C4.1

Populations & Communities

Species
A group of organisms that can interbreed and produce fertile offspring.

Population
A group of organisms of the same species who live in the same area at the same time.

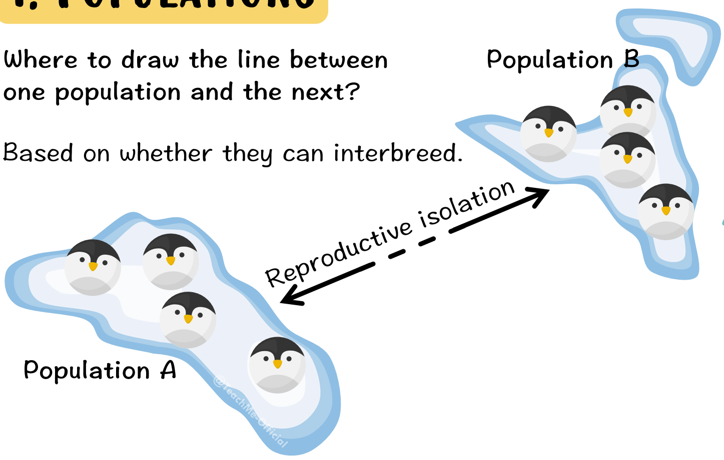
Community
A group of populations living and interacting with each other in an area.

Ecosystem
A community and its abiotic environment.

I. Populations

Where to draw the line between one population and the next?

Based on whether they can interbreed.



Abiotic (non-living) factors:

Sunlight intensity and duration
Water availability
Soil composition
Temperature range
Salinity
pH range

[These factors can limit the survival of organisms]

A. Carrying capacity

NO HABITAT can accommodate an **unlimited** number of organisms: growth of a population eventually stops or plateaus.

What: The maximum number of individuals that a particular habitat can support. It is represented by the letter K.

Limiting factor: A factor that LIMITS the survival of an organism. These factors define the carrying capacity of a habitat.

Example: Forest trees, new tree seedling, and sunlight.

Population growth → Higher density

Density Dependent Factors
Ones that affect a population more as the population number increases.

Predators
Availability of recources
- Shelter
- Water
- Space
- Sunlight
- Oxygen

Nutrient supply (food)
Disease spread
Accumulation of waste
- Urine & feces
- Dead organisms

P A N D A P A W

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Density Independent Factors
Ones that affect the population no matter how big or how small the population is.

Phenomena (natural disasters)
- Forest fires
- Volcanic eruptions
- Earthquakes

Abiotic factors
- Temperature
- Carbon dioxide levels (ocean acidity)

Weather conditions
- Climate Change
- Storms, hurricanes
- Floods

Keep population at carrying capacity

Help or hinder the population

Negative feedback Feedback system that works to return a condition back to its normal range.

Positive feedback Feedback system that reinforces a response or change in a condition.

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Populations & Communities

B. HOW ARE POPULATIONS CONTROLLED?

A population is controlled usually within its own food chain, whether from the TOP by a predator feeding on it or from the BOTTOM due to availability of resources.

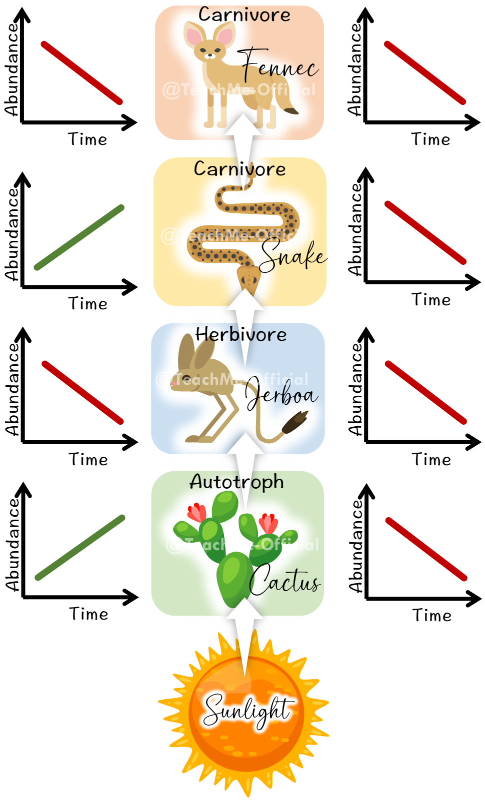
For example; let's consider the population of **Jerboas** in a desert:

TOP DOWN

When a population is reduced by other species feeding on it.

