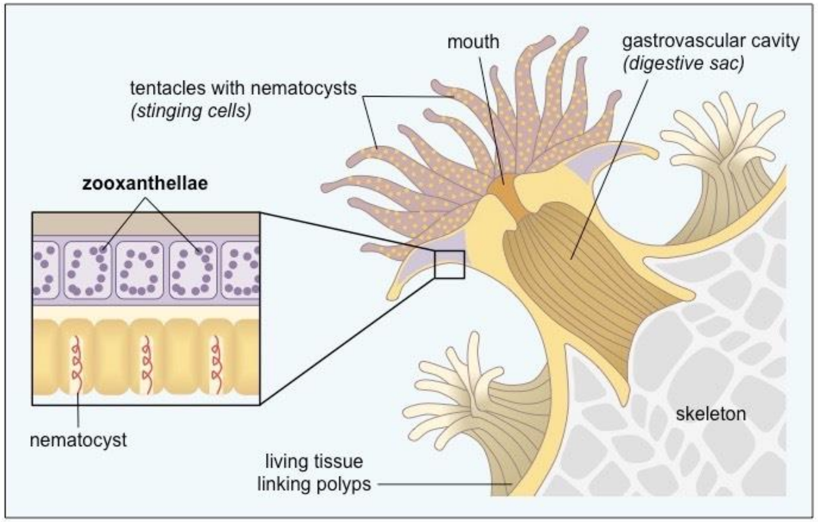
Ecology Option C

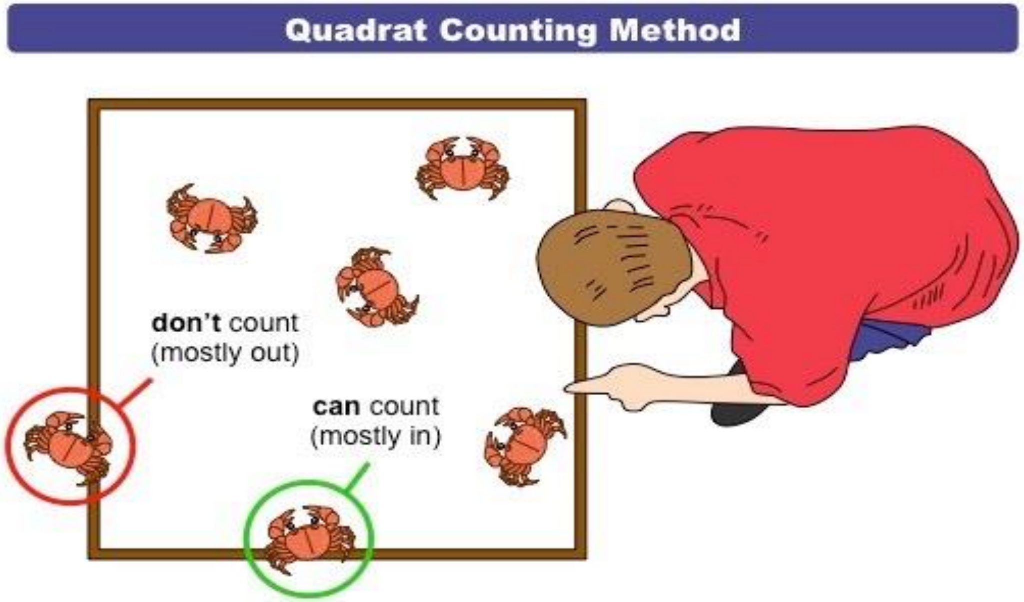
C1 Communities

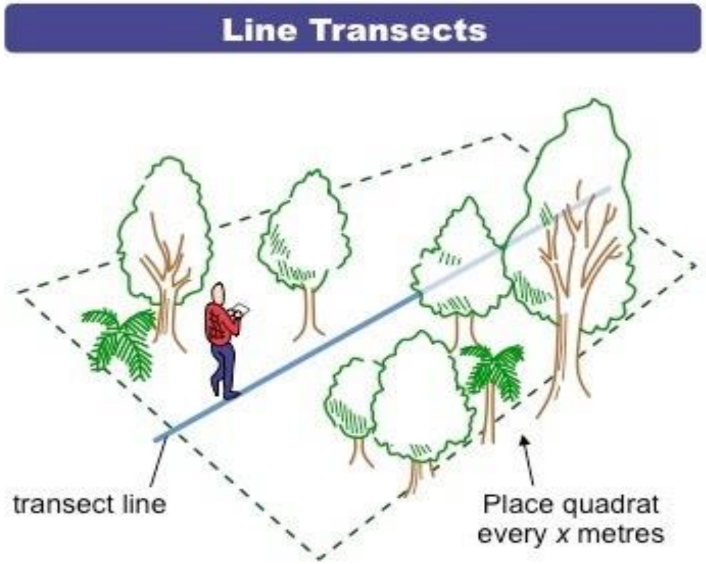
Coral and Zooxanthellae

- Mutualism: Algae lives inside coral's endodermis (for protection) and algae provides nutrition for corals (oxygen and glucose from photosynthesis)
- When environmental changes kill Zooxanthellae (temp, ocean acidification, sedimentation (blocks light), coral bleaching happens and corals will starve to death



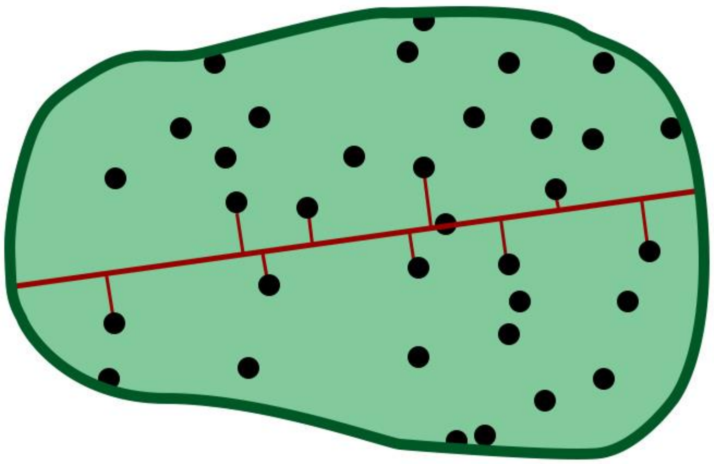
Measuring Species Distribution



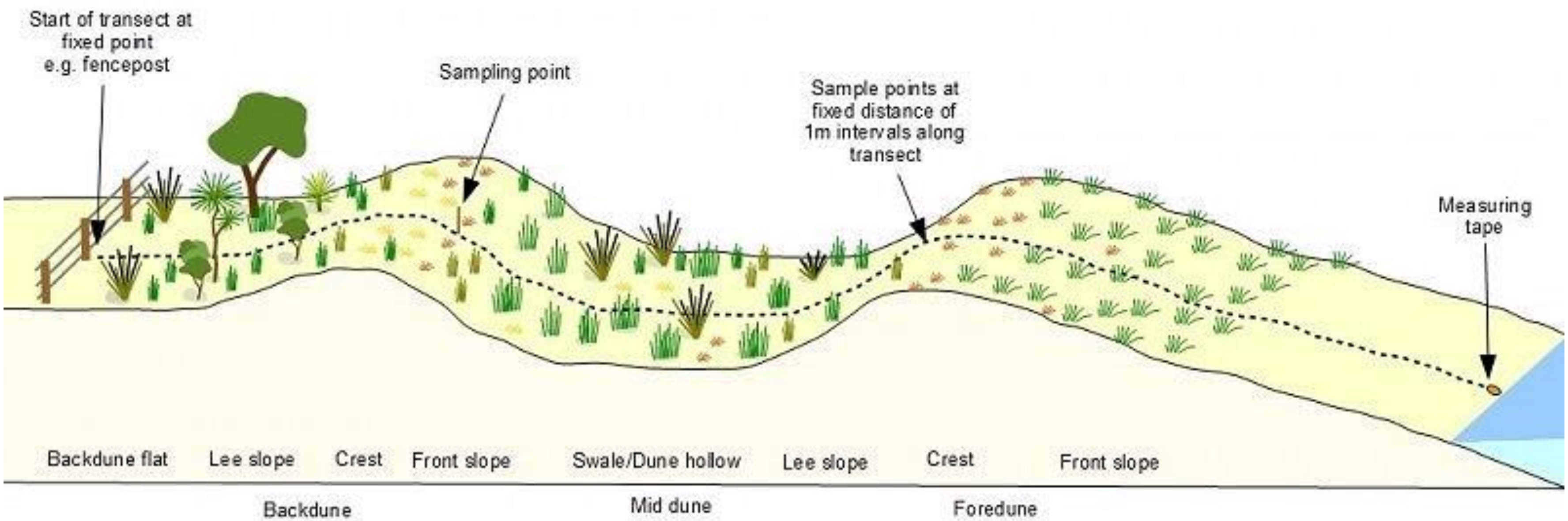


Transects

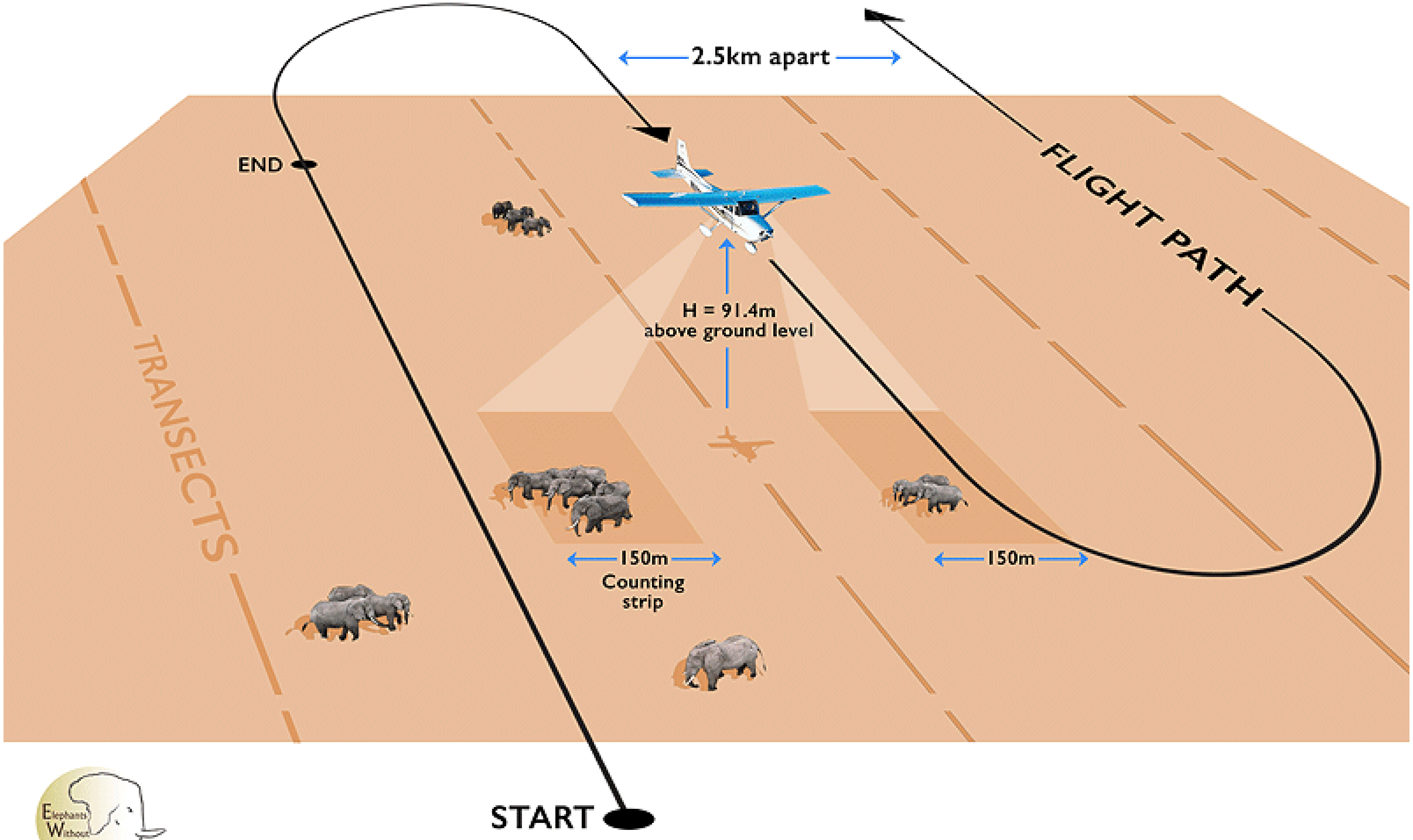
- Straight line throughout ecosystem where you record species seen only within that line
- Used for assessing:
  - Population density
  - Species distribution in correlation with any abiotic factor that varies across a measurable distance
    - Ex: elevation, elemental exposure, temperature, light levels, pH, humidity



- Samples are taken along a line to see what changes there are
- Usually follows an environmental gradient

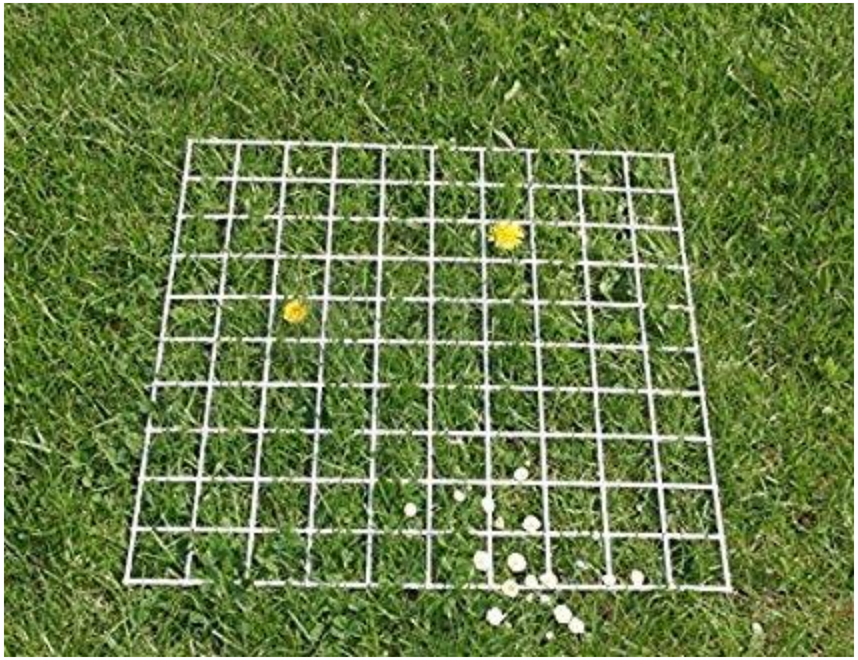


Elephant Transect Activity



Quadrats

- Quadrats – rectangular frames that are used to calculate population density in an area
  - Count number of organisms only in rectangle
  - Can place at regular intervals along a transect to look at species distribution patterns (zones of tolerance)



How to Use Quadrat:
https://www.youtube.com/watch?v=KuG-UjpQzm0

- Can calculate percent cover or population size
- Only useful for non-motile or slow moving organisms
  - Ex: plants, snails, etc.

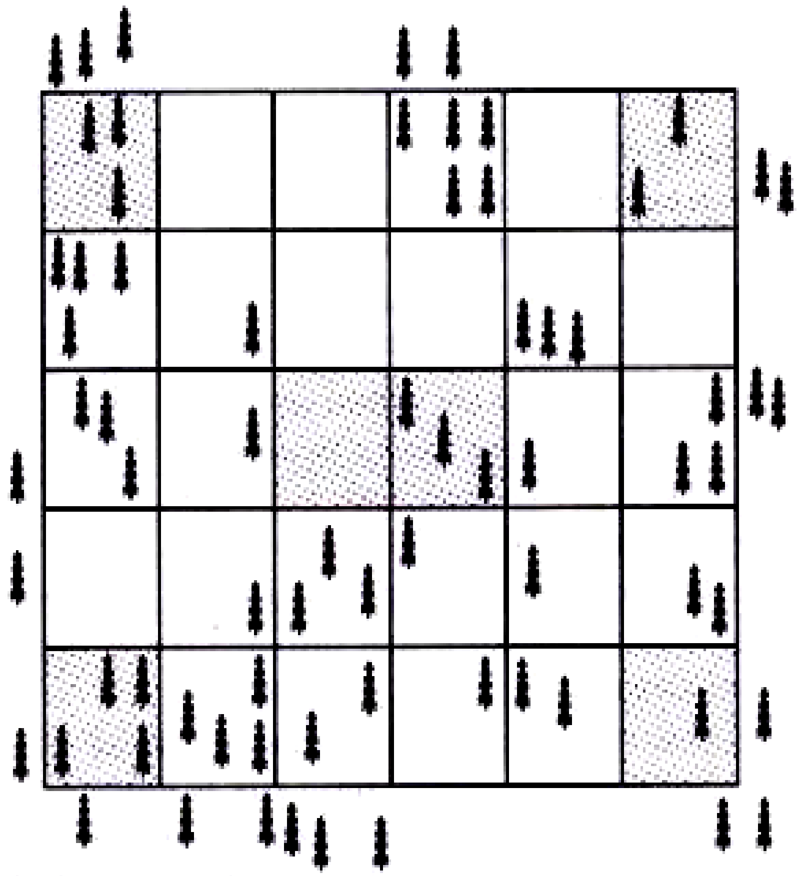
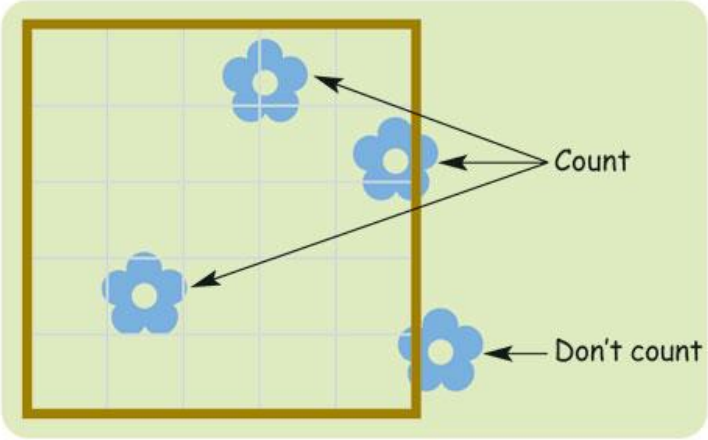
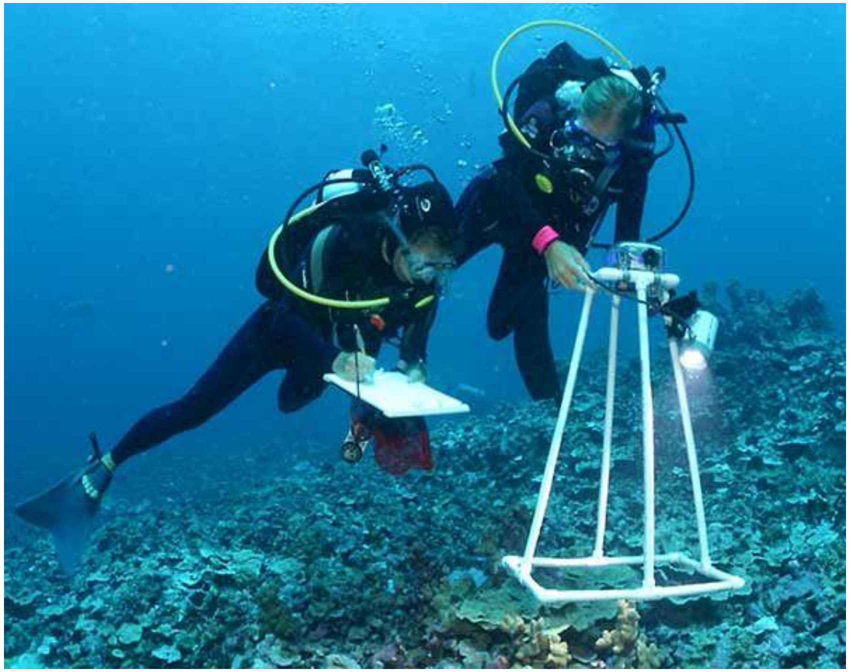


Fig. 6.4. Quadrat sampling method for population estimation.



Quadrats

- Example: Coral Reefs

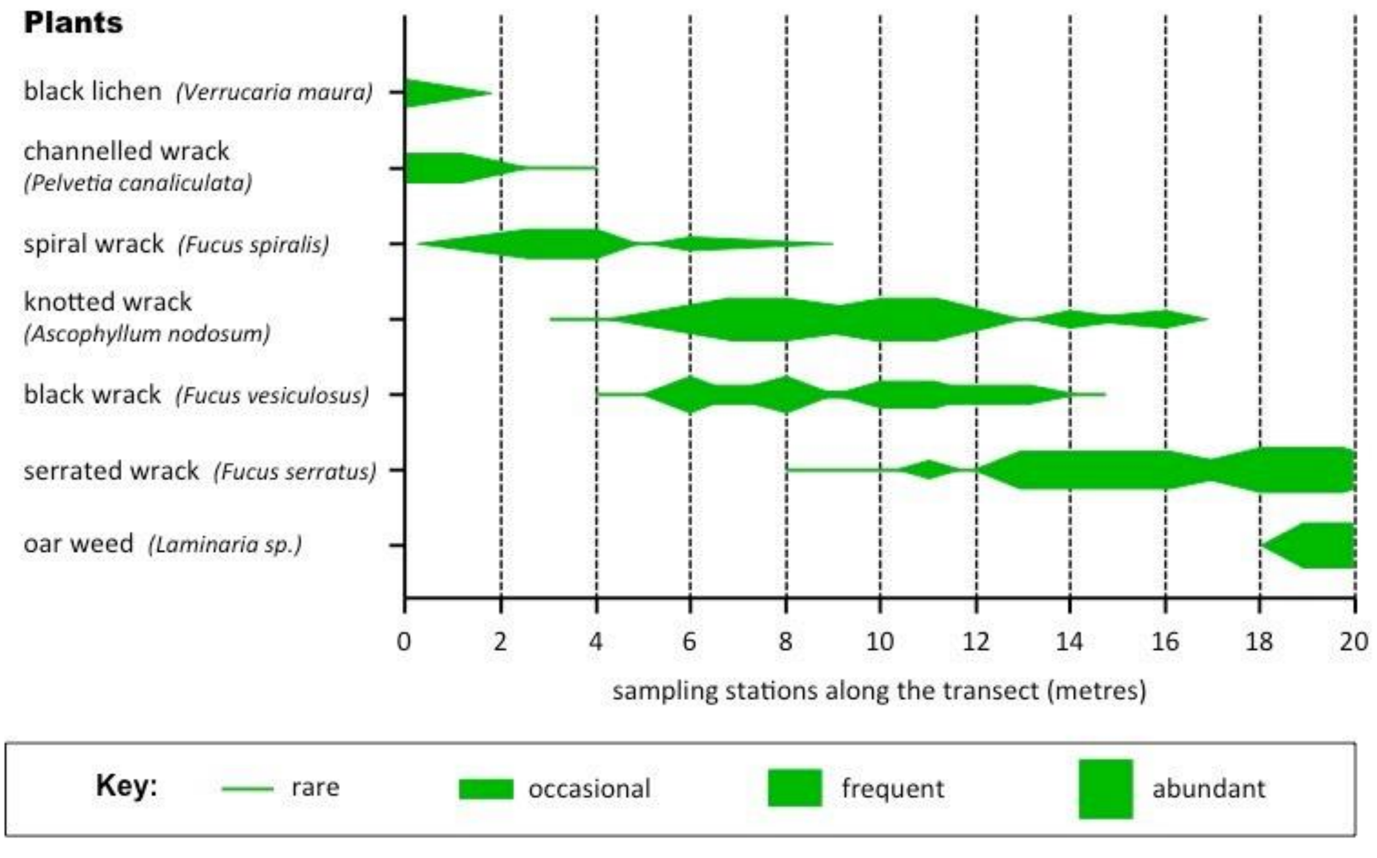


Video: Laser Quadrat Mapping

https://www.youtube.com/watch?v=pY12SHRkBDc

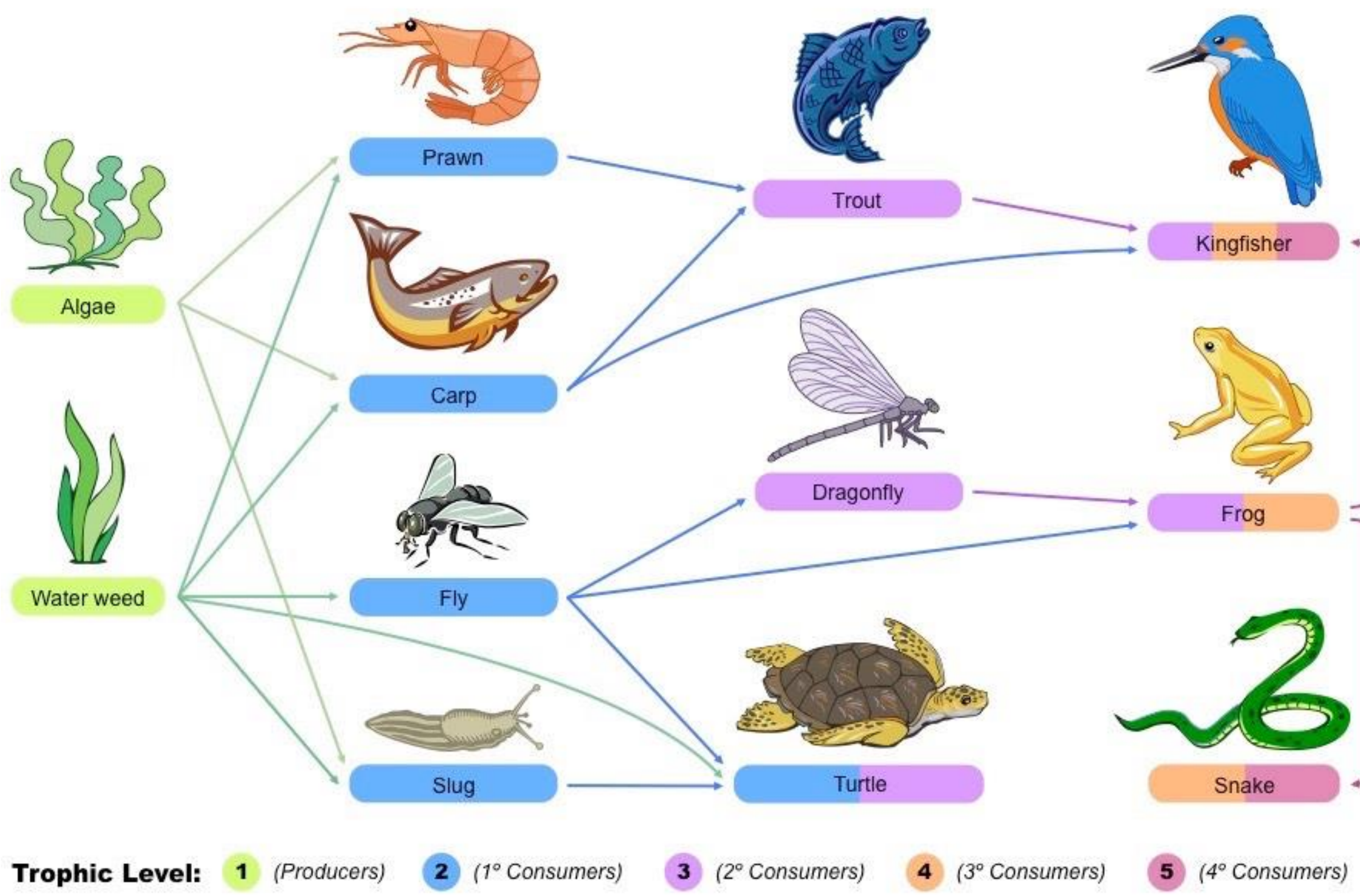
Kite Graph

- Used to show changes in species distribution along a transect
  - Thickness of bands indicates abundance of organism in that area along the transect



