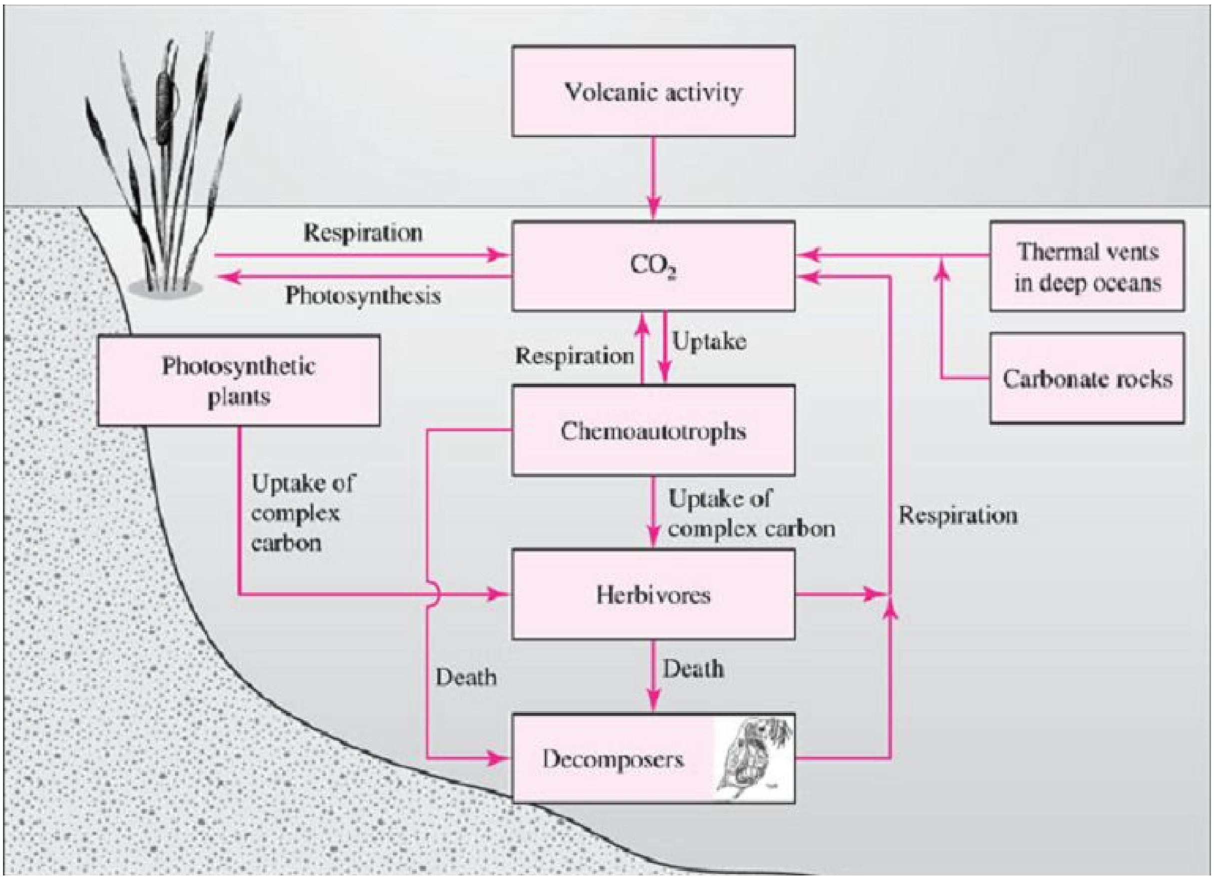
Bioconcentration: The uptake of chemicals from dissolved phase. Usually refers to chemicals foreign to the organisms not the natural chemicals

Concentration fish = (concentration in water) x (bioconcentration factor)

4. Nutrient Cycles

4.1 Carbon cycle

- Photosynthesis is the major driving force for carbon cycle.