Examples: Predatory, Herbivory

If the fennec population at a higher trophic level decreases for example due to hunting, it allows for the snakes to thrive as they are not being predated on. This increases the number of predators which feed on jerboas, ultimately decreasing its population.



If sunlight hours were to be reduced, the growth of cacti would be affected, reducing its population of time, thus reducing the amount of food available to the jerboa, thus also decreasing its population. Notice how all the trophic levels are affeced in a bottom up population control.

Examples: Lack of food, sunlight, mineral etc.

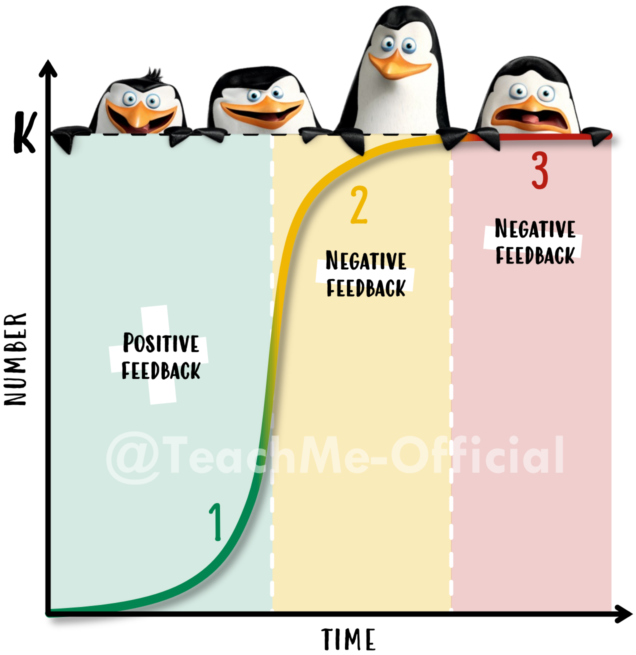
When a population is reduced by a lack of resources.

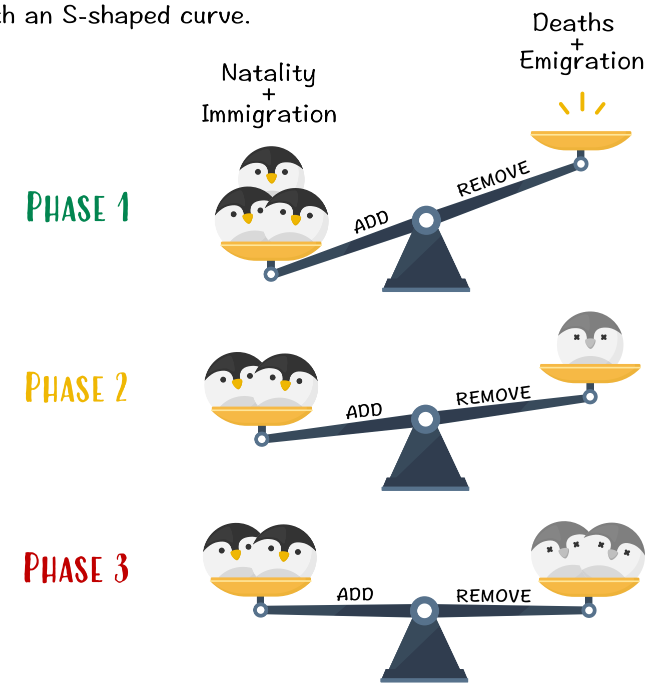
BOTTOM UP

Populations & Communities

C. Population growth

Population growth over time has three stages. Shown with an S-shaped curve.





Phase 1 Exponential (logarithmic) phase

Number of individuals increases at a faster and faster rate (positive feedback)

Mechanism:

Small population breeds → More individuals → More reproduction → More individuals.

Reasons:

- Plentiful resources, such as food, space and light (for photosynthetic organisms).
- Little or no competition for other inhabitants.
- Favorable abiotic factors, including temp, oxygen (especially for aquatic organisms).
- Little or no predation or disease.

Phase 2 Transitional phase

The growth rate slows down considerably (due to negative feedback)

Mechanism:

Density dependent factors works to control the size of the population so that it cannot go over its carrying capacity.