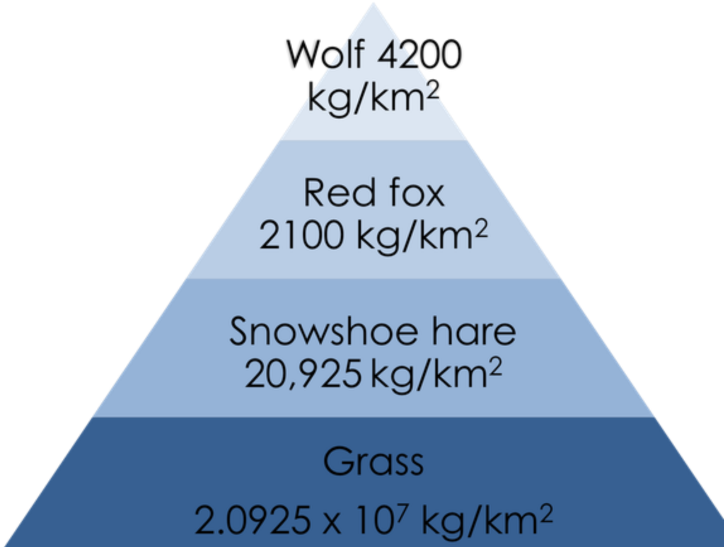
C2 Ecosystems

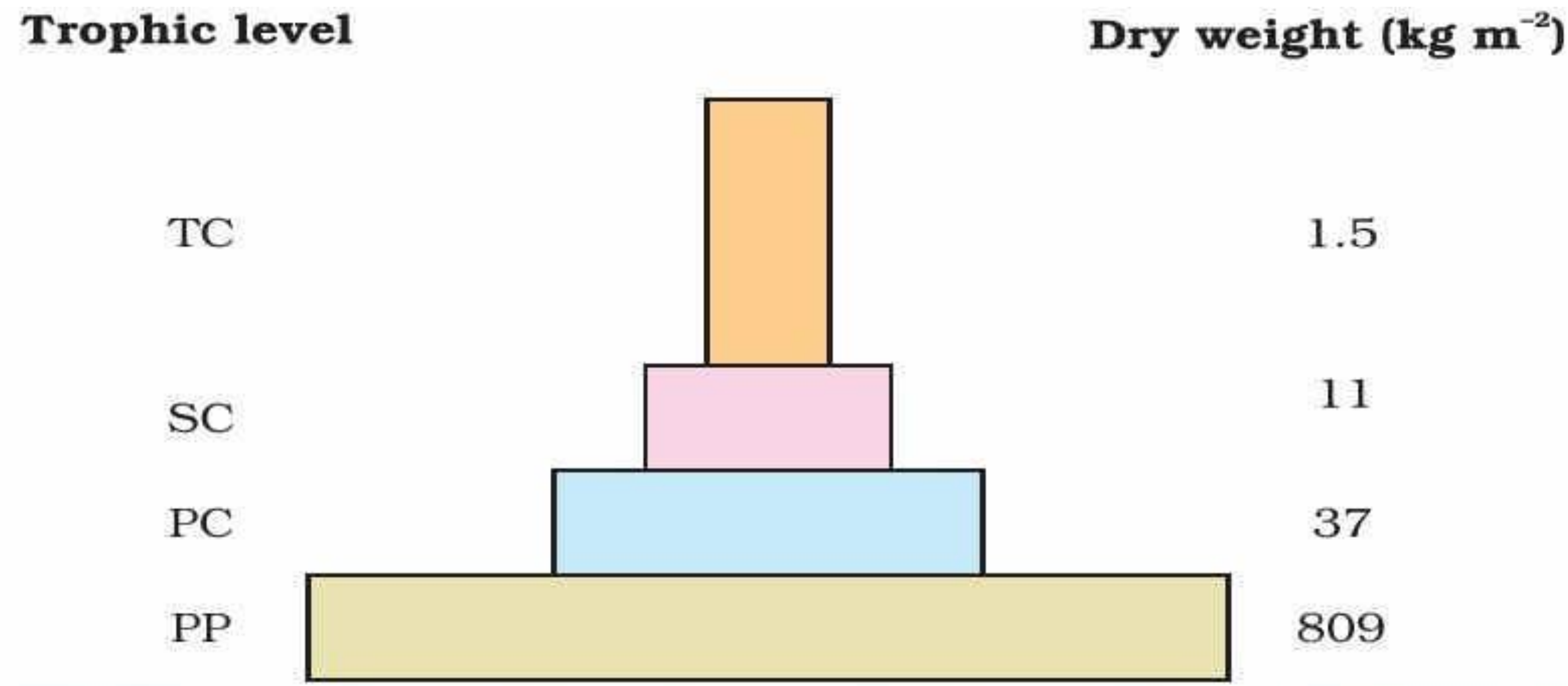
What can you predict might happen to algae populations if trout were overharvested to extinction?



Biomass

- The total **dry weight** of an organism from organic matter (protein, carbs, lipids, nuc. acids
  - Essentially weight minus water, other minerals found in organism
- Energy converted into biomass depends on how much is lost to:
  - ***inedible materials*** – such as bones, teeth and hair
  - ***excretion*** of undigested and unabsorbed materials
  - ***heat*** from cellular respiration (higher respiration rate results in more heat lost)
  - ***metabolism*** (fuel activities)





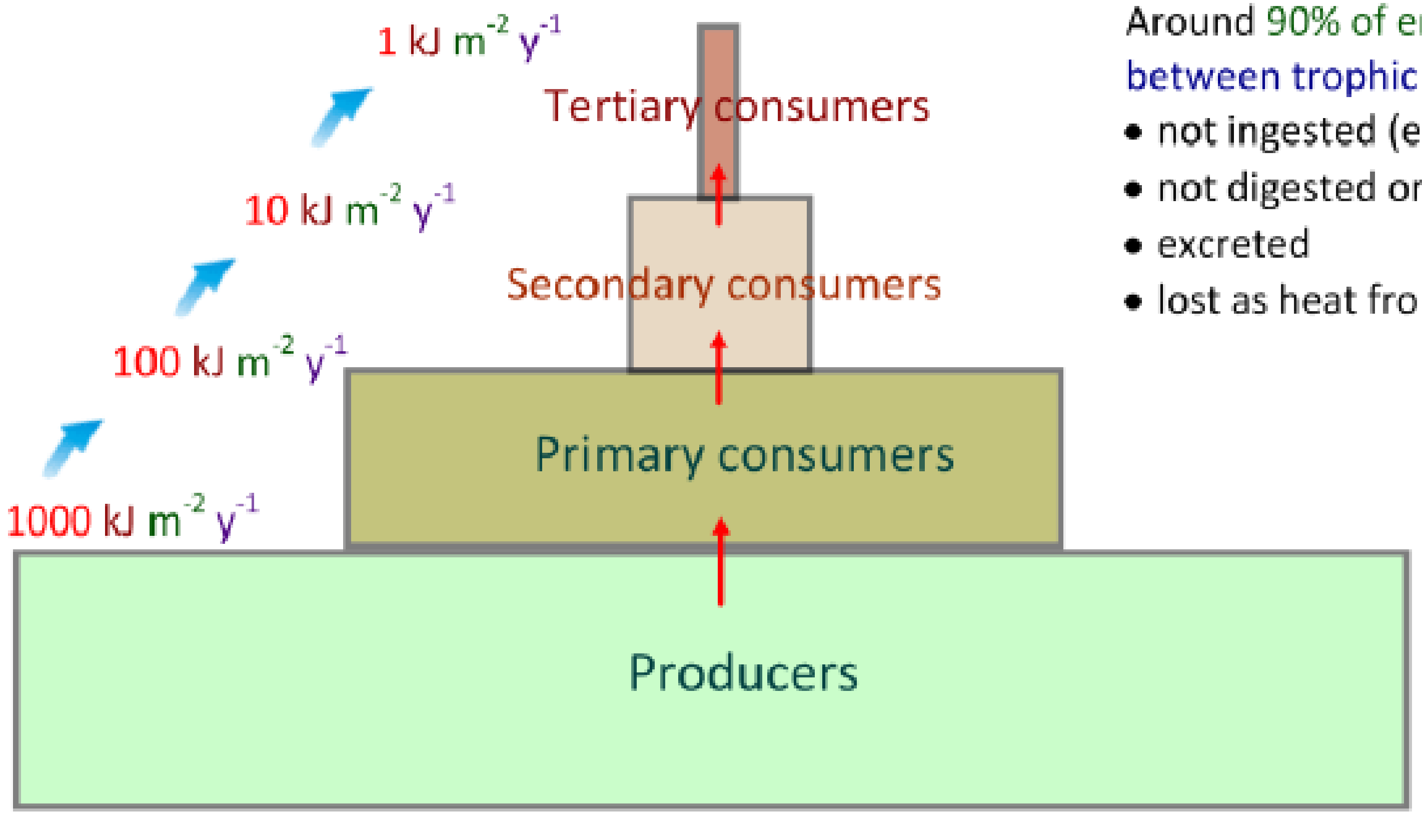
Pyramid of biomass shows a sharp decrease in biomass at higher trophic levels

Pyramids of energy show the flow of energy between trophic levels

(From 5.1)

Measured in units of energy per unit area per unit time: $kJ\ m^{-2}\ y^{-1}$

Transfer of energy is never 100% efficient.

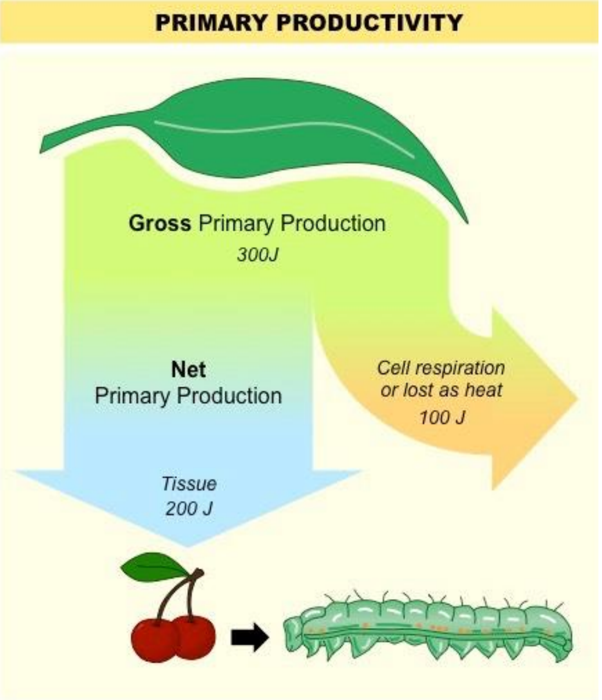


Around 90% of energy is lost between trophic levels:

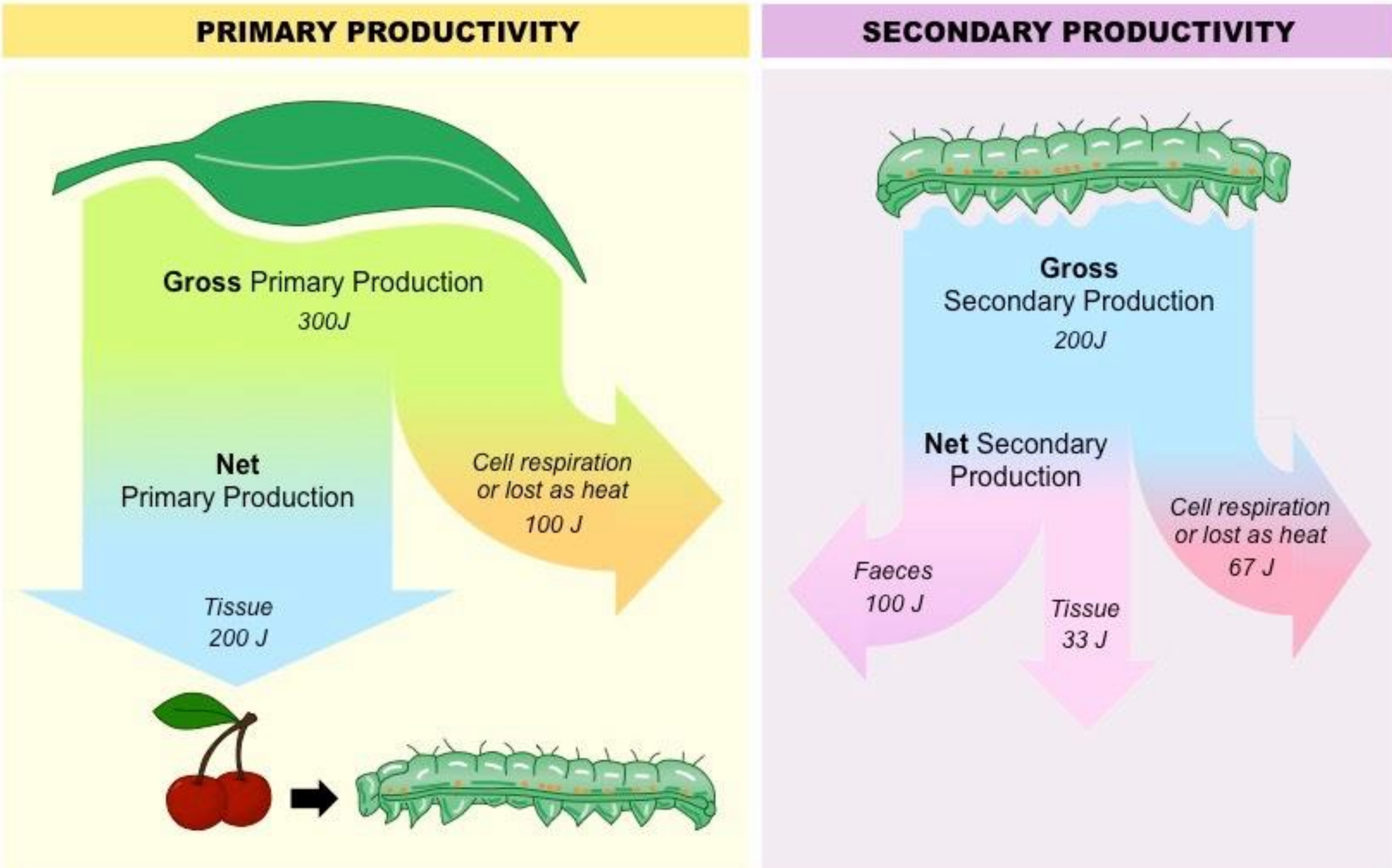
- not ingested (eaten)
- not digested or assimilated
- excreted
- lost as heat from respiration

GPP vs NPP

- Primary production = production of chemical energy that gets trapped in organic matter by primary producers
  - **Gross production (GPP)-** is the total amount of energy trapped in organic matter produced by plants in a certain amount of time
  - **Net production (NPP)** – amount of energy that is not lost to respiration (NPP = GPP – respiration)



Energy in Producers | Energy in Consumers



Practice Question

The total solar energy received by a grassland is 5×10^5 kJ m^{-2} $year^{-1}$.
The gross production is 4.35×10^3 kJ m^{-2} $year^{-1}$.
The net production of the grassland is 1.95×10^3 kJ m^{-2} $year^{-1}$.

A: *Calculate the percentage of solar energy converted into chemical energy by photosynthesis.*

B: *Calculate the energy lost by plant respiration.*

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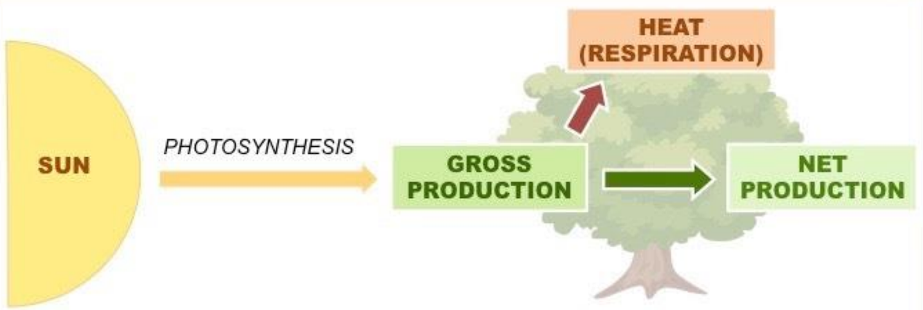
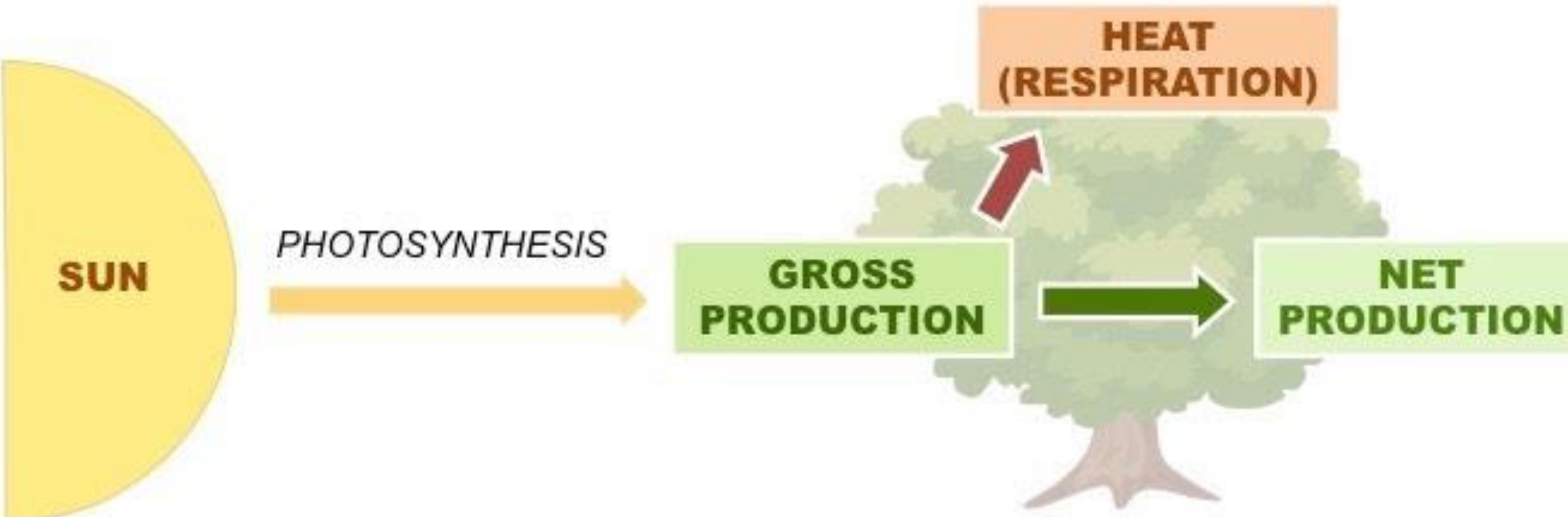


A. % Conversion = (Gross Production ÷ Total Solar Energy) × 100
% Conversion = $(4.35 \times 10^3) \div (5 \times 10^5) \times 100$ = **0.87%**

B. R = GP – NP
Respiration = $(4.35 \times 10^3) - (1.95 \times 10^3)$ = **2400** kJ m^{-2} y^{-1}

Look at bioknowledgy ppt



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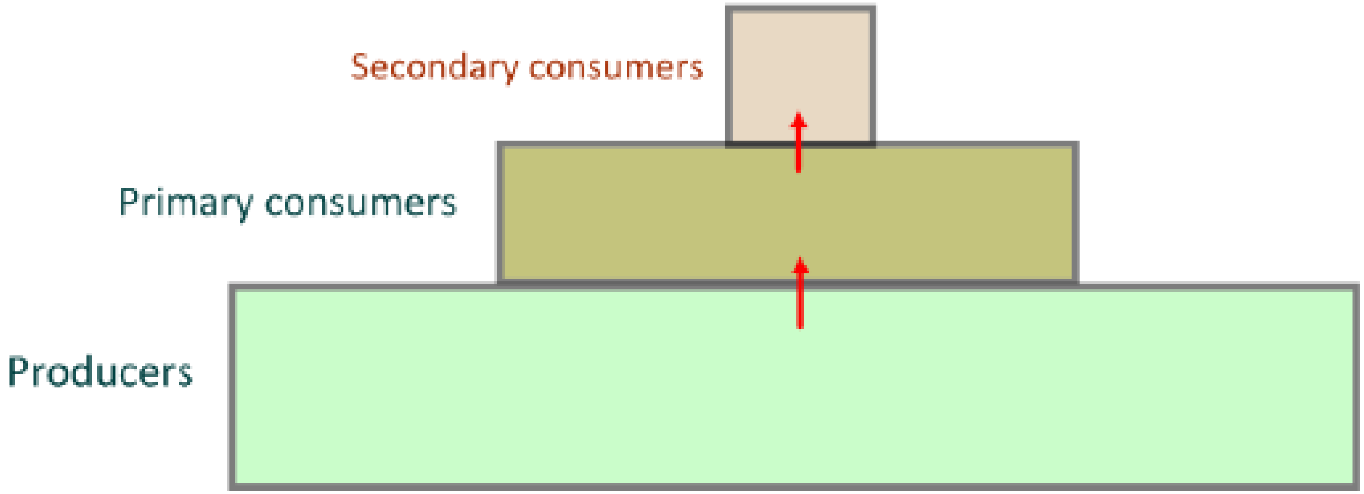
Produce a pyramid of energy using this information:

The total solar energy received by a grassland is 5×10^5 kJ m^{-2} y^{-1}.

The net production of the grassland is 5×10^2 kJ m^{-2} y^{-1} and its gross production is 6×10^2 kJ m^{-2} y^{-1}.

The total energy passed on to primary consumers is 60 kJ m^{-2} y^{-1}.

Only 10 % of this energy is passed on to the secondary consumers.



