



Univerzitet u Beogradu  
Fakultet veterinarske medicine

*Katedra za biologiju*

Predmet:  
**ZOOLOGIJA**  
2024/2025

Lanci ishrane i biomagnifikacija.  
Metabolizam ekosistema i biogeohemijski ciklusi.  
Kisele kiše i eutrofizacija

# Lanci ishrane



# Odnosi ishrane u biocenozi

spadaju među najznačajnije ekološke odnose između organizama nastanjenih u biocenozi

## 1. Proizvođači (producenti) (autotrofi)

## 2. Potrošači (konzumenti) (heterotrofi)

herbivori (fitofagi)

karnivori (zoofagi)

saprofagi

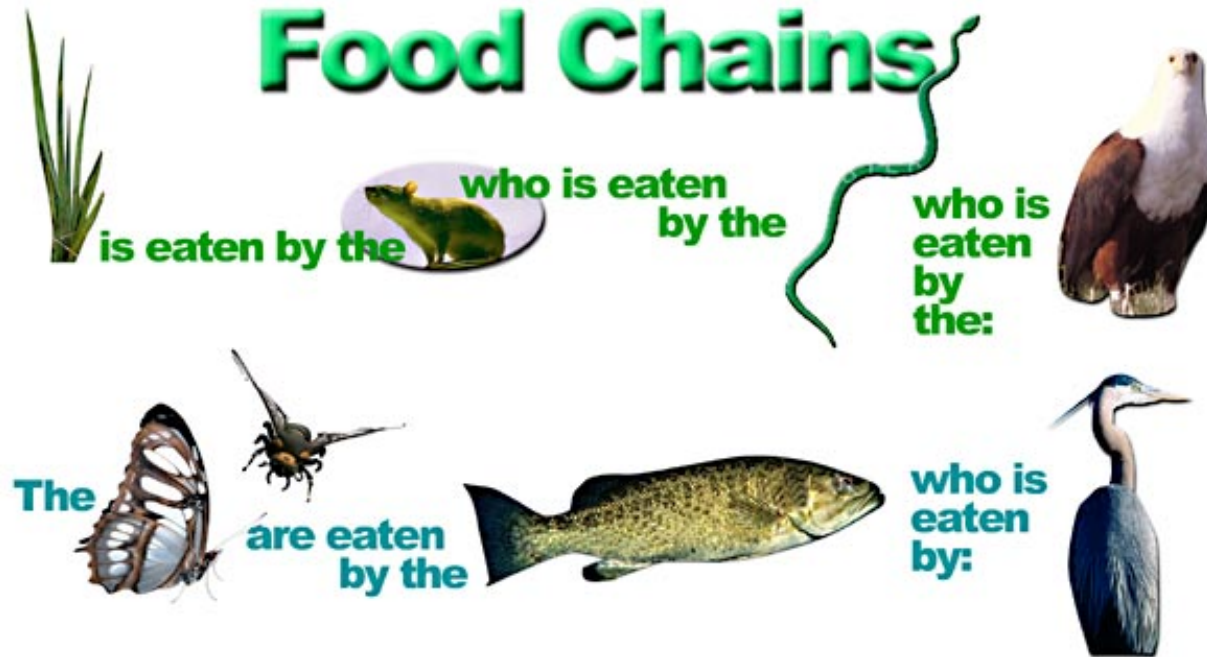
omnivori

## 3. Razlagači (reducenti)



# Producenti, konzumenti i reducenti su međusobno povezani

## LANCIMA ISHRANE



**We are part of a food chain too. Can you fill it in?**

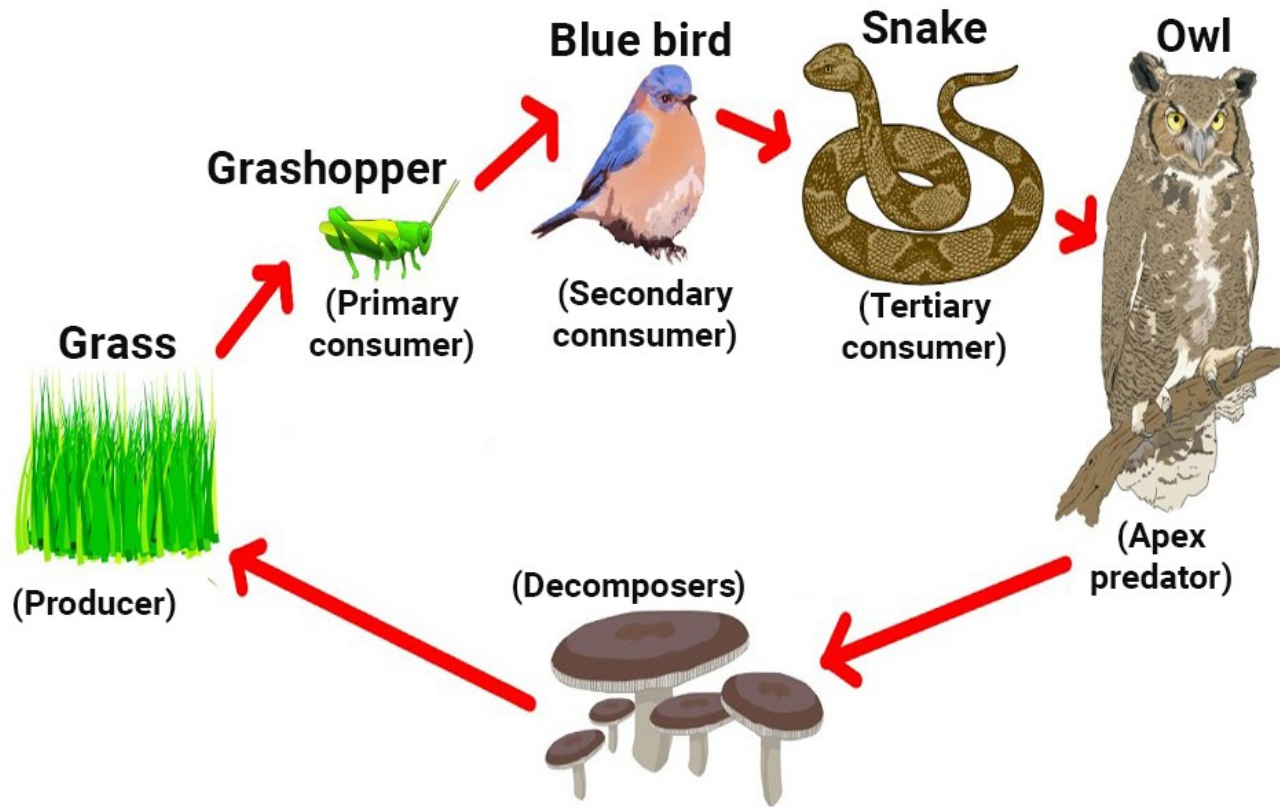
The \_\_\_\_\_ is eaten

by the \_\_\_\_\_

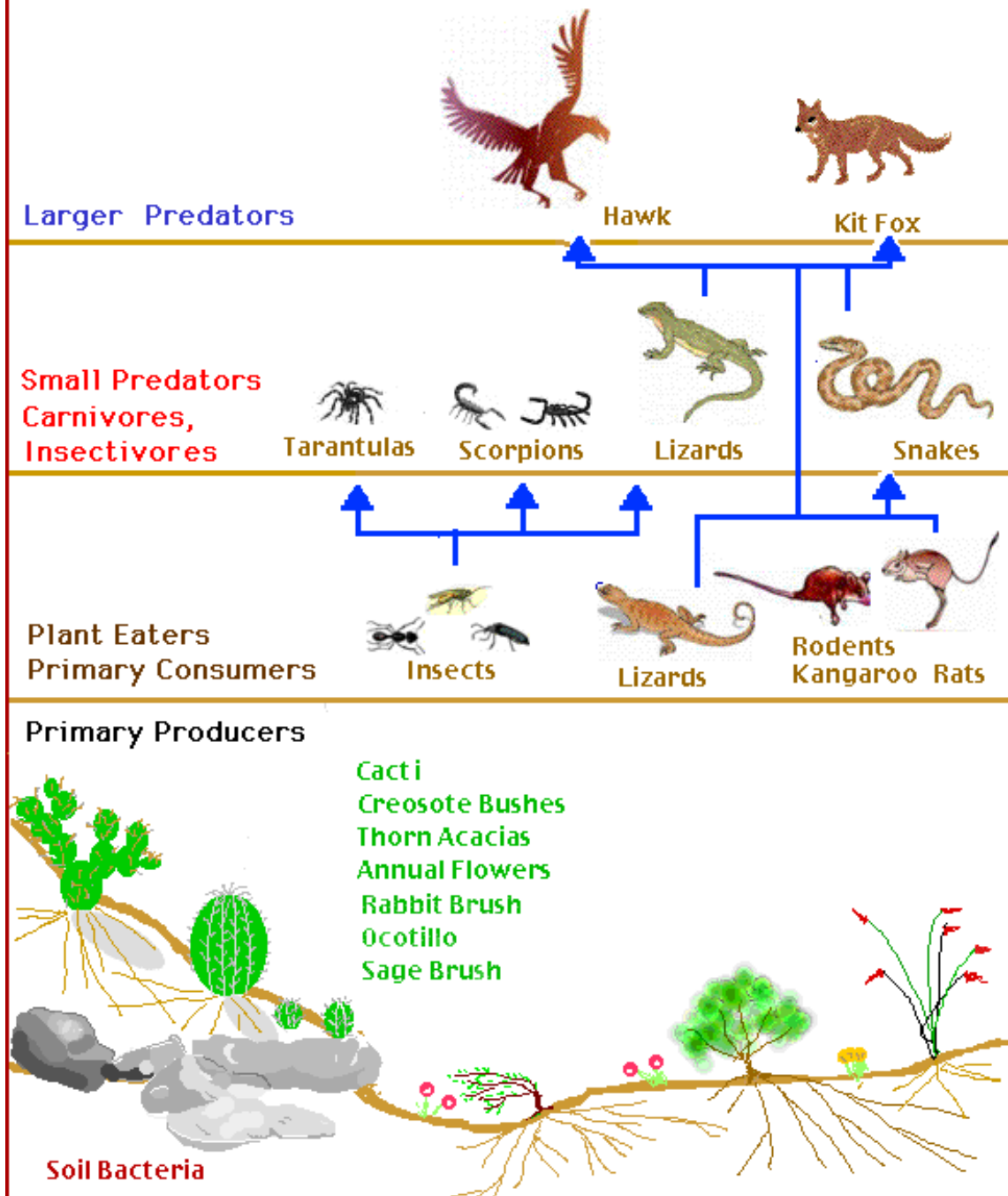
who is eaten by: \_\_\_\_\_



# Predatorski lanac ishrane

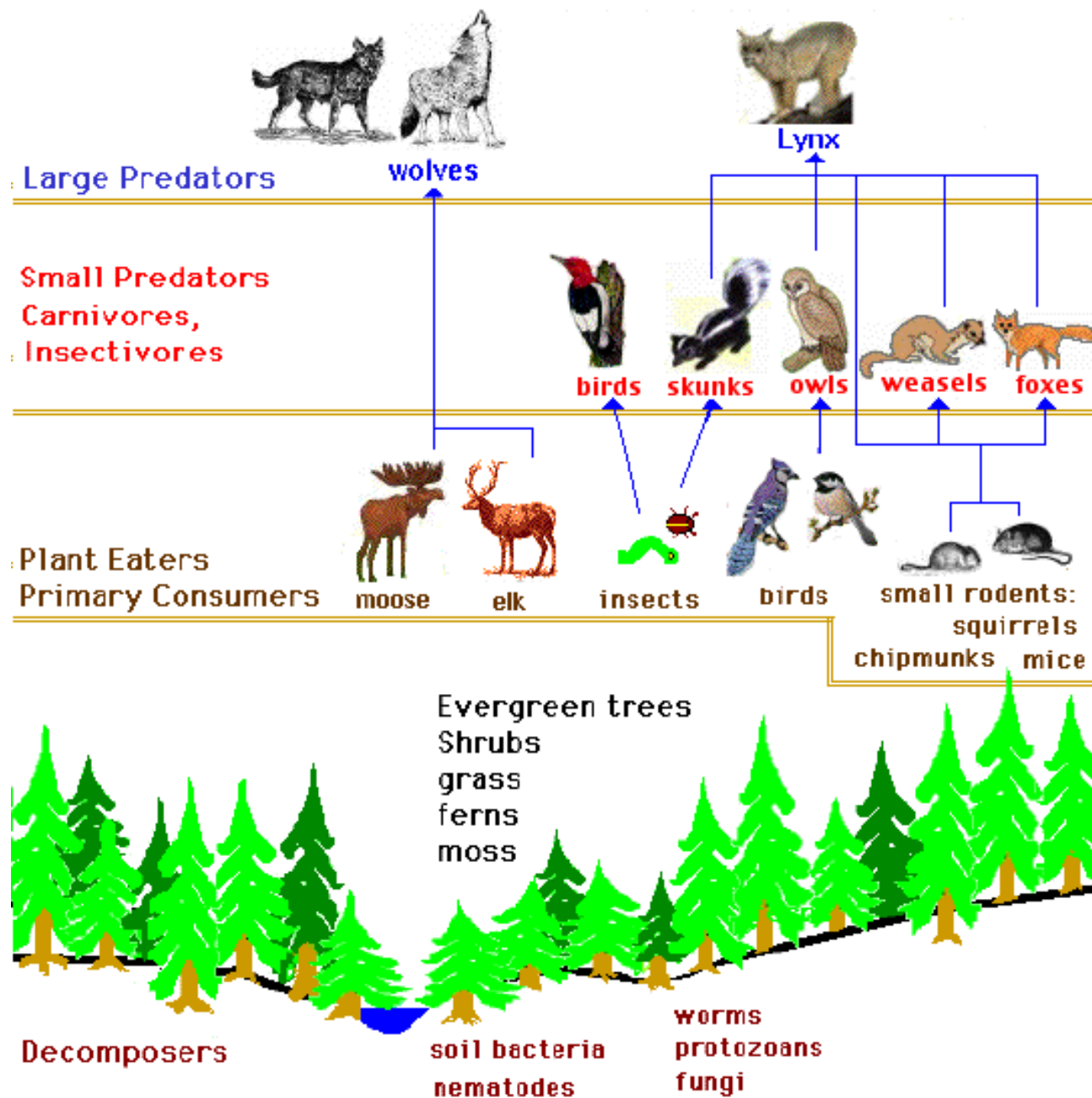


## A Food Web in the Desert Biome



**Lanac  
ishrane  
u pustinji**

# A Food Web in the Coniferous Forest Biome



Lanac  
ishrane  
u  
četinarskoj  
šumi

# Lanac ishrane u močvarnoj oblasti

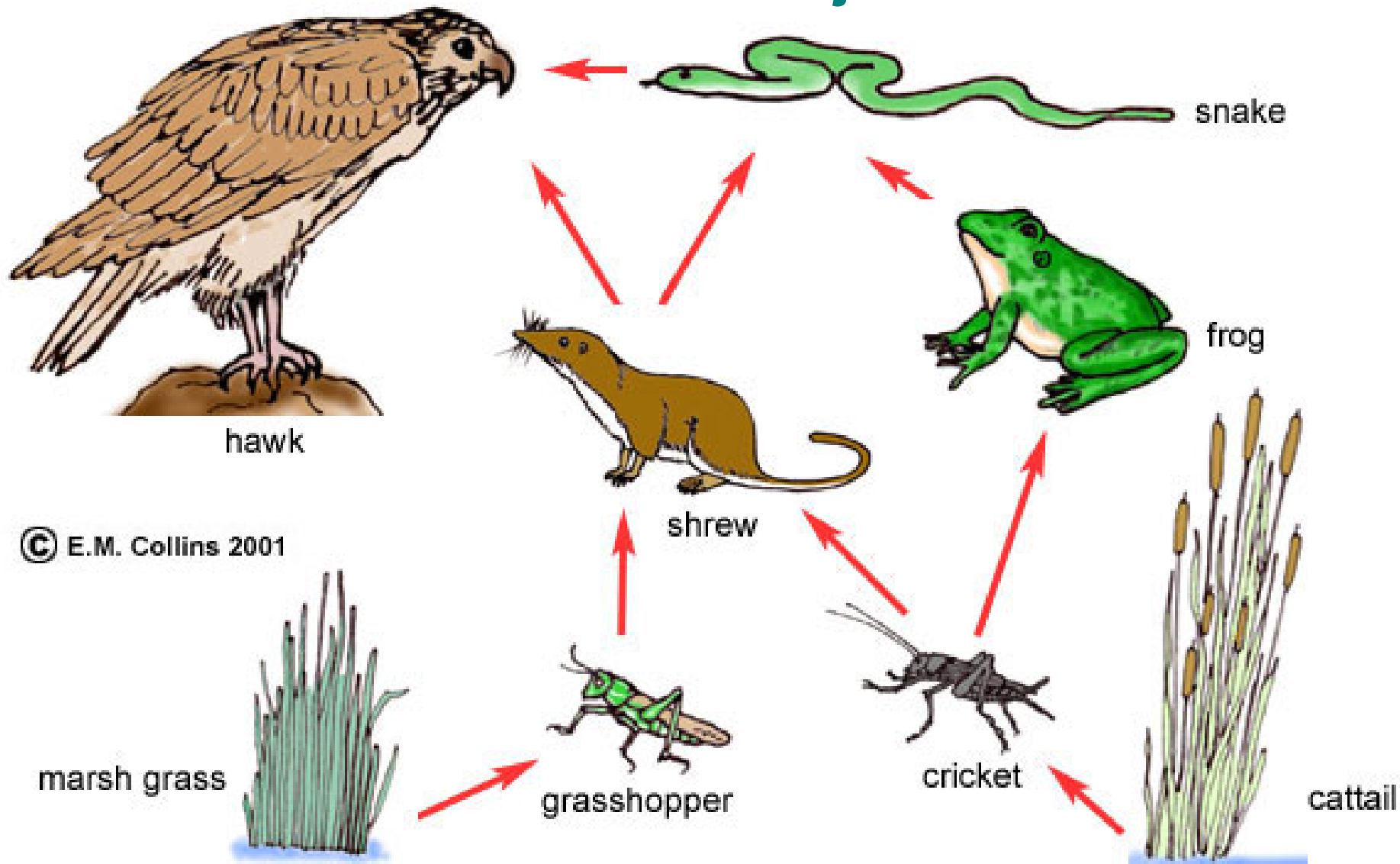
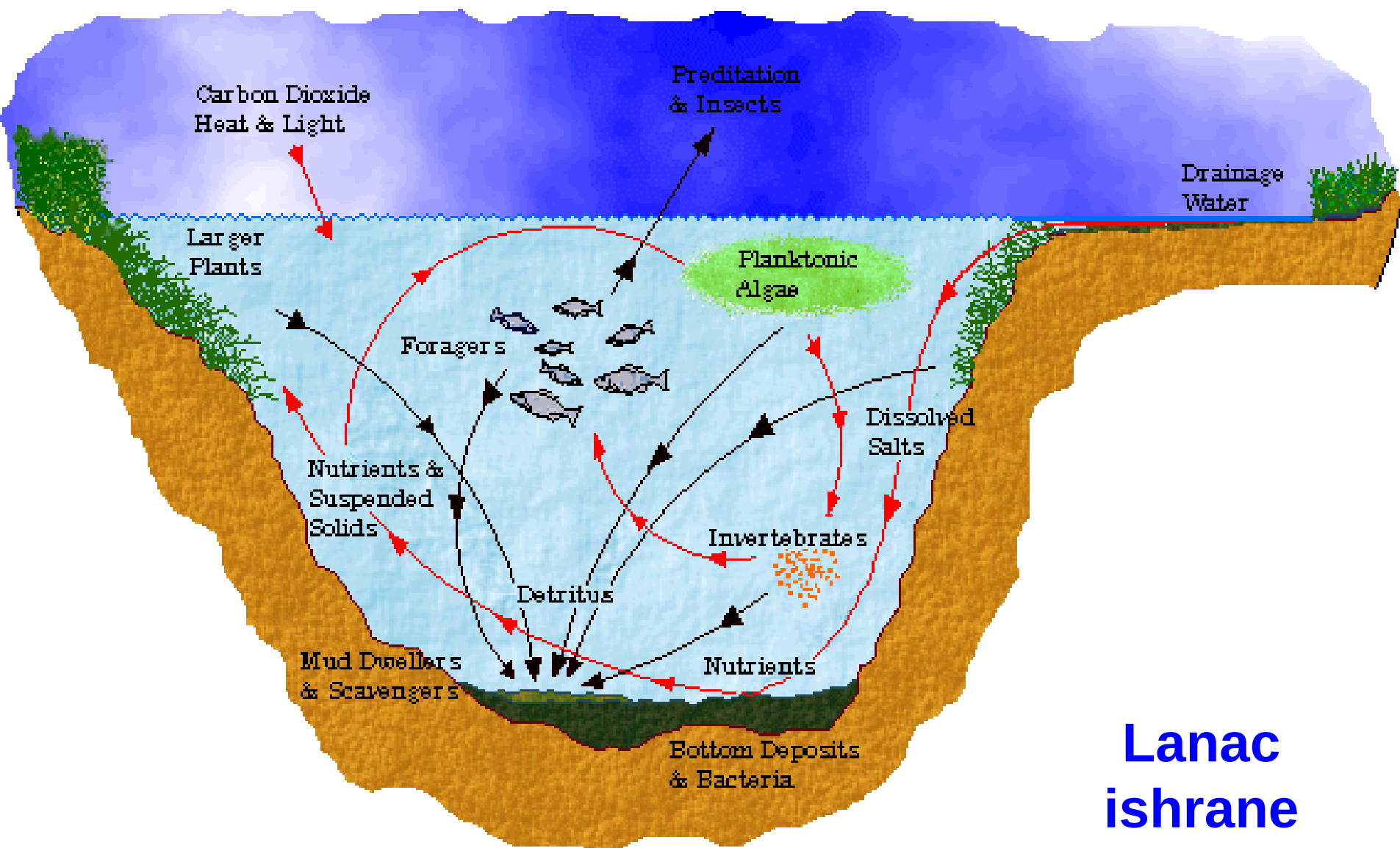




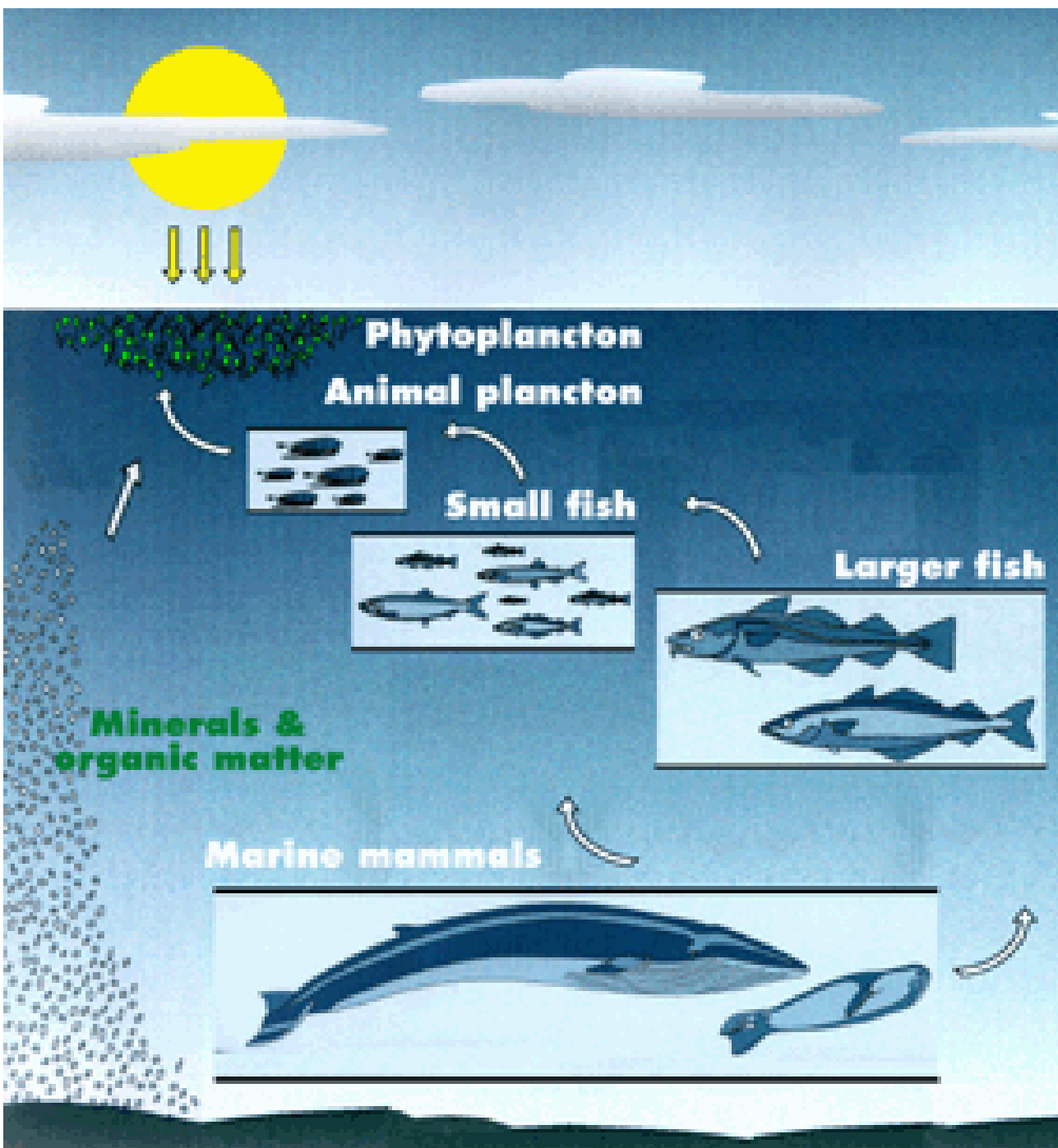


Figure 54-8 A simplified food web.