Reasons:

- More individuals leads to more competition for resources.
- Predators are attracted by growing food supply.
- More people in limited space, easier for disease spread.

Phase 3 Plateau (stationary) phase

The number of individuals stabilizes, and there is no more growth (negative feedback)

Mechanism:

Density dependent factors continue to works to control the size of the population so that it cannot go over its carrying capacity.

Reasons:

- Plants, less available space for seeds produced to germinate.
- Limited food supply for herbivores. less offspring/migrate.
- Predators and disease
- Number of births plus immigrations = deaths + emigrations.

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D. Estimating population size

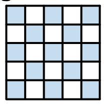
Things to measure:

Population number | Population density | Geographical distribution

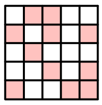
(1) Count each individual
- ✗ Time consuming, difficult, moving, hiding, swimming etc.

(2) Count with estimates → Take Sample
- ✗ Error, low reliability

Take Sample:
- **Systematic**: A grid/line is set up and measurements are carried out at specified, regular intervals.



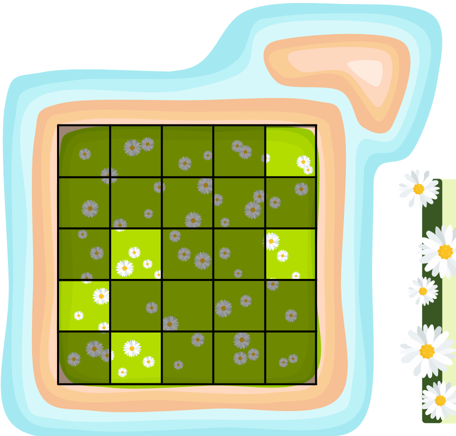
- **Random**: Arbitrarily chosen zones are sampled.



Sampling sessile organisms

Method: Random or systematic sampling can be used.

Quadrat: a square of a particular dimension, that can be made of a rigid material such as metal, plastic or wood. Ensures surface area of sample is the same for each count you take.



Useful for plants, lichens and corals (of very slow organisms)

"Sampling error"

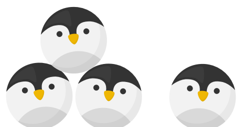
Example — extrapolating the number of daisies

$$\textit{total number of daisies} = \frac{\textit{number of daisies counted}}{\textit{number of quadrats}} \times \textit{total number of quadrats}$$

$$\frac{2+4+3+3+3}{5} \times 25 = \frac{15}{5} \times 25 = 3 \times 25 = 75$$

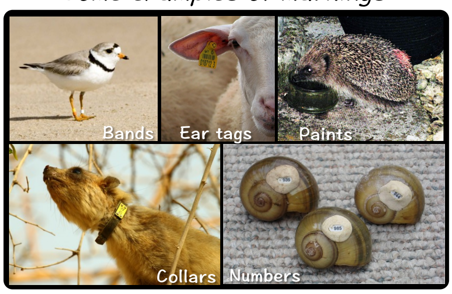
Sampling motile organisms

Method: Capture-mark-release-recapture method



1. Capture animals, count them.
2. Mark them.
3. Release marked animals back. Remix with others in the population.
4. Recapture them and count them..

Some examples of markings

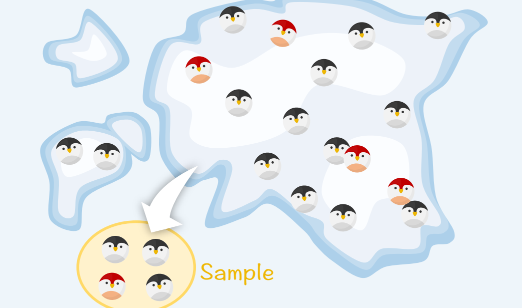


Lincoln Index

total population = n. of individual caught and marked initially (M) × number of all individual recaptured (N) / number of marked individuals recaptured (R)

$$\text{total population} = M \times \frac{N}{R}$$

Example Estimating a penguin population size



Initially, 5 penguins were captured and marked

4 were recaptured, one of which was already marked

Using the Lincoln index we find:

$$\textit{total population} = 5 \times \frac{4}{1} = 20$$

Assumptions

- The population is closed, with no immigration or emigration.
- Mixing is complete between release and recapture.
- Equally easy to catch each individual in the population.
- Marks are not removed/disappear between capture and recapture.