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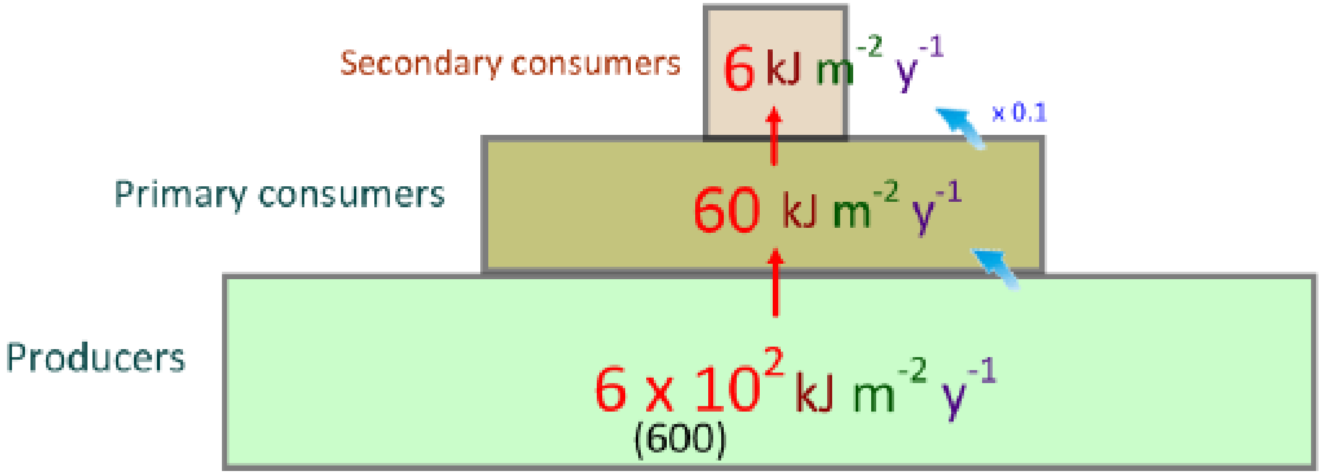

What is the efficiency of the conversion of solar energy by photosynthesis?

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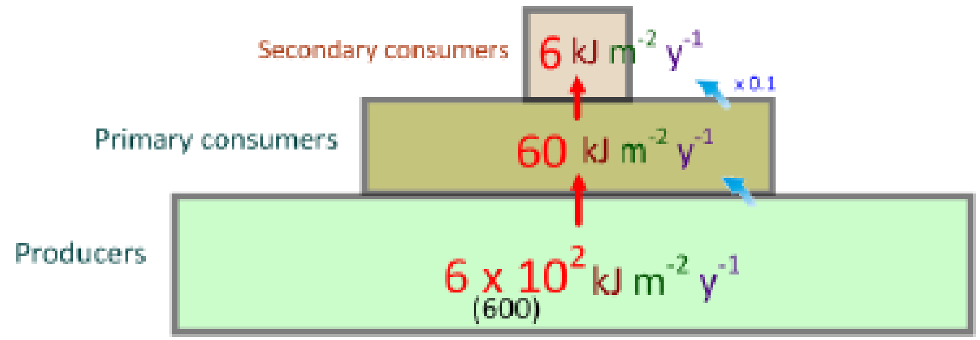

$$\text{Efficiency} = \frac{\text{Gross production}}{\text{Energy in}} \times 100$$

$$\text{Efficiency} = \frac{6 \times 10^2 \text{ kJ m}^{-2} \text{ y}^{-1}}{5 \times 10^5 \text{ kJ m}^{-2} \text{ y}^{-1}} \times 100 = 0.12\%$$

Calculate the energy lost by plant respiration.

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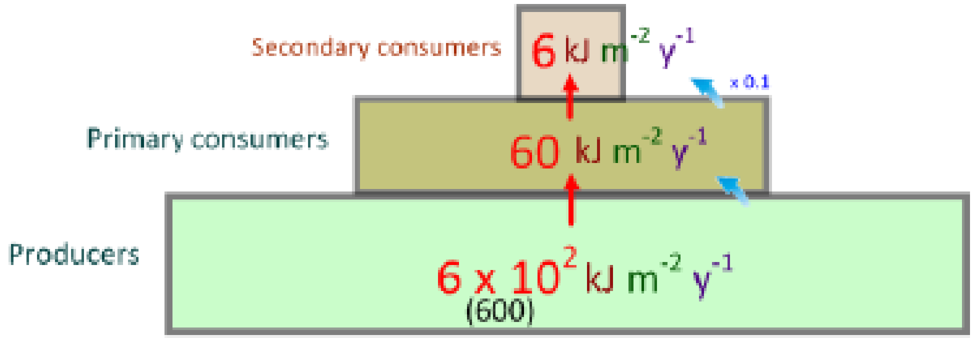

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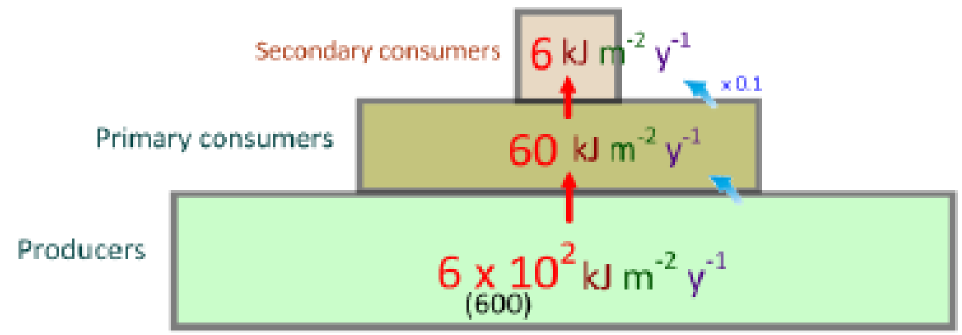


$$NP = GP - R \quad \therefore \quad R = GP - NP$$

$$= 6 \times 10^2 \text{ kJ m}^{-2} \text{ y}^{-1} - 5 \times 10^2 \text{ kJ m}^{-2} \text{ y}^{-1}$$

$$= 1 \times 10^2 \text{ kJ m}^{-2} \text{ y}^{-1}$$

(100 kJ m^{-2} y^{-1})

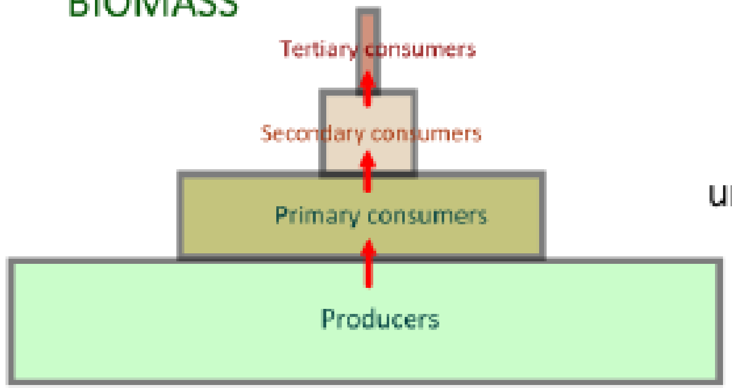
Why are biomass and numbers small at higher trophic levels?

Around 90% of energy is lost between trophic levels:

- not ingested (eaten)
- not digested or assimilated
- excreted
- lost as heat from respiration

This energy is not available for conversion into biomass.

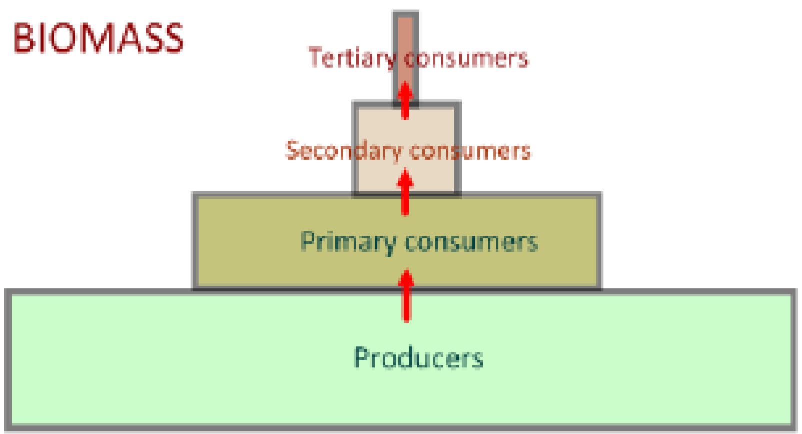
BIOMASS



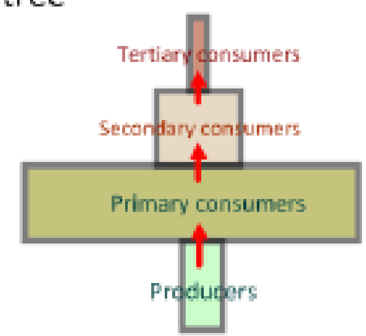
Carbon, in the form of CO_2, is also lost through respiration and unavailable for conversion to organic matter.

As so much energy is lost between trophic levels, less food is available to organisms further along the food chain - consumers need to eat many of their prey in order to survive.
This gives lower numbers in higher trophic levels.

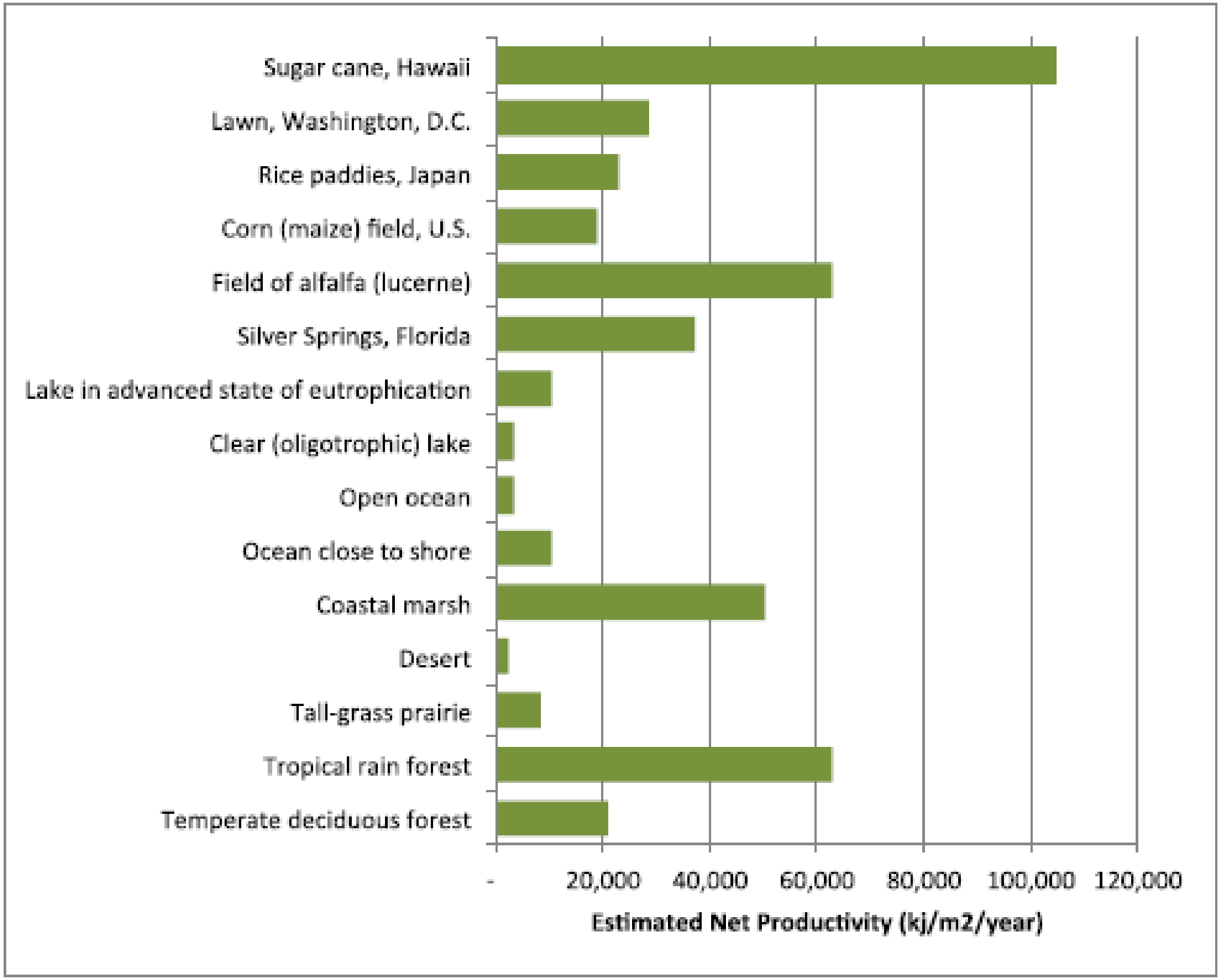
BIOMASS



This pyramid of numbers represents a community supported by one large producer, such as a tree



Net productivity of different ecosystems varies greatly



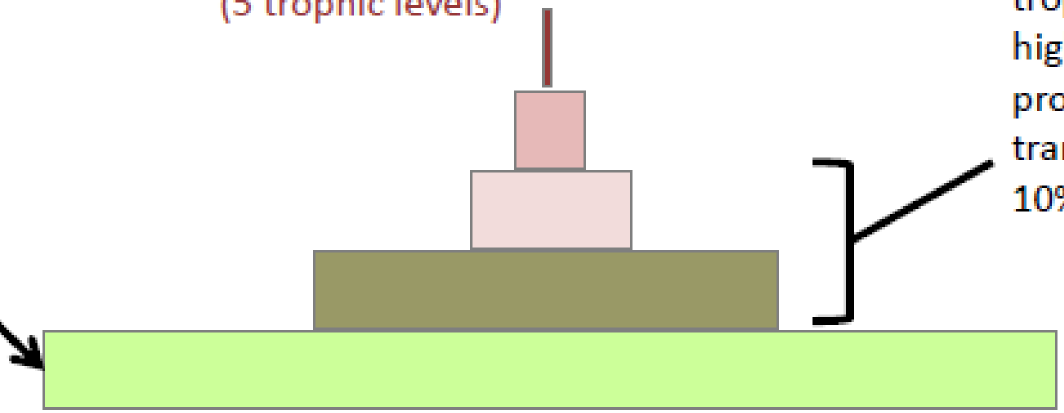
To understand why analyse the energy pyramids of the different ecosystems.

Reasons for high net productivity of an ecosystem

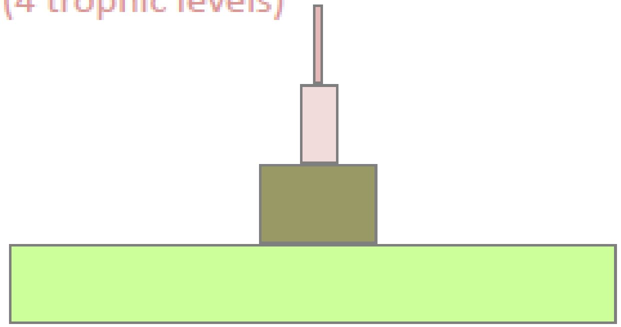
1. **High primary productivity** (by producers) means more energy is available to the ecosystem.

2. The higher the **efficiency of energy transfer** between trophic levels the higher the net productivity. Energy transfer is typically 10%.

(5 trophic levels)



(4 trophic levels)



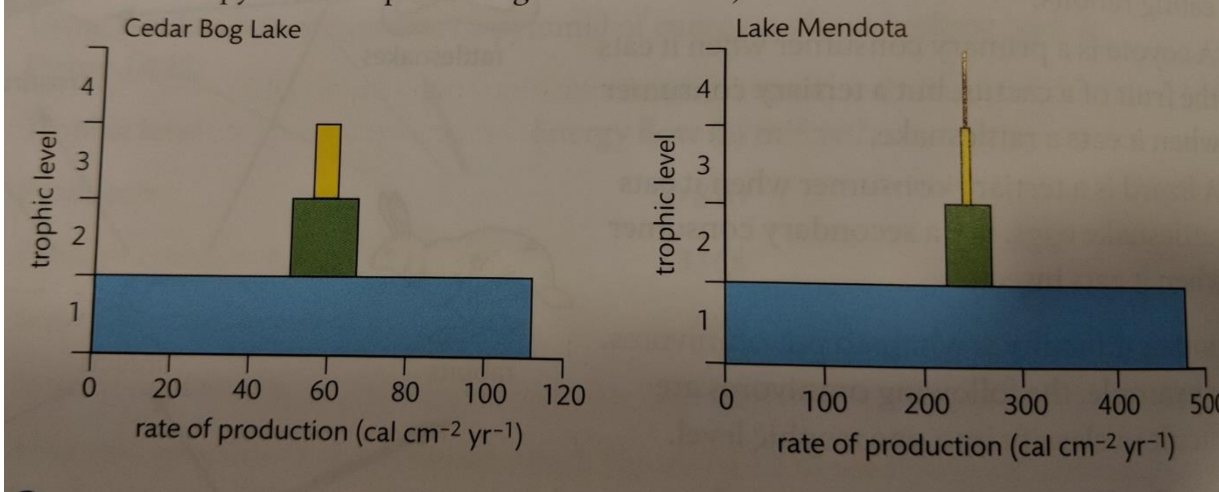
3. Higher the primary productivity and greater the effeciency of energy transfer mean that more energy is available at high trophic levels. This can support longer the food chains, hence and **more trophic levels** increasing net productivity. Ecosystems rarely have more than 4 or 5 trophic levels.

What percentage of energy is passed on to herbivores in

- -Cedar Bog Lake
- -Lake Mendota

Trophic level	Cedar Bog		Lake Mendota	
	Productivity (cal cm^{-2} yr^{-1})	Efficiency (%)	Productivity (cal cm^{-2} yr^{-1})	Efficiency (%)
Solar radiation	119.000		119.000	
Plants	111	0.1	480	0.4
Herbivores	14.8	13.3	41.6	8.7
Carnivores	3.1	22.3	2.3	5.5
Higher carnivores			0.3	13.0

Here are two pyramids representing what we have just seen in Table 14.4.



In commercial (animal) food production, farmers measure the **food conversion ratio (FCR)**. It is a measure of an animal's efficiency in converting feed mass into the desired output. For dairy cows, for example, the output is milk, whereas animals raised for meat, for example, pigs the output is the mass gained by the animal.

It is calculated by:

$$FCR = \frac{\text{mass of the food eaten (g)}}{\text{(increase in) desired output (g)}} \quad \text{(per specified time period)}$$

Animal	FCR
Beef Cattle	5 - 20
Pigs	3 - 3.2
Sheep	4 - 6
Poultry	1.4 - 2
Salmon	1.2 - 3

The lower the FCR the more efficient the method of food production.

A good (low) FCR is obtained by minimising the losses of energy by respiration, for example:

- Restricting animal movement
- Slaughtering the animal at a young age (older animals have higher FCRs as they grow more slowly)
- Optimising feed so it is efficiently digested

Animal	FCR
Beef Cattle	5 - 20
Pigs	3 - 3.2
Sheep	4 - 6
Poultry	1.4 - 2
Salmon	1.2 - 3

How ethical are the practices that lead to a low FCR?
What is more important, efficient food production or the ethical treatment of animals?

Example:

- Calculate the feed conversion ratio if a pig is fed 8 kg of food and gains 1 kg of body weight

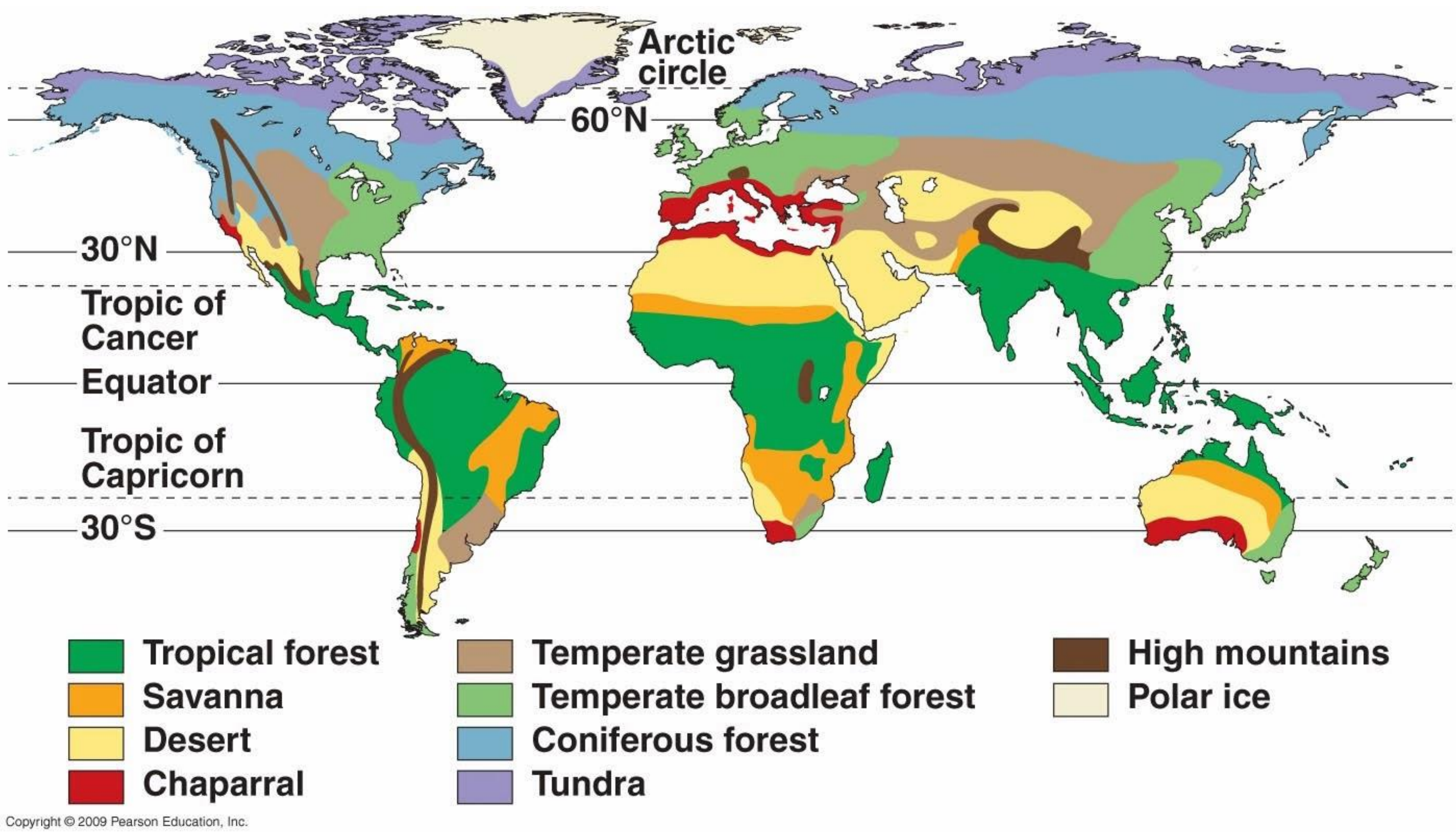
Example:

- Calculate the feed conversion ratio if a pig is fed 8 kg of food and gains 1 kg of body weight

- Mass of food eaten ÷ body mass gain = 8 kg ÷ 1 kg = 8

Biomes

- Region characterized by specific temperature, precipitation, and animal/plant species



Biome Summary Chart

Biome	Location	Climate	Soil	Plants	Animals
Desert	midlatitudes	generally very hot days, cool nights; precipitation less than 10 inches a year	poor in animal and plant decay products but often rich in minerals	none to cacti, yuccas, bunch grasses, shrubs, and a few trees	rodents, snakes, lizards, tortoises, insects, and some birds. The Sahara in Africa is home to camels, gazelles, antelopes, small foxes, snakes, lizards, and gerbils
Tundra	high northern latitudes	very cold, harsh, and long winters; short and cool summers; 10-25 centimeters (4-10 inches) of precipitation a year	nutrient-poor, permafrost layer a few inches down	grasses, wildflowers, mosses, small shrubs	musk oxen, migrating caribuou, arctic foxes, weasels, snowshoe hares, owls, hawks, various rodents, occasional polar bears
Grassland	midlatitudes, interiors of continents	cool in winter, hot in summer; 25-75 centimeters of precipitation a year	rich topsoil	mostly grasses and small shrubs, some trees near sources of water	american grasslands include prairie dogs, foxes, small mammals, snakes, insects, varous birds. African grasslands includeelephants, lions, zebras, giraffes.
Deciduous Forest	midlatitudes	relatively mild summers and cold winters, 76-127 centimeters (30-50 inches) of precipitation a year	rich topsoil over clay	hardwoods such as oaks, beeches, hickories, maples	wolves, deer, bears, and a wide variety of small mammals, birds, amphibians, reptiles, and insects.
Taiga	mid- to high latitudes	very cold winters, cool summers,; about 50 centimeters (20 inches) of precipitation a year	acidic, mineral-poor, decayed pine and spruce needles on surface	mostly spruce, fir, and other evergreens	rodents, snowshoe hares, lynx, sables, ermine, caribout, bears, wolves, birds in summer
Tropical Rainforest	near the equator	hot all year round, 200-400 centuimeters (80-100 inches) of rain a year	nutrient-poor	greatest diversity of any biome; vines, orchids, ferns, and a wide variety of trees	more species of insects, reptiles, and amphibians than anyplace else; monkeys, other small and large mammals, including in some places elephants, all sorts of colorful birds