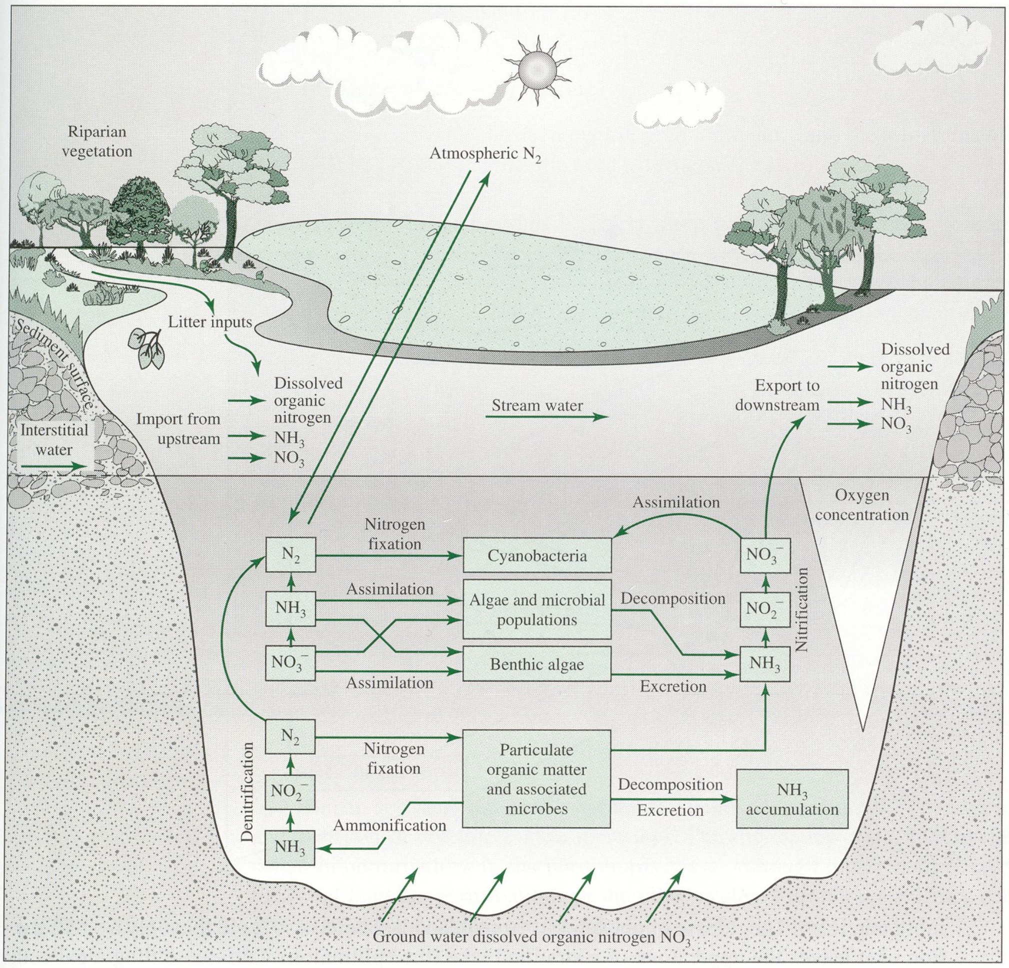


- Ocean serves as the greatest reservoir of carbon (e.g., dissolved carbon dioxice gas, and carbonate and bicarbonate ions)
- Human effects: Combustion of fossil fuels, large-scale production of livestock, burning of forests, etc. “Global warming”

4.2 Nitrogen cycle

FIGURE 4–7

The nitrogen cycle (*Source:* O’Keefe, T. C., S. R. Elliott, R. J. Naiman, D. J. Norton. *Introduction to Watershed Ecology,* October 10, 2002. www.epa.gov/watertrain/ecology/rl.html; http://www.epa.gov/watertrain/ecology/s33.jpg)



- Nitrification:

$$4NH_4^+(\text{ammonium}) + 6O_2 = 4NO_2^-(\text{nitrite}) + 8H^+ + 4H_2O \quad \text{(nitrosomonas)}$$

$$4NO_2^-(\text{nitrite}) + 2O_2 = 4NO_3^-(\text{nitrate}) \quad \text{(nitrobacter)}$$

- Denitrification

$$2NO_3^-(\text{nitrate}) + \text{organic carbon} = N_2 + CO_2 + H_2O$$

- Nitrogen fixation (땅콩을 포함한 콩류, 클로버 등)