Limitations

- Capturing and marking the animals may injure them.
- Mark makes animals can be more visible to predators (marked animals are eaten, second sample not reliable).

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II. Communities

A. Intraspecific Relationships

(Intra = Within; specific = Species)

Relationships that occur between individuals of the same species.

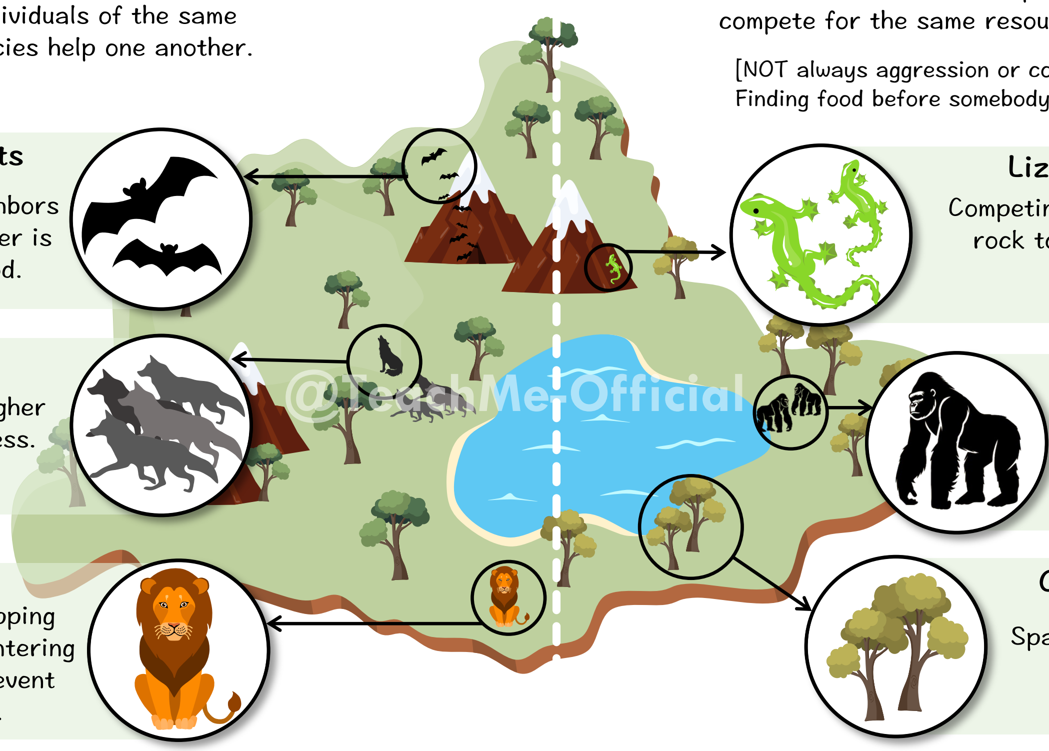
Cooperation (win/win)

Individuals of the same species help one another.

Competition (win/lose)

Individuals of the same species compete for the same resources.

[NOT always aggression or combat. Finding food before somebody else.]



Vampire bats

Caring for a neighbors young while mother is looking for food.

Wolves

Pack hunting. Higher chance of success.

Lions

Take turns stopping intruders from entering territory to prevent exhaustion.

Lizards

Competing for sunny rock to bask on.

Gorillas

Alpha males, leading to mating.