Analyzing a Climograph

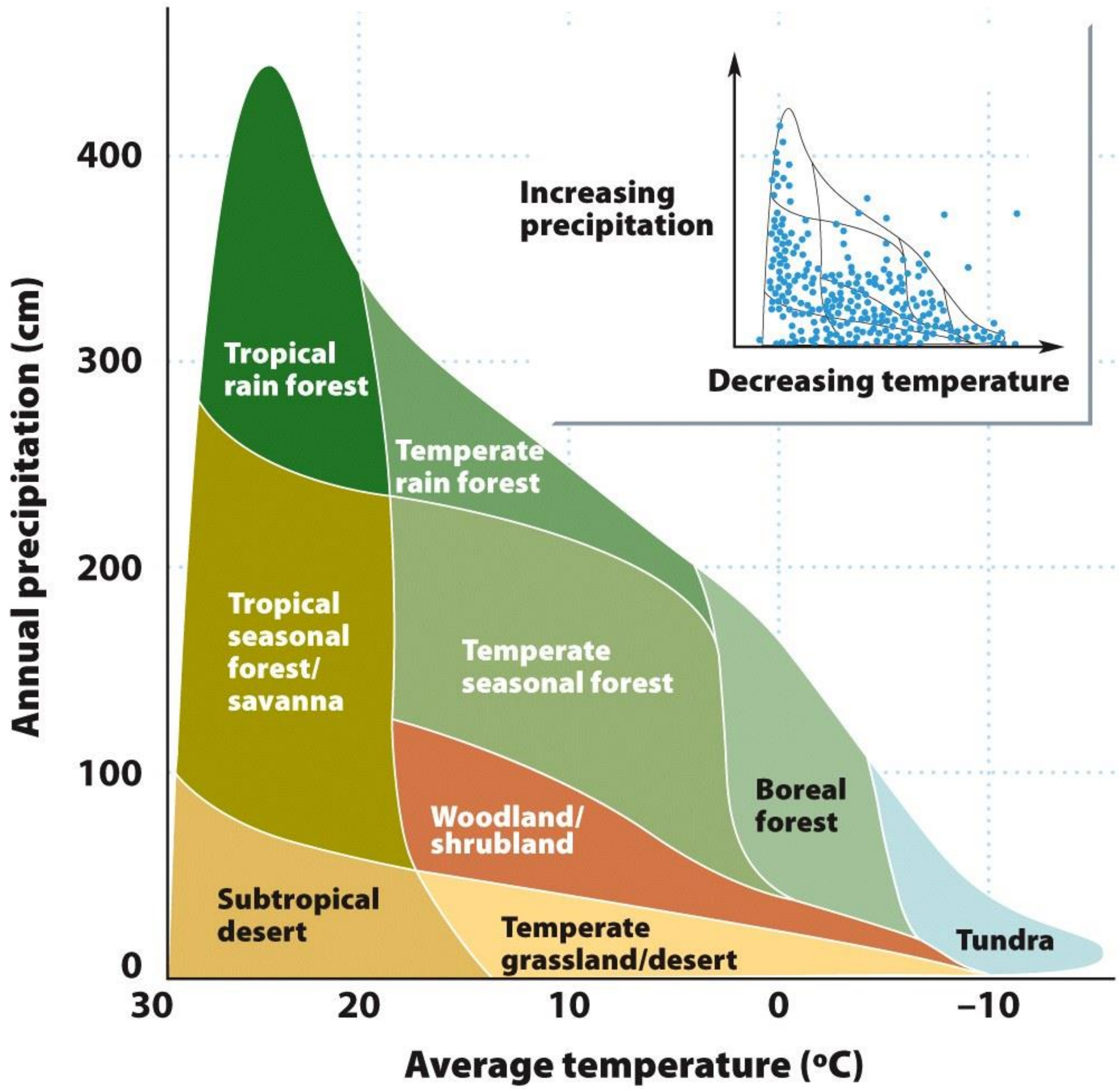


Figure 5.5
The Economy of Nature, **Sixth Edition**

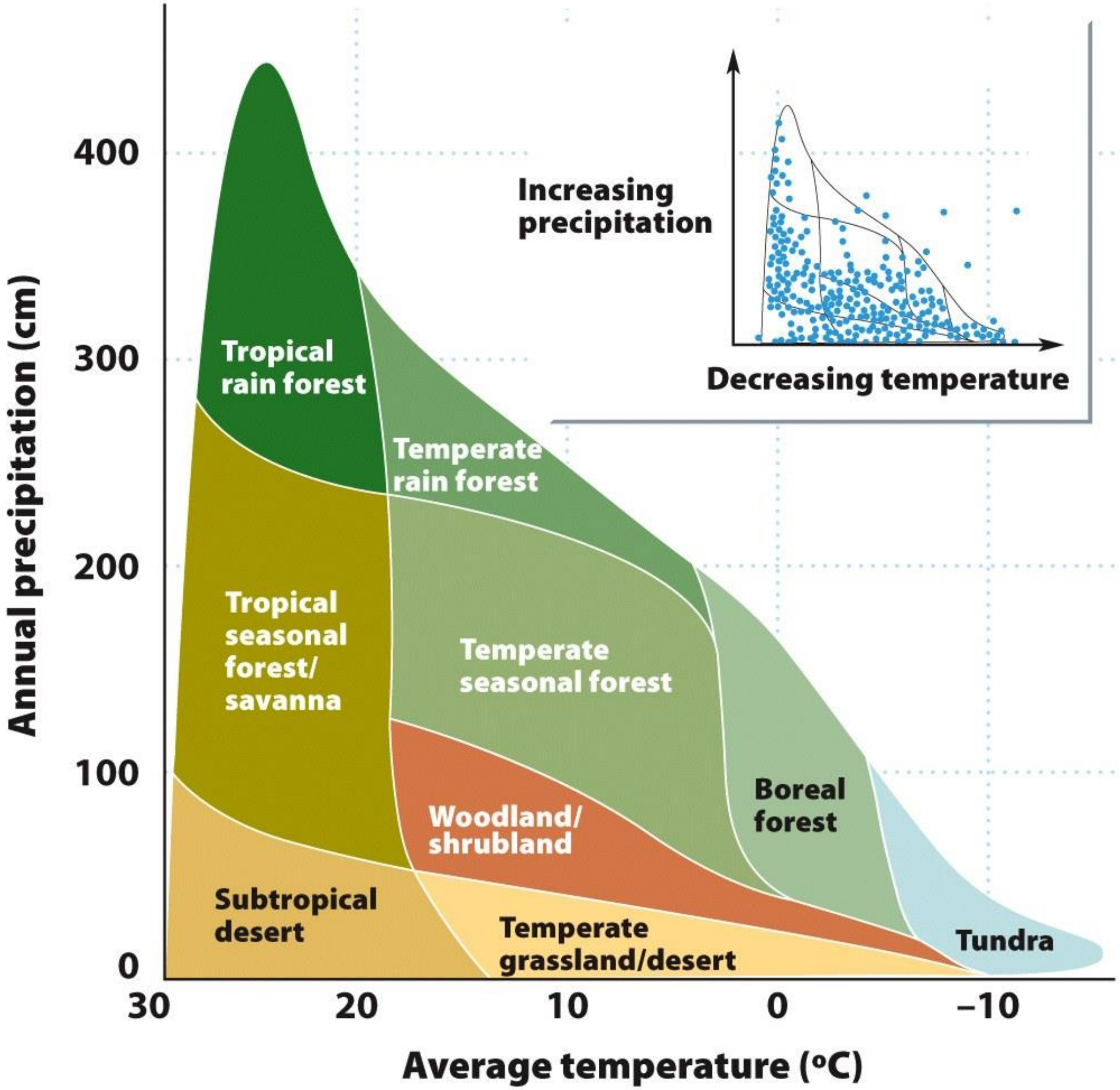
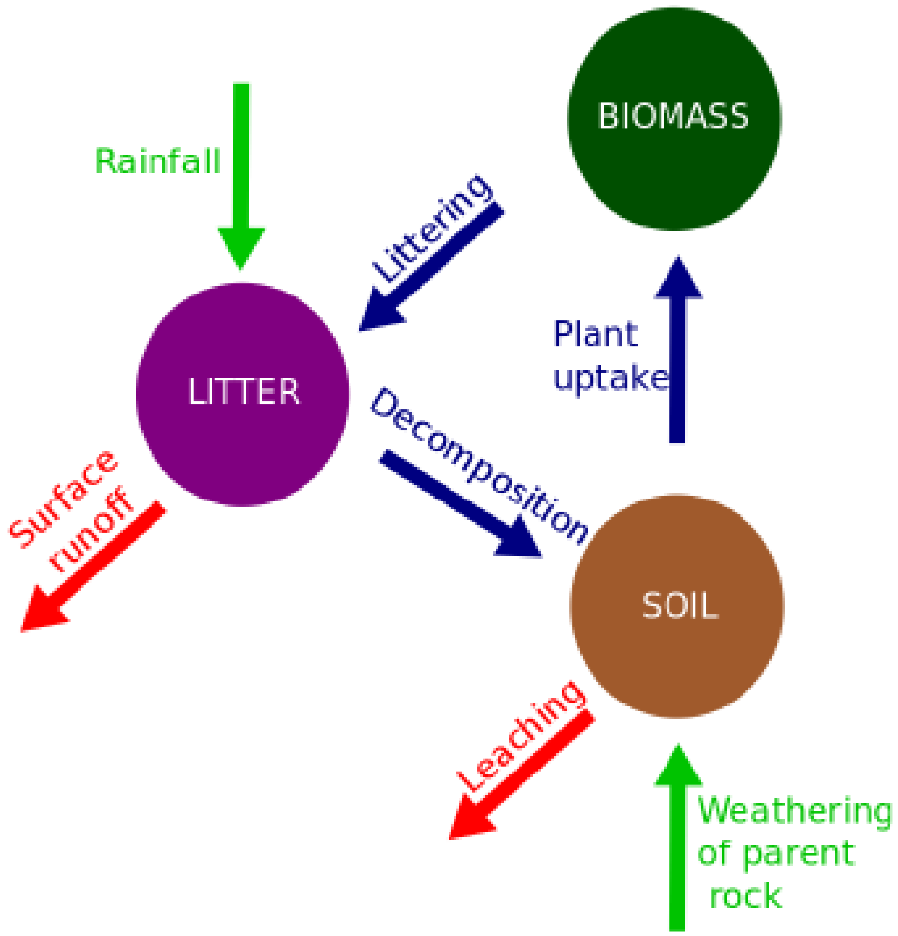


Figure 5.5
The Economy of Nature, Sixth Edition

1. What is the average temperature range of a subtropical desert?
2. What is the highest amount of precipitation for a subtropical desert?
3. Compare the mean annual temperature for grasslands and tropical forests.
4. Compare the mean annual temperatures for temperate seasonal forest and temperate rainforest

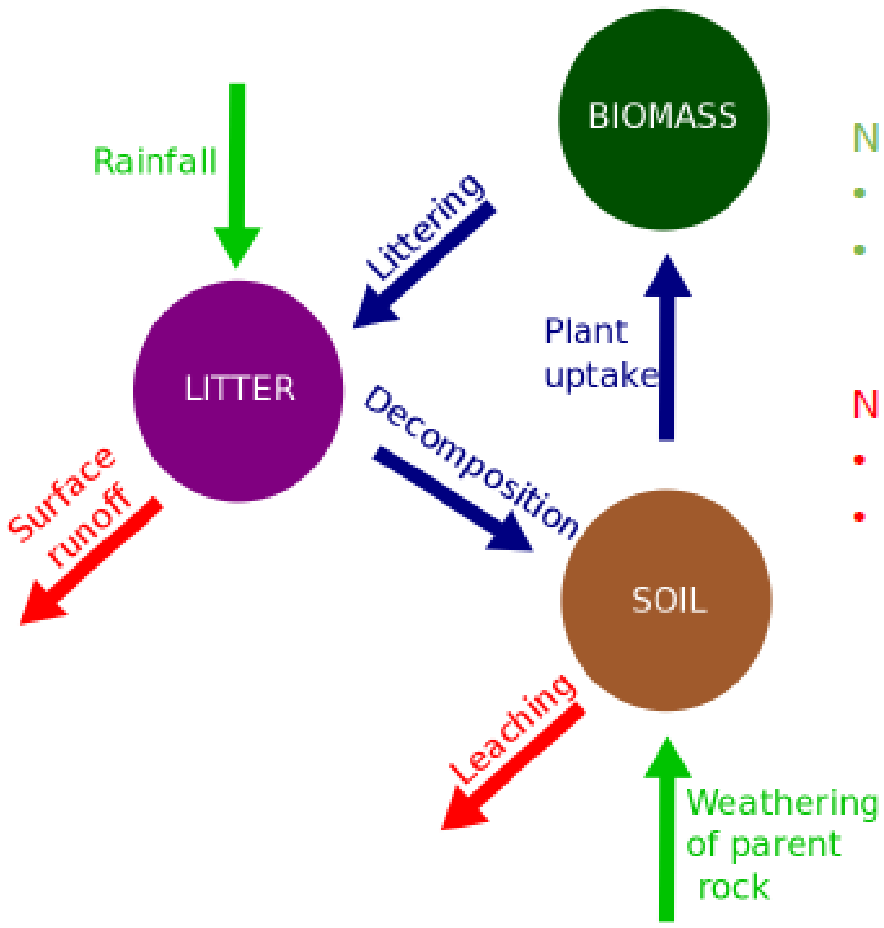
Gersmehl diagrams were first developed in 1976, by P.F. Gersmehl, to show the differences in nutrient flow and storage between different ecosystems



Sinks for nutrient storage:

- **Biomass (flora and fauna)**
- **Litter**
- **Soil**

Gersmehl diagrams were first developed in 1976, by P.F. Gersmehl, to show the differences in nutrient flow and storage between different ecosystems



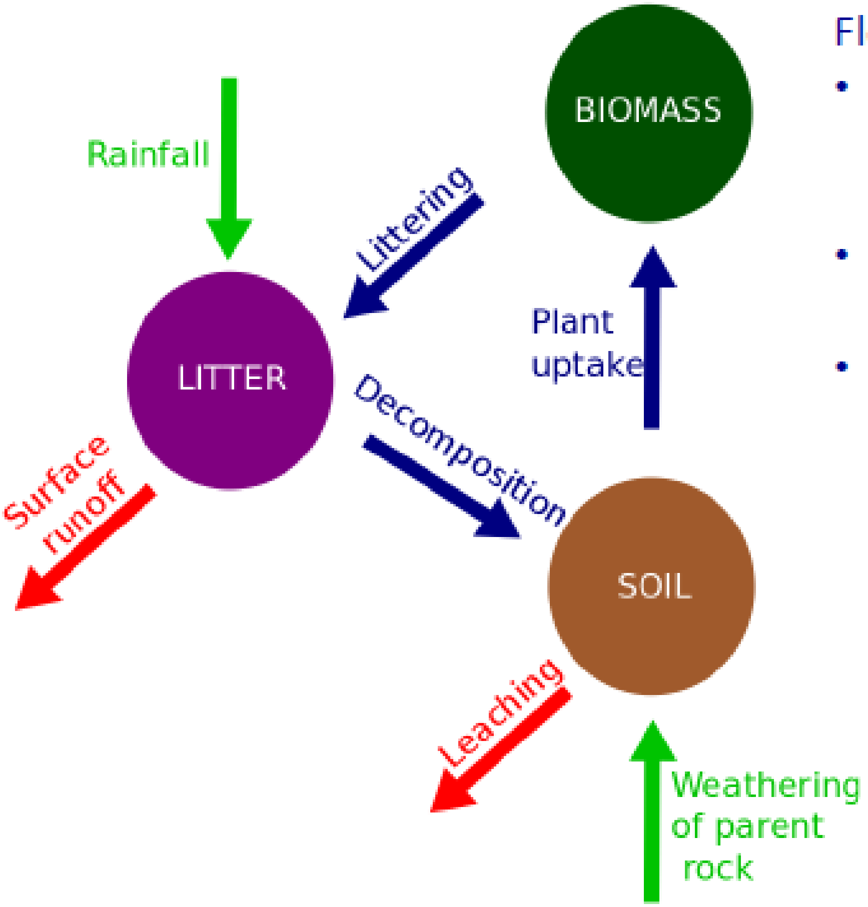
Nutrient inputs into the ecosystem:

- Nutrients dissolved in raindrops
- Nutrients from weathered rock

Nutrient outputs (losses) from the ecosystem:

- Nutrients lost through surface runoff
- Nutrients lost through leaching

Gersmehl diagrams were first developed in 1976, by P.F. Gersmehl, to show the differences in nutrient flow and storage between different ecosystems



Flows between the sinks:

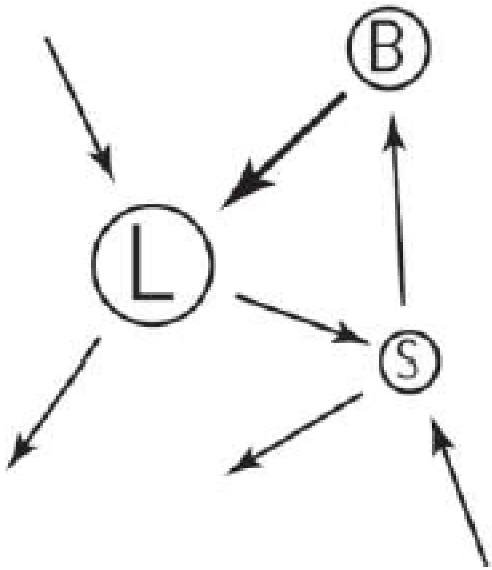
- Littering (including withering, defoliation, excretion, unconsumed parts left over, dead bodies of animals, and so on) *
- Decomposition of the litter into inorganic nutrients, which are then stored in the soil
- Nutrient uptake by plants

When used to analyse a particular ecosystem:

- Diameter of sinks are proportional to the mass of nutrients stored in each sink
- the thickness of the arrows are proportional to the rate of nutrient flow

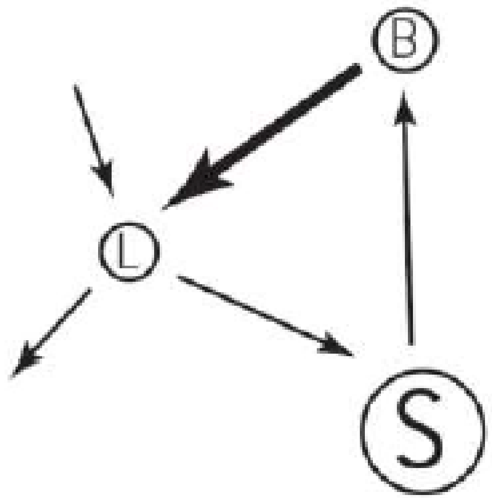
* **Human interactions are not considered** – do not confuse littering with dropping trash

tagia
(temperate forest)



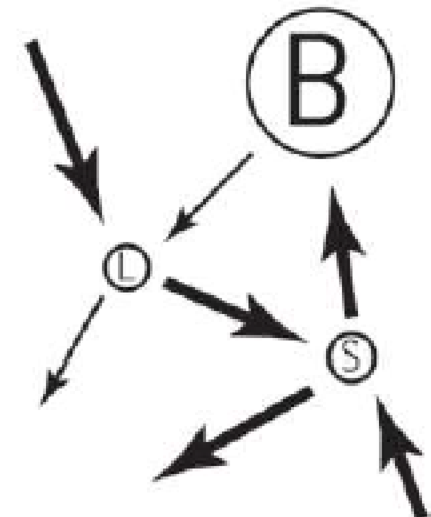
- *Litter (pine needles) is the main store*
- *Slow rate of nutrient transfer between stores*

desert



- *Soil is the main store*
- *Slow rate of nutrient transfer between stores (except for the transfer from biomass to litter)*

tropical rainforest



- *Biomass is the main store (soil is nutrient poor)*
- *Fast rate of nutrient transfer between stores*

Gersmehl Interactive

- Explore the diagrams for the different biomes. Be sure to reset parameters between trials.

- What happens when precipitation increases? Decreases?
- What happens when temperature decreases? Increases?

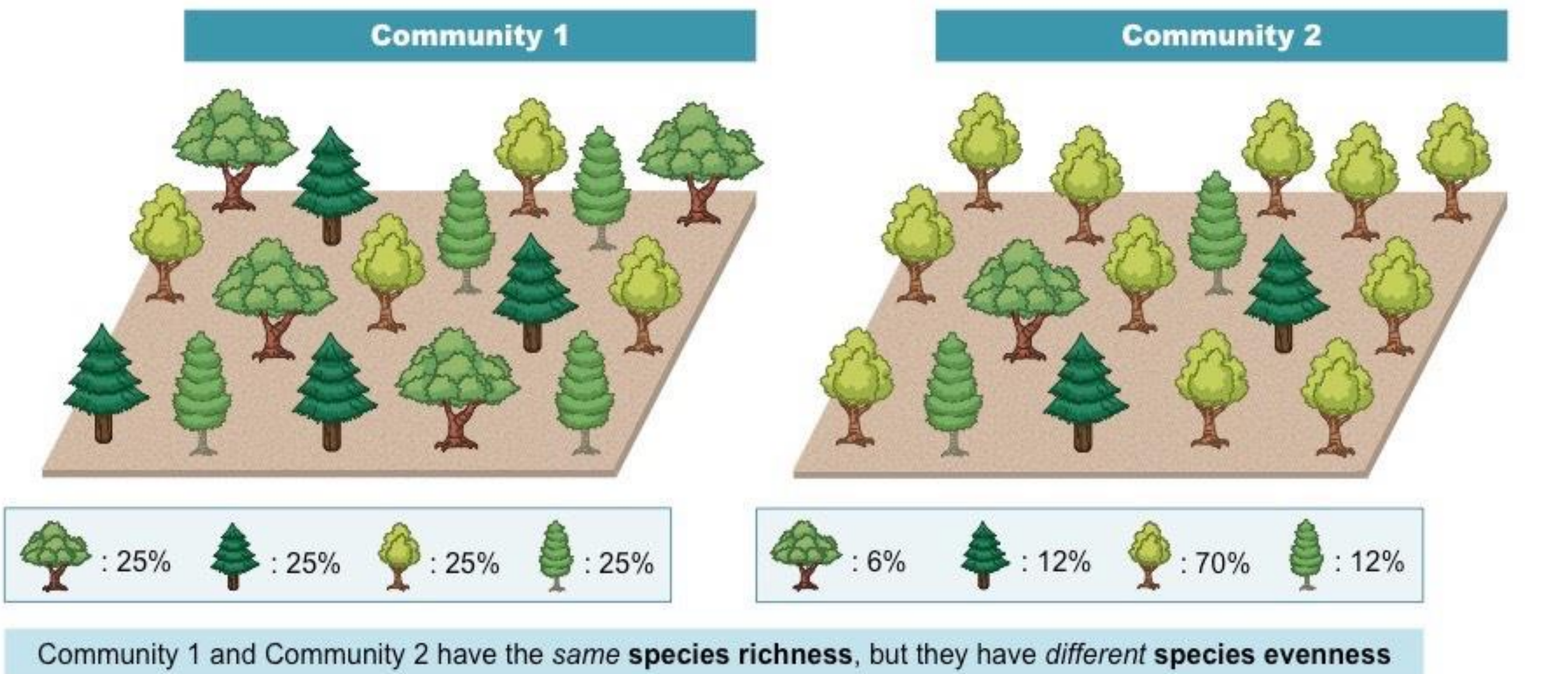
Gersmehl Interactive
https://scratch.mit.edu/projects/143609898/#player