**Lanac  
ishrane  
u močvari**



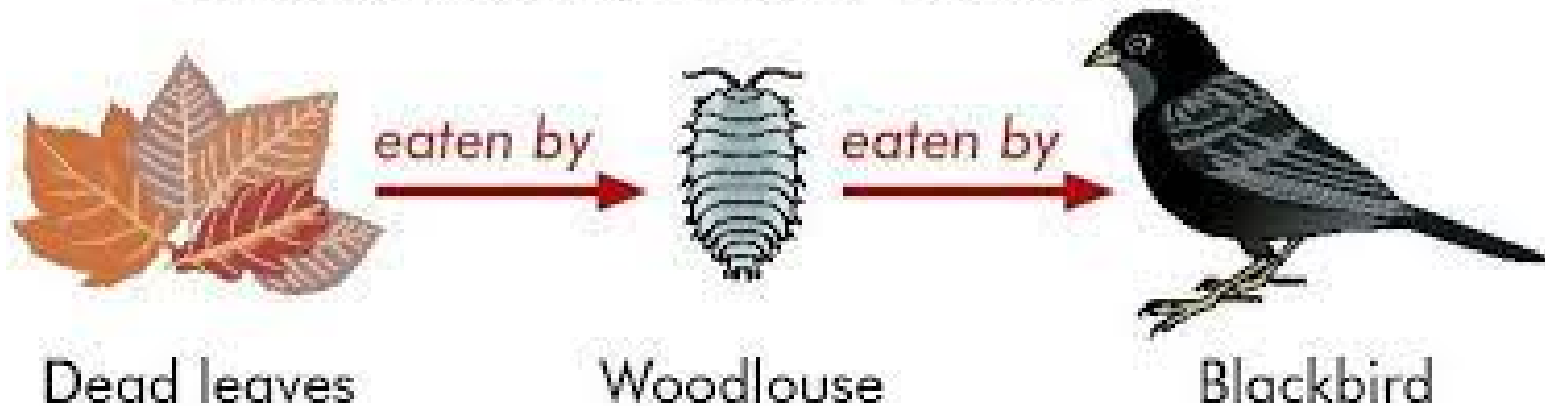
**Lanac  
ishrane  
u jezeru**



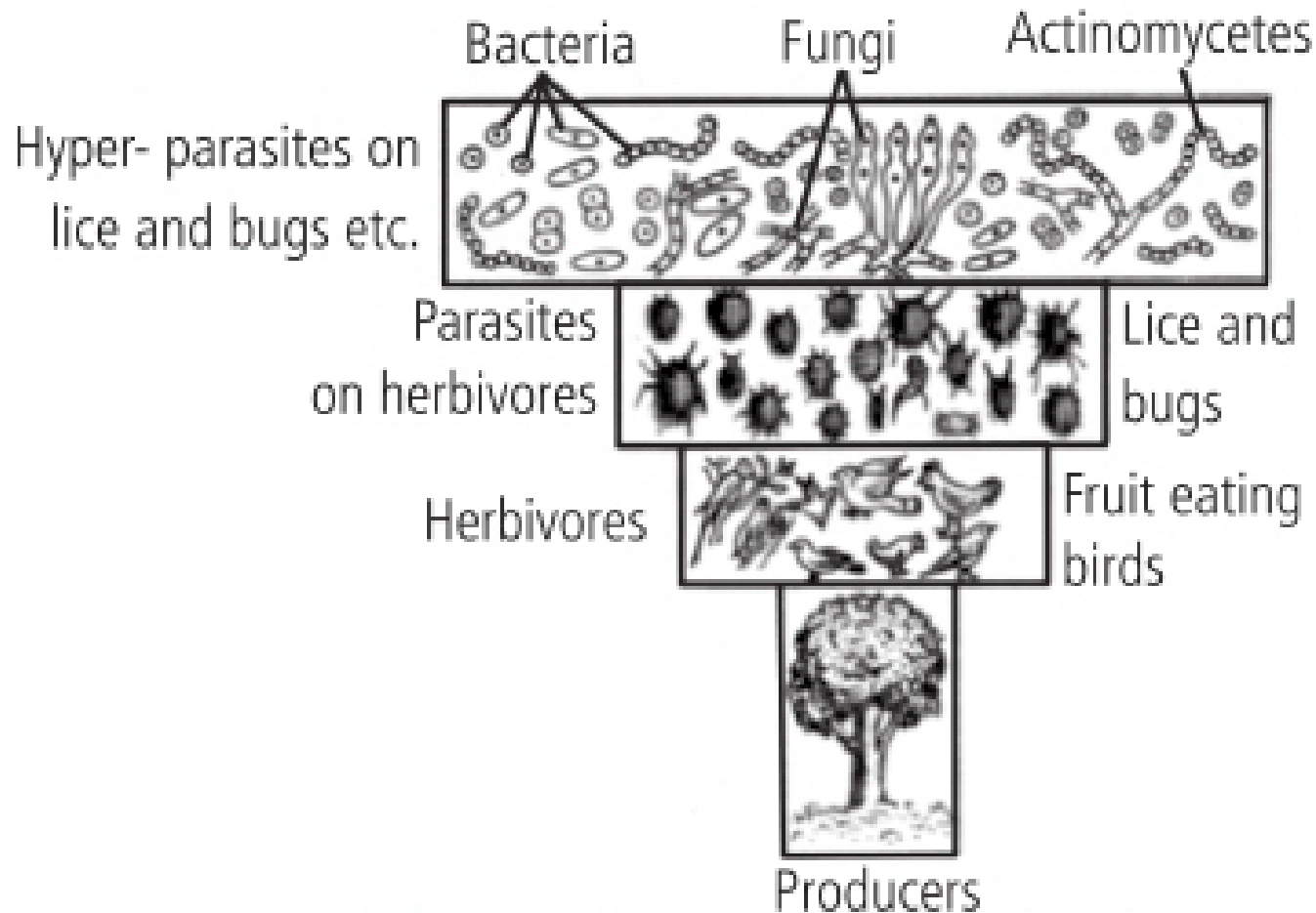
Lanac  
ishrane  
u moru

# Saprophytic food chain

## Detritus Food Chain

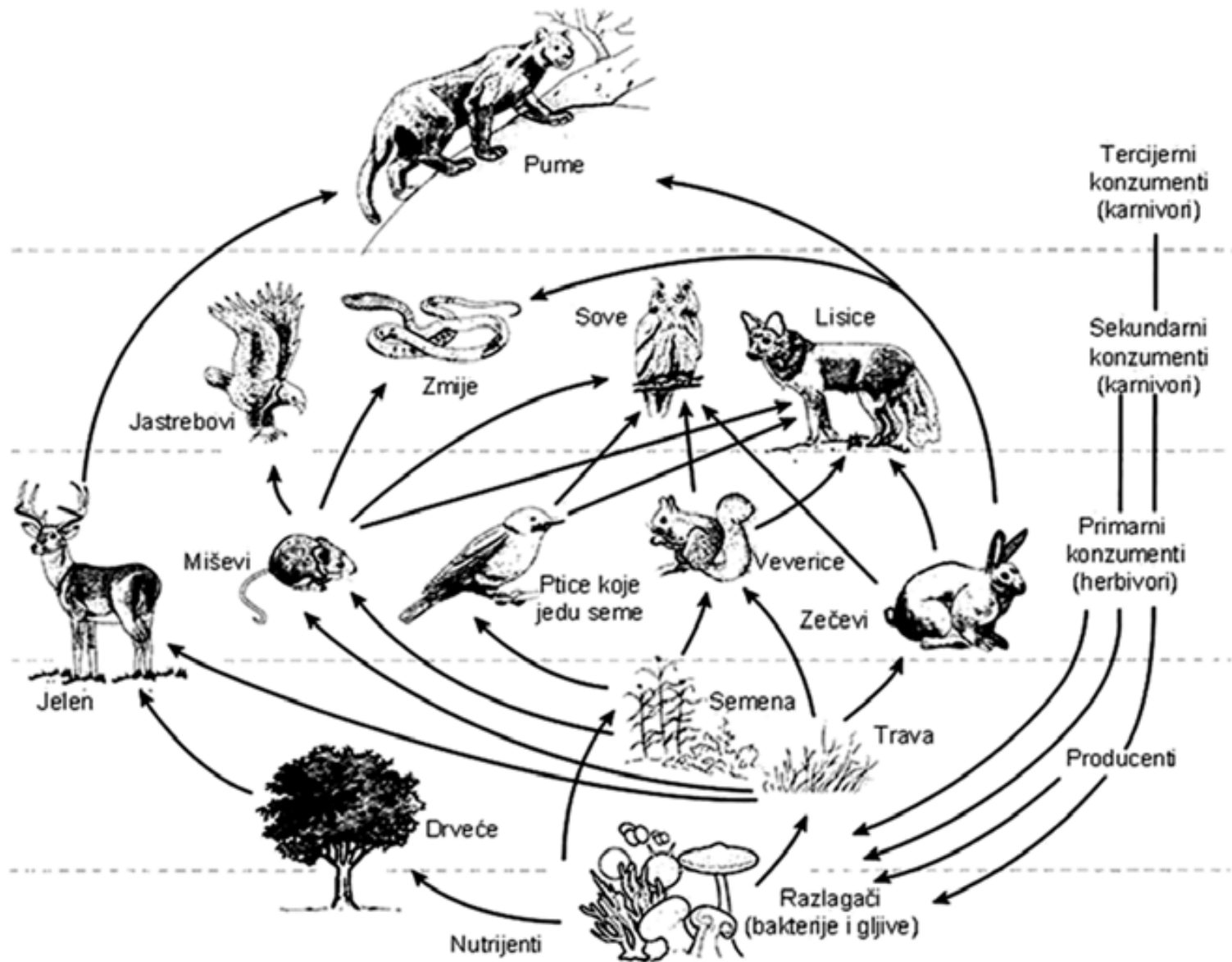


# Parazitski lanac ishrane



**Fig.:** Pyramid of numbers in parasitic food chain





Jedan isti organizam često pripada većem broju lanaca ishrane, tako da se u prirodi realno susreće **mreža lanaca ishrane**

# EKOLOŠKE PIRAMIDE

grafički prikazi

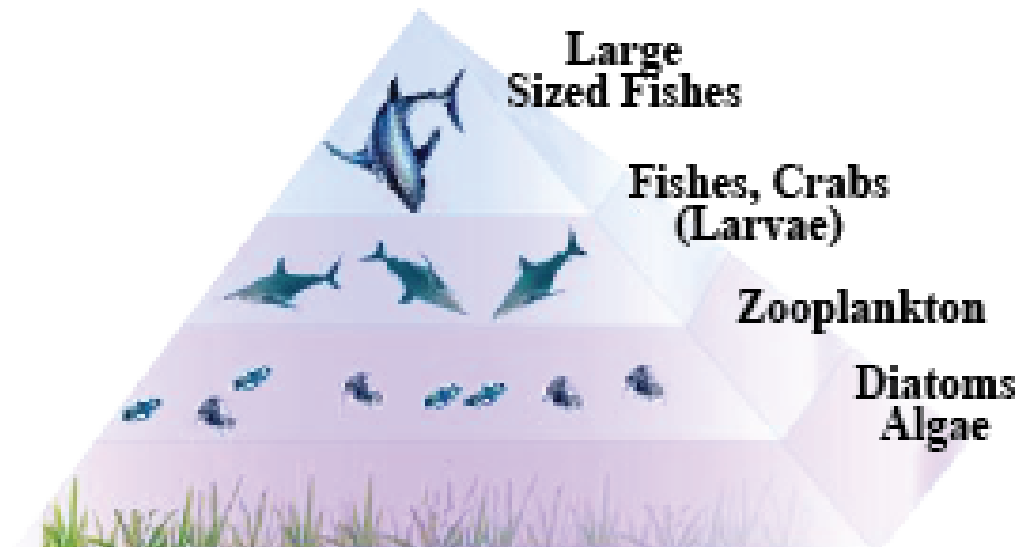
- broja jedinki,
- biomase i
- energije

na trofičkim stupnjevima

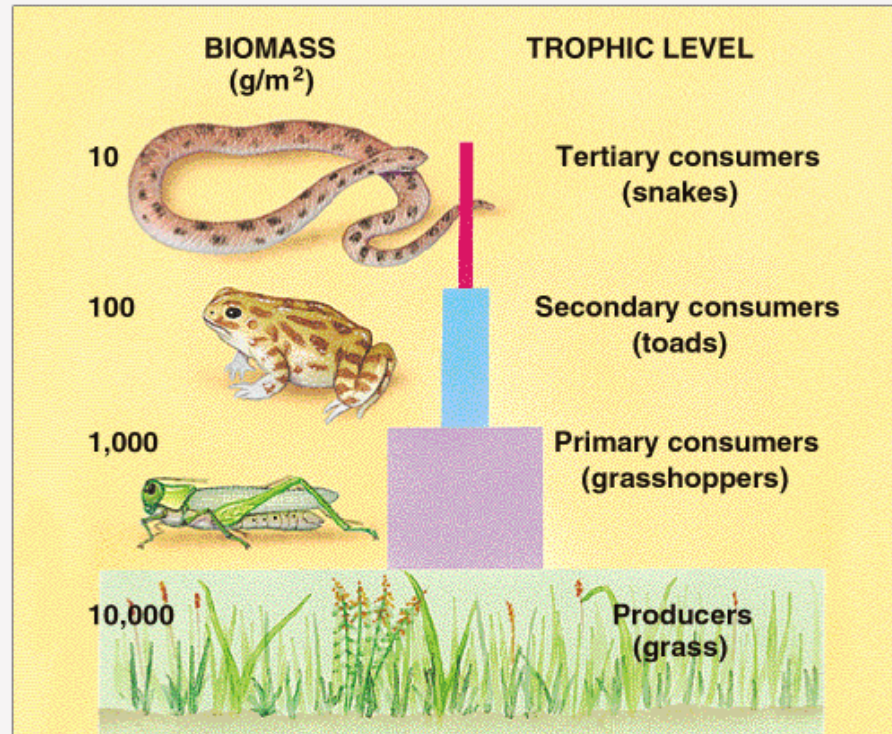
Zavisno od načina predstavljanja podataka razlikujemo tri osnovna tipa ekoloških piramida:

- piramide **brojeva**
- piramide **biomase**
- piramide **energije**

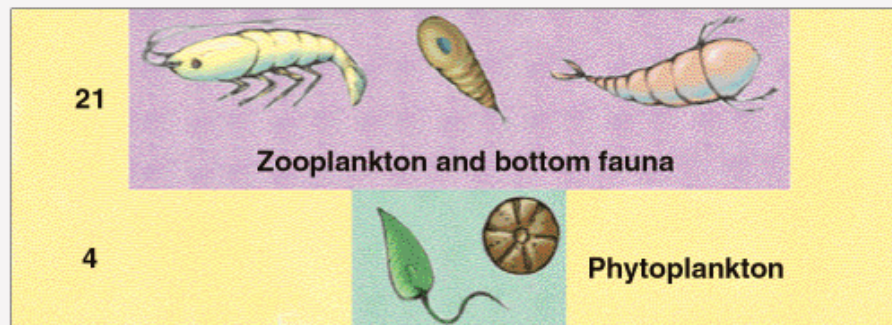
## Piramide brojeva



# Piramida biomase

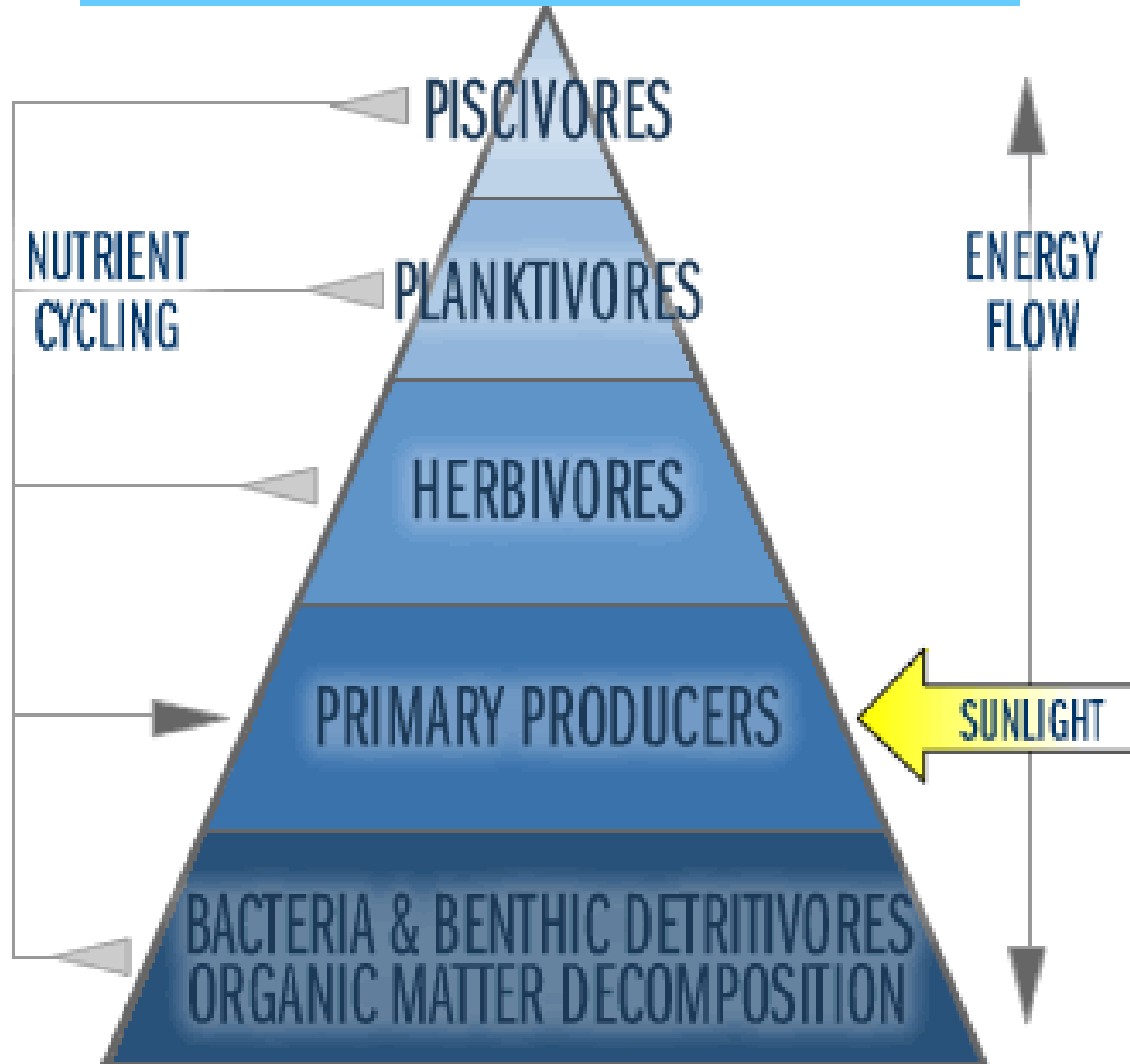


(a)