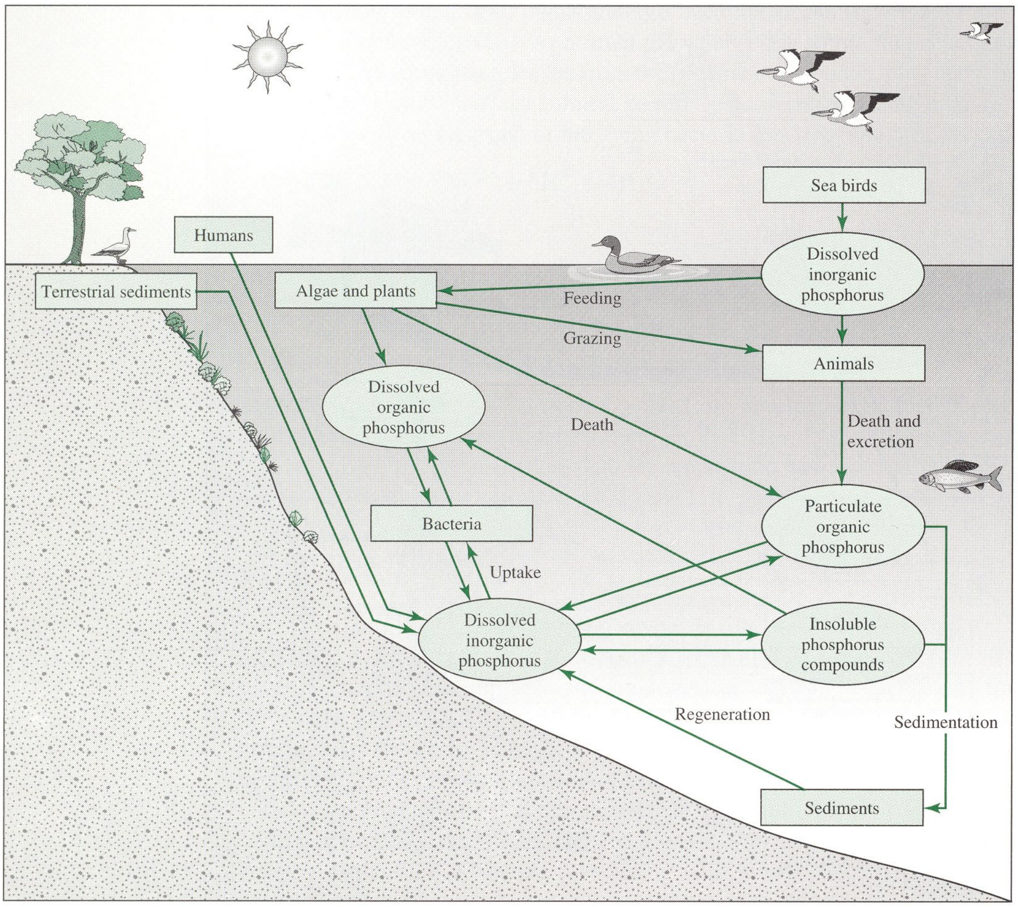
$$N_2 + 8e^- + 8H^+ + ATP \rightarrow 2NH_3 + H_2 + ADP + P_I\ (\text{inorganic phosphate})$$

- Human effect: industrial fertilizers, fossil fuel combustion, large-scale production of nitrogen-fixing crops.

4.3 Phosphorus cycle

FIGURE 4–8

The phosphorus cycle. (*Source: Virginia Estabrook, The Michigan Water Resource Center, Michigan Water Research Center, Central Michigan University.* http://www.cst.cmich.edu/centers/mwrc/phosphorus%20cycle.htm)



- Natural sources of P: weathering of rock.
- Artificial sources: detergents, fertilizers, excretion, etc.

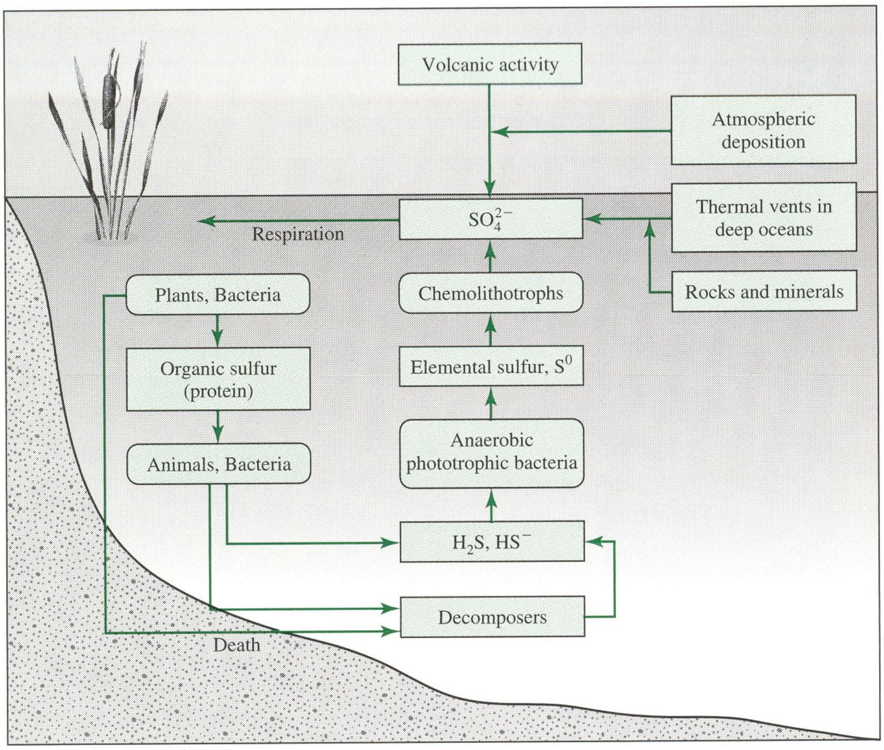
- Especially, important in a lake water quality.