C4 Conservation

Biodiversity

- The variety of species present in a given habitat or ecosystem

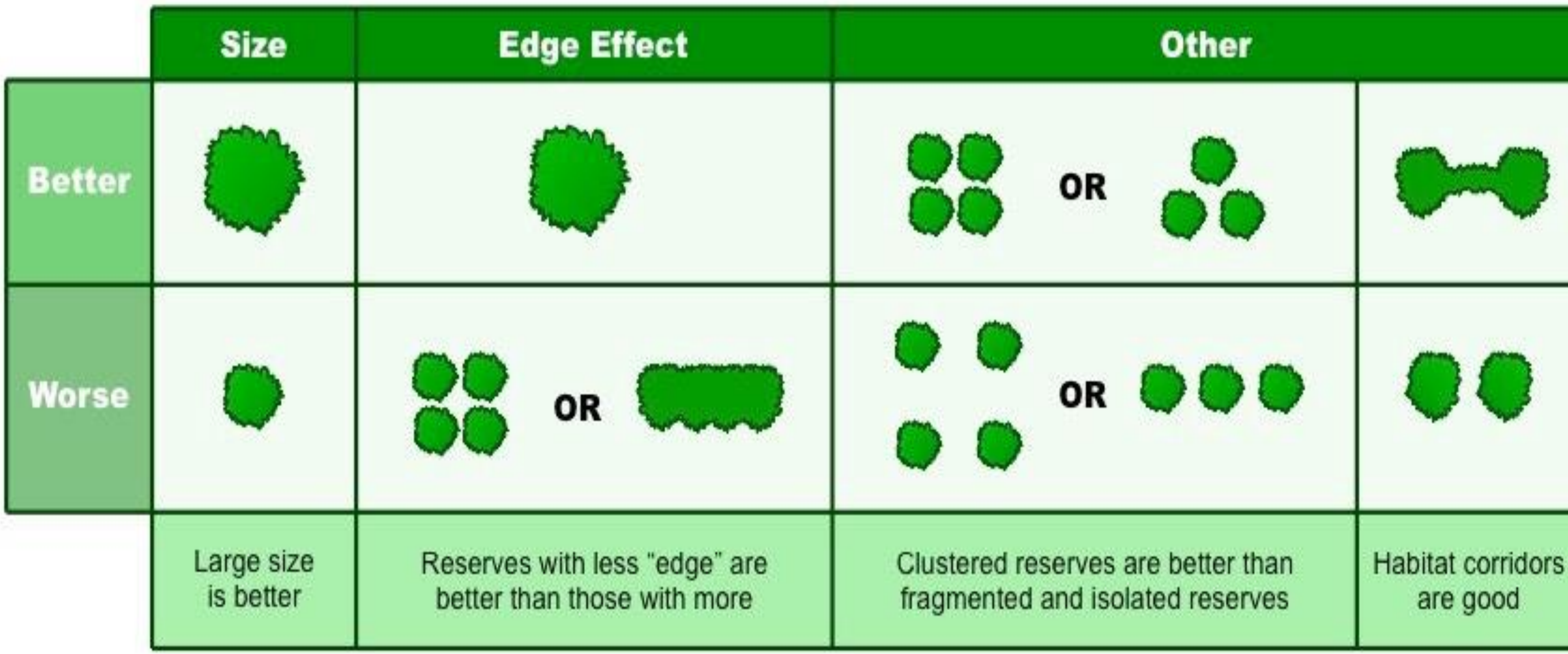
- *Species richness* - the number of different species present in an area (more species = greater richness)
- *Species evenness* - the relative abundance of the different species in an area (similar abundance = more evenness)



Biogeographic Factors Affecting Diversity

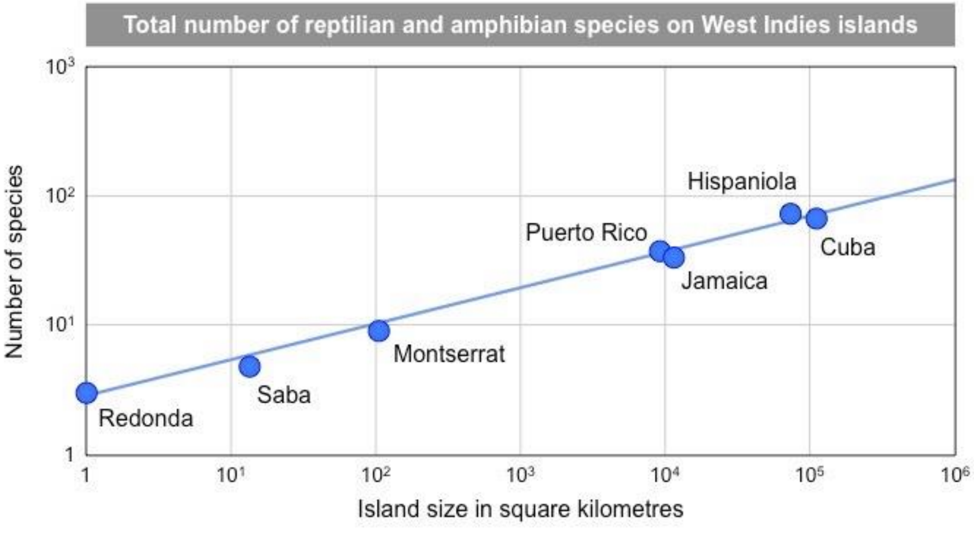
- Larger habitats tend to promote biodiversity better than smaller habitats (more available niches = less competition)
- Ecology at the edges of ecosystems is different from central areas (e.g. more sunlight, more wind, etc.)
  - This is known as the *edge effect*, whereby species distribution is influenced by the divergent environmental conditions
  - Edges tend to have greater biodiversity, as different habitats with different abiotic factors exist in close physical proximity
  - However edges tend to have more competition than central regions, which may restrict survival prospects of certain species
- Habitat corridors between parts of a fragmented habitat can connect disparate regions to improve genetic diversity

We use these principles when setting aside land as a nature reserve to improve the conservation of biodiversity



Island/Land Size and Biodiversity

- The biodiversity of an island is typically proportionate to island size (i.e. larger islands have greater biodiversity)
- Larger islands support a greater range of habitats (and hence more available niches for species to occupy)
- Larger islands can sustain higher population numbers for each species (increases species evenness)
- Larger islands have greater productivity at each trophic level, leading to longer and more stable food chains



How Do We Conserve Biodiversity?

Photo credits:
Habitat: Dale Coker, NPS

In situ (on site) Conservation

- Preservation of species within their natural habitat
  - Ex: Protected areas (nature preserves/national parks)
- Involves:
  - Population monitoring, interventions to prevent habitat degradation or competition from invasive species, legislation
- Benefits:
  - Species lives in environment adapted to and occupies natural niche
  - Maintain normal behaviors (offspring learn from parents and peers)
  - Protecting habitat ensures it remans for other endangered species
  - Provides areas for reintegration from breeding programs
  - Reserves can act as place of scientific study and help raise public awareness

https://state.1keydata.com/national-parks-by-state.php

Ex situ (off site) Conservation

- Preservation of species outside their natural habitat
  - Typically required for critically endangered species when urgent intervention is needed
- Involves
  - Captive Breeding – raised and bred in containment (zoos) to ensure survival
  - Botanical Gardens – areas devoted to collection, cultivation, and display of a variety of plants
  - Seed banks – secure sites that store and catalogue seeds to preserve plant genetic diversity

Ex situ (off site) Conservation

- Benefits:
  - Greater control of essential conditions (ex: climate control, diet, veterinary care)
  - Improve chances of successful breeding using artificial insemination (embryo transfer, IVF)
- Drawbacks:
  - Doesn't prevent potential destruction of their natural habitats
  - Species raised in captivity are less likely to be successfully reintroduced back into the wild (loss of autonomous survival)
  - Increases inbreeding by restricting the gene pool (which in turn restricts evolution of the species)

Captive Breeding and Reintroduction of Red Wolves

<u>Stakeholders Writing Directions:</u>

Write a short paragraph explaining how each stakeholder listed below would feel about the red wolf reintroduction; would they want the red wolf reintroduction continued as is, continued with changes, or stopped completely?

Explain your answer using evidence from personal experience and the article above, if you say the stakeholder would want reintroduction continued with changes explain what changes.

https://news.nationalgeographic.com/2015/03/150318-red-wolves-north-carolina-conservation-reintroduction-science/

PROYECTO TITI

CONSERVING COLOMBIA'S WILDLIFE

Biotic Index

- **Living things are very sensitive to changes in their environment with different organisms being more tolerant to the changes than others**
- **Changes in populations of certain kinds of organisms can be used to monitor water quality**

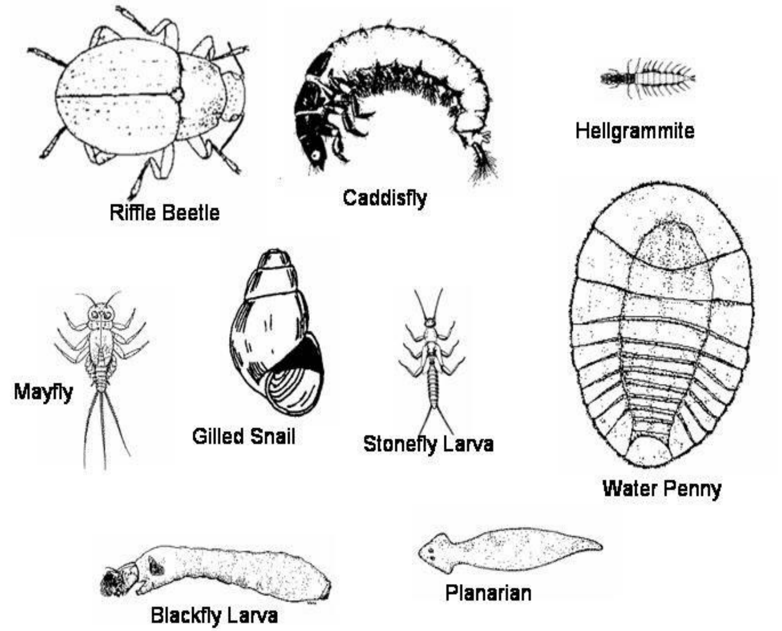
Macroinvertebrates

(macro = big invertebrate = no backbone)

- **Aquatic organisms that are quite small but can be seen with the naked eye**
  - **Includes worms, insects, and crustaceans**

Populations Affected by

- **Sewage and fertilizers can cause eutrophication consuming their oxygen**
- **Excess sediment from construction smothers where they live killing them off**
- **Pollution changes pH and temperature of their water**



How to Use them for Aquatic Health

Group A: Very sensitive to Environmental Stresses

(live only in a healthy ecosystem)

Stoneflies Mayflies Caddisflies Dobsonflies Water penny

Group B: Somewhat sensitive to Environmental Stresses

(Ecosystem has some pollutants/stressors…monitor frequently)

Dragonflies Craneflies Damselflies Crayfish Scuds

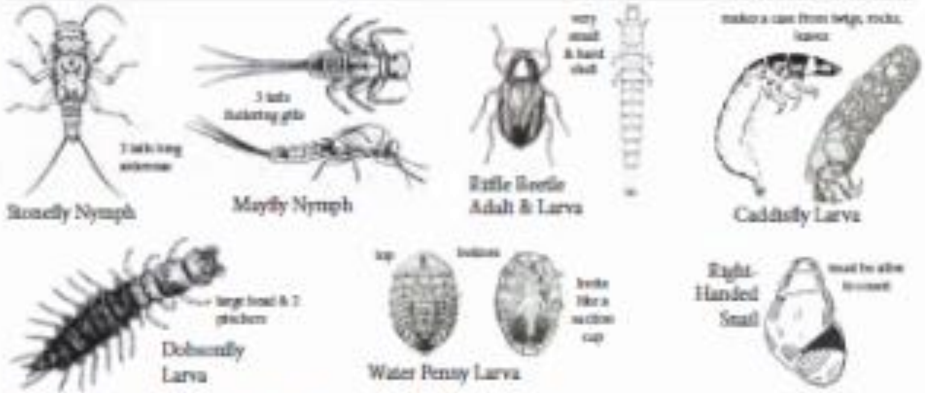
Group C: Tolerant to Environmental Stresses

(Ecosystem is in harm/not healthy…needs intervention)

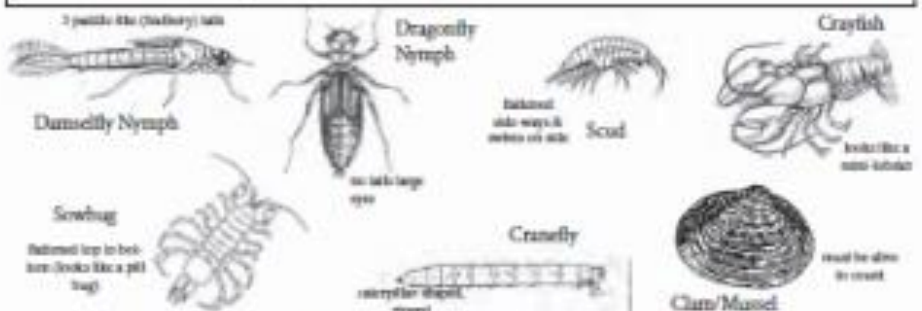
Midges Leeches Snails Pouch Snails Blackfly larva

Macroinvertebrate Identification Key

GROUP 1 – Very Intolerant of Pollution

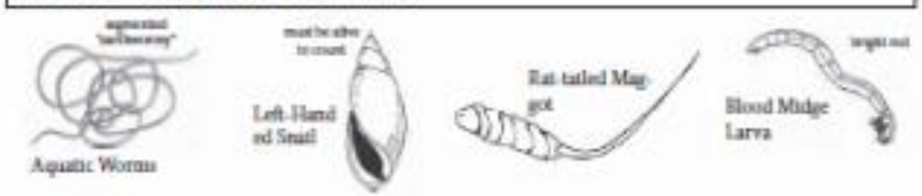


GROUP 2 – Moderately Intolerant of Pollution



GROUP 3 – Fairly Tolerant of Pollution

GROUP 4 – Very Tolerant of Pollution



Sources of Water Pollution

Biodiversity

is variety of organisms present in an ecosystem

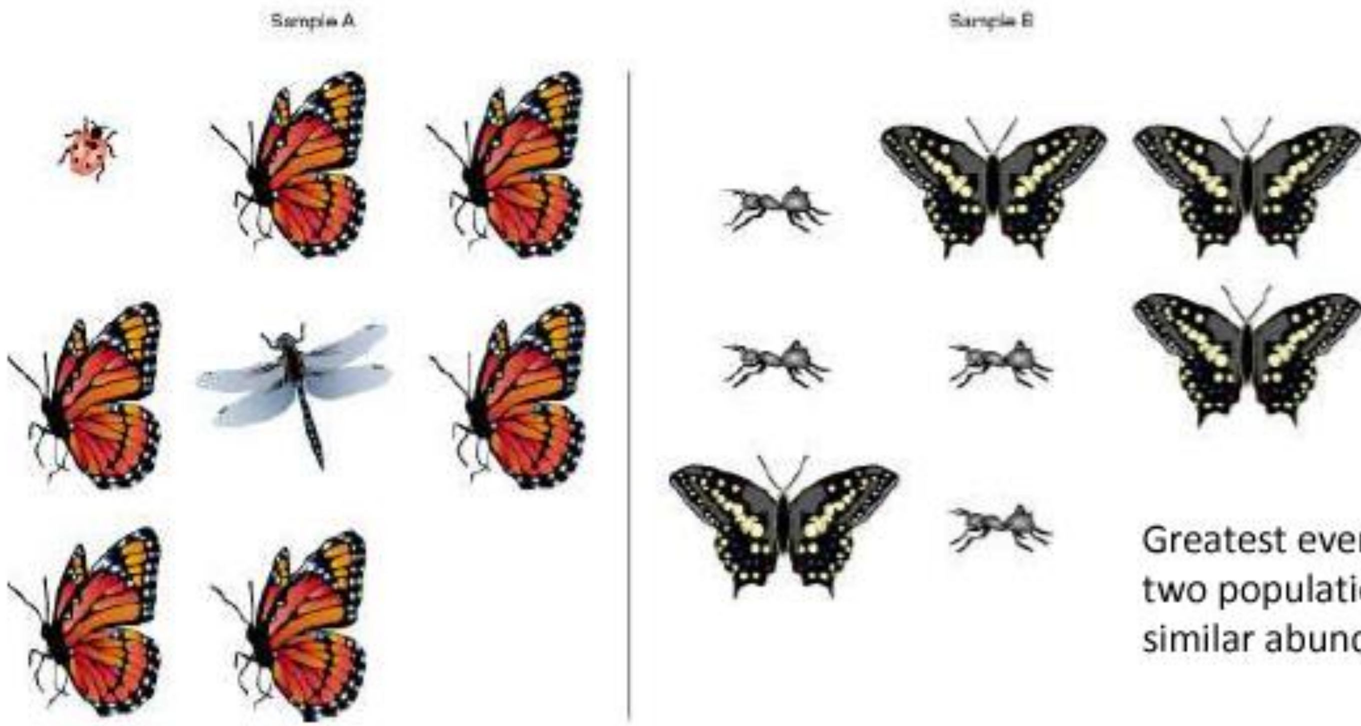
Richness

The number of different species present.

Evenness

If a habitat has similar abundance for each species present, the habitat is said to have eveness.

More species therefore highest richness



Greatest eveness as the two populations have similar abundance.

Simpson's reciprocal index can be used to calculate biodiversity.

$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

- D: Simpson's Reciprocal Index
- N: total of organisms of all species
- Σ: the sum of (all species)
- n: number of organisms of a single species

- It takes into account both richness and evenness
- The greater the biodiversity the higher the value of D
- The lowest possible defined value of D is 1 (only one species found)
- The maximum value is equal to the number of species found, this only occurs if all species are equally abundant.

Compare the biodiversity of the two samples:

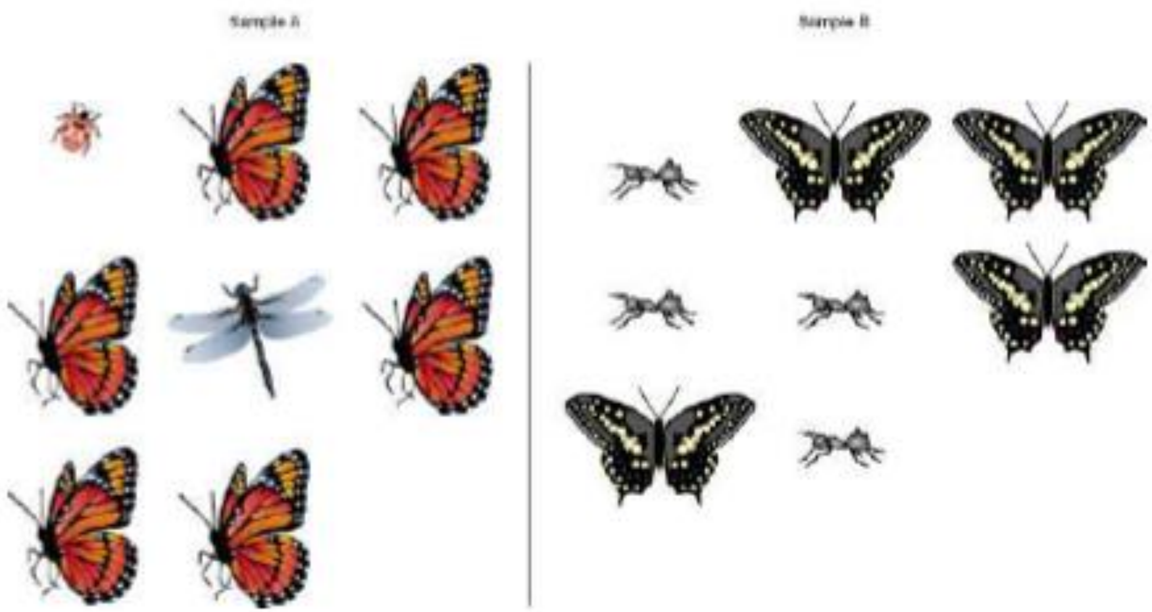
Simpson's Reciprocal Index

total of organisms of all species

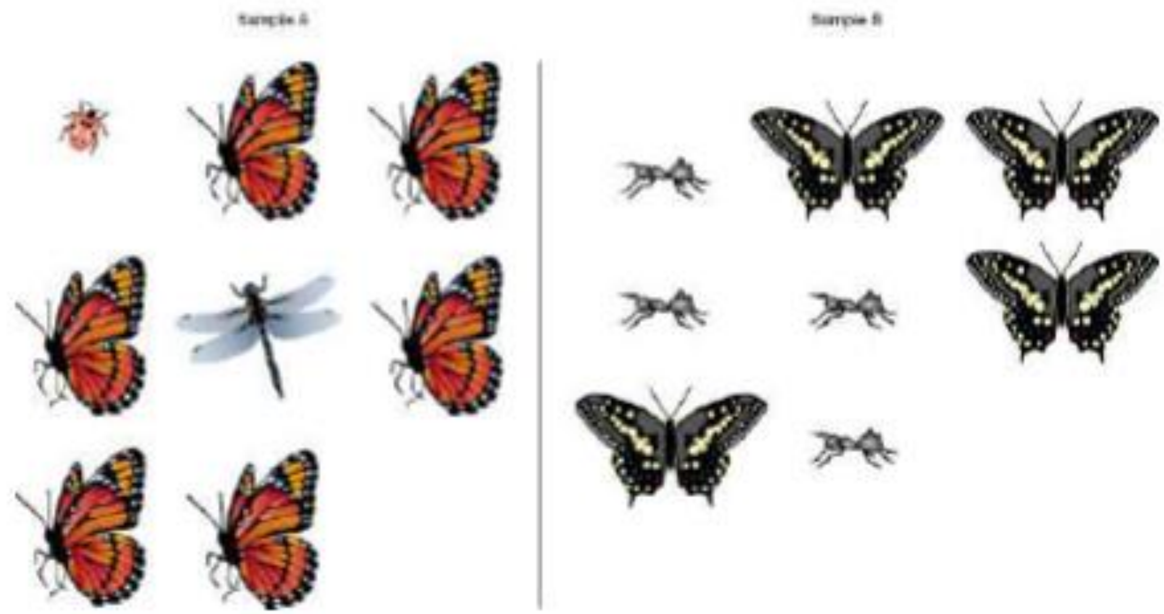
$$D = \frac{N(N-1)}{\Sigma\, n(n-1)}$$

the sum of (all species)

number of organisms of a single species



Compare the biodiversity of the two samples:



Species*	Count
A	6
B	1
C	1
Total	8

Species*	Count
A	4
B	4
Total	8

**correct names not required*

Compare the biodiversity of the two samples:

Sample A

Species*	Count
A	6
B	1
C	1
Total	8

total of organisms of all species

Simpson's Reciprocal Index

$$D = \frac{N\,(N - 1)}{\Sigma\, n\,(n - 1)}$$

the sum of (all species)

number of organisms of a single species

$$D = \frac{8\,(8 - 1)}{6\,(6 - 1) + 1\,(1 - 1) + 1\,(1 - 1)} = \frac{56}{30 + 0 + 0}$$

$$D = 1.87$$

Compare the biodiversity of the two samples:

Sample B

Species*	Count
A	4
B	4
Total	8

Simpson's Reciprocal Index

$$D = \frac{N(N-1)}{\Sigma n(n-1)}$$

N: total of organisms of all species

Σ: the sum of (all species)

n: number of organisms of a single species

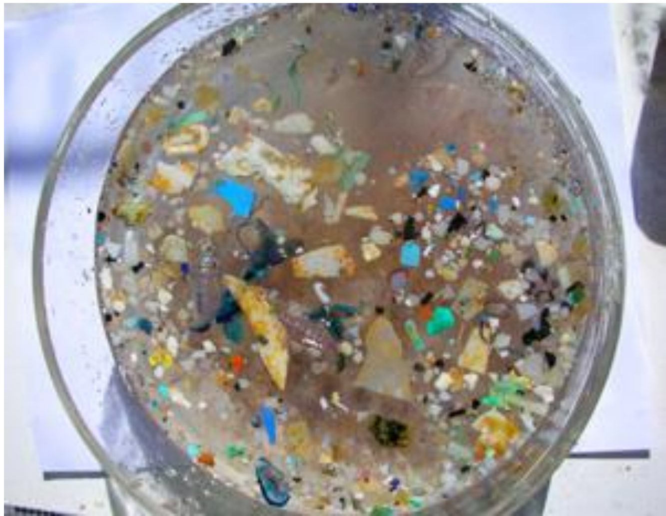
$$D = \frac{8(8-1)}{4(4-1) + 4(4-1)} = \frac{56}{12 + 12}$$

$$D = 2$$

Sample B has slighter higher biodiversity

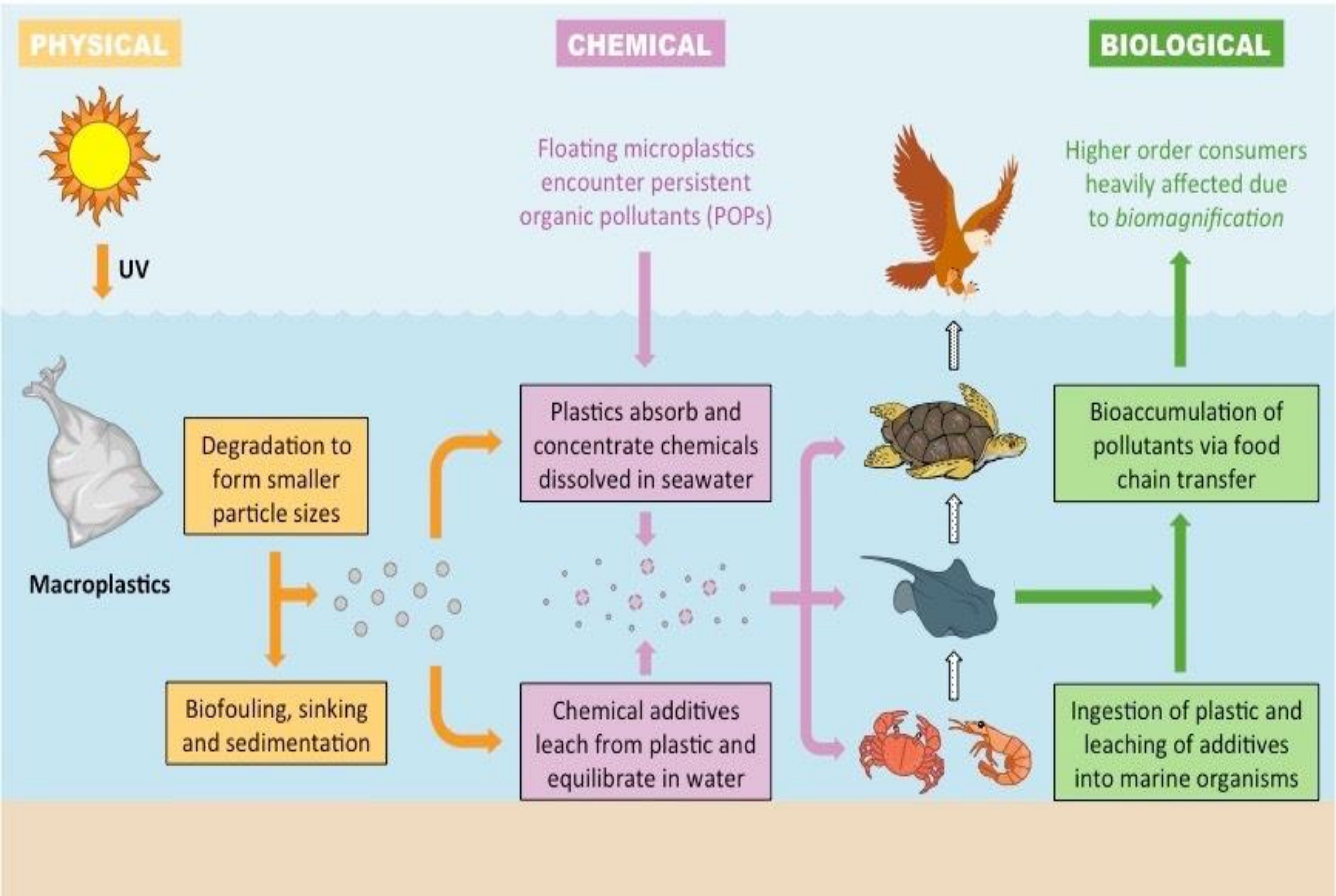
Plastic Pollution

- Plastics are a type of synthetic polymer found in certain types of clothes, bottles, bags, food wrappings and containers
- Most plastics are not biodegradable and persist in the environment for many centuries
- Large visible plastic debris (> 1 mm) is defined as **macroplastic**, while smaller debris (< 1 mm) is defined as **microplastic**