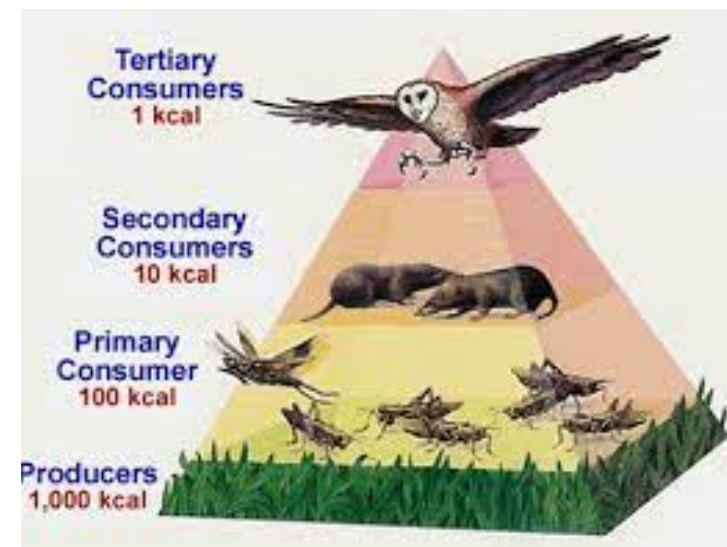
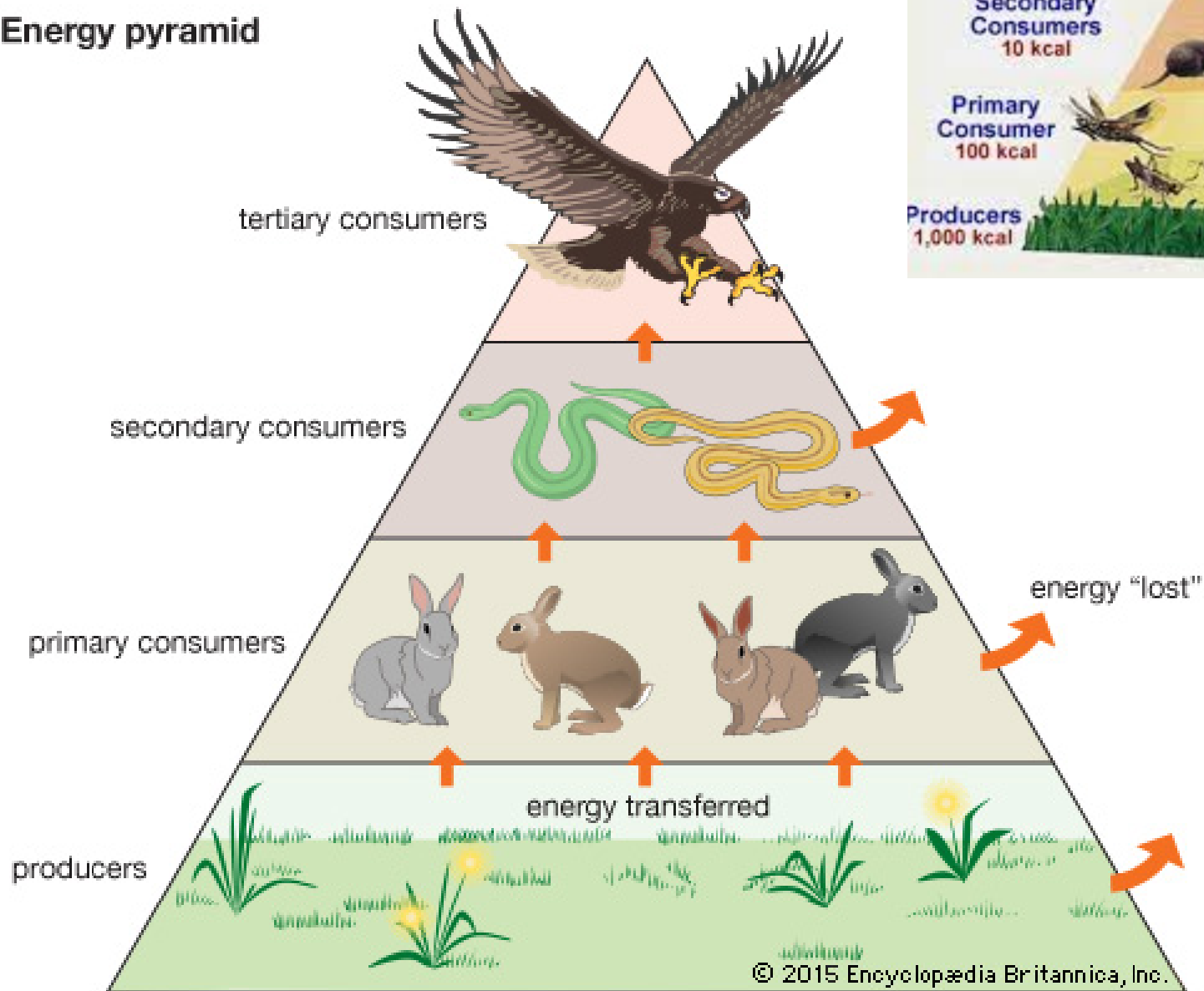
(b)

# Piramida energije u vodenom ekosistemu



# Piramida energije u kopnenom ekosistemu

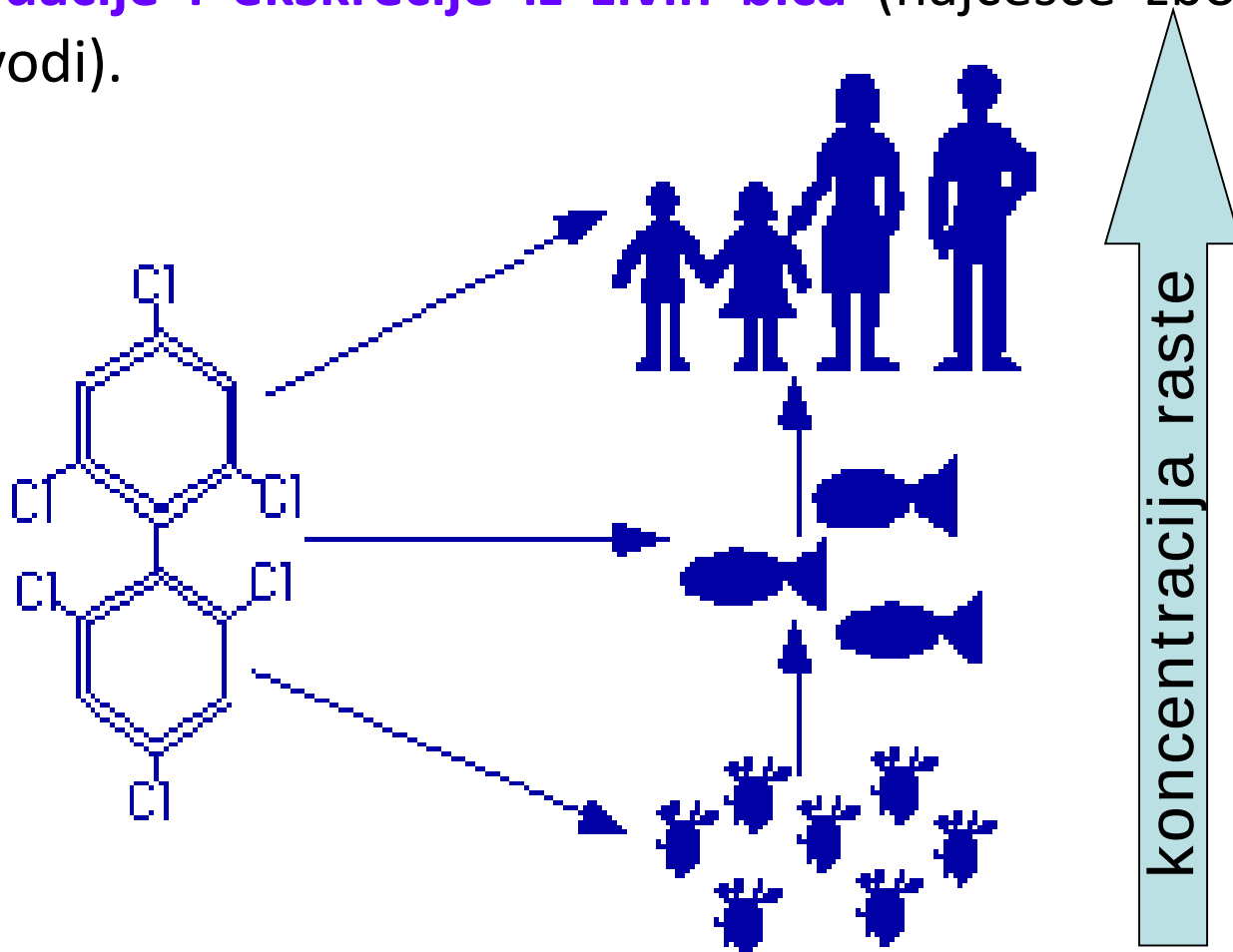
Energy pyramid





# Biomagnifikacija = bioamplifikacija

- povećanje koncentracije supstance kroz lanac ishrane kao posledica postojanosti te supstance (nemogućnosti njenog raspada u životnoj sredini) i slabe (ili potpuno odsutne) metaboličke degradacije i ekskrecije iz živih bića (najčešće zbog nerastvorljivosti u vodi).



Treba razlikovati **biomagnifikaciju**  
od **bioakumulacije** i **biokoncentracije**

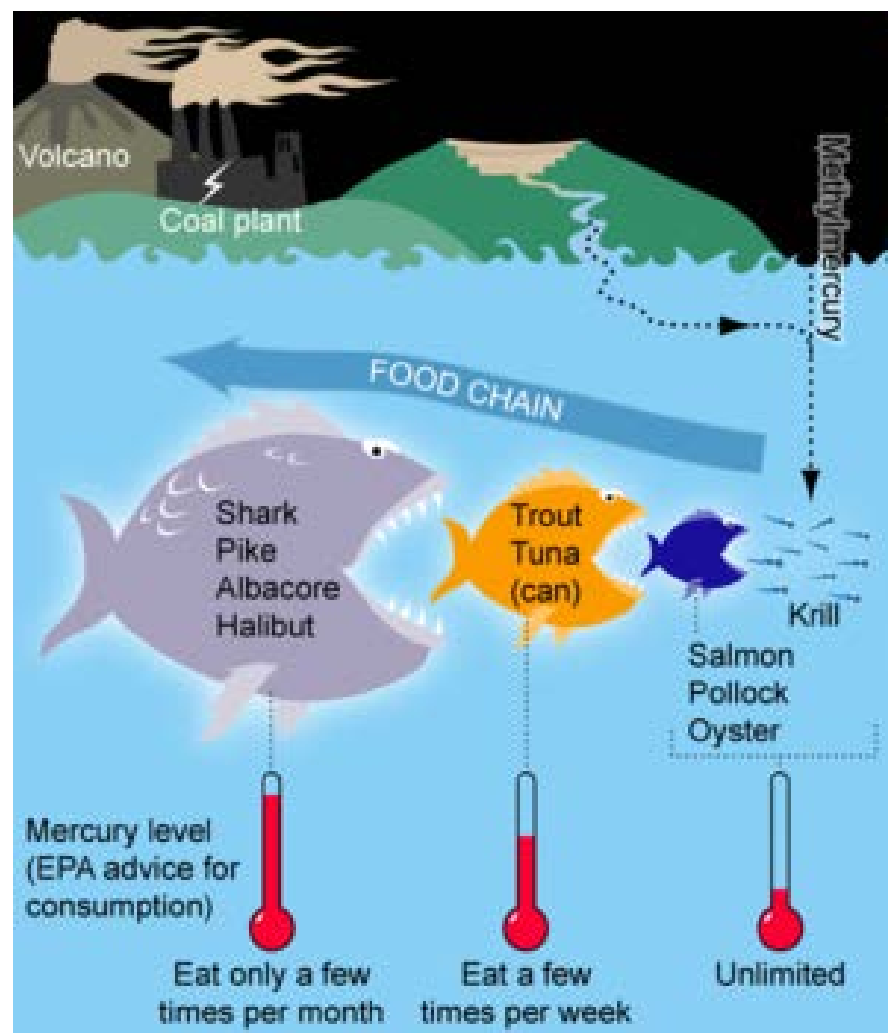
- **Bioakumulacija** se dešava unutar trofičkog nivoa i predstavlja povećanje koncentracije supstance u nekim tkivima jednog organizma usled apsorpcije te supstance iz hrane i životne sredine.
- **Biokoncentracija** je proces koji se dešava kada je unošenje neke supstance iz vode veće od izlučivanja.

Znači, **biokoncentracija** i **bioakumulacija** su procesi koji se dešavaju unutar organizma, a **biomagnifikacija** se dešava **kroz lanac ishrane**.

# Biomagnifikacija

## = bioamplifikacija:

najviše se odnosi na teške metale, pesticide i herbicide, odnosno sve toksične supstance koje preko otpadnih voda dospevaju u reke, jezera u mora, gde bivaju apsorbovane od strane organizama koje su u osnovi trofičkih piramida, a zatim **preko lanaca ishrane** dolazi do koncentrovanja tih toksičnih supstanci u masnim tkivima organizama koji su na višim trofičkim nivoima.

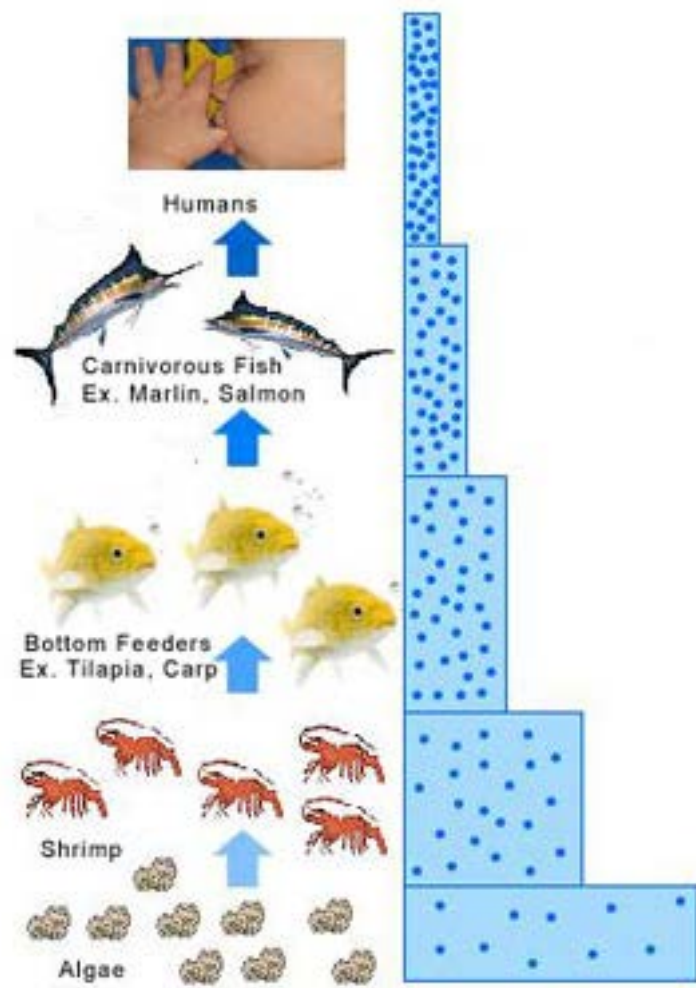


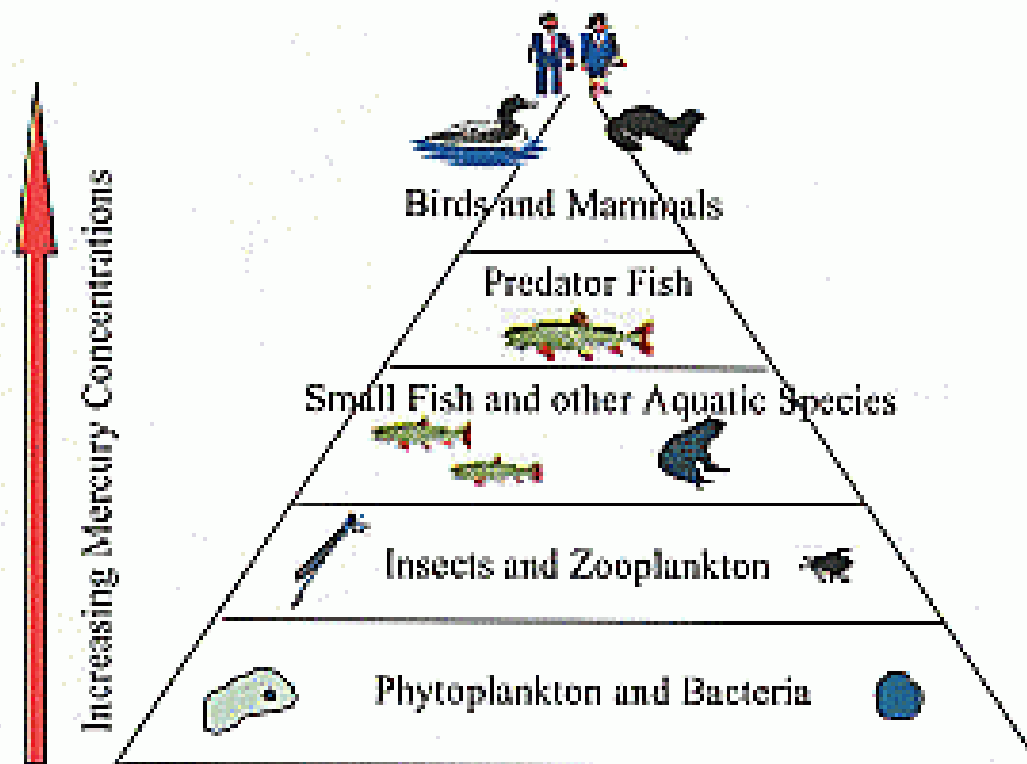
# Biomagnifikacija žive (Hg)

**Živa (Hg)** je prisutna u morskoj vodi u malim količinama, ali se ona **efikasno apsorbuje, ali veoma slabo izlučuje iz organizma**. Živu apsorbuju alge, a zatim, preko lanca ishrane, živa dospeva do ostalih trofičkih nivoa (insekata i zooplanktona, raznih morskih beskičmenjaka, zatim manjih riba, većih riba, ptica i sisara).

**Prolaskom kroz lanac ishrane, dolazi do bioakumulacije i biokoncentracije žive u masnim tkivima sukcesivnih trofičkih nivoa.** Tako se u **ajkulama nalazi 100 puta veća koncentracija žive** (> 1 ppm) **nego u haringama** (~ approximately 0.01 ppm (EPA 1997)).

## Biomagnifikacija žive (Hg) kroz lanac ishrane





**Figure 1. Accumulation of mercury in the food chain.**

(Reprinted from Clean the Rain, Clean the Lakes: National Wildlife Federation, 2000)

**Biomagnifikacija žive**

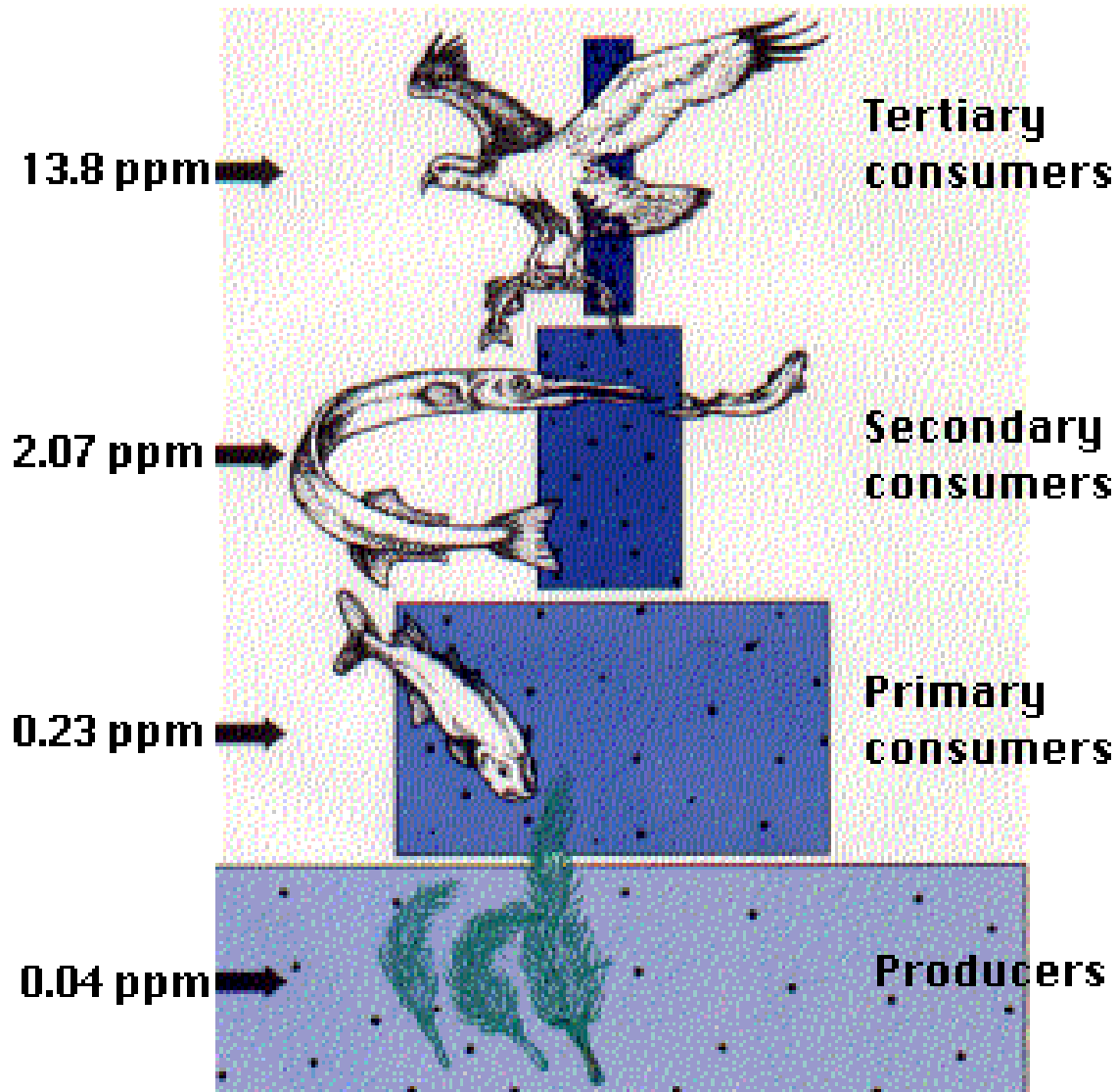


# Biomagnifikacija insekticida DDT

Povećanje koncentracije **DDT-a** u tkivima živih bića prilikom prolaska kroz sukcesivne trofičke nivoe lanca ishrane.