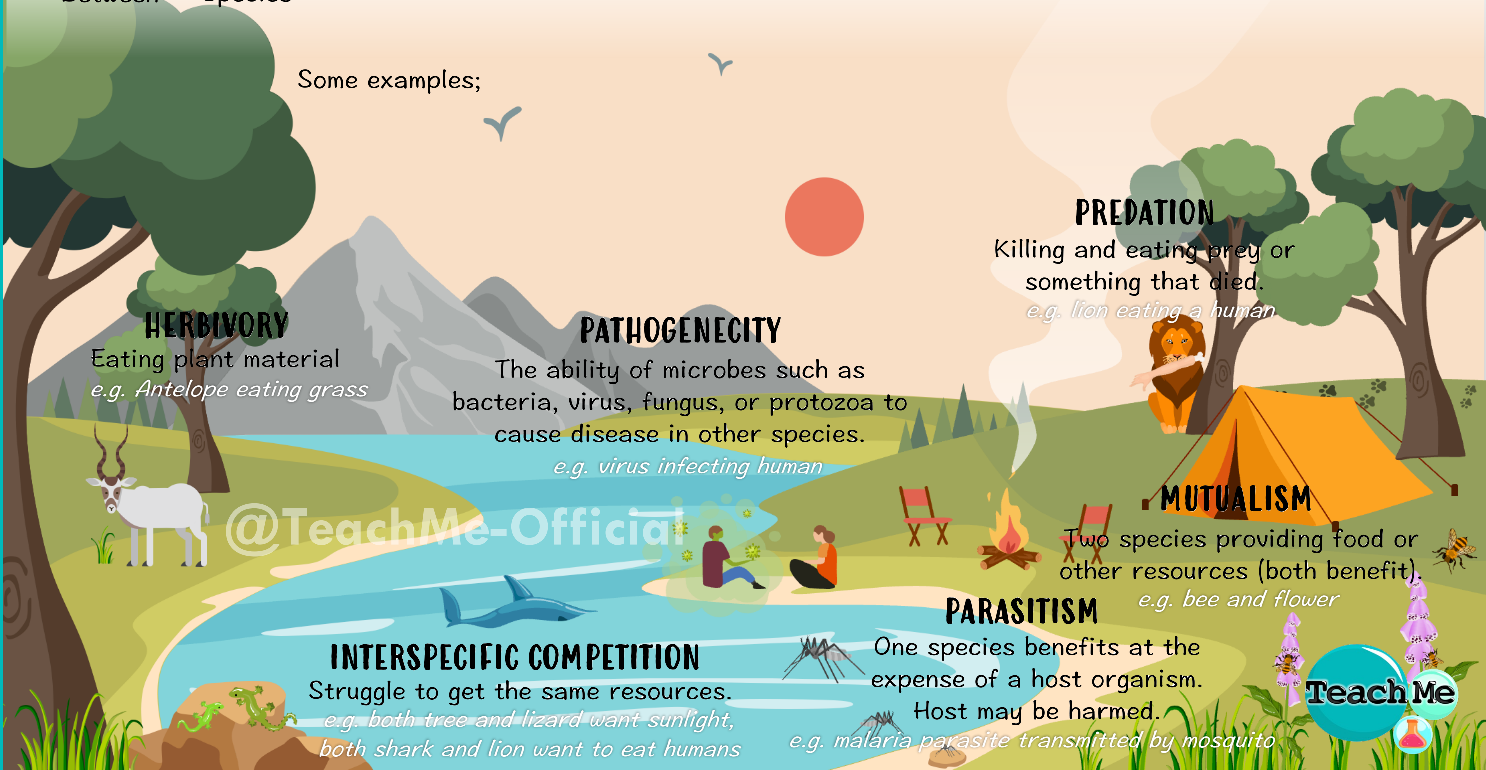
Oak trees

Space and sunlight.

B. Interspecific Relationships

(Inter = Between; specific = Species)

Relationships between different species in a community.



Some examples;

HERBIVORY

Eating plant material

e.g. Antelope eating grass

PATHOGENECITY

The ability of microbes such as bacteria, virus, fungus, or protozoa to cause disease in other species.

e.g. virus infecting human

PREDATION

Killing and eating prey or something that died.

e.g. lion eating a human

MUTUALISM

Two species providing food or other resources (both benefit).

e.g. bee and flower

PARASITISM

One species benefits at the expense of a host organism. Host may be harmed.

e.g. malaria parasite transmitted by mosquito

INTERSPECIFIC COMPETITION

Struggle to get the same resources.