Microbeads in Cosmetics

- Macroplastic debris can be degraded and broken down into microplastic debris by UV radiation and the action of waves
  - Ocean currents will concentrate plastic debris in large oceanic convergence zones called *gyres*
- Plastic debris will leach chemicals into the water and also absorb toxic contaminants called persistent organic pollutants
  - Microplastics will absorb more persistent organic pollutants (POPs) due to their smaller size (more available surface area)


PHYSICAL
CHEMICAL
BIOLOGICAL
UV
Floating microplastics encounter persistent organic pollutants (POPs)
Higher order consumers heavily affected due to *biomagnification*
Macroplastics
Degradation to form smaller particle sizes
Plastics absorb and concentrate chemicals dissolved in seawater
Bioaccumulation of pollutants via food chain transfer
Biofouling, sinking and sedimentation
Chemical additives leach from plastic and equilibrate in water
Ingestion of plastic and leaching of additives into marine organisms

- Both macroplastic and microplastic debris is ingested by marine animals, which mistake the debris for food
  - This leads to the bioaccumulation and biomagnification of persistent organic pollutants within marine animals
  - It may also damage the stomach of animals or cause them to stop feeding (by taking up space in the digestive tract)

Population Growth

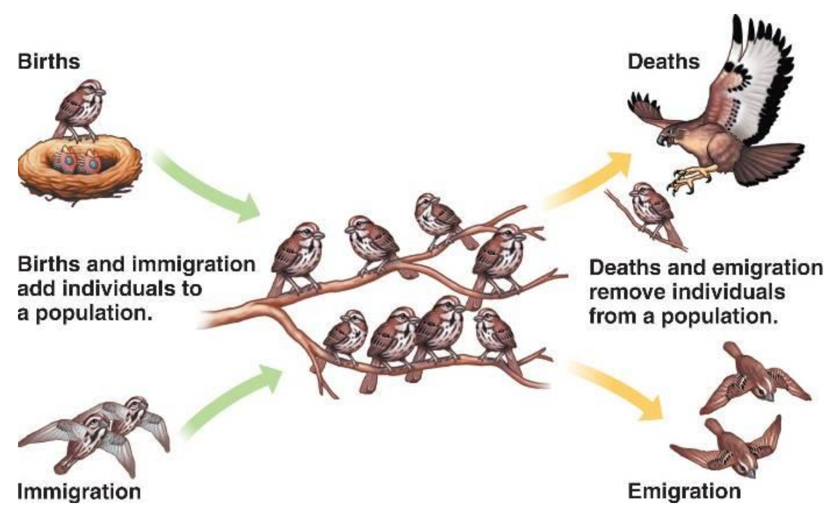
US and World Population Clock
http://www.census.gov/popclock/

- Factors that affect population growth
  - Increase
    - # of Births
    - individuals entering (immigration)
  - Decrease
    - # of Deaths
    - # of individuals leaving (emigration)

Population Size = (*Immigration* + *Natality*) - (*Mortality* + *Emigration*)

⬆ Factors *increasing* population size (birth and arrivals)

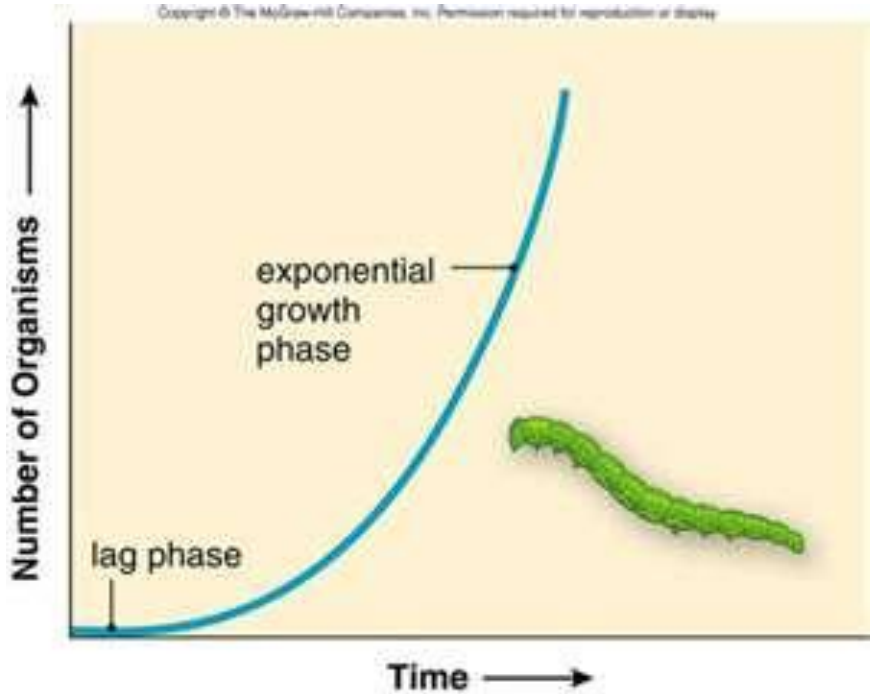
⬇ Factors *reducing* population size (death and departures)



Population Growth is Exponential!

Given enough food, water, sunlight and space, a population will grow uncontrollably

- Occurs when conditions are ideal
  - There are unlimited resources!!!
- Makes a J-shaped curve



Population Growth

- Has limits
- **Limiting factors**- cause a population to stop increasing
  - **Density dependent factors** get worse as the population increases
    - ***Numbers matter!***
    - **Density-** the number of individuals per unit area

Density Dependent Factors

- Disease
- Competition for resources-
  - food, water, mates, territories, nesting sites
- Predation
- Stress

*Disease can spread more quickly in a population with members that live close together.

Density independent factors – affect all populations regardless of density

Numbers don't matter!

- Temperature
- Weather
  - Floods
  - Droughts
- Natural disasters
- Human activities

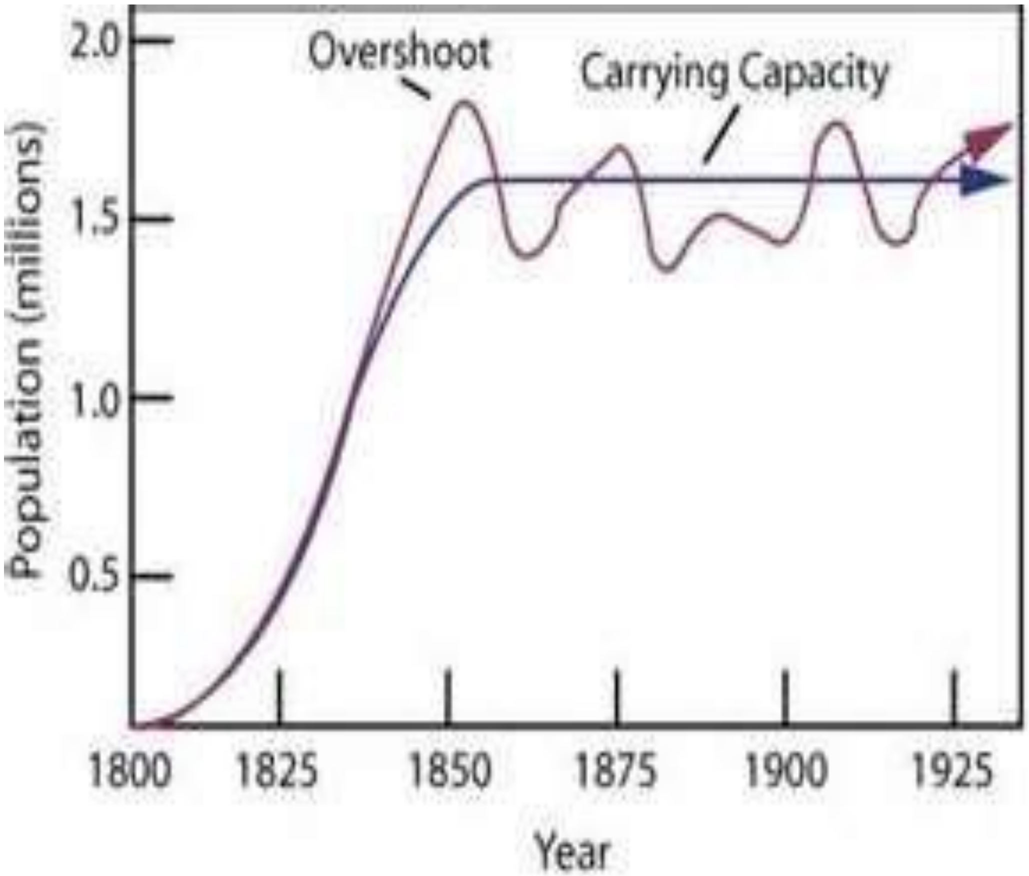
Density Dependent Factors
Predators
Availability of resources (e.g. shelter, water)
Nutrient supply (i.e. food source)
Disease / pathogenic spread
Accumulation of wastes

Density Independent Factors
Phenomena (e.g. natural disasters)
Abiotic factors (e.g. temperature, CO_2 levels)
Weather conditions (e.g. floods, storms, etc.)

Mnemonic: PANDA PAW

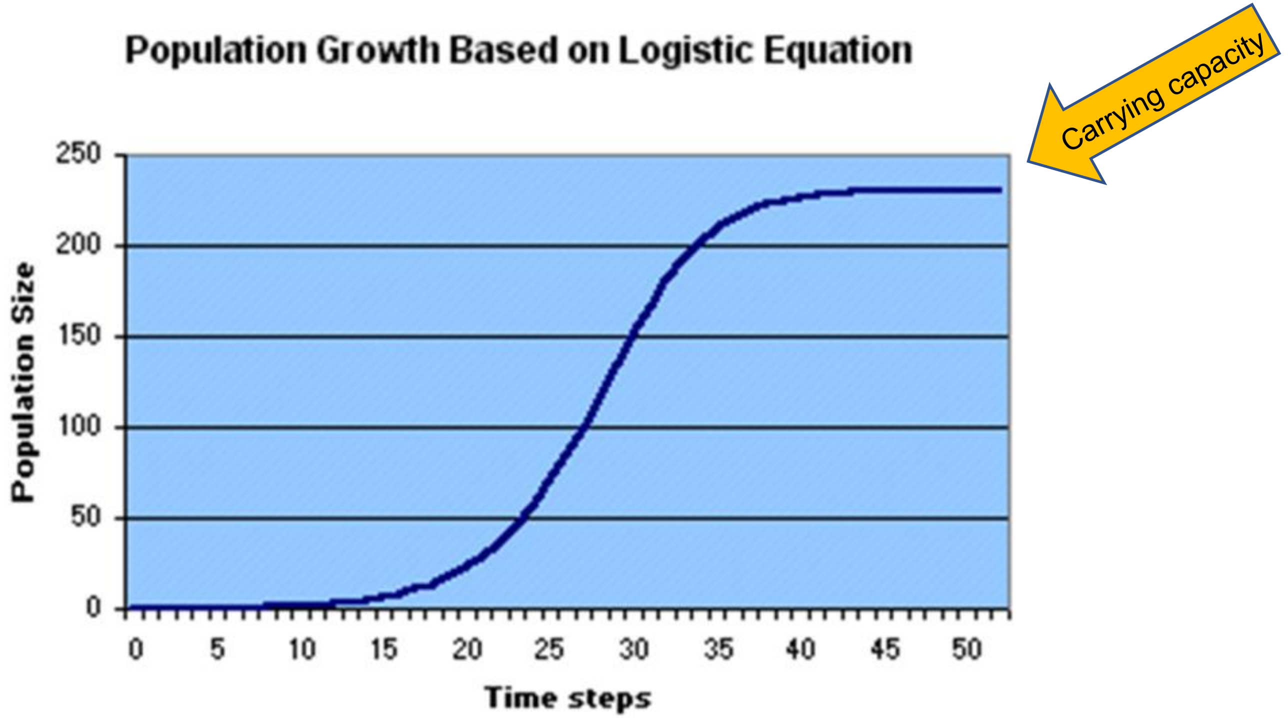
Effects of limiting factors result in a **carrying capacity**-

the number of individuals in the population that an environment can support



Logistic Growth

- Occurs when a population's growth slows or stops
  - S-curve
  - Resources are limited
  - Carrying capacity – set by <u>limiting factors</u>



1. Lag Phase (beginning growth)

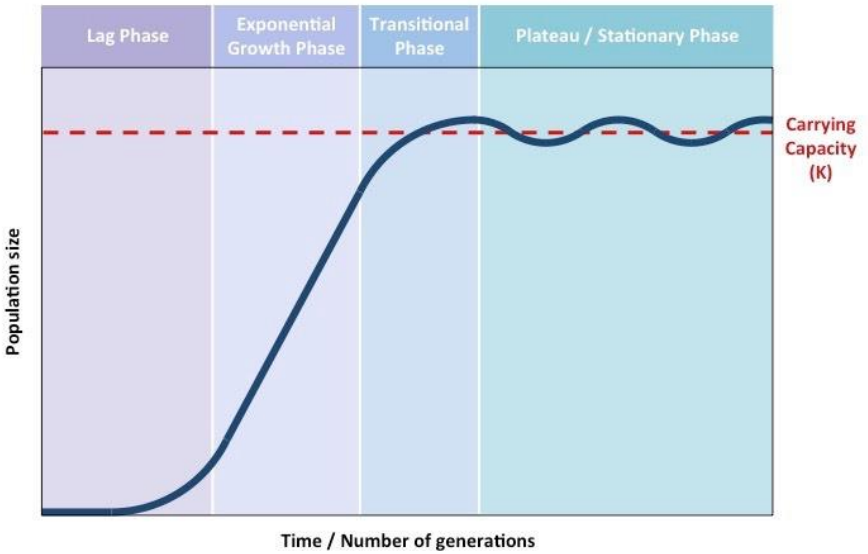
- Few starting members have offspring
  - The population increases slowly

2. Exponential Growth

- As numbers increase, many organisms reproducing
  - Rapid increase

3. Leveling Off

- Becomes more difficult for each organism to meet its needs
- Effect of density dependent factors increases
- Growth slows



3. Plateau

- Reach carrying capacity (K)
  - Growth is static

Exponential Growth Phase

- Initially, population growth will be slow *(lag period)* as there are few reproductive individuals that are likely widely dispersed
- As numbers accumulate, there is a rapid increase in population size as natality greatly exceeds mortality
- Mortality is low because there are abundant resources and minimal environmental resistance

Transitional Phase

- As the population continues to grow, resources eventually become limited, which leads to competition for survival
- Natality rates start to fall and mortality rates begin to rise, leading to a slowing of population growth

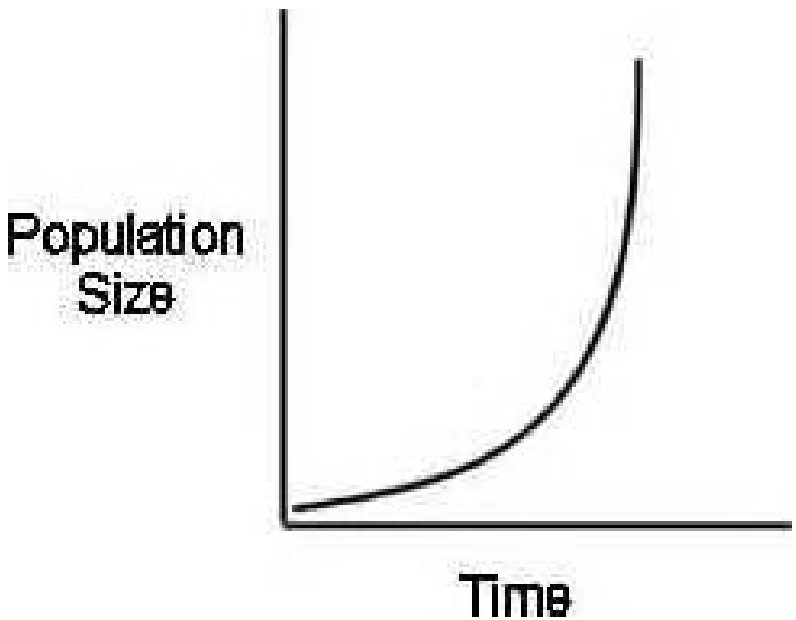
Plateau Phase

- Eventually the increasing mortality rate equals the natality rate and population growth becomes static
- The population has reached the carrying capacity (**κ**) of the environment, with limiting factors keeping the population stable
- The population size at this point will not be constant, but will oscillate around the carrying capacity to remain even

Population Growth Recap

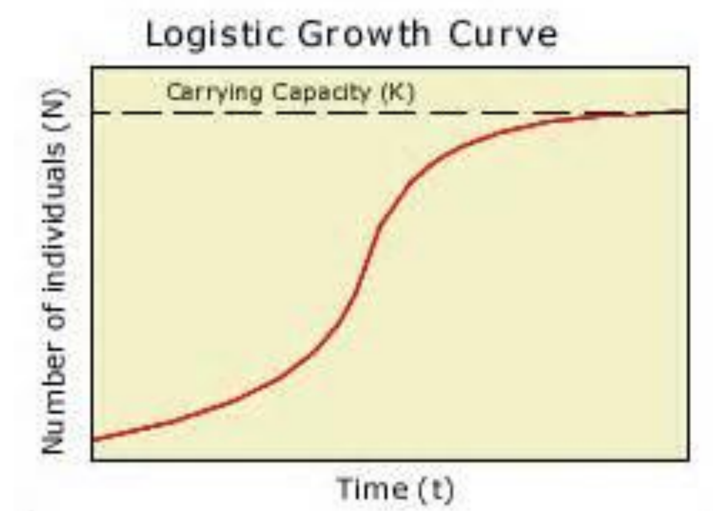
Exponential Growth

- No limits
- J curve



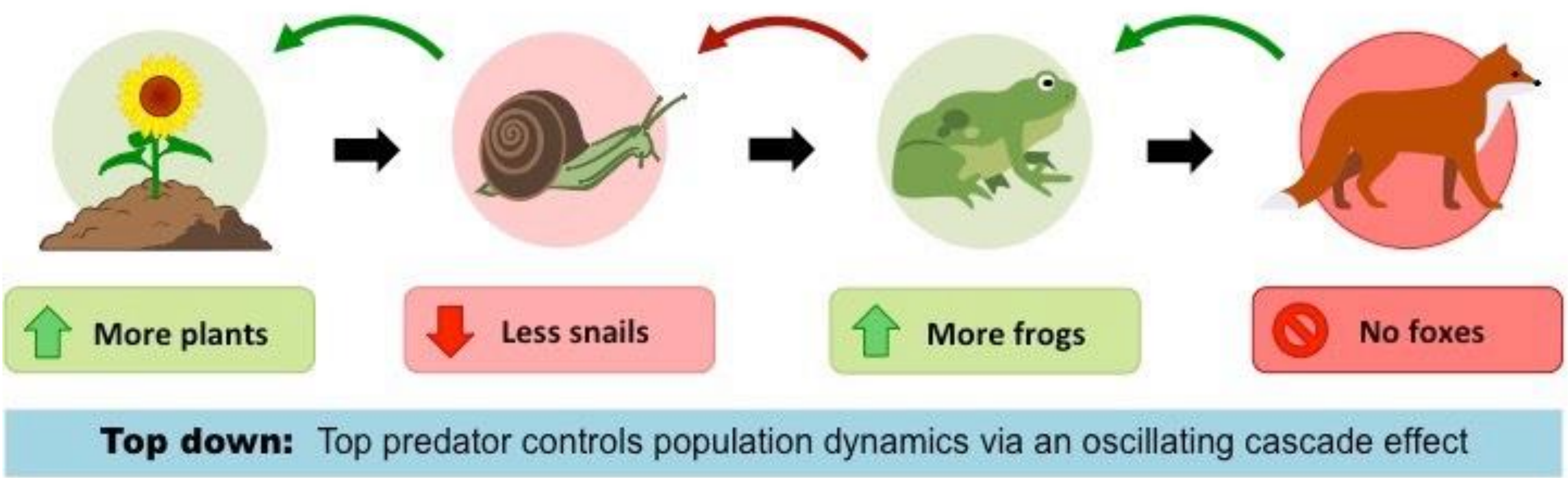
Logistic Growth

- Limiting factors
- S curve



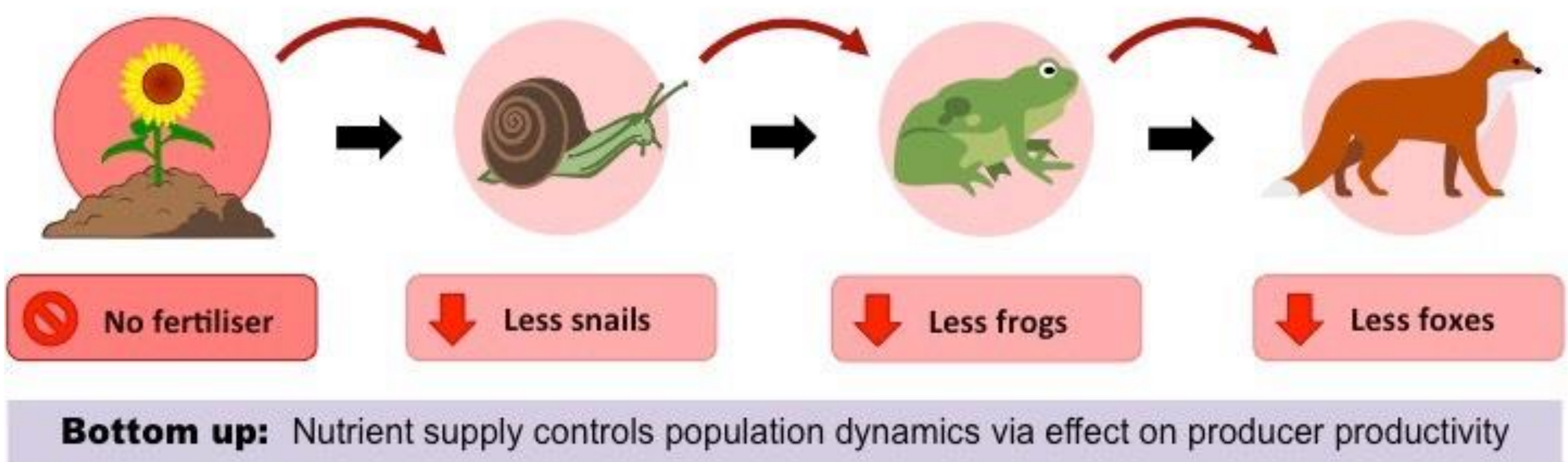
Top Down Control

- Top down factors are pressures applied by a *higher trophic level* to control the population dynamics of the ecosystem
- The top predator either suppresses the abundance of its prey or alters its behavior to limit its rate of population growth
  - Top down control results in an oscillating trophic cascade (suppression at one level increases numbers at the next level)
- Keystone species commonly exert top down control by preventing lower trophic levels from monopolizing essential resources