4.4 Sulfur cycle

- Natural sources: volcano
- Artificial sources: fertilizers, combustion of fossil fuels, mining, etc.

FIGURE 4–9

The sulfur cycle. The lithosphere is the earth's crust and includes rocks and minerals. (*Source:* vanLoan, G. W., Duffy, S. J. *Environmental Chemistry: A Global Perspective.* Oxford University Press, Oxford, UK, 2002, p. 345.)



- Sulfur-reducing bacteria reduce sulfate to hydrogen sulfide in anaerobic condition.

5. Population Dynamics

5.1 Bacterial population dynamics

Bacterial growth requirements

(1) A terminal electron acceptor

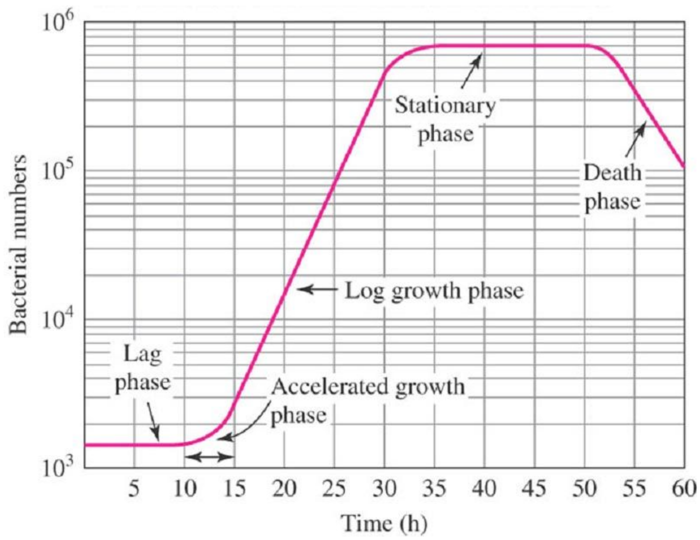
(2) Macronutrients (e.g., carbon, nitrogen, phosphorus, etc.)

(3) Micronutrients (e.g., trace metals, vitamins, etc.)

(4) Appropriate environment (moisture, temperature, pH)

e.g., psychrophiles (< 20°C), mesophiles (25-40 °C), thermophiles (45-60 °C), stenothermophiles (> 60 °C)

Growth in pure culture



- Lag phase: Initially nothing happens because bacteria must adjust to their new environment.

- Accelerated growth phase: Due to the binary fission (each cell divides two new cells), log growth (or exponential growth)

  $P_t = P_0 \cdot 2^n$

$\log P_t = \log P_0 + n \cdot \log 2$

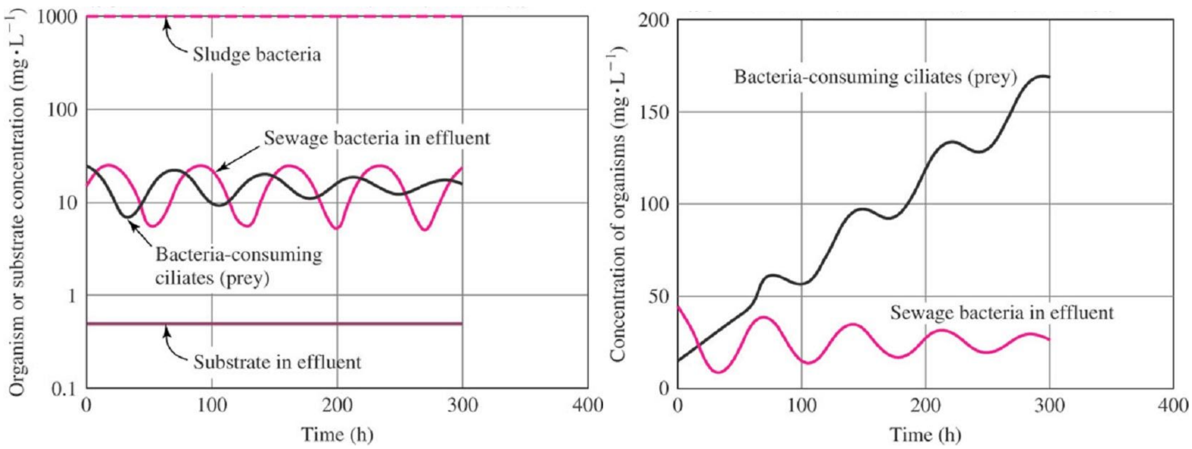
- Stationary phase: due to cession of fission (분열 중지) or balance in death and reproduction

- Death phase: bacteria die faster than they produce

- Carrying capacity: the point at which decline of population occurs

EXAMPLE 4–5 If the initial density of bacteria is 10^4 cells per liter at the end of the accelerated growth phase, what is the number of bacteria after 25 generations?