Koncentracija DDT-a se povećava jer se on **razlaže i izlučuje mnogo sporije nego hranljive materije prilikom prolaska iz jednog trofičkog nivoa u drugi.**

**DDT** se zato **akumulira u telima (naročito u masnim tkivima).**



The numbers are representative values of the concentration in the tissues of **DDT** and its derivatives (in parts per million, ppm)



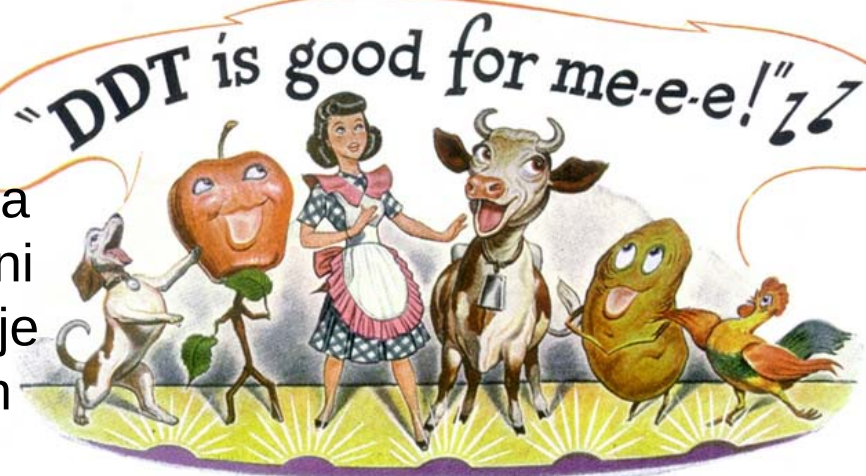
# DDT... FOR CONTROL OF HOUSEHOLD PESTS

Prepared by the  
Bureau of Entomology and Plant Quarantine  
Agricultural Research Administration  
United States Department of Agriculture, and  
United States Public Health Service  
Federal Security Agency  
Washington, D. C. • Revised March 1947

## DDT

- '40-ih godina XX veka hvaljen kao spasonosni insekticid (za suzbijanje malarije, tifusa i drugih bolesti koje prenose insekti

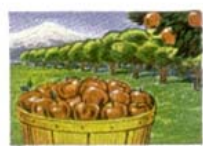
- 1972 zabranjen zbog izrazite toksičnosti i biomagnifikacije u živim bićima.



The great expectations held for DDT have been realized. During 1946, exhaustive scientific tests have shown that, when properly used, DDT kills a host of destructive insect pests, and is a benefactor of all humanity.

Pennsalt produces DDT and its products in all standard forms and is now

one of the country's largest producers of this amazing insecticide. Today, everyone can enjoy added comfort, health and safety through the insect-killing powers of Pennsalt DDT products . . . and DDT is only one of Pennsalt's many chemical products which benefit industry, farm and home.



**GOOD FOR FRUITS**—Bigger apples, juicier fruits that are free from unsightly worms . . . all benefits resulting from DDT dusts and sprays.



**GOOD FOR STEERS**—Beef grows meatier nowadays . . . for it's a scientific fact that—compared to untreated cattle—beef-steers gain up to 50 pounds extra when protected from horn flies and many other pests with DDT insecticides.



**KNOX FOR THE HOME**—helps to make healthier, more comfortable homes . . . protects your family from dangerous insect pests. Use Knox-Out DDT Powders and Sprays as directed . . . then watch the bugs "bite the dust"!



**KNOX FOR DAIRIES**—Up to 20% more milk . . . more butter . . . more cheese . . . tests prove greater milk production when dairy cows are protected from the annoyance of many insects with DDT insecticides like Knox-Out Stock and Barn Spray.

## KILLING SALT

CHEMICALS

97 Years' Service to Industry • Farm • Home



**GOOD FOR ROW CROPS**—25 more barrels of potatoes per acre . . . actual DDT tests have shown crop increases like this! DDT dusts and sprays help truck farmers pass these gains along to you.



**KNOX FOR INDUSTRY**—Food processing plants, laundries, dry cleaning plants, hotels . . . dozens of industries gain effective bug control, more pleasant work conditions with Pennsalt DDT products.

**This Year's Most Powerful Fly Spray IS LIQUID DDT KILL-COAT**  
**\*The 2-WAY SPRAY!**

**\*YES SIR 2-WAY BECAUSE**

- \* 3 MONTHS KILLING WHEN SPRAYED ON SURFACES!
- \* INSTANT KILLING WHEN SPRAYED ON INSECTS!

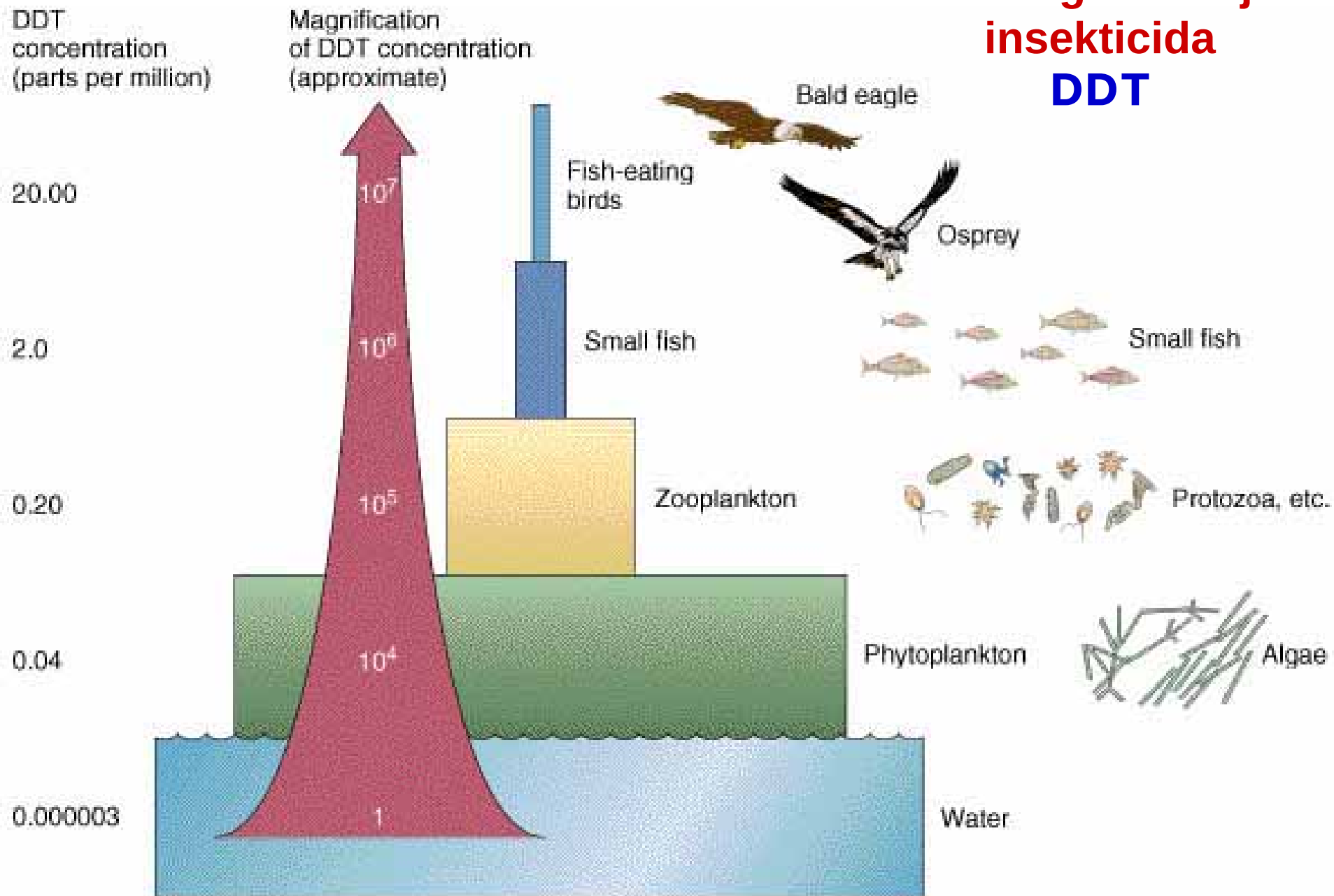
**QUICK KILLING!** When you spray DDT Kill-Coat AT insects it kills at once. **KILLS ALL HOUSEHOLD INSECT PESTS!** Used either way DDT Kill-Coat kills Flies, Silverfish, Mosquitoes, Fleas, Bugs, etc.

**3 MONTHS LASTING ACTION**  
When you spray a coat of DDT Kill-Coat on walls, window sills, table tops, carpet edges, etc., it leaves a "killing-coat" of DDT. This "killing-coat" remains effective for 3 months. No touch-up with us to it and you.

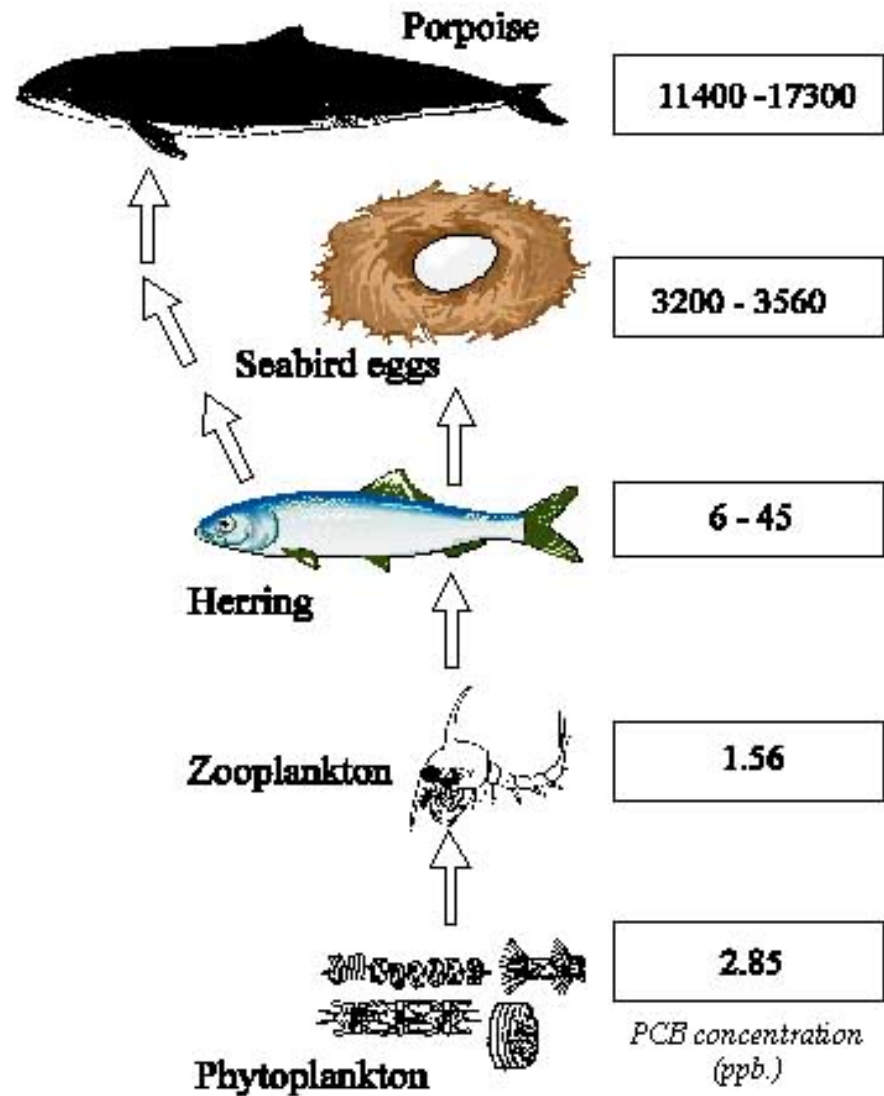
**Liquid DDT. KILL-COAT**

**THIS YEAR'S MOST POWERFUL FLY SPRAY**

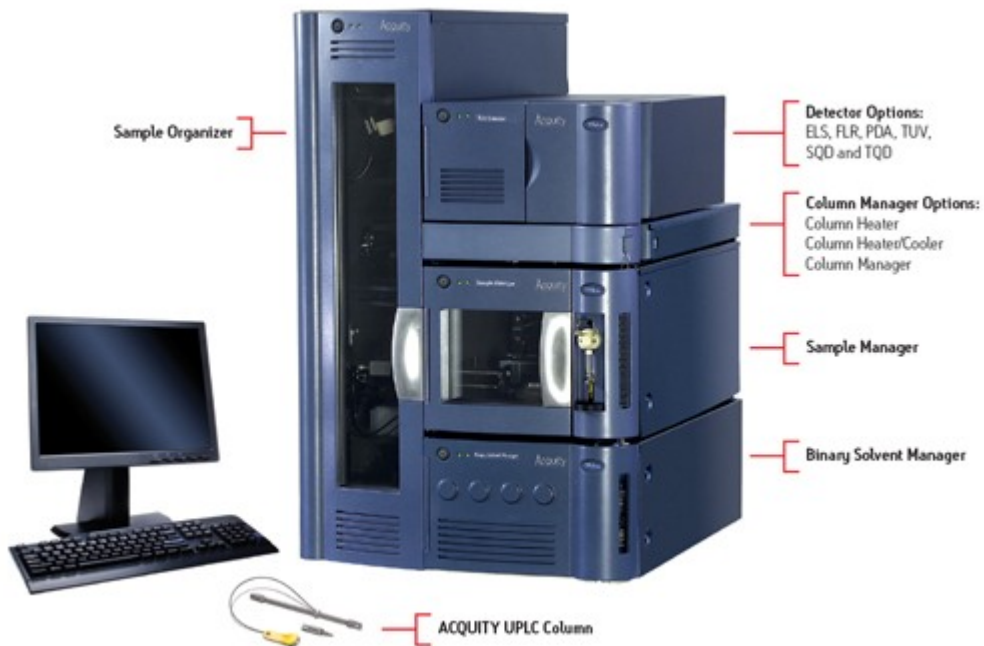
# Biomagnifikacija insekticida DDT



# Biomagnifikacija polihlornih bifenila (PCBs)



*The concentration of PCB's tends to increase in the tissues of organisms at higher levels in the marine food chain, a phenomenon termed 'biomagnification'.  
[From: Percy, Wells and Evans MS, 1996: see Further Reading]*



**HPLC** (engl. *high performance liquid chromatography*) koristi se u identifikaciji organskih polutanata životne sredine



**AAS** - atomski apsorpcioni spektrofotometar je uređaj za određivanje koncentracija teških metala u uzorcima (Pb, Zn, Cd, Cu itd.).



# Metabolizam ekosistema

EKOSISTEM:  
integralna celina sastavljena iz  
BIOTOPA I BIOCENOZE

BIOTOP karakteriše splet abiotičkih faktora koji utiču  
na ŽIVA BIĆA.

Međutim, i ŽIVA BIĆA utiču na BIOTOP, nekad čak toliko da  
promene klimatske faktore.

BIOTOP I BIOCENOZA (neživa i živa priroda) su tesno  
povezane i međusobno uslovljene komponente ekosistema.

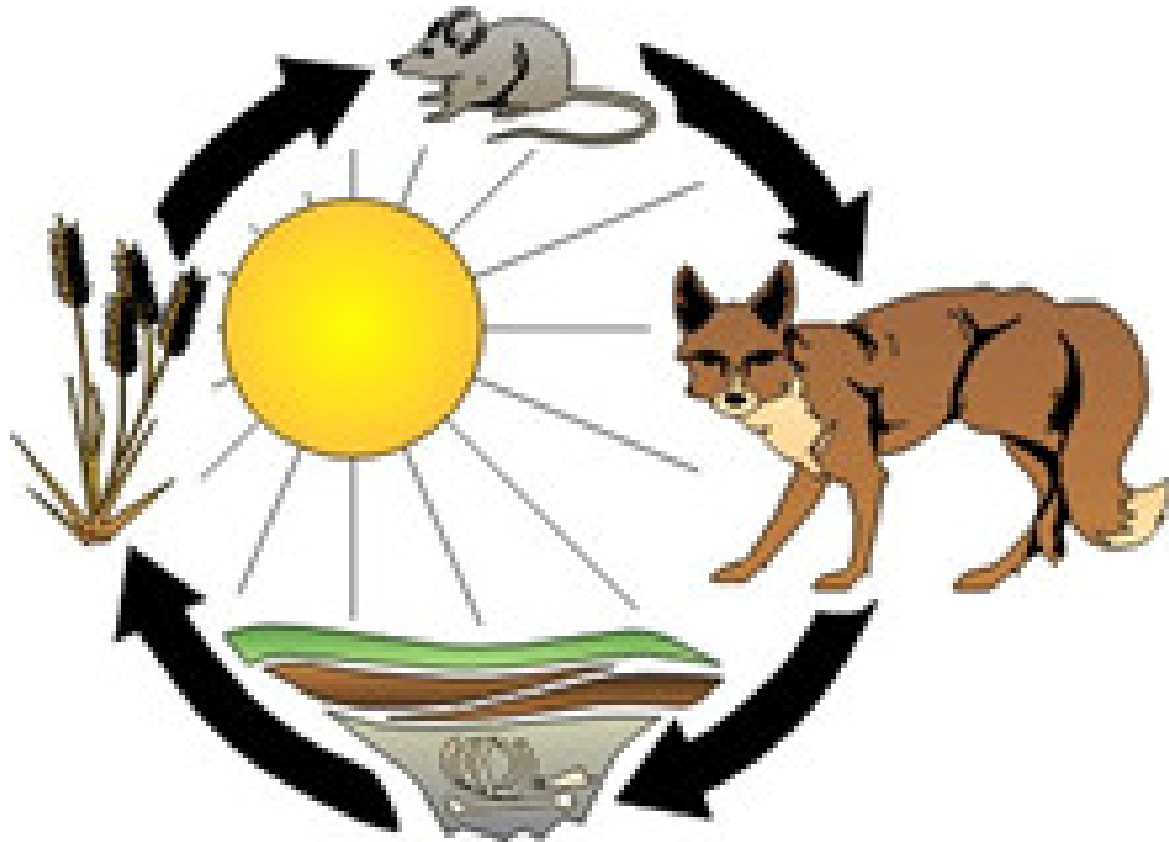


# Metabolizam ekosistema

**EKOSISTEM** je veoma dinamičan i u njemu se neprekidno odvijaju dva procesa: **PROTICANJE ENERGIJE I KRUŽENJE MATERIJJE**

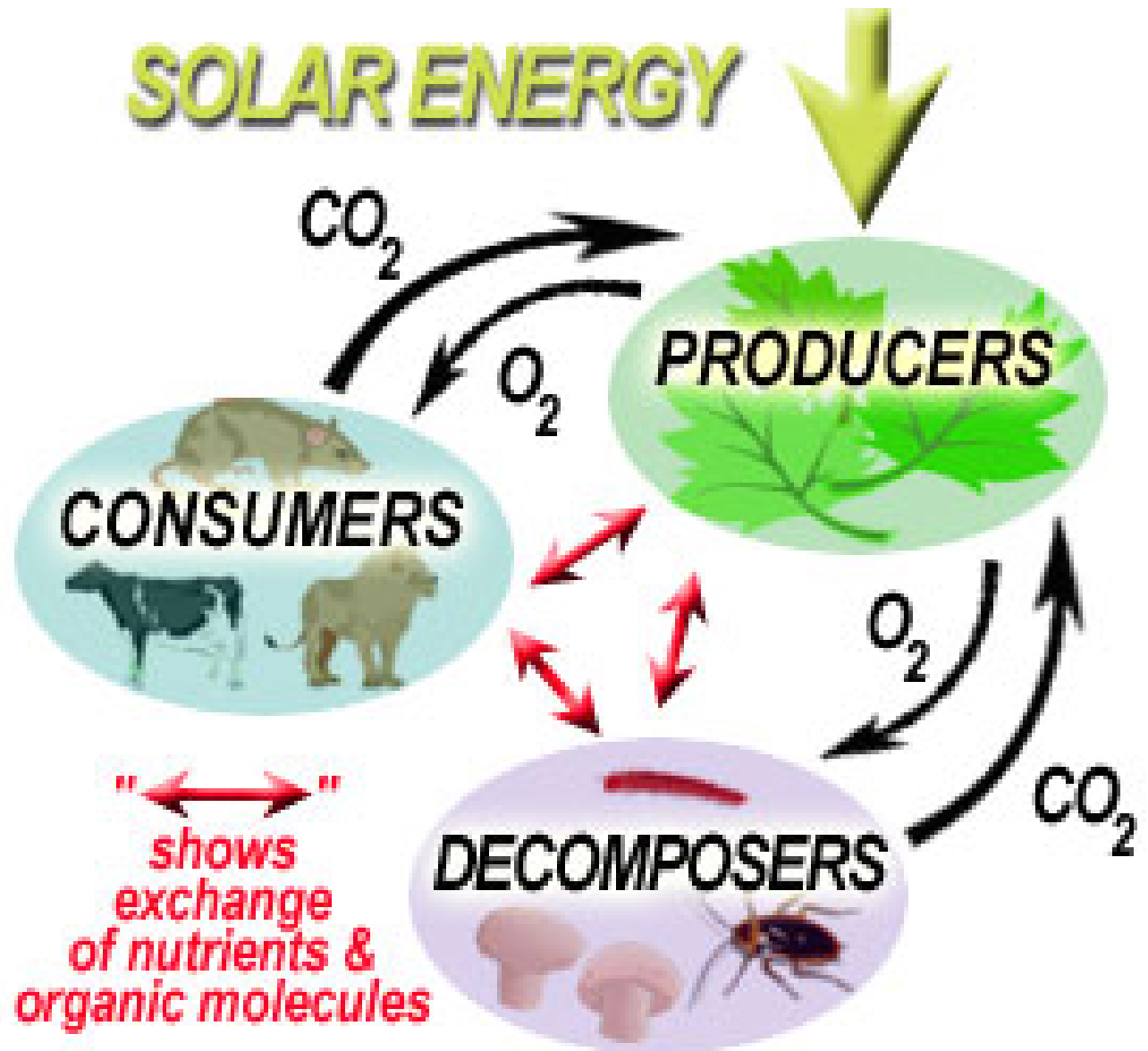
**PROMENE KOJE TRPI MATERIJJA SU REVERZIBILNE**

**TOK ENERGIJE JE IREVERZIBILAN.**



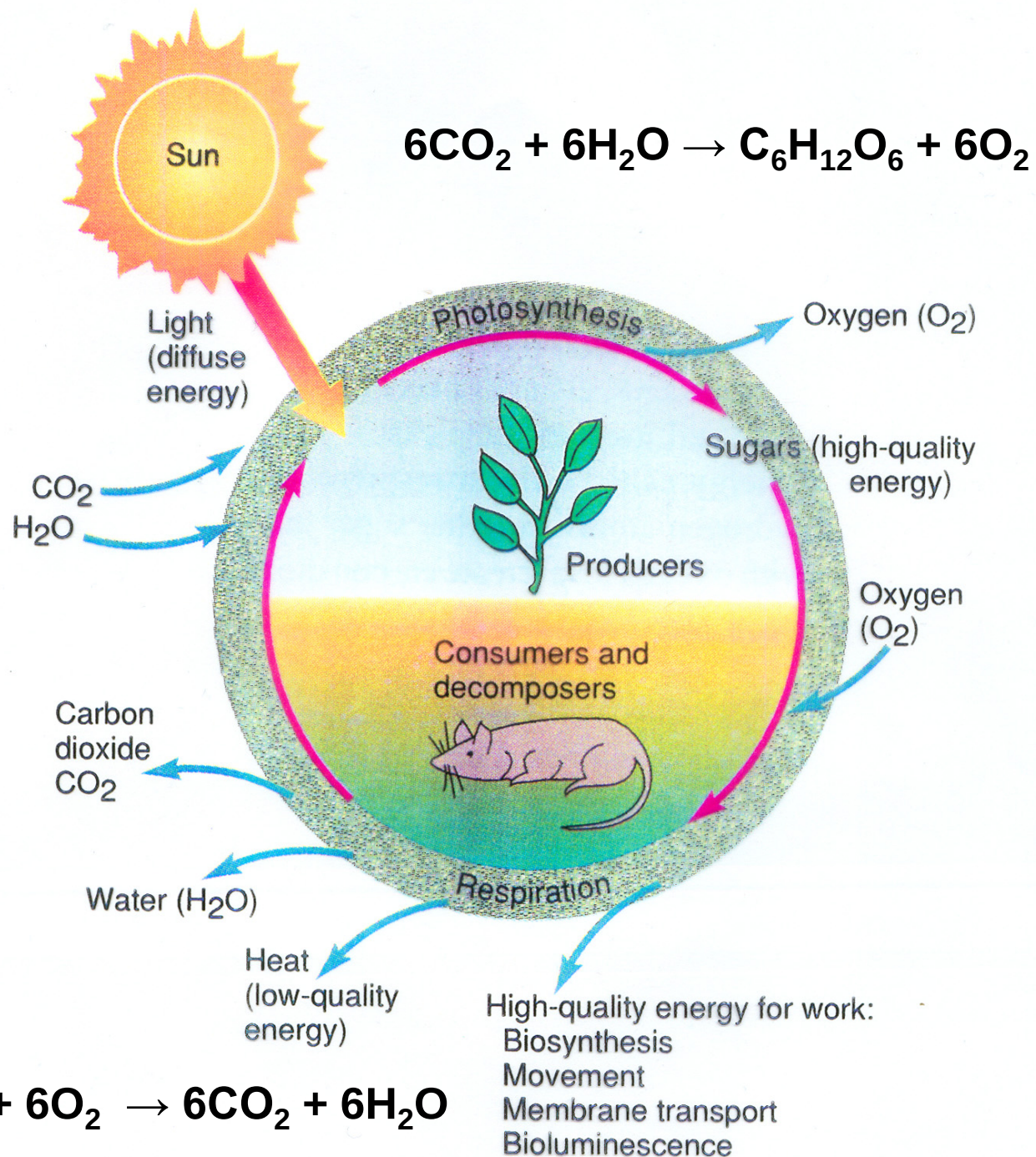
Za sve  
processe u  
ekosistemu  
neophodna  
je energija.