Bottom Up Control

- Bottom up factors are pressures that limit the availability of resources to *lower trophic levels* (e.g. producers)
- A lack of resources at lower trophic levels suppresses the abundance of organisms at higher trophic levels
- Population growth will be reduced for all higher levels as the suppression of the 'bottom’ restricts energy supply to the ‘top'
- Human activity can often limit resource availability and hence inadvertantly exert bottom up pressure on an ecosystem



Sustainable Yield

- Amount of a natural resource that can be taken from an ecosystem without reducing the base stock
- Determine this by measuring population numbers
  - Capture-mark-release-recapture
  - Echo sounders (sonar to id size of schools of fish)
  - Analysis of fish catch data

Sustainable Fishing Practices

- There are a number of factors that must be considered when developing and implementing sustainable fishing practices
- These include considerations of the population size, age and reproductive status of the targeted fishing stock

1. Population Size

- The maximum sustainable yield should be half the carrying capacity of the species (this is the point of highest growth rate)
- Harvesting above this threshold (overfishing) will lead to a decline in population size over time
- Limiting total allowable catch sizes and registering the number of fishing vessels in use are ways to control population size
- Certain oceanic regions may also be cordoned off for biological conservation (prevent population decline)

2. Age

- If a population is growing, then the relative proportion of younger fish will be higher (greater potential for future reproduction)
- If a population is in decline, then the relative proportion of older fish will be higher (higher probable mortality rates)
- Introducing mesh size restrictions on nets can allow younger fish to evade capture (as they are smaller in size)
- Also, using fish farms instead of open water fishing allows for a level of control over the age at which fish are harvested

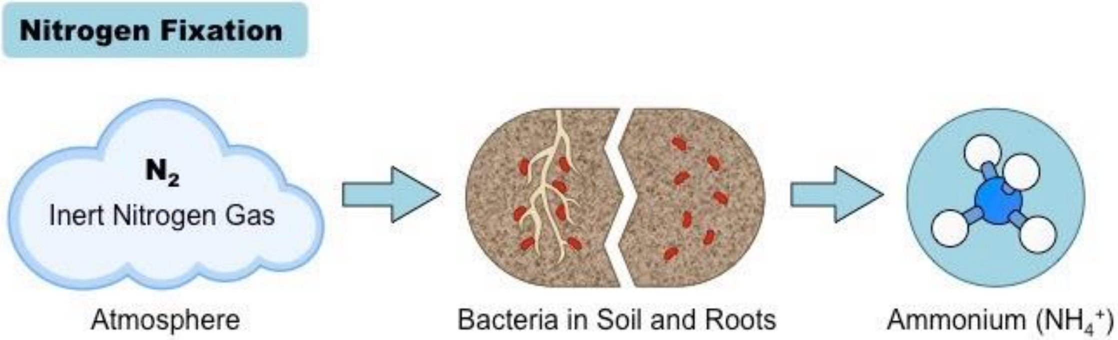
3. Reproductive Status

- Efforts must be taken to ensure fish are able to reproduce and repopulate stock lost to fishing practices
- If there are insufficient numbers of fish of a suitable reproductive age (too young or too old), population numbers will fall
- Closed seasons are often declared to allow for uninterrupted breeding periods via which fish species can repopulate
- Specific exclusion zones may also be introduced at these times to avoid fishing in breeding areas

Nitrogen Fixation

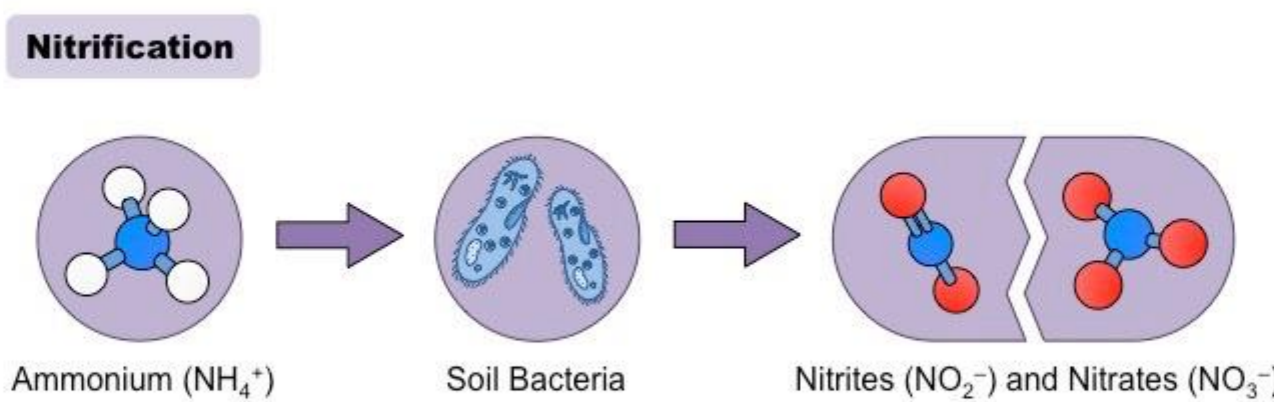
The first stage of the nitrogen cycle is the conversion of inert nitrogen gas (N_2) into ammonia (NH_3)

- This reaction is catalysed by the enzyme nitrogenase, which is produced by nitrogen-fixing bacteria in the soil
- *Azotobacter* is found living freely in the soil, while *Rhizobium* forms a mutualistic association with the roots of legumes
- *Rhizobium* forms nodules within the plant roots and supplies ammonia to the plant in exchange for carbohydrates
- Ammonia (NH_3) becomes ammonium (NH_4^+) when mixed with water, and this can be used by plants



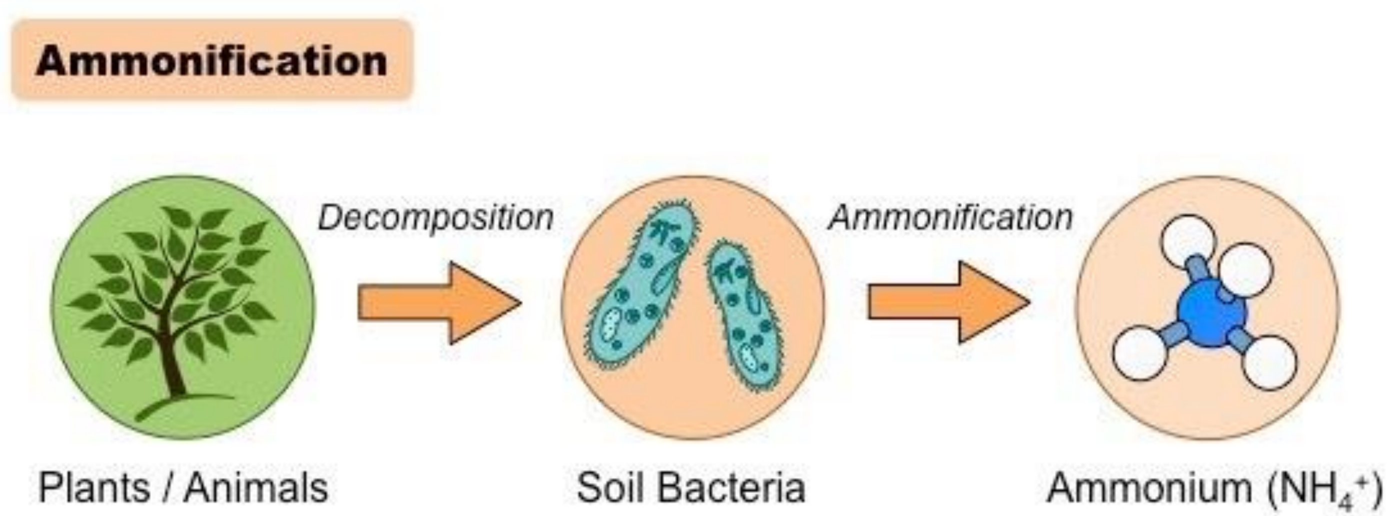
Nitrification

- Nitrification is the conversion of ammonium ions into nitrites (NO_2^-) and nitrates (NO_3^-) by nitrifying bacteria in the soil
- *Nitrosomonas* converts ammonium ions into nitrites, while *Nitrobacter* can convert the nitrites into nitrates
- These reactions require oxygen and hence soil must be well aerated to ensure a rich supply of nitrites and nitrates
- Nitrites and nitrates are easier for plants to assimilate and hence function as a predominant source of nitrogen for plants



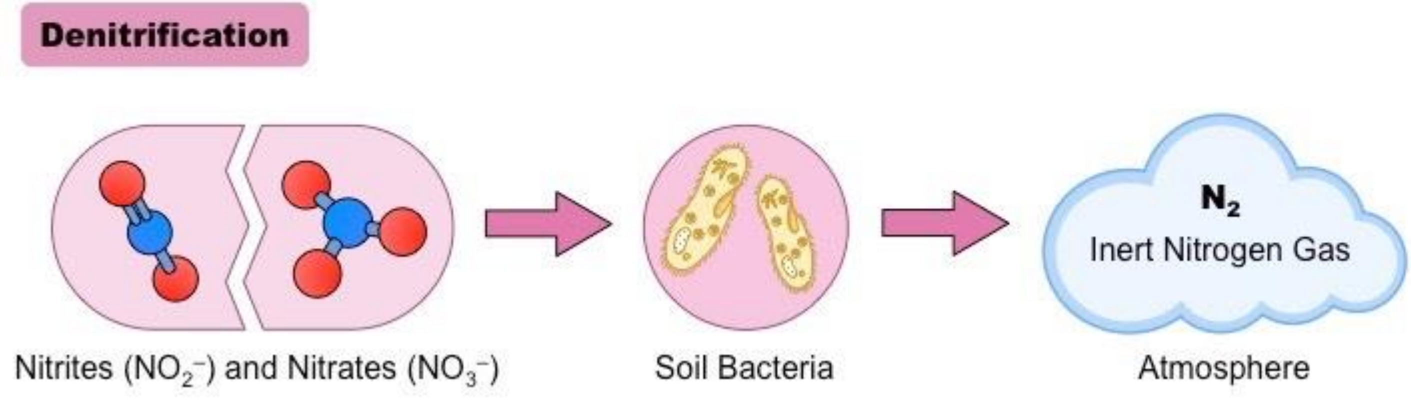
Ammonification

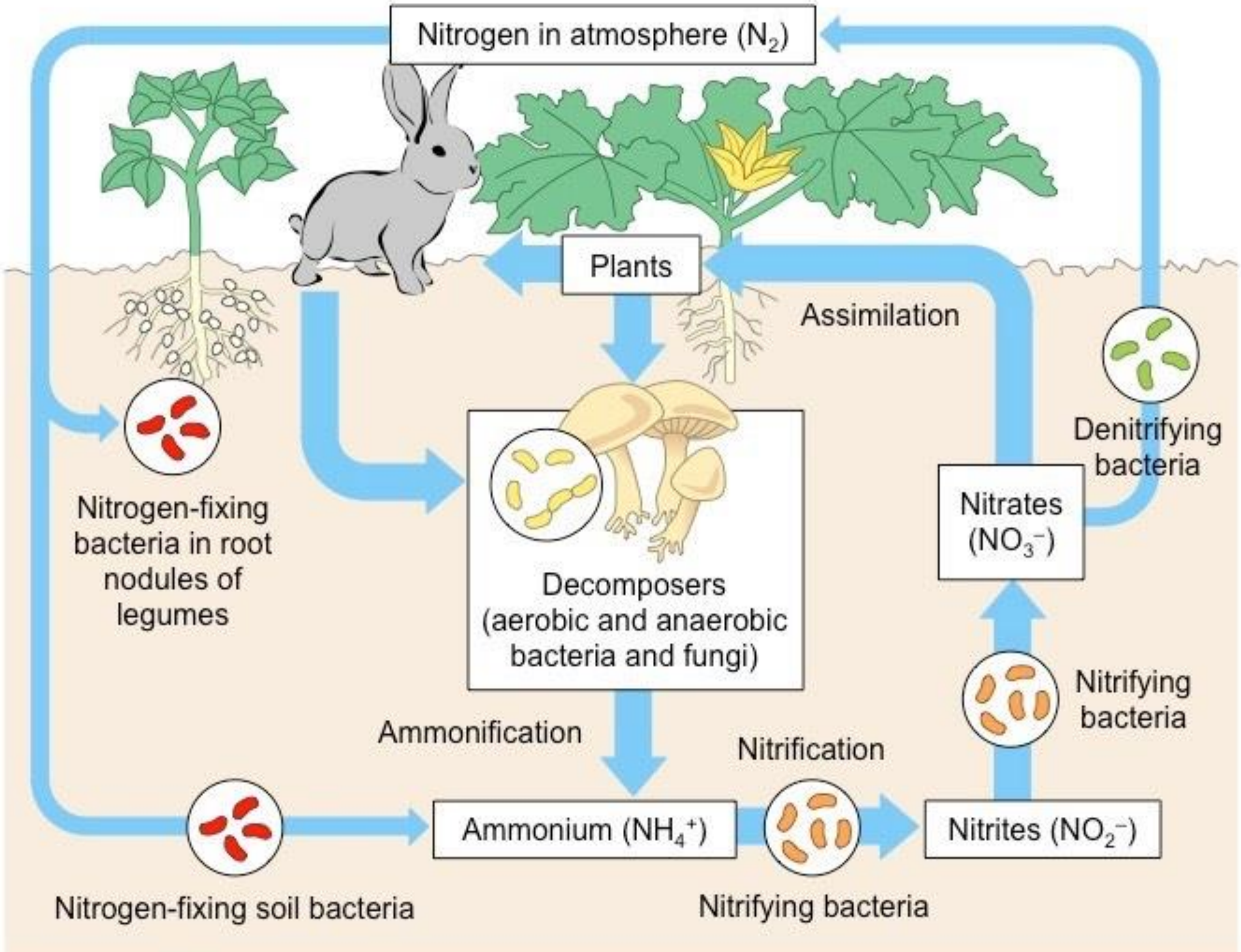
- Ammonia can also be produced from organic sources of nitrogen (e.g. amino acids) when broken down by decomposers
- As a plant or animal decays, saprotrophs will decompose organic materials to produce ammonia (and ammonium ions)
- This process is known as ammonification and releases ammonium ions into the soil which can be absorbed by plants



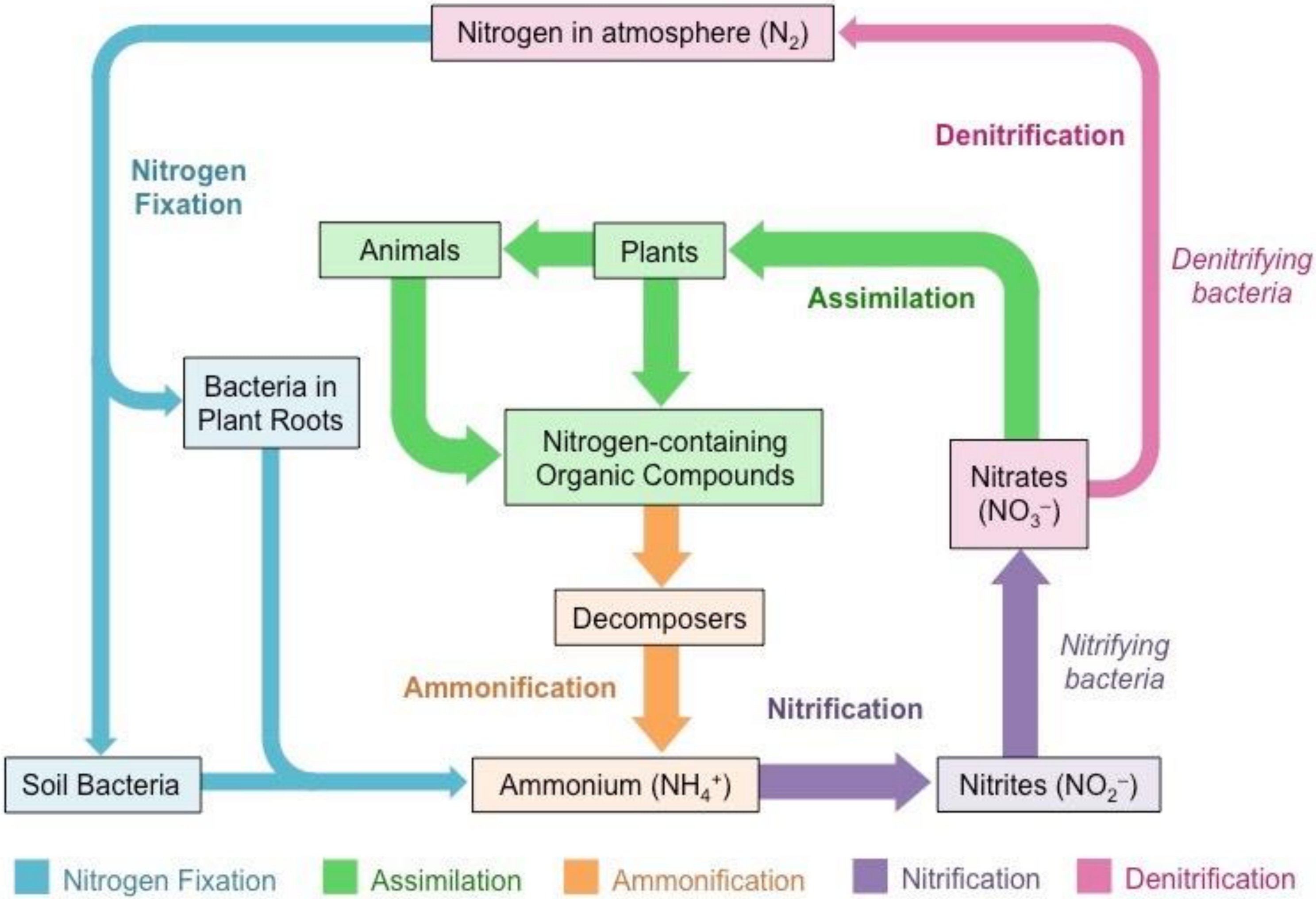
Denitrification

- Denitrification is a chemical reduction process that converts nitrates (NO_3^-) into nitrogen gas (N_2)
- It is carried out by denitrifying bacteria (e.g. *Pseudomonas denitrificans*) in the absence of oxygen (i.e. anoxic conditions)
- Nitrates can be used instead of oxygen as an electron acceptor during cellular respiration, producing nitrogen gas
- This will only occur in oxygen-poor conditions (such as waterlogged soils) and reduces the availability of nitrates to plants





Nitrogen in atmosphere (N_2)
Plants
Assimilation
Denitrifying bacteria
Nitrogen-fixing bacteria in root nodules of legumes
Decomposers (aerobic and anaerobic bacteria and fungi)
Nitrates (NO_3^-)
Nitrifying bacteria
Ammonification
Nitrification
Ammonium (NH_4^+)
Nitrites (NO_2^-)
Nitrogen-fixing soil bacteria
Nitrifying bacteria


Nitrogen in atmosphere (N_2)
Nitrogen Fixation
Denitrification
Animals
Plants
Assimilation
Denitrifying bacteria
Bacteria in Plant Roots
Nitrogen-containing Organic Compounds
Nitrates (NO_3^-)
Decomposers
Nitrifying bacteria
Ammonification
Nitrification
Soil Bacteria
Ammonium (NH_4^+)
Nitrites (NO_2^-)
Nitrogen Fixation
Assimilation
Ammonification
Nitrification
Denitrification

Waterlogging

- Waterlogging occurs when the soil becomes inundated with water, either through flooding or irrigation with poor drainage
- Impacts the nitrogen cycle by reducing the levels of nitrates and nitrites in the soil
  - Waterlogged soil will lose nitrates and nitrites via the process of denitrification
  - Waterlogging reduces oxygen availability in the soil, creating oxygen-poor conditions favored by denitrifying bacteria
  - This bacteria (*Pseudomonas*) will convert available stocks of nitrates into nitrogen gas, reducing soil nitrogen content

Waterlogging

- Waterlogged soil will also lose nitrates and nitrites via the process of leaching
  - Whenever rainfall exceeds evaporation, there will be a build up of water within the porous soil
  - As this water drains downwards through the soil, soluble minerals (like nitrates and nitrites) are removed with it
  - Continual leaching impoverishes the upper layers of soil and concentrates dissolved minerals in the lower bedrock
  - Leaching is most common in highly porous soils (e.g. sandy soils) and least common in textured soils (such as clay)

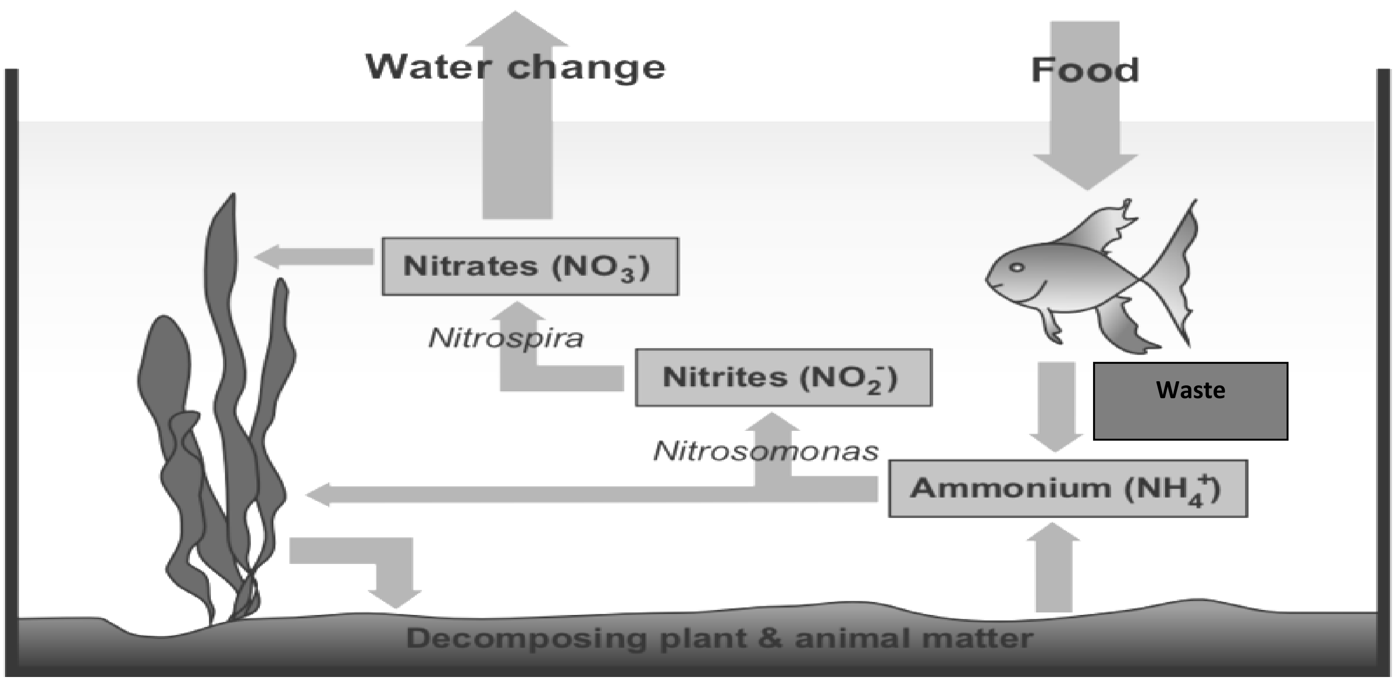
Waterlogging

- Insectivorous plants are able to obtain nitrogen in low-nutrient environments by feeding on invertebrates
- Insectivorous plants include the Venus fly trap, which is native to subtropical wetlands that have waterlogged soil
- The plant's terminal leaves form a trapping structure that is baited by nectar to attract insects
- When trapping has occurred, the plant releases digestive enzymes that allow it to absorb nutrients from the insect
- Insectivorous plants only obtain nitrogen from feeding on insects – they still derive energy from photosynthesis

Eutrophication

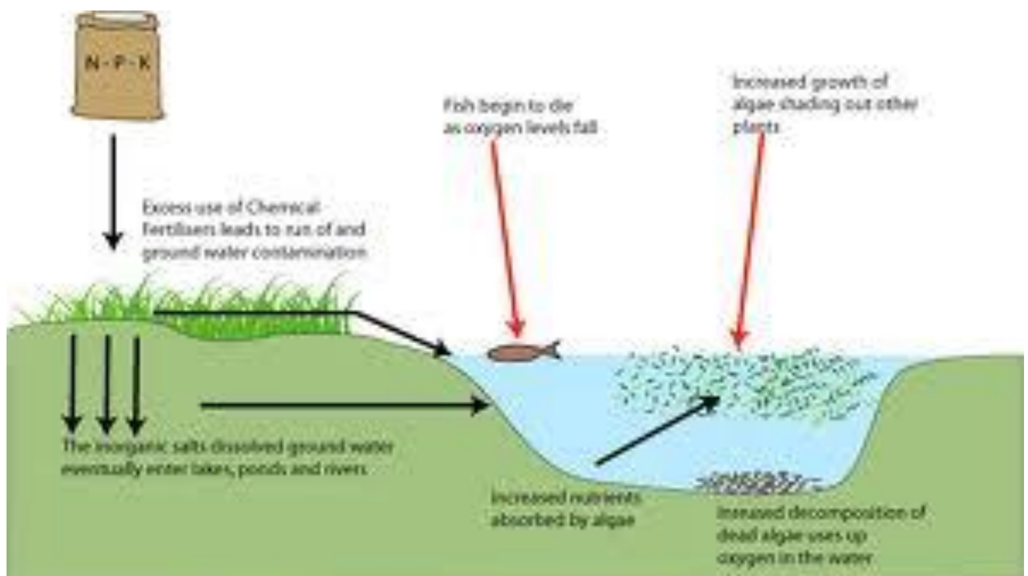
Nitrates/Nitrites

- Nitrogen is a necessity of life used to build proteins
- Bacteria “fix” nitrogen from air into nitrates that plants can actually take up, then animals eat the plants to get their nitrogen source



Human Sources of Nitrates

- Nitrates are relatively harmless to freshwater fish, but act as a fertilizer for plant growth.
- Levels increase as a results of human/animal waste and agricultural run-off containing fertilizers or excess nutrients.
- Excess nitrates will allow more photosynthesis to take place in plants and algae, leading to **eutrophication**.