Growth in mixed culture



- Food competition
- Predator - Prey relationship

5.2 Animal population dynamics

- Exponential model: unlimited resources

$$\frac{dN}{dt} = r \cdot N$$

where r = specific rate of change (if r = 0, no change)

N = number of animals

$$N_t = N_0 \cdot \exp(r \cdot t)$$

- Geometric (logistic) model: unlimited resources, however, growth occurs in discrete intervals, λ (불연속 성장)

$$\frac{N(t+1)}{N(t)} = \lambda = e^r$$

where N(t+1) = population after (t+1) numbers in years

N(t) = population after t years

r = specific rate of change (if r = 0, no change)

EXAMPLE 4–6 Use the following data along with the exponential model to determine the population of the predicted eastern gray wolf in the state of Wisconsin in the year 2005. Compare that result with that obtained with the geometric model.

Year	1975	1980	1990	1995	1996	1997	1998	1999
Number	8	22	45	83	99	148	180	200

- Sigmoidal (or S-shape) curve

$$\frac{dN}{dt} = r \cdot N \cdot \left[\frac{K\text{-}N}{K}\right]$$

where K = carrying capacity

$$N(t) = \frac{K \cdot N_0}{N_0 + (K - N_0) \cdot e^{-r \cdot t}}$$

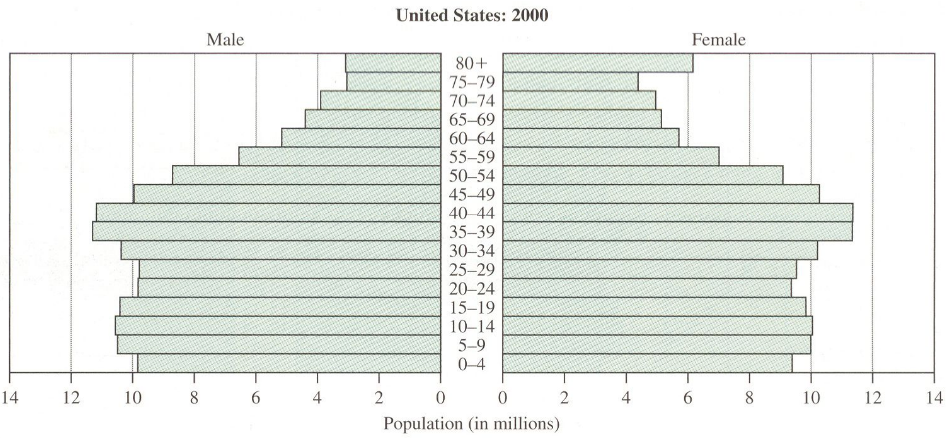
EXAMPLE 4–7 Assume that the population of the greater roadrunner in the Guadelope Desert was 200 per hectare at the beginning of 1999. If the carrying capacity, K, is 600 and $r = 0.25 \cdot \text{year}^{-1}$, what is the number of roadrunners one, five and ten years later? What happens when the number of roadrunners equals K?

5.3 Human population dynamics

Population pyramids: the age by gender data of a community at one point in time

FIGURE 4-14

Population pyramids for the United States, Ghana, and Spain for 2000. (*Source:* International Database, U.S. Census Bureau, International Programs Office, Washington DC, October 2002. http://www.census.gov/ipc/www/idbpyr.html)



$$P(t) = P_0 \cdot \exp(r \cdot t)$$

where P(t) = population at time, t

P_0 = population at time, 0

R = rate of growth

= (birth rate) – (death rate) + (immigration rate) – (emigration rate)

EXAMPLE 4-8 A population of humanoids on the island of Huronth on the Planet Szacak has a net birth rate (*b*) of 1.0 individuals/(individual × year) and a net death rate (*d*) of 0.9 individuals/(individual × year). Assume that the net immigration rate is equal to the net emigration rate. How many years are required for the population to double? If in year zero, the population on the island is 85, what is the population 50 years later?