Osnovni  
izvor  
energije na  
Zemlji je  
**Sunčevo  
zračenje.**



Sunce je  
pokretač života  
na Zemlji.

Naseljavanje  
biotopa počinje  
**FOTOSINTEZOM**  
kada se stvaraju  
organska  
jedinjenja iz  
neorganskih



Metabolizam ekosistema obuhvata nekoliko faza:

1. primanje i vezivanje sunčeve energije fotosintezom
2. stvaranje primarne organske materije u kojoj je energija Sunca pretvorena u energiju hemijskih veza
3. konzumenti troše primarnu organsku materiju
4. razlaganje uginulih organizama
5. producenti ponovo koriste mineralizovanu materiju



# Biogeohemijski ciklusi



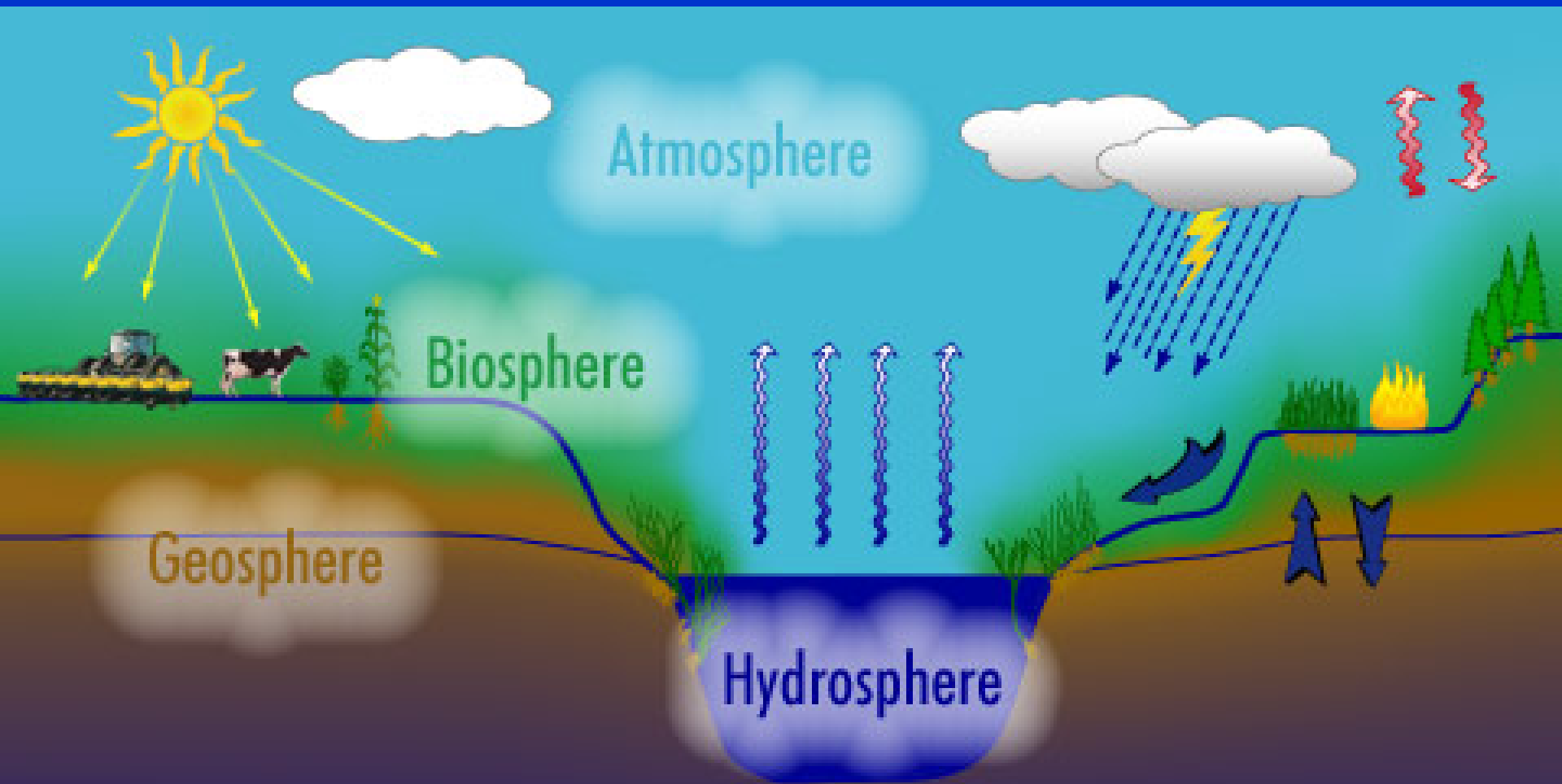
© Dan Ballard Photo

**NAPOMENA:**

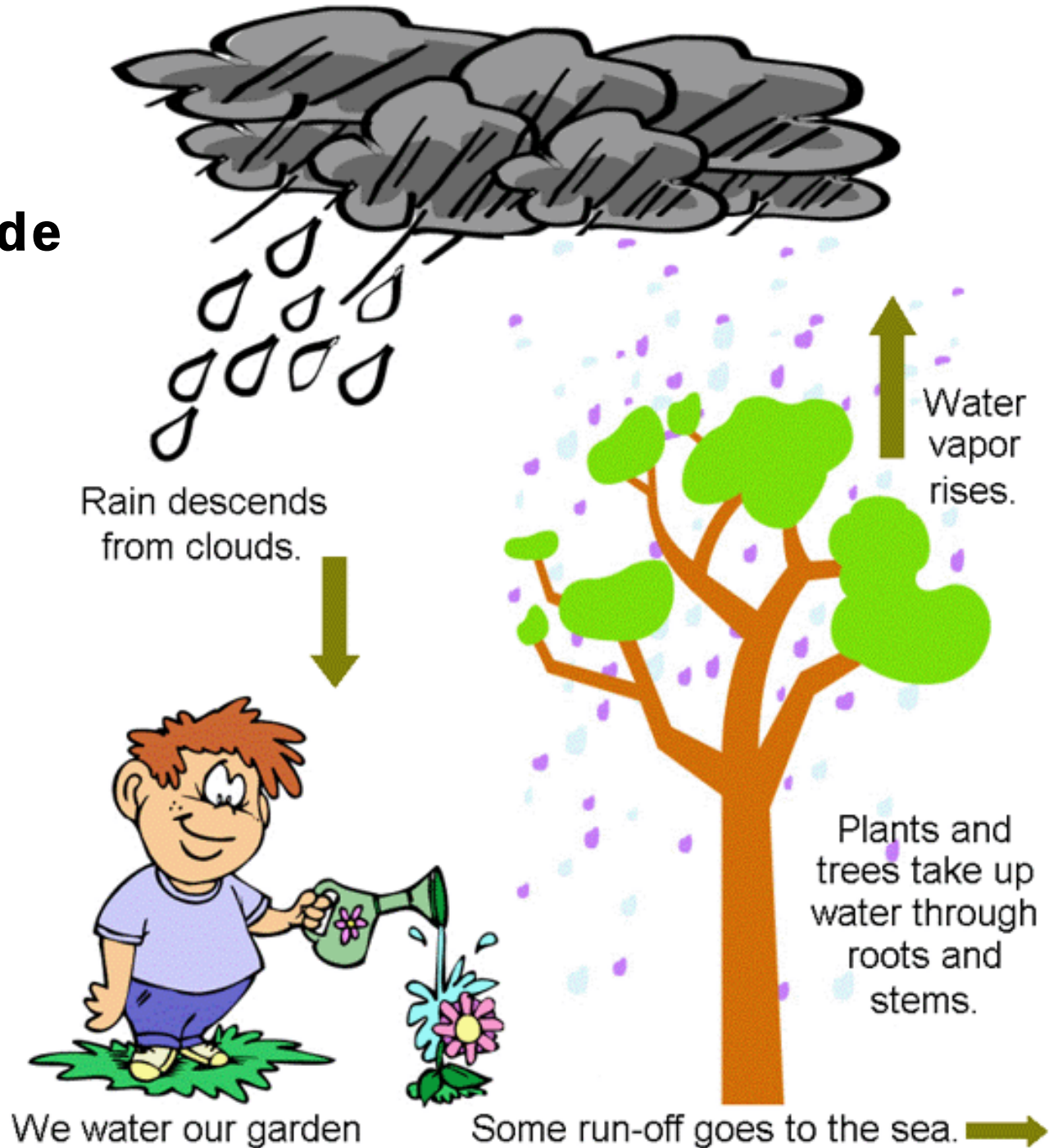
**UKUPNA KOLIČINA MATERIJE NA ZEMLJI OD  
NJENOG NASTANKA DO DANAS NIJE SE BITNO  
MENJALA**



U ekologiji, **biogeochemijski ciklus** podrazumeva **put koji hemijski element ili jedinjenje prolazi** kroz biotičke (biosfera) i abiotičke (litosfera, hidrosfera i atmosfera) komponente planete Zemlje.



# Kruženje vode



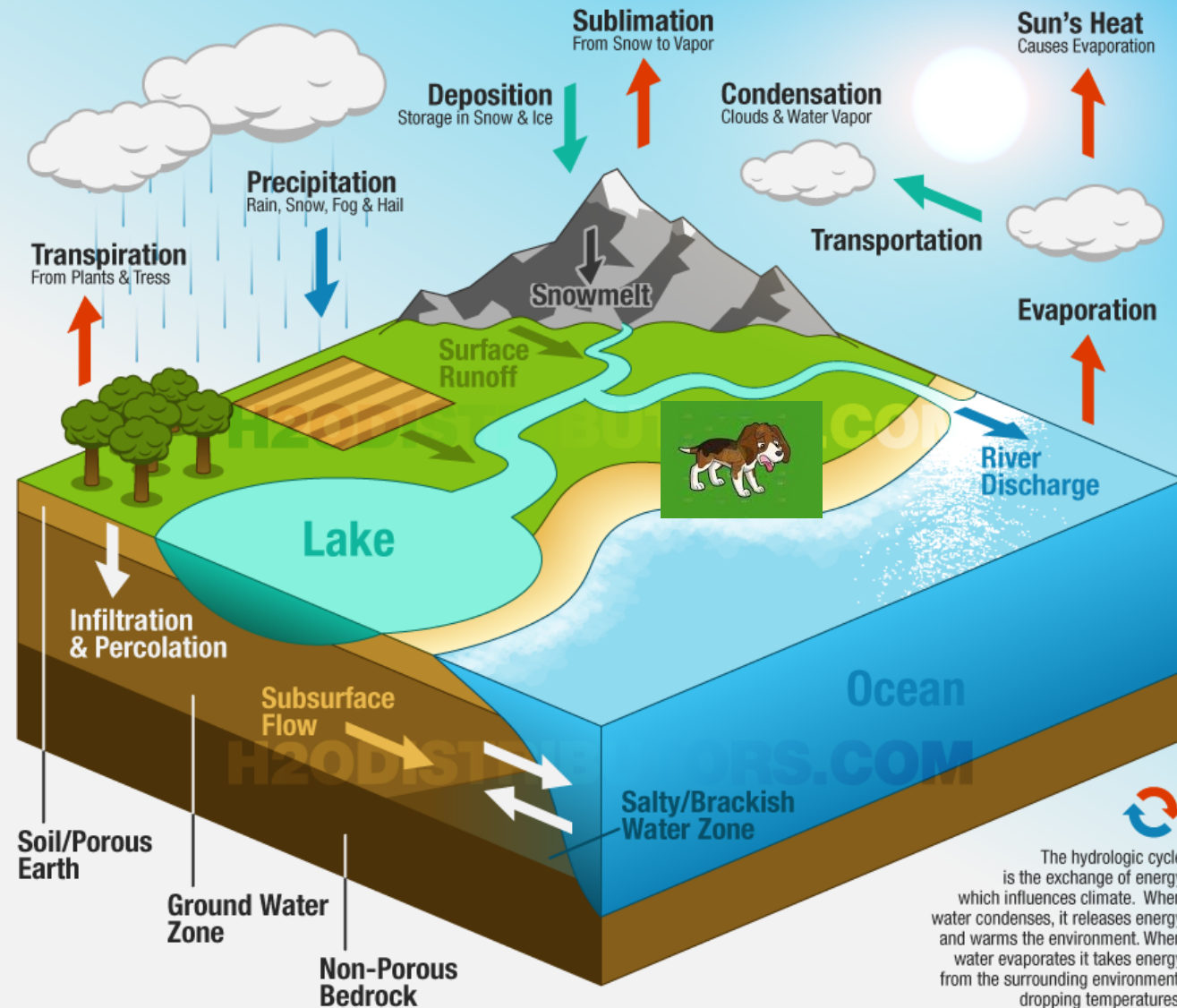
# Kruženje vode

## Hydrologic Cycle

The Hydrologic Cycle (also called the Water Cycle) is the continuous movement of water in the air, on the surface of and below the Earth.

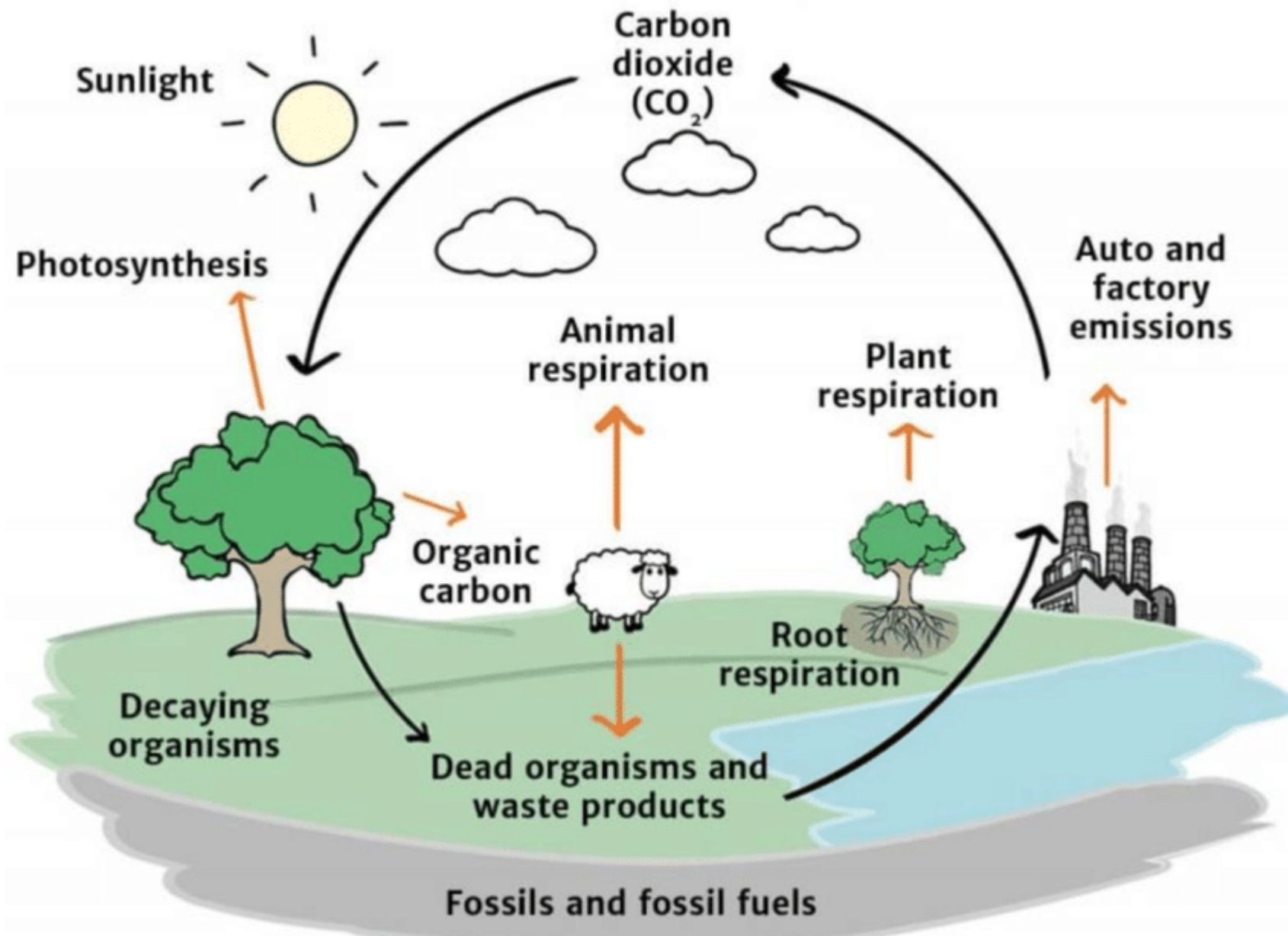
### Human activities that alter the water cycle:

- Alteration of Atmosphere
- Construction of Dams
- Deforestation and Afforestation
- Water Abstraction from Rivers
- Agriculture
- Industry
- Urbanization

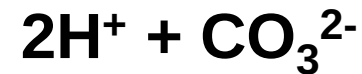
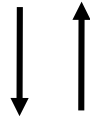
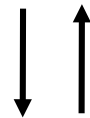
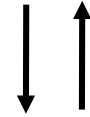
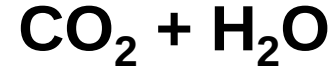
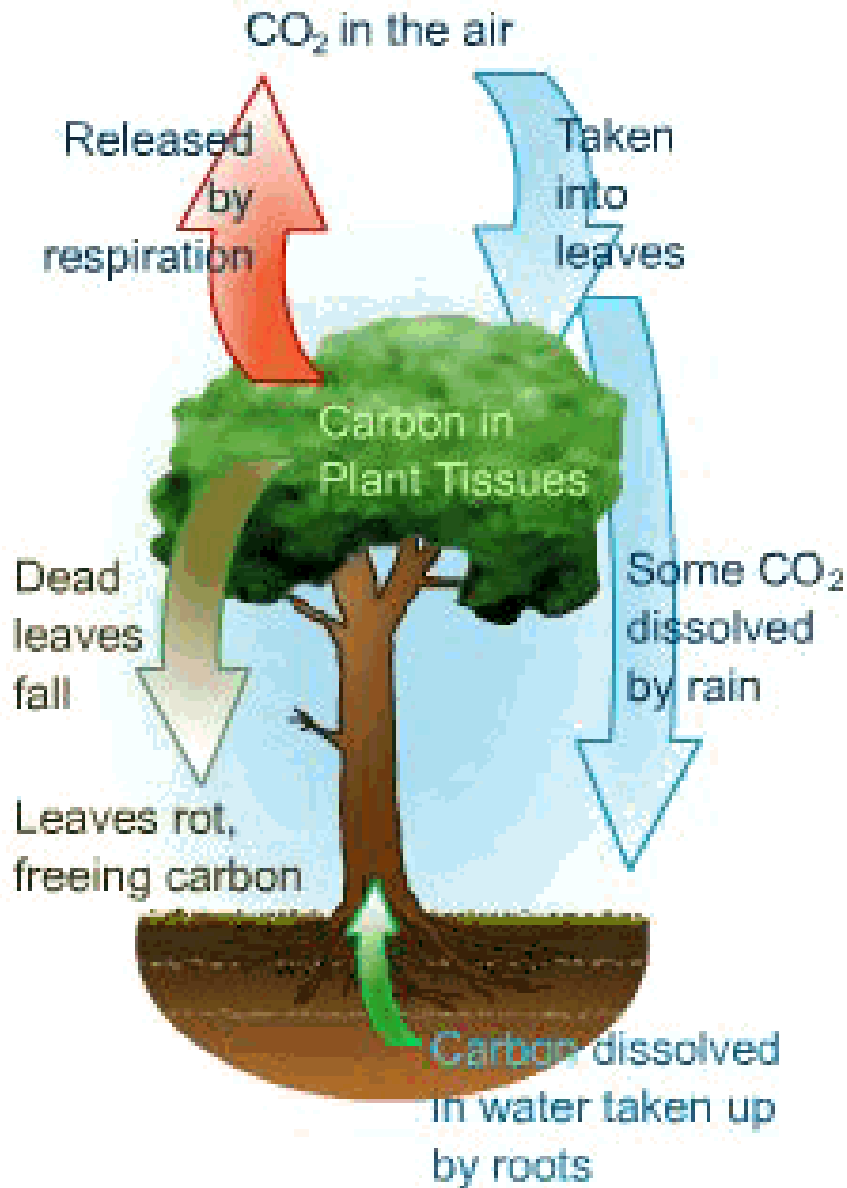


The hydrologic cycle is the exchange of energy which influences climate. When water condenses, it releases energy and warms the environment. When water evaporates it takes energy from the surrounding environment, dropping temperatures.