Eutrophication

- When excess nutrients enter a water body from fertilizer run-off, it can cause an algal bloom
- As resources get used up (space, light, and CO_2), the algae will start to die off.
- Bacteria will begin to rapidly decompose the dying/dead algae, using up LOTS of oxygen
- DO supply is depleted by bacteria, causing extremely low levels of DO (hypoxia/anoxia)
- Bacterial decomposition uses up all of the oxygen, causing other organisms to die too.
- The spread of algae will block out sunlight below the surface and reduce photosynthesis by phytoplankton and seaweeds

C5 Application

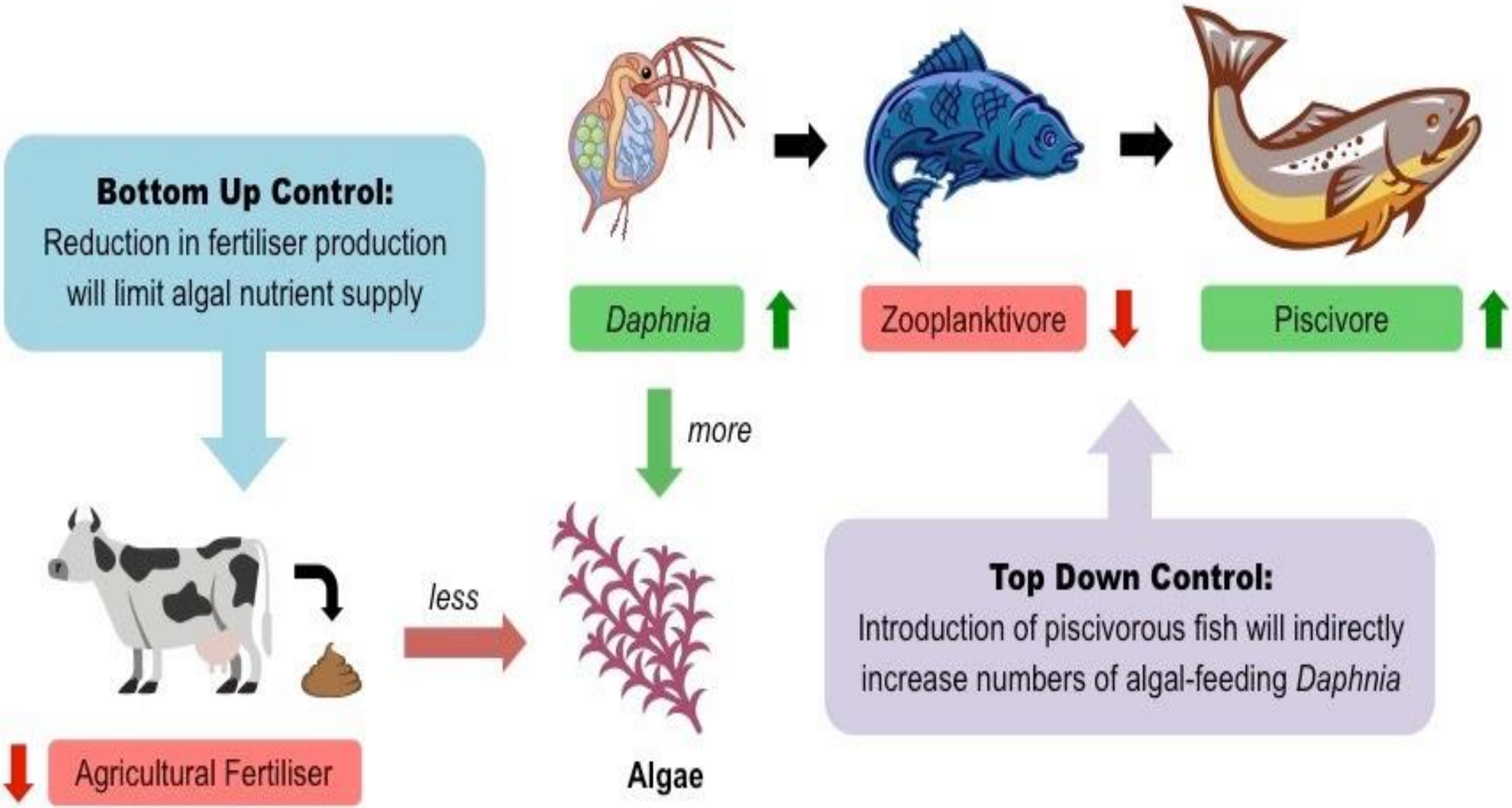
- Algal blooms can be limited by measures that exert either bottom up control or top down control
- The most success will be had if bottom up and top down control measures are used in combination

Bottom Up Control:

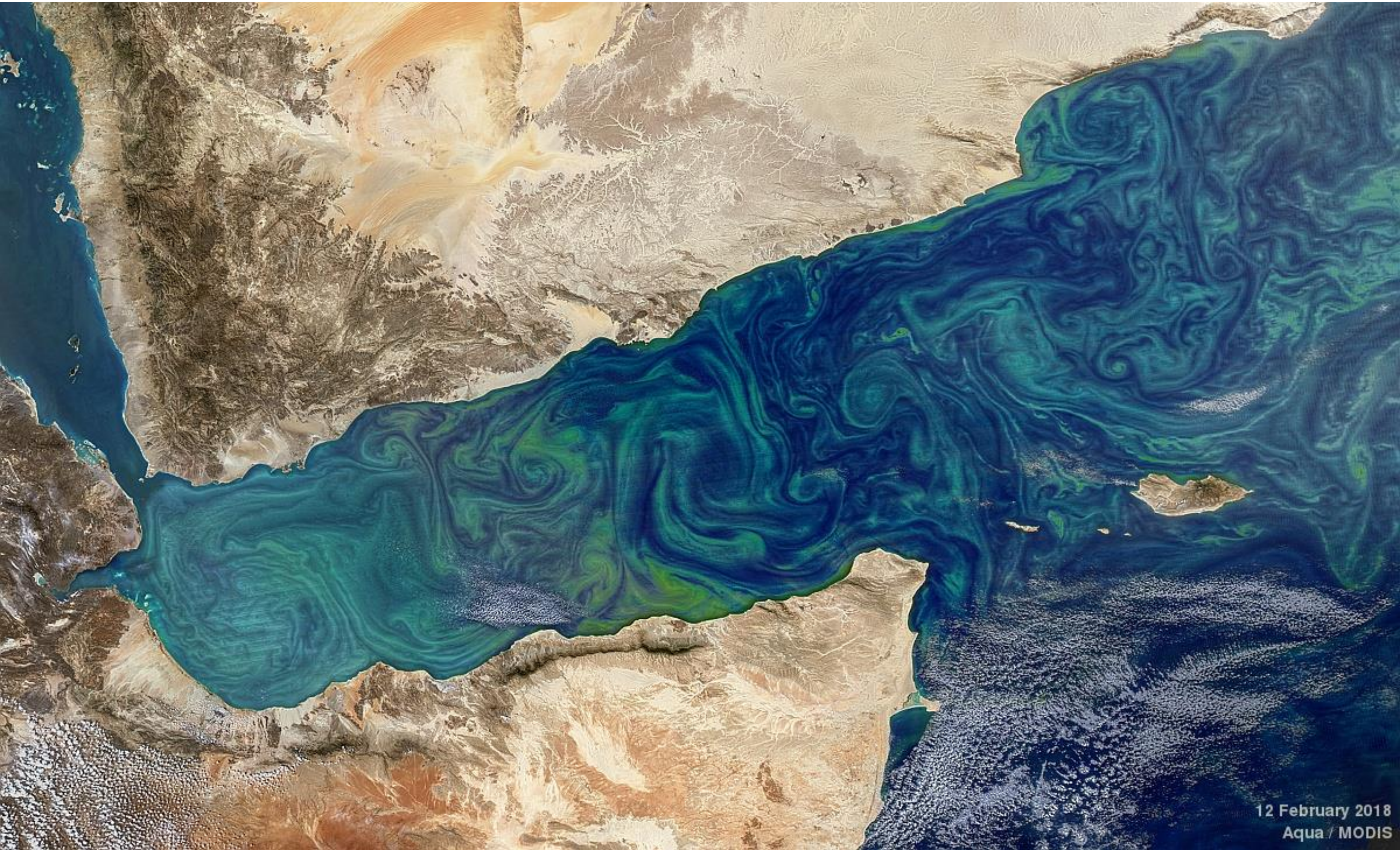
- Algal blooms can be reduced by limiting the supply of nutrients such as nitrogen and phosphorus in the water
- This may involve reducing the use of fertilizers for agricultural practices to limit the nutrient input from surface runoff
  - Nutrient reduction can be expensive to implement and difficult to police, as it requires a concerted community effort

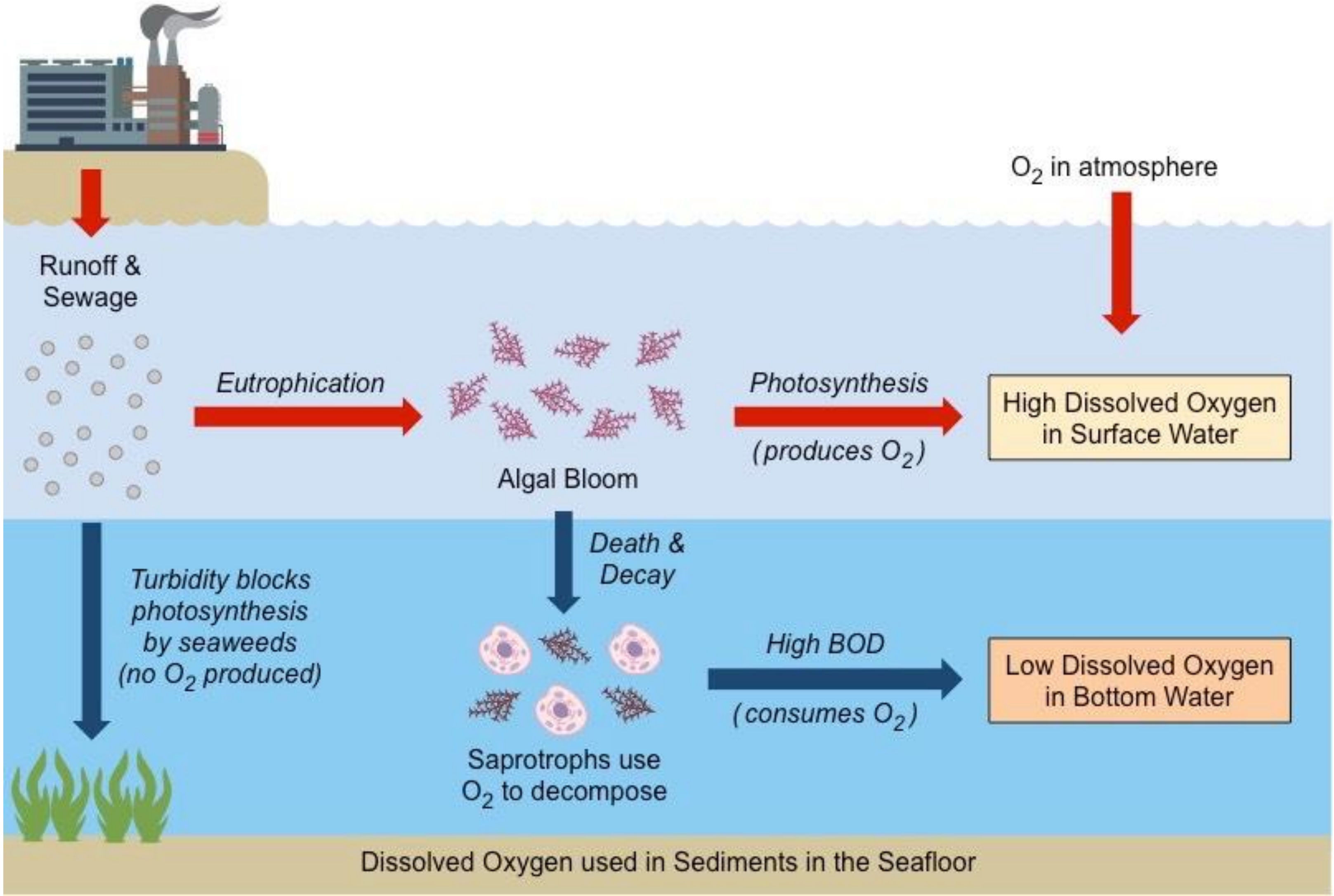
Top Down Control:

- Algal blooms can be reduced by introducing piscivorous (fish-eating) fish into the aquatic ecosystem
- The piscivores will feed on zooplanktivores – and by reducing their numbers, will increase the number of zooplankton
- Zooplankton (such as Daphnia) feed on algae, and hence will reduce the population of algae via herbivory
  - Introducing piscivores can have unintended consequences on food webs and should be done with caution


Bottom Up Control:
Reduction in fertiliser production will limit algal nutrient supply
Daphnia
Zooplanktivore
Piscivore
more
less
Agricultural Fertiliser
Algae
Top Down Control:
Introduction of piscivorous fish will indirectly increase numbers of algal-feeding Daphnia

This Aqua/MODIS scene of the Gulf of Aden on the western end of the Arabian Sea, shows populations of phytoplankton carried along by the turbulent surface currents that are common in this region. This particular scene was collected on February 12, 2018, but the Gulf supports phytoplankton blooms during other seasons of the year as well.





O_2 in atmosphere
Runoff & Sewage
Eutrophication
Algal Bloom
Photosynthesis
(produces O_2)
High Dissolved Oxygen in Surface Water
Turbidity blocks photosynthesis by seaweeds (no O_2 produced)
Death & Decay
Saprotrophs use O_2 to decompose
High BOD
(consumes O_2)
Low Dissolved Oxygen in Bottom Water
Dissolved Oxygen used in Sediments in the Seafloor

Eutrophication Bioninja

- A rapid growth in algal populations will occur (algal blooms) as a result of the increased availability of nutrients
- As the algae die, there will be a subsequent spike in the numbers of decomposing bacteria
- The high rate of decomposition will result in an increased biochemical oxygen demand (BOD) by bacteria
- The bacteria will consume available quantities of dissolved oxygen, leading to deoxygenation of the water supply
- Eutrophication will also increase the turbidity of the water, which will block ligt from reaching photosynthetic seaweeds at the bottom of the water, further reducing oxygen supply
- This will stress the survival of marine organisms, potentially leading to a reduction in biodiversity within the ecosystem

- Algal blooms generally have a detrimental effect on the wider aquatic ecosystem:
- The spread of algae will block out sunlight below the surface and reduce photosynthesis by phytoplankton and seaweeds
- The reduction in light will cause algae to respire instead of photosynthesize, reducing levels of dissolved oxygen in the water
- As algae begin to die, an increase in the numbers of bacterial decomposers will further reduce levels of dissolved oxygen
- Without adequate levels of light or dissolved oxygen, most aquatic organisms within the environment will struggle to survive

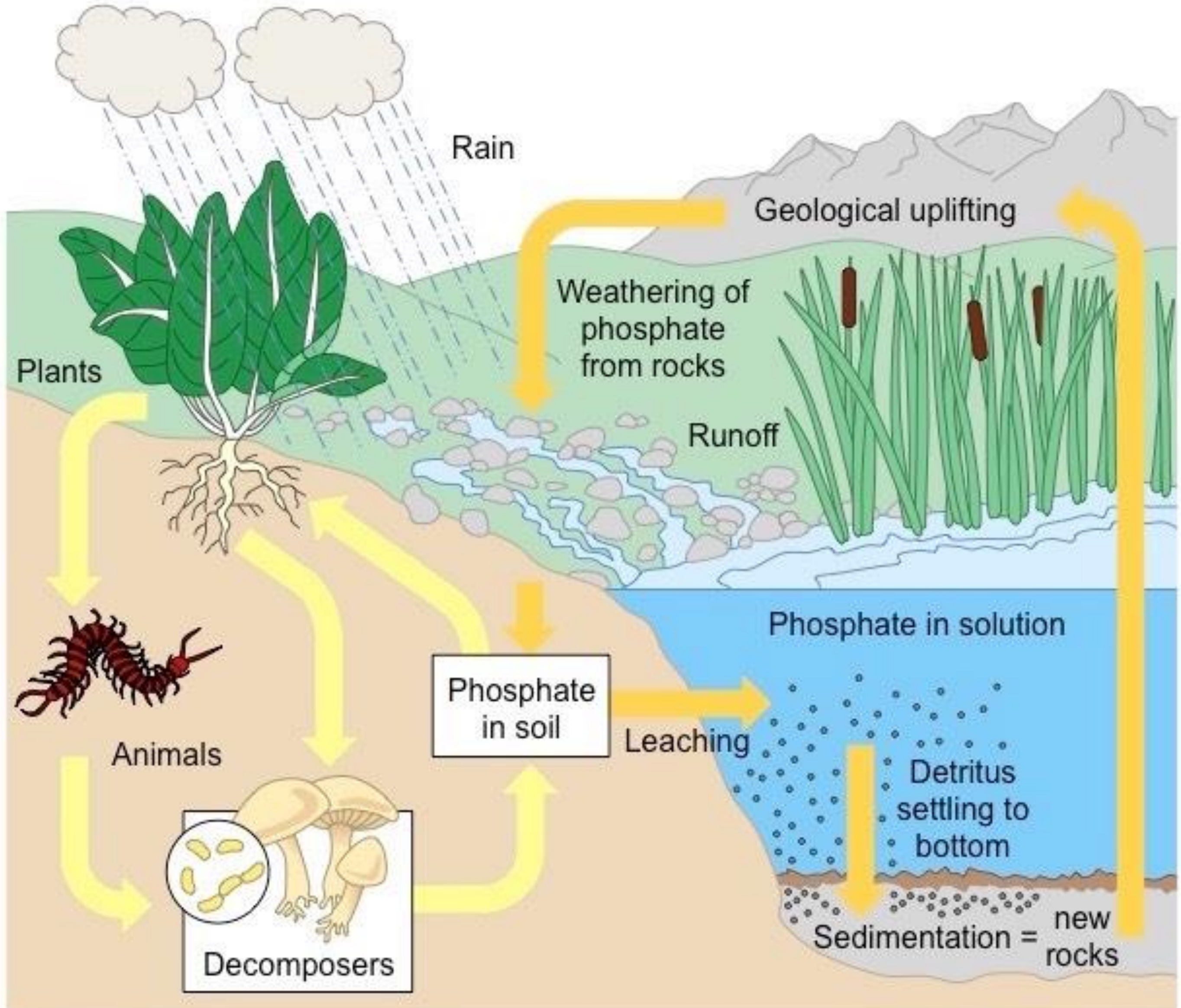
Eutrophication Links

- https://www.nationalgeographic.org/encyclopedia/dead-zone/
- http://new.coolclassroom.org/files/adventures/1/Eutrophication_Teacher.pdf
- https://www.epa.gov/ms-htf/northern-gulf-mexico-hypoxic-zone

Phosphorus Cycle

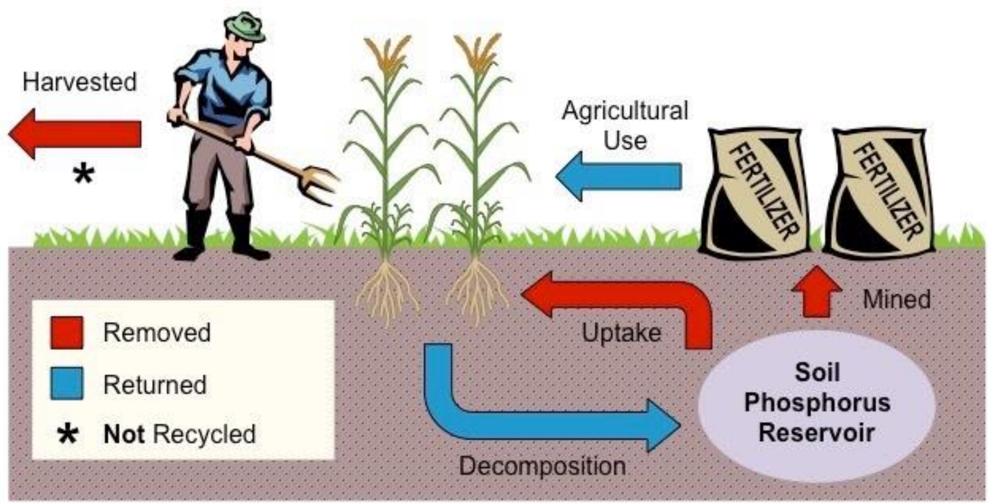
- The phosphorus cycle shows how different forms of phosphorus are transitioned within the environment
  - Certain rocks contain high levels of phosphate, which can be released into the soil and water via chemical weathering
  - Organisms require these phosphates to synthesize nucleic acids, membranes (phospholipids) and ATP
  - Phosphates are returned to the soil upon the decomposition of plant and animal remains

- The phosphorus cycle does **not** include a gaseous component (i.e. it does not involve the atmosphere)
  - This means the rate of turnover in the phosphorus cycle is *much lower* than other cycles (it is released slowly by weathering)
  - This also means the rate of replenishment is extremely slow (phosphates removed from the soil are not quickly replaced)


Rain
Geological uplifting
Weathering of phosphate from rocks
Plants
Runoff
Phosphate in solution
Phosphate in soil
Leaching
Animals
Detritus settling to bottom
Decomposers
Sedimentation = new rocks

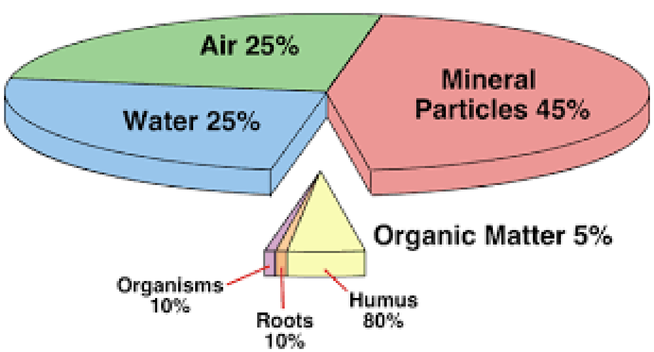
Role of Fertilizers in P Cycle

- Phosphates can be removed from the lithosphere via mining and converted into phosphate-based fertilizers
  - This allows phosphates that would otherwise remain inaccessible in buried rocks to become available for plant use
- The fertilizers are then transported to crops in order to increase their productivity by increasing plant access to phosphate
  - When the crops are harvested, the phosphates that comprise part of the plant's biomass are lost from the phosphorus cycle
- While the application of fertilizer adds phosphorus at one site, it causes the depletion of phosphorus reserves at another site
  - The continued production of phosphate-based fertilizers is depleting global phosphorus reserves at a rapid rate



Soil Content

- The bulk of soil is made up of a mixture of organic matter, rock and mineral particles
  - The relative proportion of all these components, along with pH, determines soil type (e.g. sand, clay, loam, silt, etc.)



- Soil testing kits can be used to identify the amounts of the different components of soil, including:
  - *Nutrients* – chemical reagents produce color changes when testing for nitrogen (N), phosphorus (P) or potassium (K)
  - *Soil pH* – color changes can be used to identify the acidity or alkalinity of a soil sample
  - *Texture* – soil can be separated into layers according to particle size (different particles retain nutrients with varying efficacy
  - *Water content* – electrical meters can determine water quantities based on the soil's capacity to transmit an electrical current