# Kruženje ugljenika

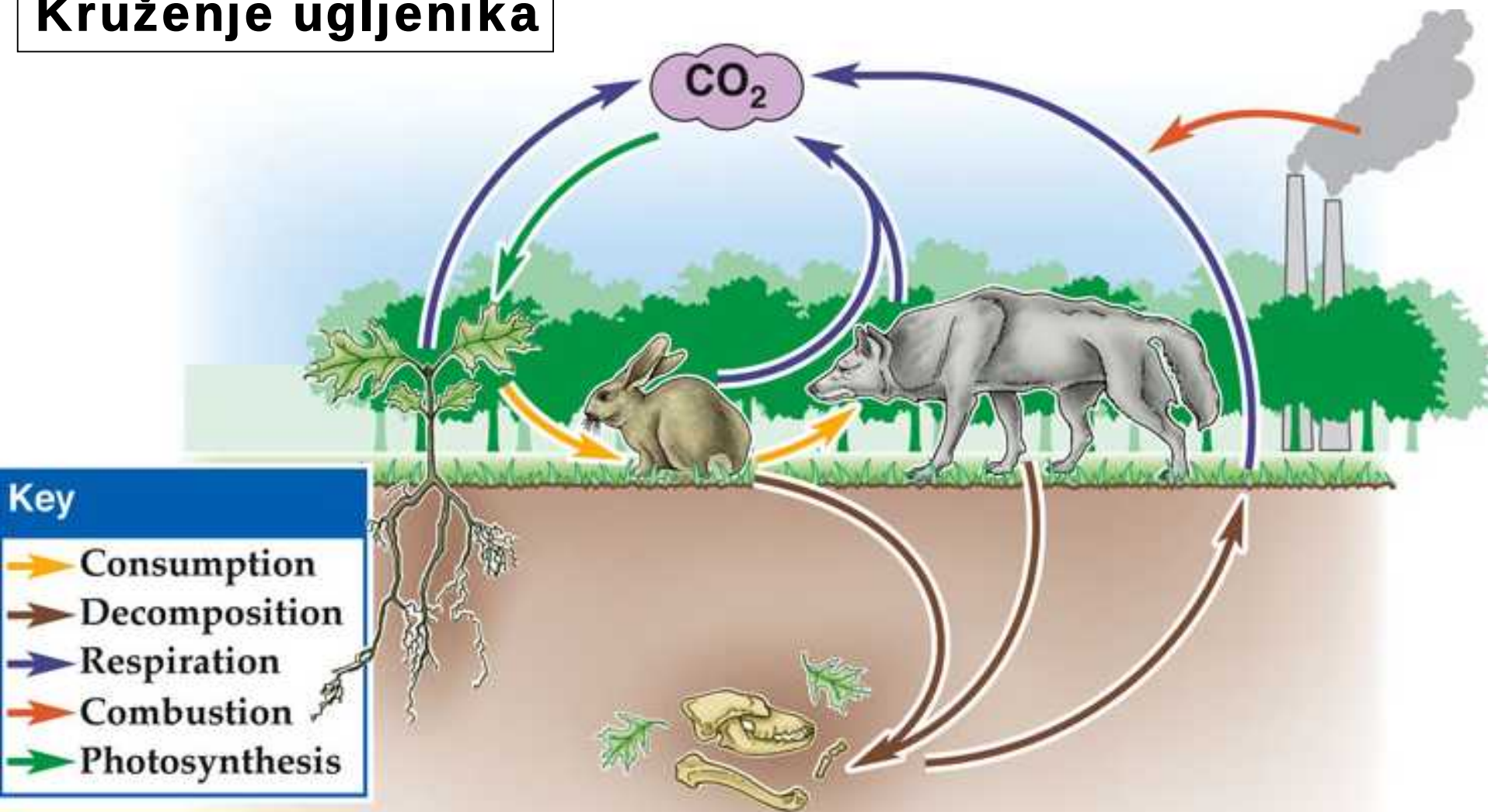


# Kruženje ugljenika

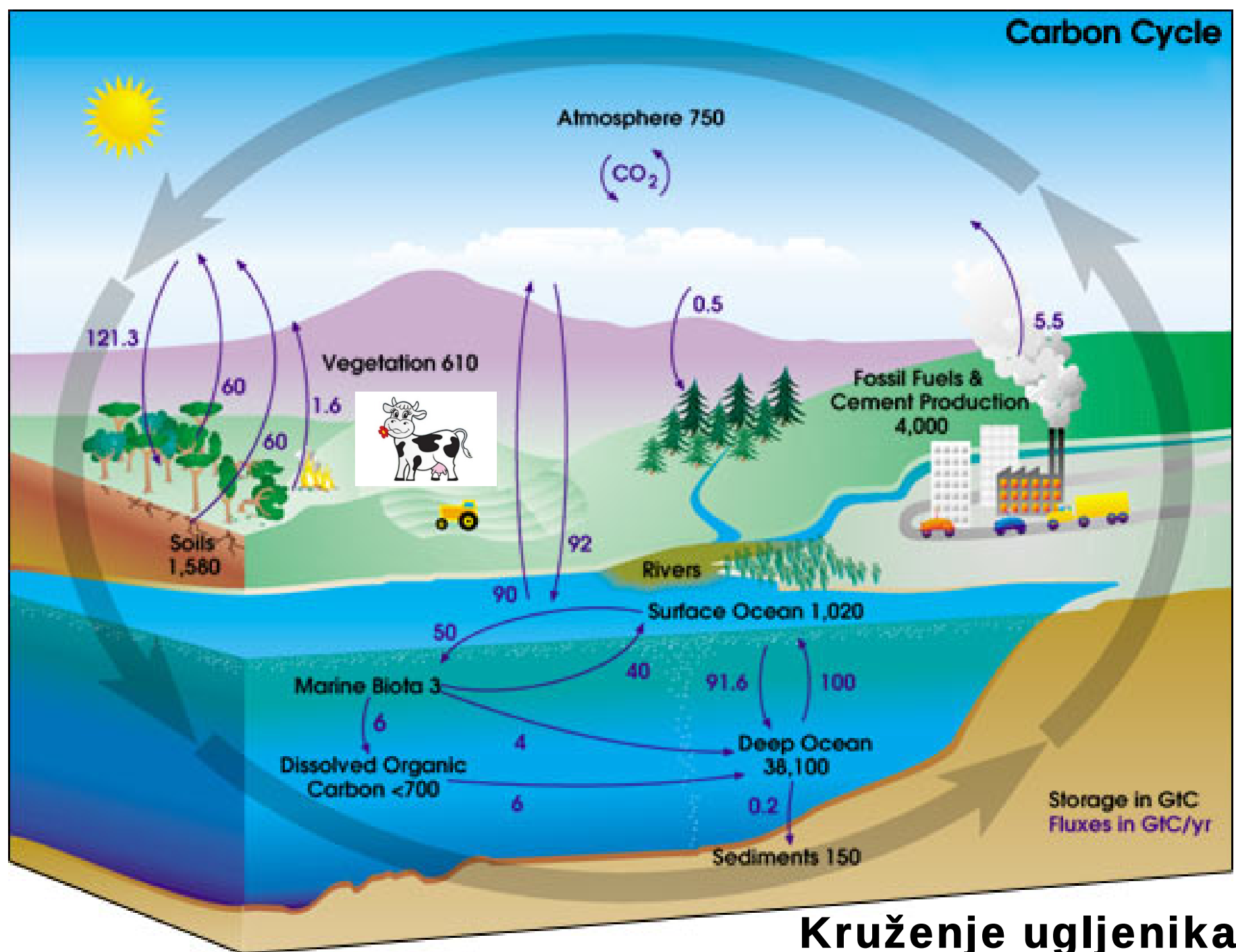




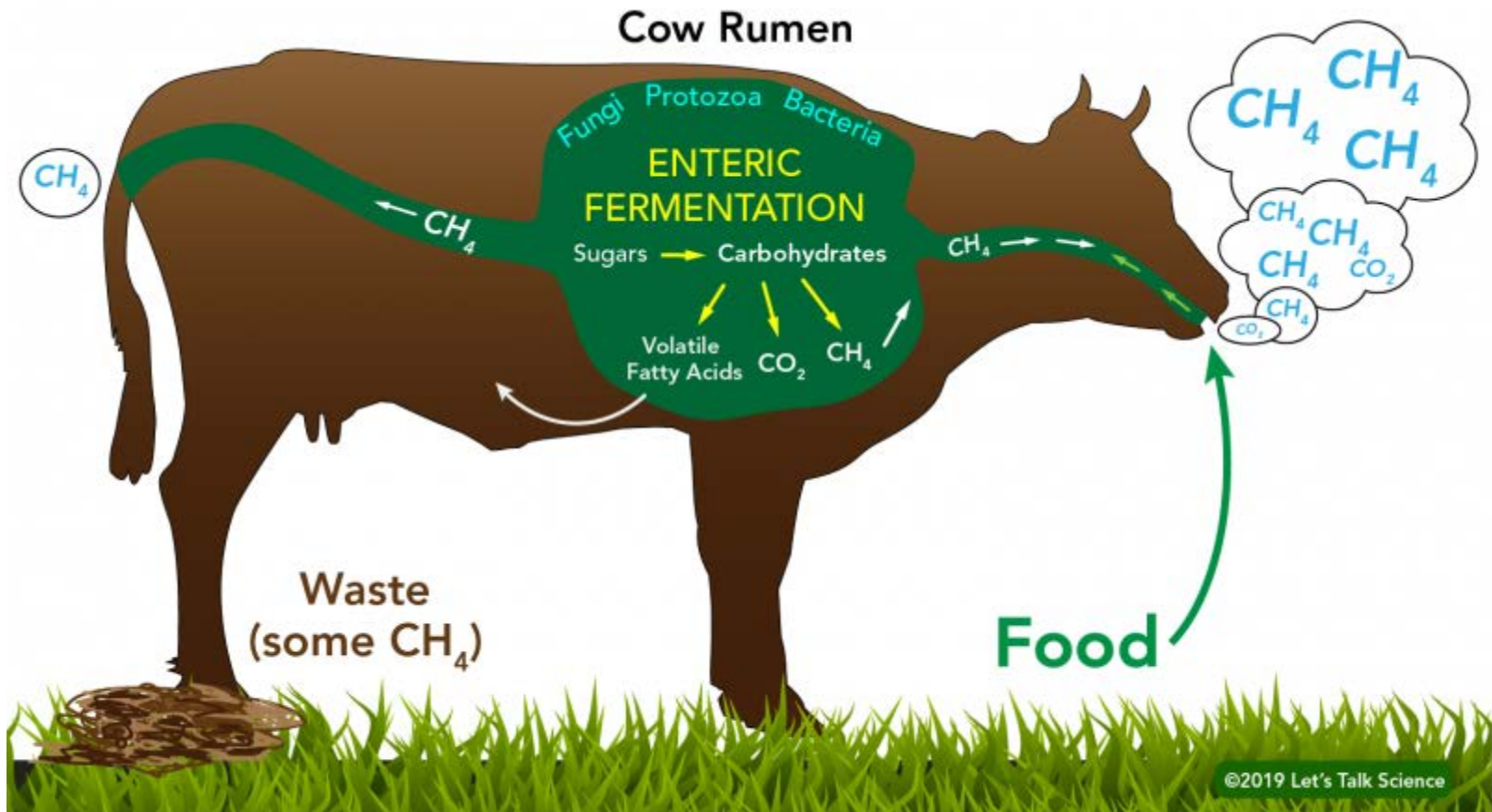
# Kruženje ugljenika



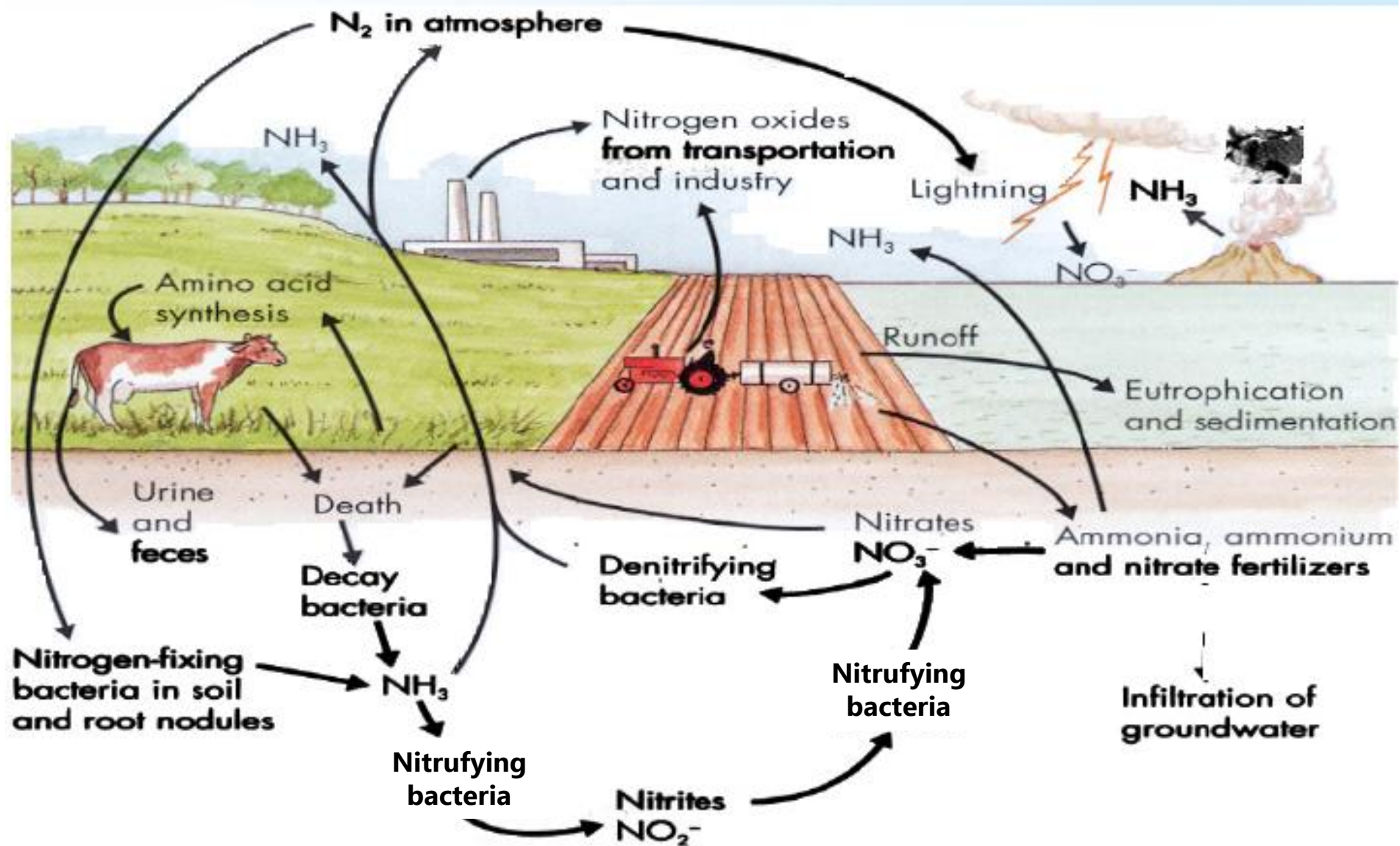
# Carbon Cycle



Kruženje ugljenika

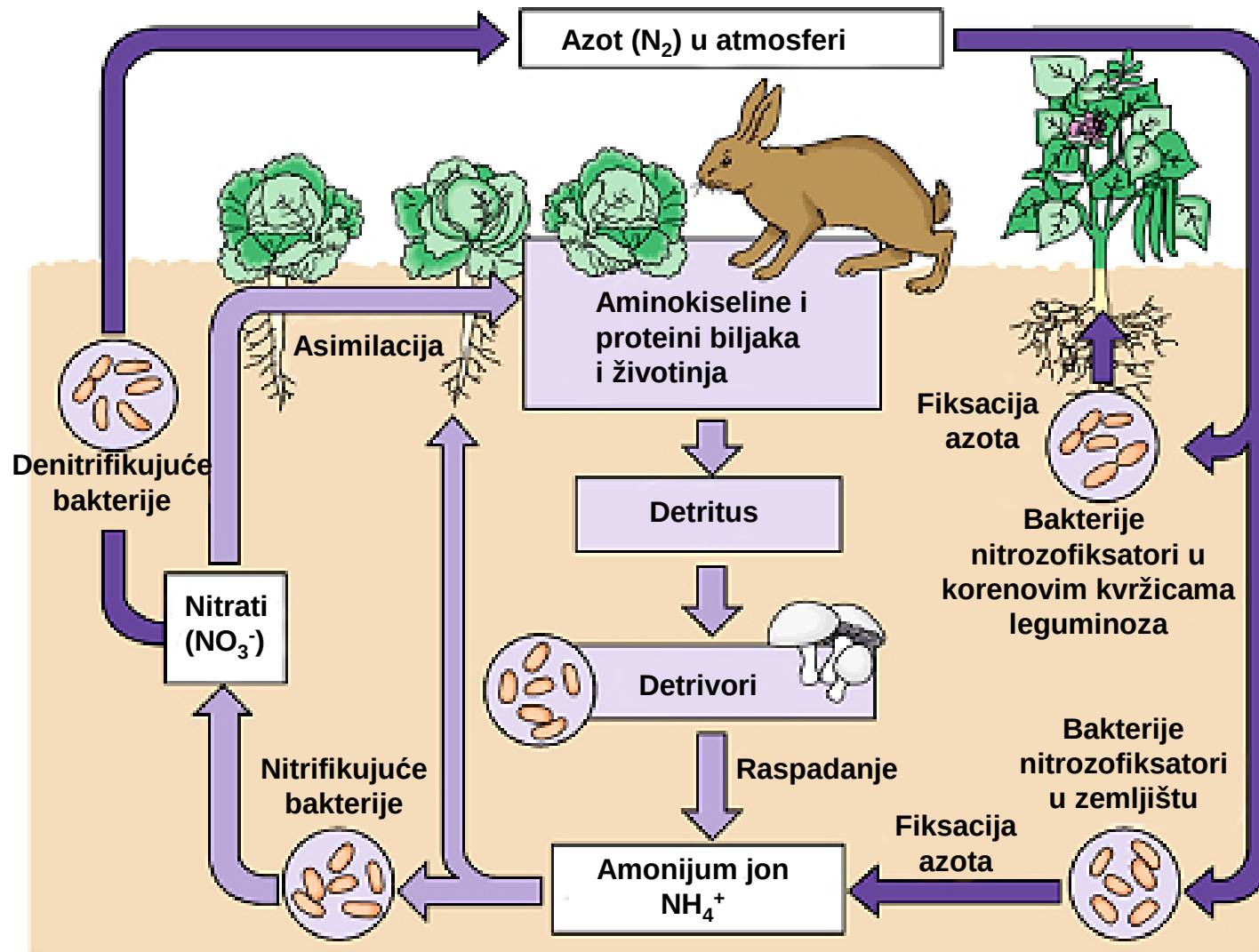


# Kruženje azota



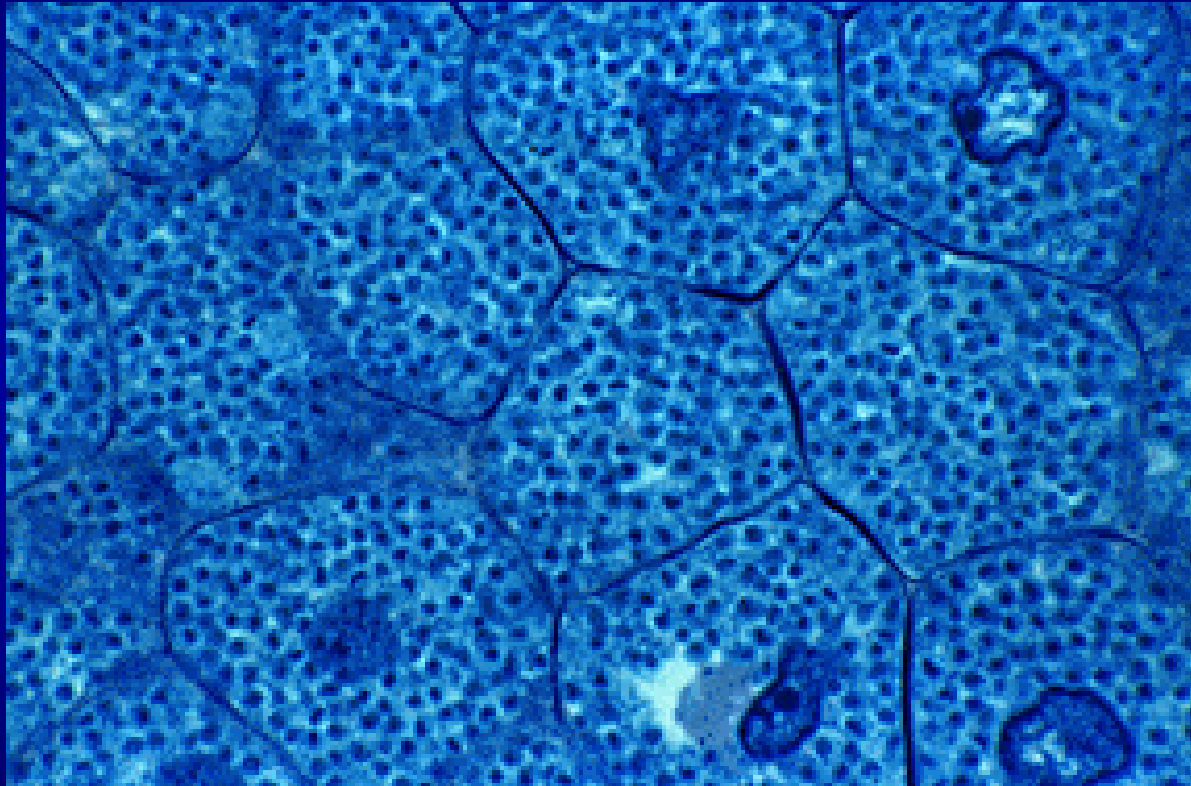


# Kruženje azota



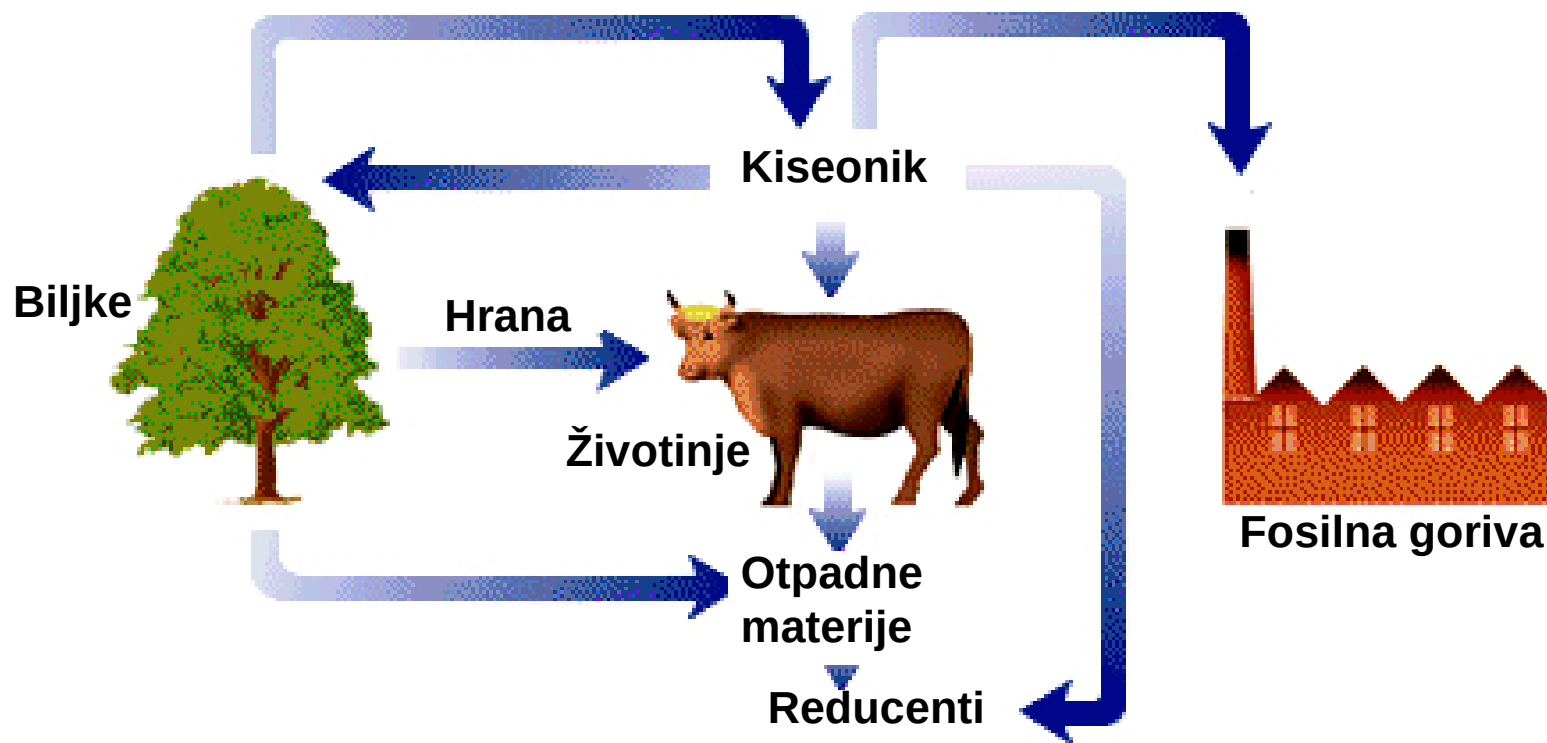


# Fiksacija azota



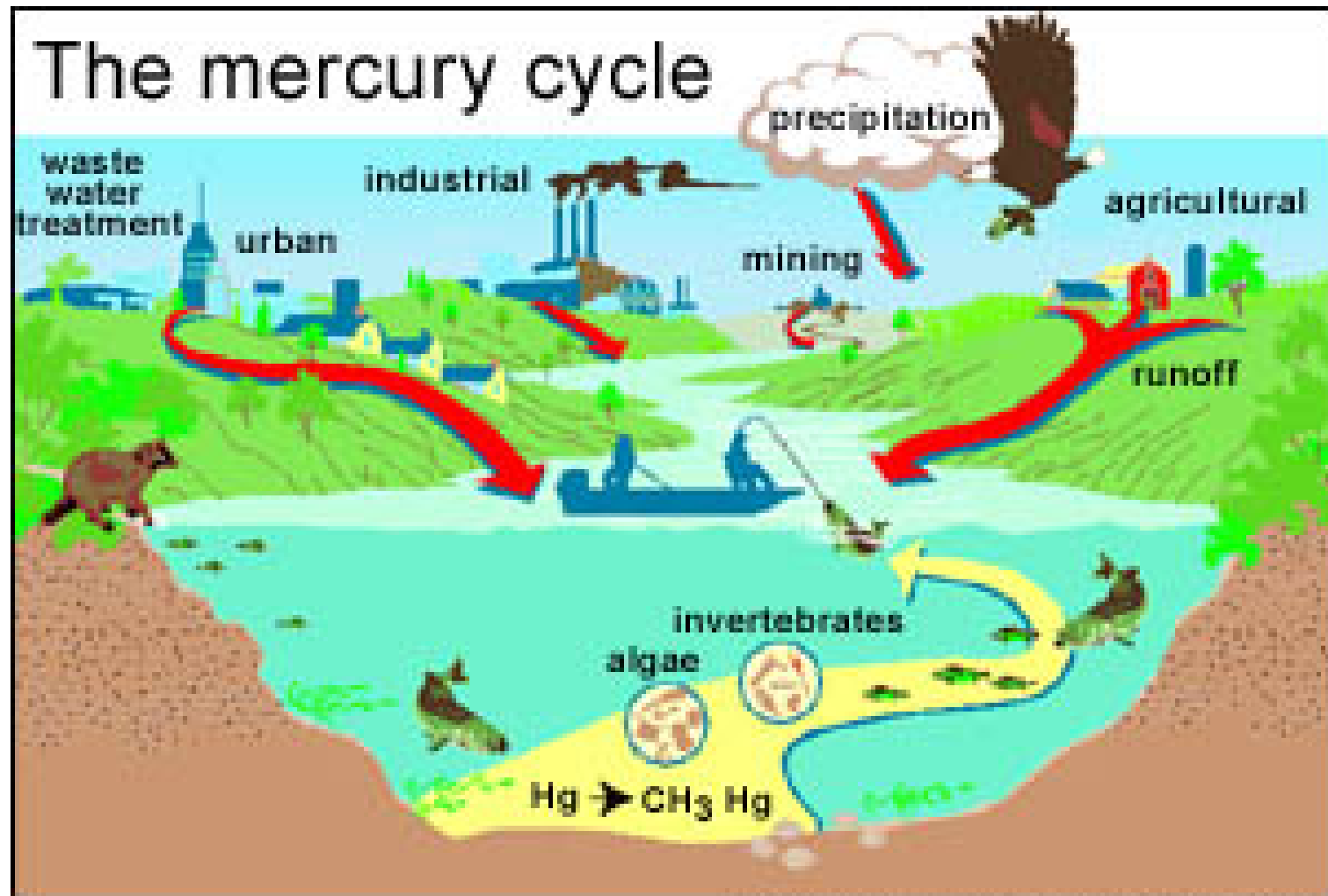
Azotofiksirajuće bakterije  
u korenima leguminoznih biljaka

# Kruženje kiseonika



# Različiti polutanti životne sredine kruže kroz prirodu

Primer: **Živa**



By Connie J. Dean / courtesy USGS

# ZAGAĐENJE ŽIVOTNE SREDINE



# ZAGAĐENJE ŽIVOTNE SREDINE

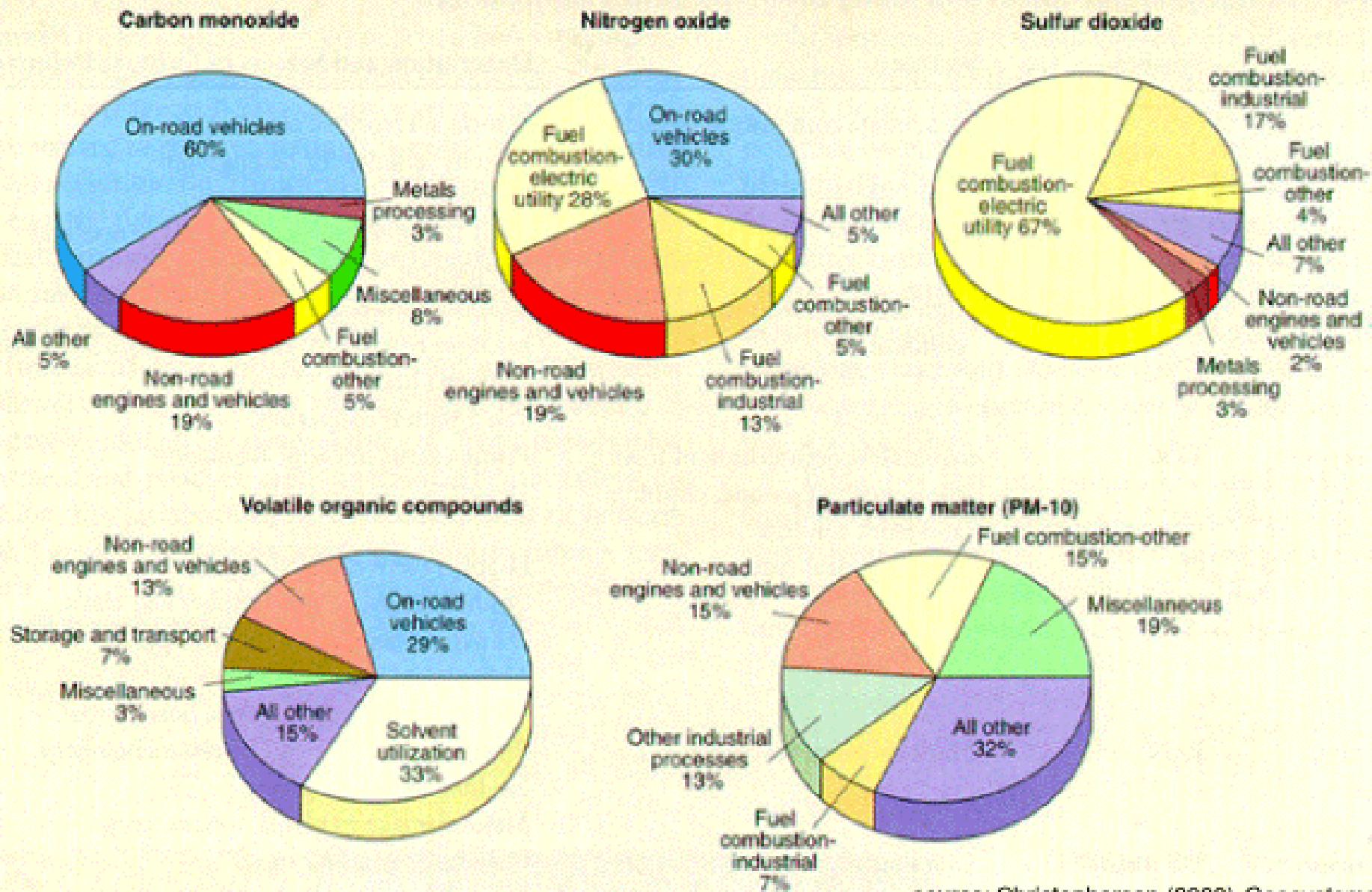




# ZAGAĐENJE ŽIVOTNE SREDINE



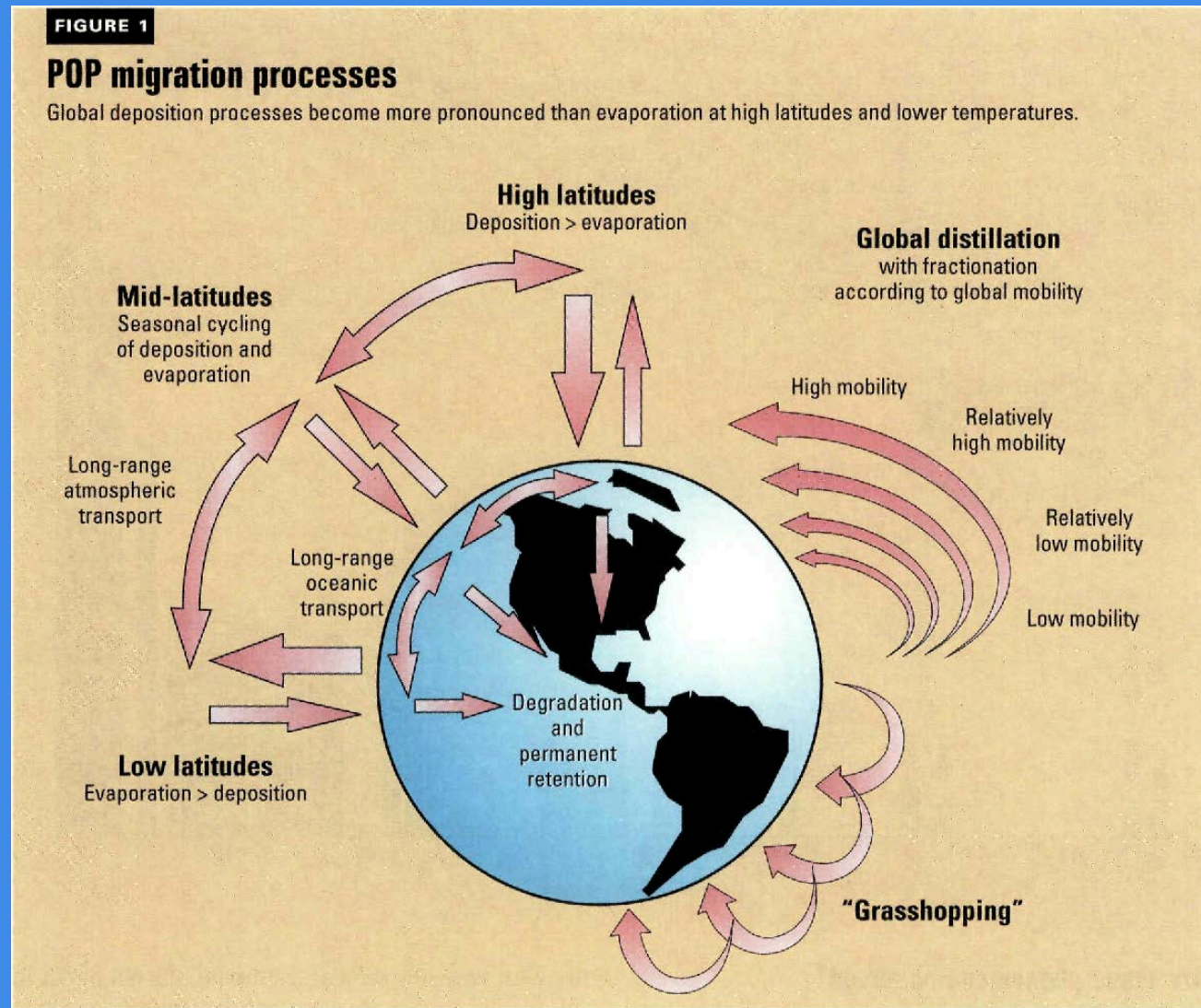
# Procentualno učešće različitih polutanata i njihovih izvora



source: Christopherson (2000) *Geosystems*



# Perzistentni organski polutanti (POP) šire se kroz biosferu različitim mehanizmima na različitim geografskim širinama

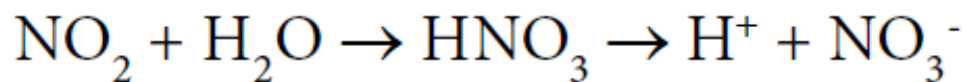
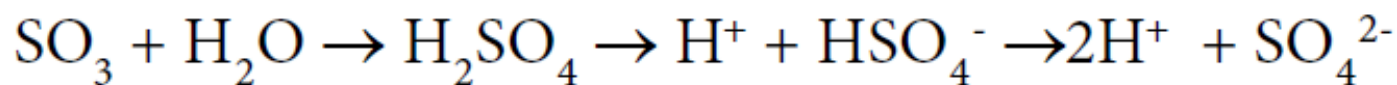
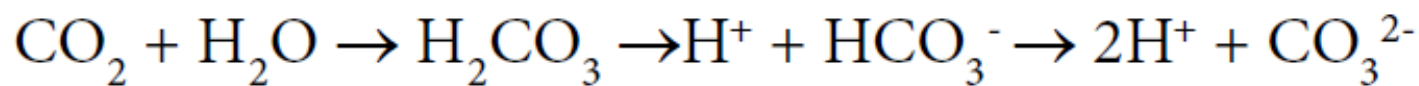




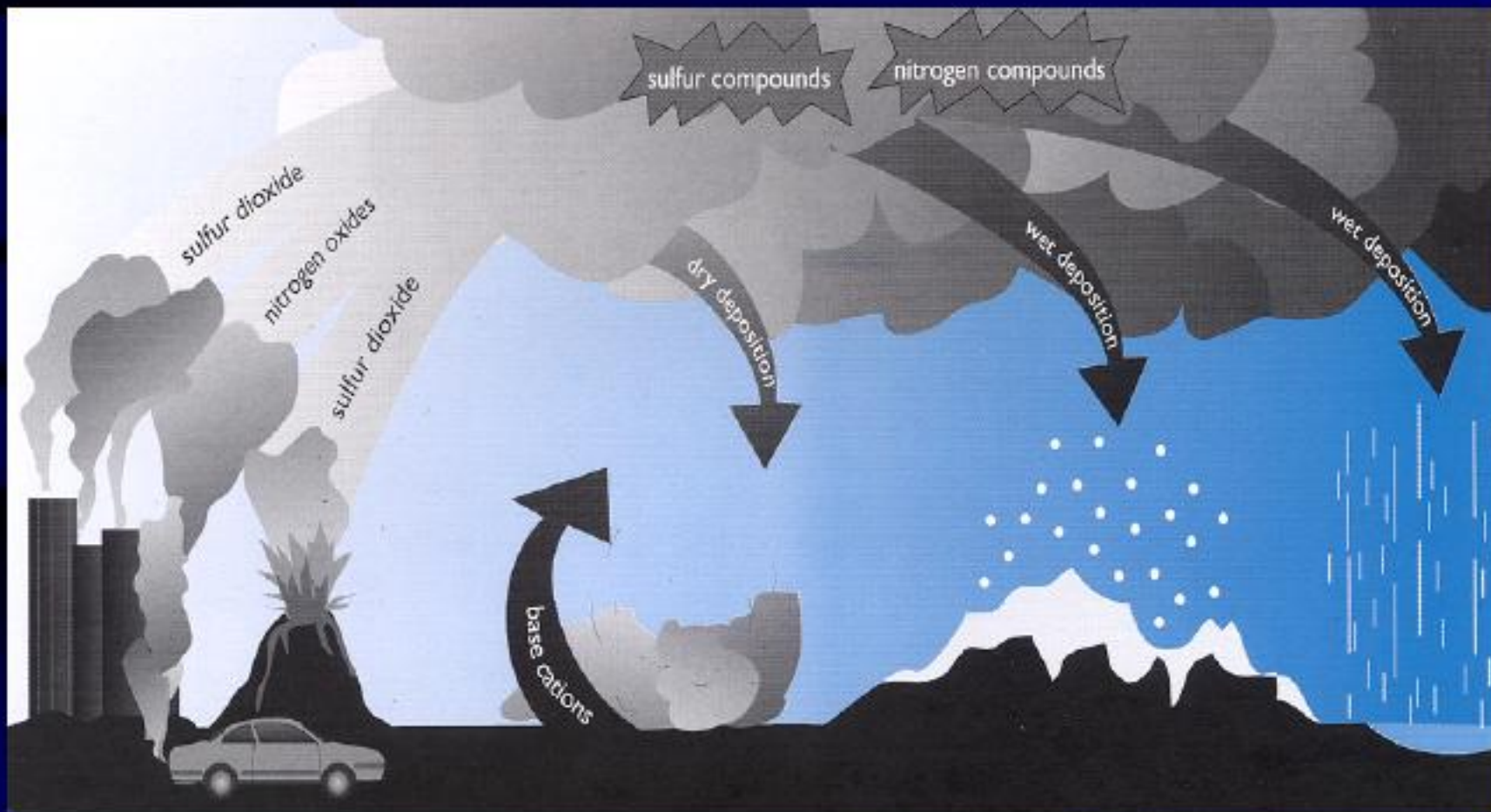
# KISELE KIŠE

Od sekundarnih polutanata formiraju se tzv. „**KISELE KIŠE**” – padavine koje su neuobičajeno kisele, tj. imaju **povećan nivo vodonikovih jona ( $H^+$ ), odnosno snižen pH.**

„**KISELE KIŠE**” nastaju tako što **oksidi nemetala** (najčešće ugljenika, sumpora i azota) **u interakciji sa vodom stvaraju kiseline.**

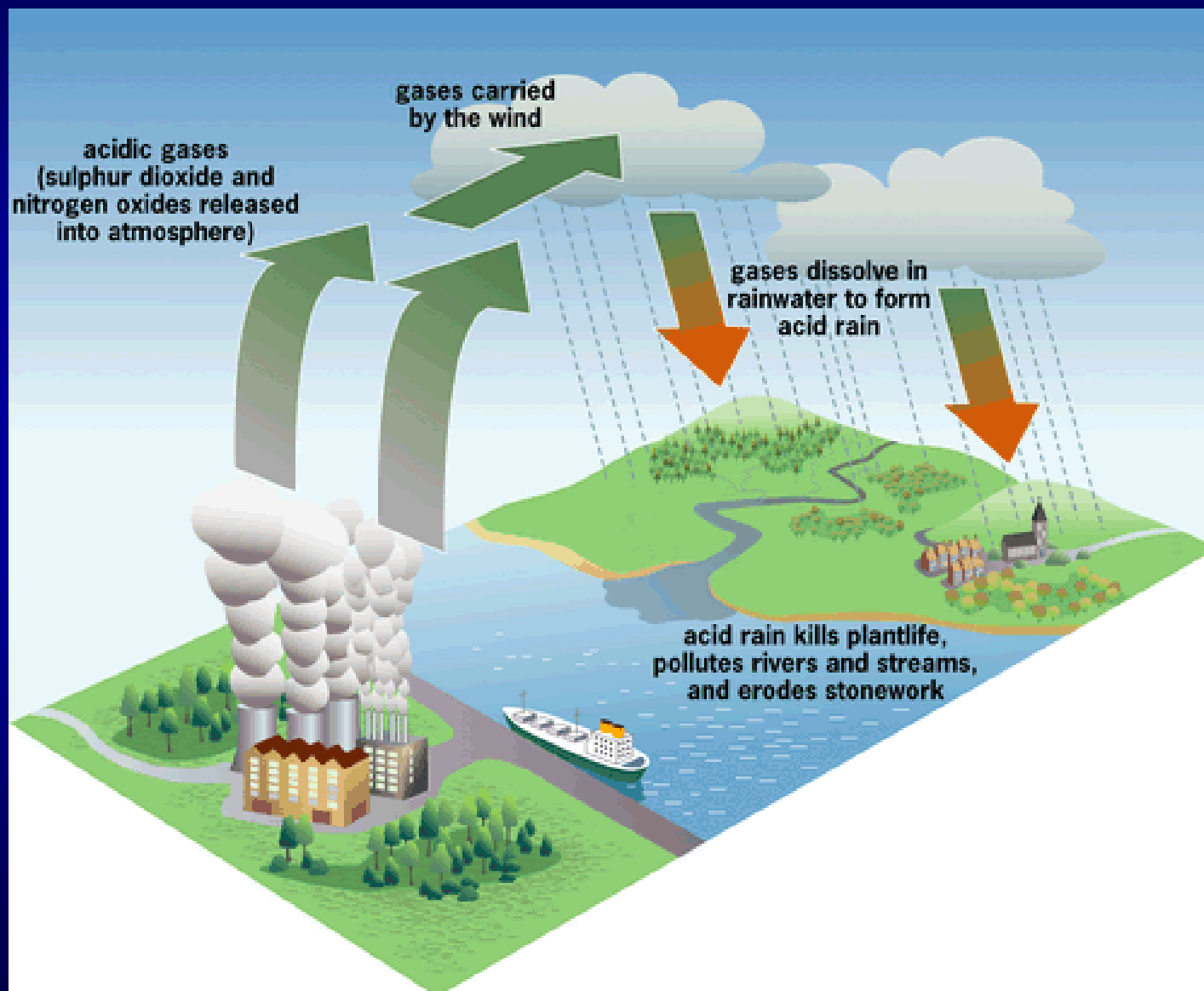


# Mehanizam nastanka kiselih kiša





# Mehanizam nastanka kiselih kiša



# Efekat kiselih kiša na biljni i žvotinjski svet



## Efekat kiselih kiša na spomenike kulture



# EFEKAT STAKLENE BAŠTE

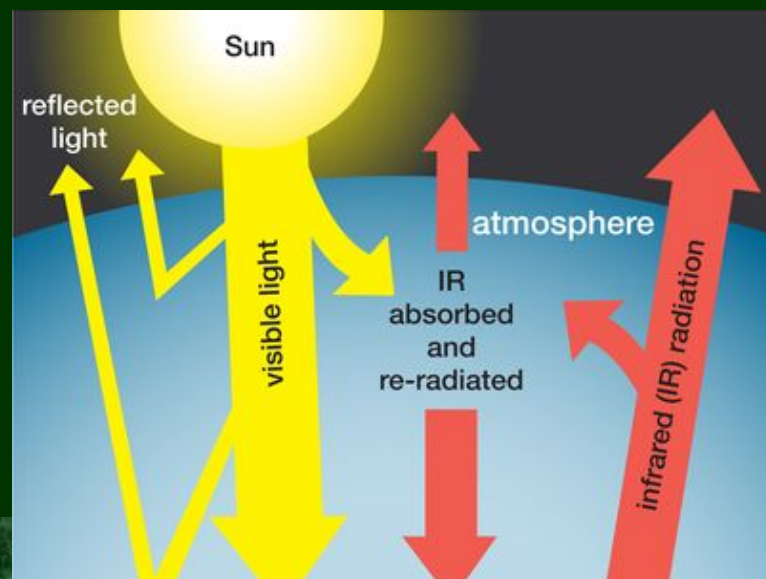
## („the greenhouse effect“)

je proces u kome toplotno zračenje sa površine Zemlje apsorbuju neki gasovi u atmosferi (vodena para,  $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{N}_2\text{O}$  i  $\text{O}_3$ ) i ponovo ga izrače u raznim pravcima.

Posledica: **temperatura Zemlje je veća od one koja bi se očekivala** u slučaju da postoji samo zagrevanje pod direktnim uticajem Sunčevog zračenja.

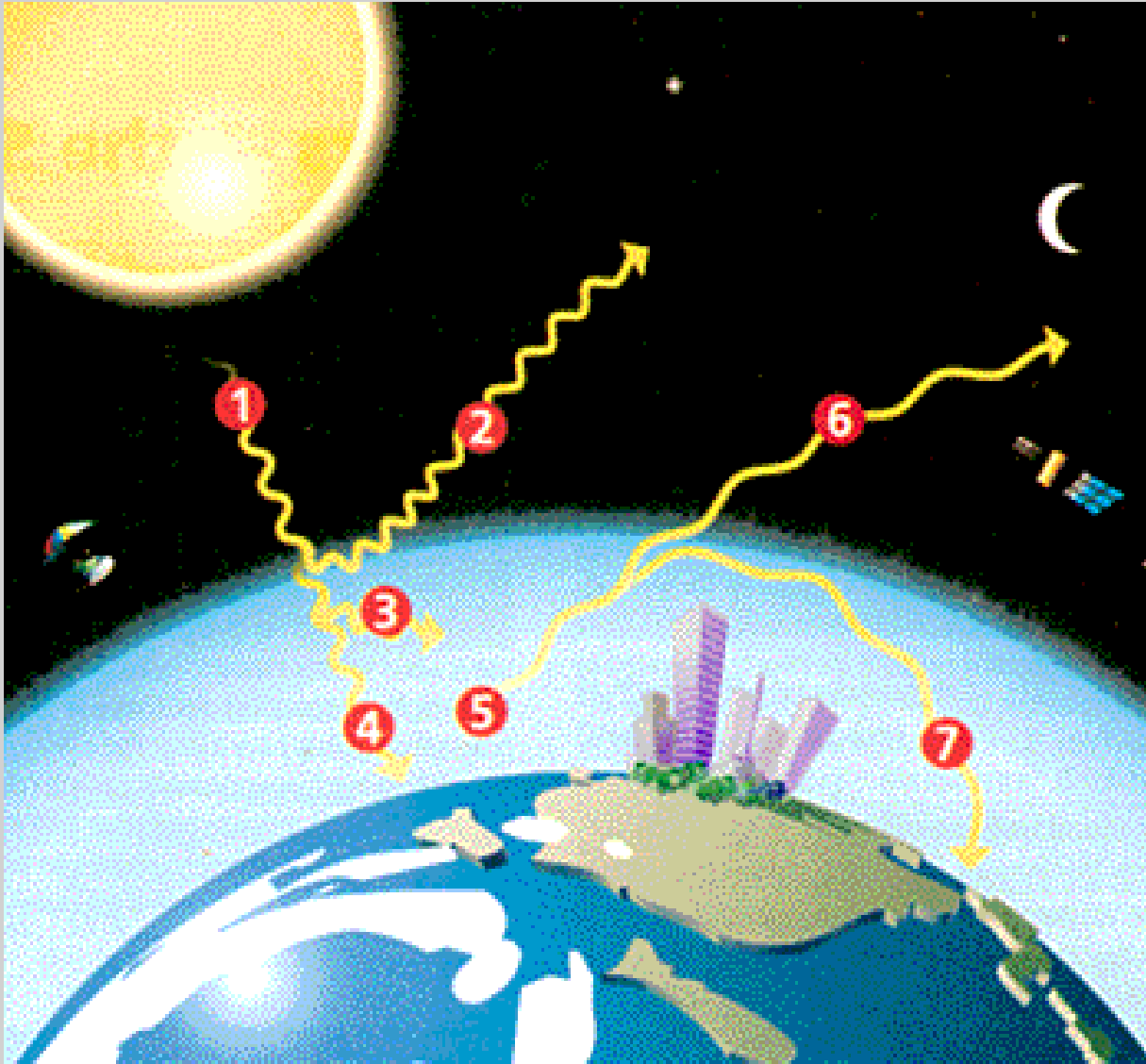
Proračunato je da bi bez efekta staklene bašte prosečna temperatura Zemlje bila **-18°C**, umesto sadašnjih +15 °C.

Međutim, nekontrolisana emisija gasova pojačava efekat staklene bašte i izaziva **globalno zagrevanje** planete Zemlje



# EFEKAT STAKLENE BAŠTE

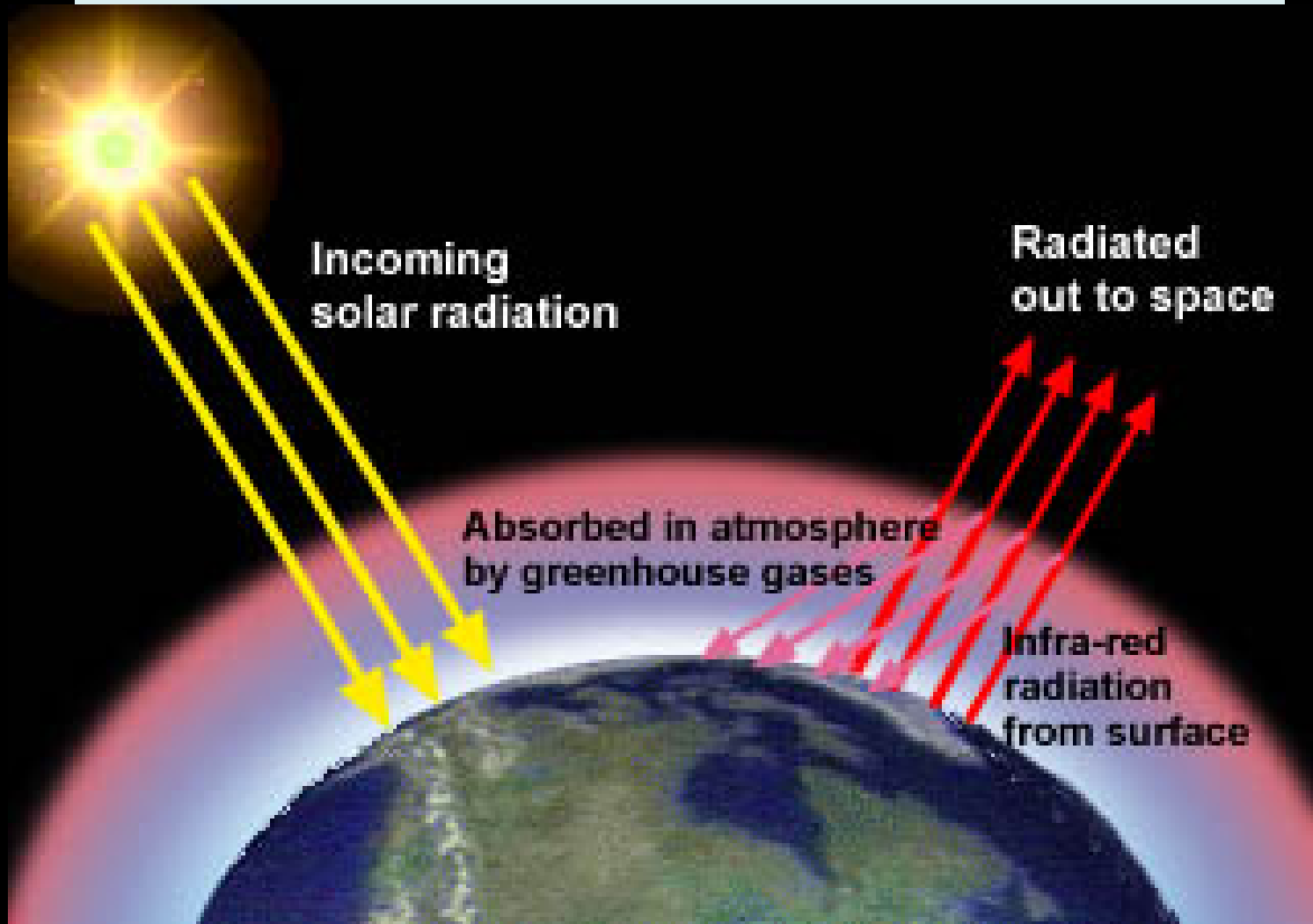
## („the greenhouse effect“)



1. E sa Sunca;
2. deo E odbija se od atmosfere i vraća u kosmos;
3. ozonski sloj apsorbuje deo UV zračenja;
4. E Sunca zagreva P Zemlje
5. Zemlja zrači u kosmos E većih talasnih dužina od E koja stiže sa Sunca
6. Kada bi se sva ova E izračila u kosmos prosečna T na Zemlji bila bi  $-18\text{ C}$  umesto sadašnjih  $+15\text{ C}$
7. Srećom, gasovi u atmosferi Zemlje onemogućavaju da se izrači sva toplotna E (tzv. "efekat staklene bašte")

# EFEKAT STAKLENE BAŠTE

Globalno zagrevanje nastaje usled ANTROPOGENIH UTICAJA koji povećavaju koncentraciju gasova sposobnih da izazovu efekat staklene bašte.





# Eutrofizacija



- Oslobođanje prevelikih količina soli azota i fosfora u vodene ekosisteme ima za posledicu prenamnožavanje algi i loš kvalitet vode (**eutrofizacija**).
- **Soli azota i fosfora** koriste se u **veštačkim đubrivima**, dok se **fosfati** nalaze u **deterdžentima za pranje rublja**.
- Preko vodotokova i otpadnih voda ove soli se slivaju u vodene basene.

Normalno jezero



Jezero sa eutrofizacijom



## Eutrophication

Rapid algae growth  
from enrichment with N or P



Decaying plants  
reduce dissolved oxygen

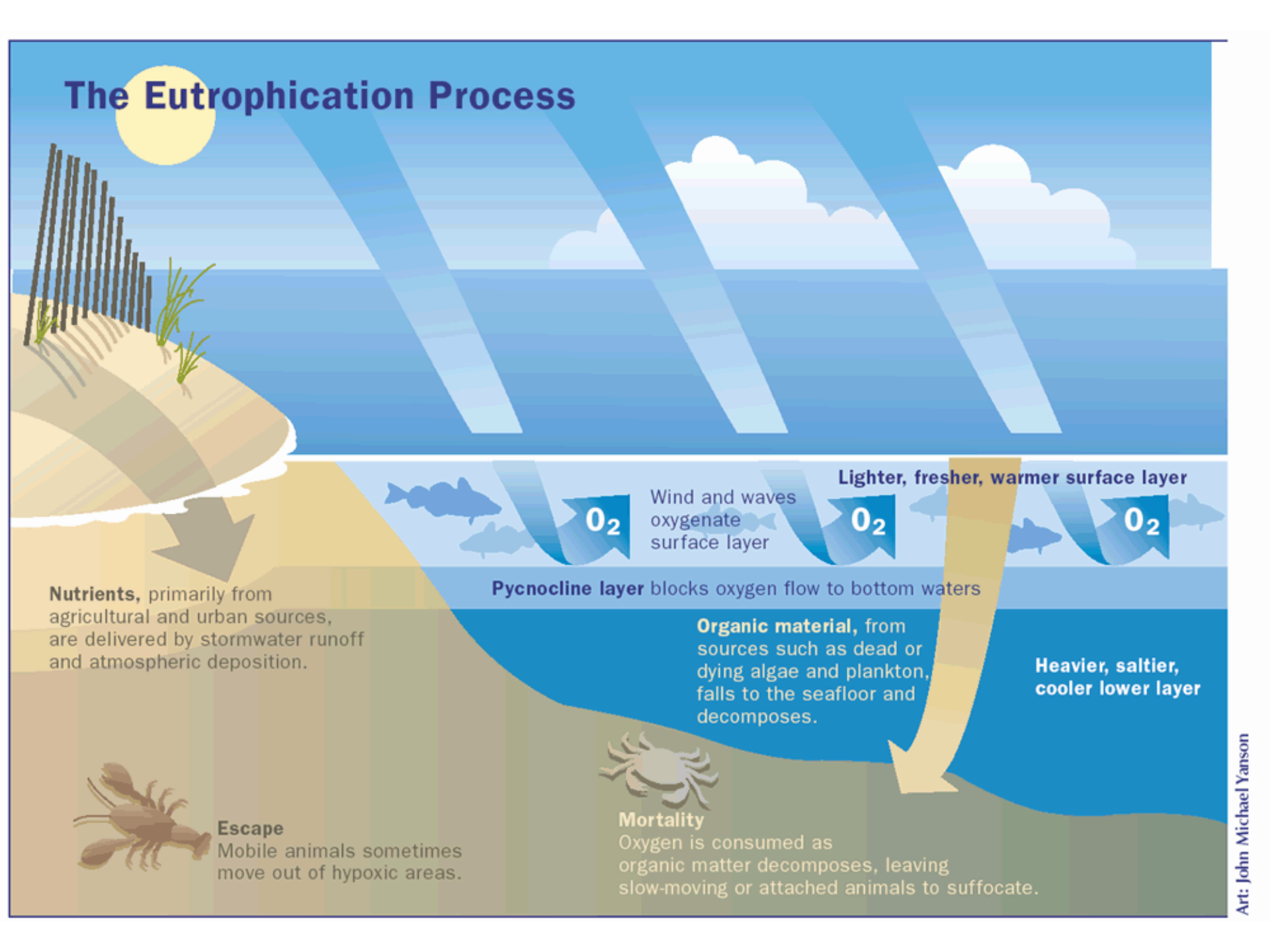


Fish and other aquatic life die

**Prenamnožavanje algi** dovodi do:

- **pada koncentracije kiseonika** rastvorenog u vodi i
- **velikog osiromašjenja u brojnosti živog sveta** naročito na većim dubinama.

# The Eutrophication Process



**Nutrients**, primarily from agricultural and urban sources, are delivered by stormwater runoff and atmospheric deposition.



## Escape

Mobile animals sometimes move out of hypoxic areas.

**Pycnocline layer** blocks oxygen flow to bottom waters

Wind and waves oxygenate surface layer

O<sub>2</sub>

Lighter, fresher, warmer surface layer

O<sub>2</sub>

O<sub>2</sub>

**Organic material**, from sources such as dead or dying algae and plankton, falls to the seafloor and decomposes.

Heavier, saltier, cooler lower layer



## Mortality

Oxygen is consumed as organic matter decomposes, leaving slow-moving or attached animals to suffocate.





Deo jezera pregrađen  
veštačkom branom  
ima zelenu boju od  
prenamnožavanja  
plavozelenih algi  
koje rastu u vodi sa  
velikom količinom  
fosfata



Pre eutrofizacije  
(1975 god.)

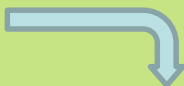


Posle eutrofizacije  
(1994 god.)  
izazvane  
eksperimentalnim  
dodavanjem fosfata  
tokom više od 20 god.

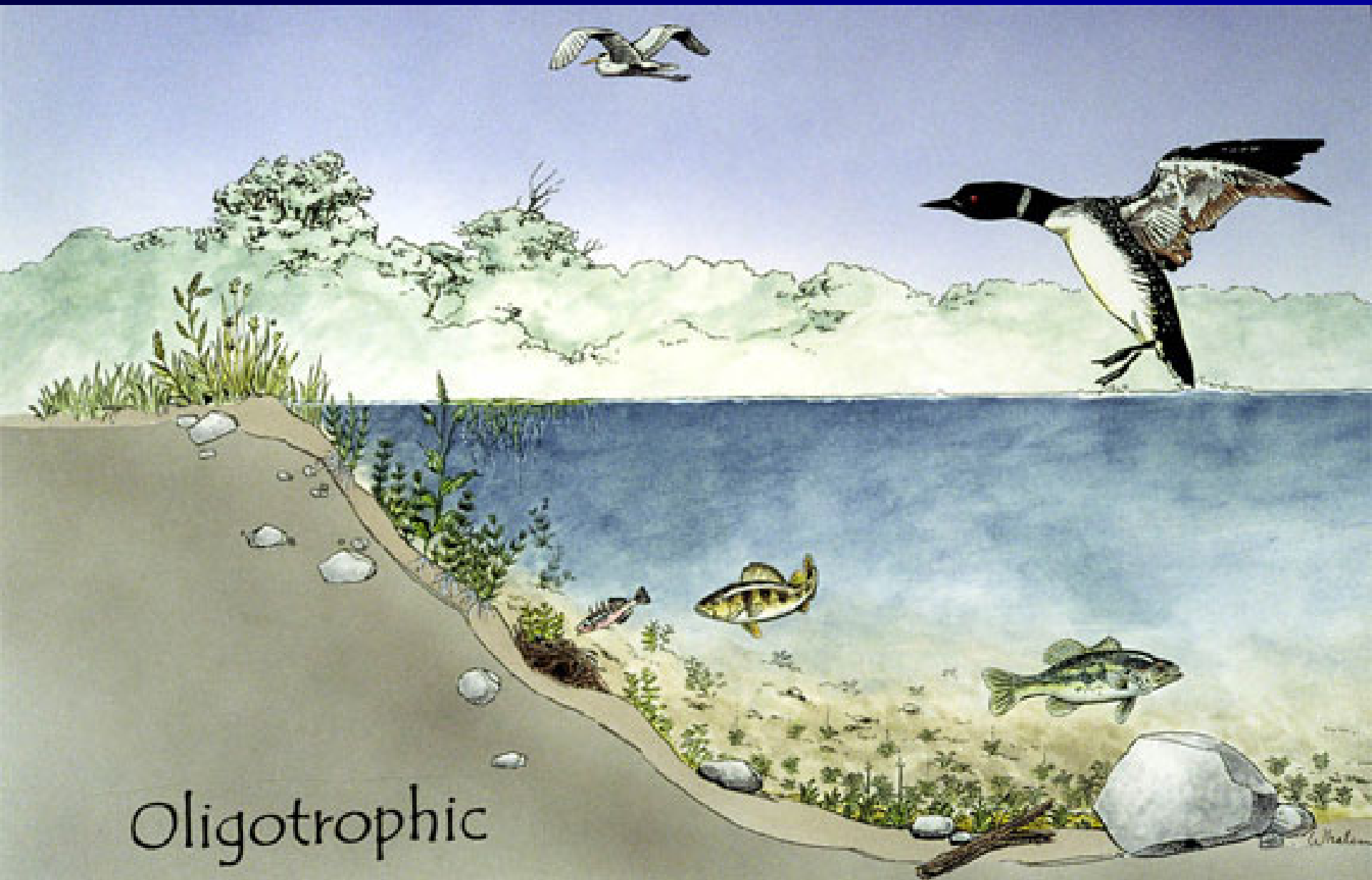


U odnosu na **količinu hranljivih materija u vodi**, pre svega **solí azota i fosfora**, razlikujemo tri tipa jezera:

- *oligotrofna*,
- *mezotrofna* i
- *eutrofna*



# Oligotrofno jezero



# Mezotrofno jezero



# Eutrofno jezero



Eutrophic

This is the end of ecology