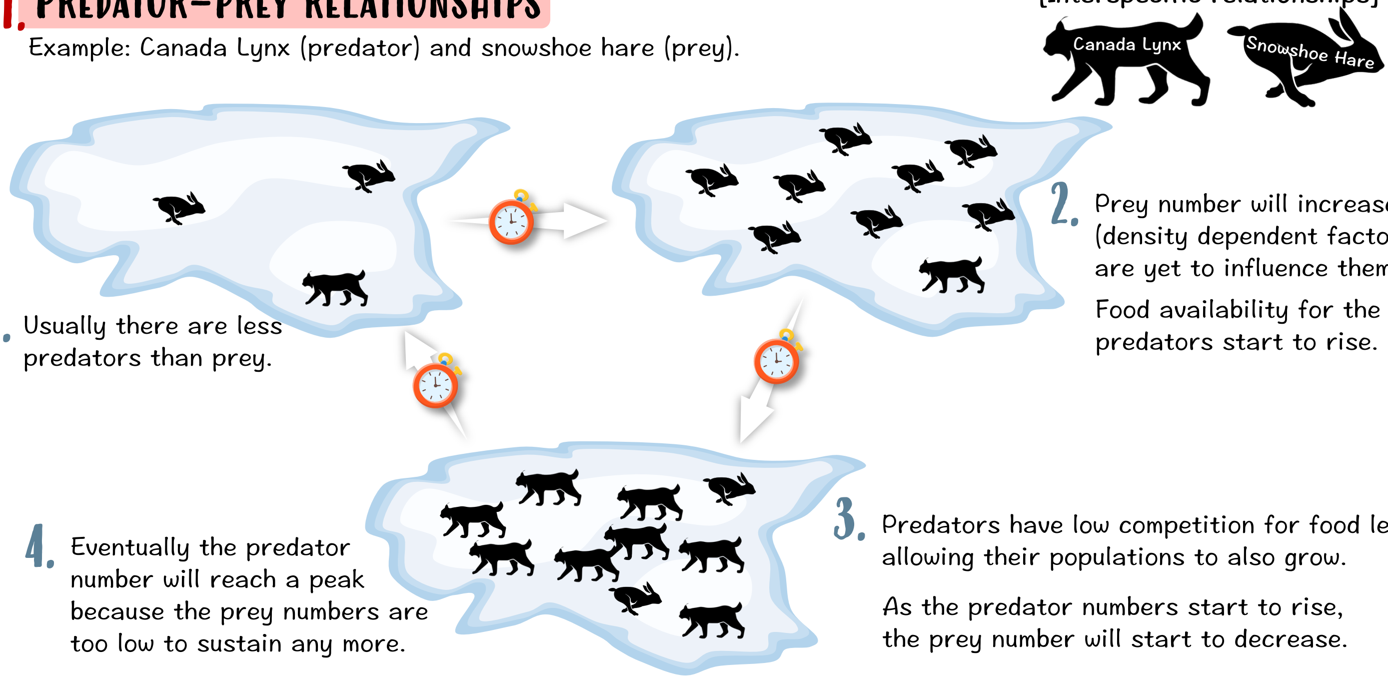
e.g. both tree and lizard want sunlight, both shark and lion want to eat humans

Populations & Communities

1. Predator-prey relationships

Example: Canada Lynx (predator) and snowshoe hare (prey).

[Interspecific relationships]



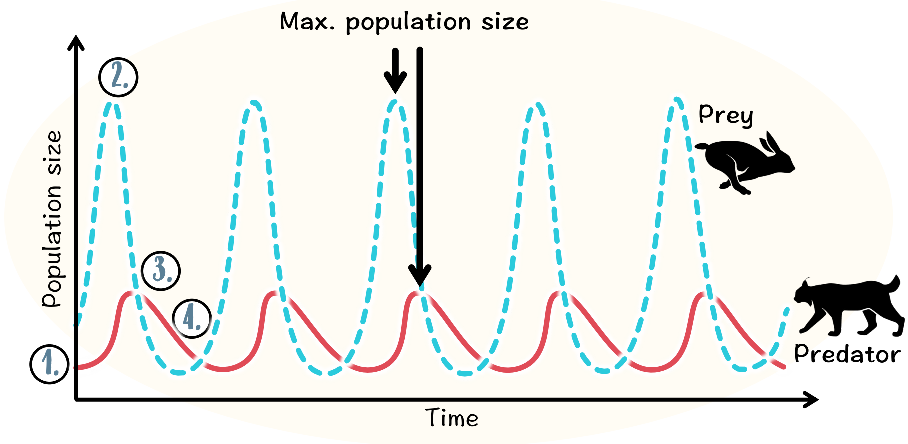
1. Usually there are less predators than prey.

2. Prey number will increase (density dependent factors are yet to influence them).
Food availability for the predators start to rise.

3. Predators have low competition for food less, allowing their populations to also grow.
As the predator numbers start to rise, the prey number will start to decrease.

4. Eventually the predator number will reach a peak because the prey numbers are too low to sustain any more.

Simplified model of the relationship between predator and prey numbers:



- The maximum is out of sync (predator always after prey).
- The two lines cross shortly after the predator population reaches its maximum, soon the prey population reaches its minimum.

C4.1 Populations & Communities

2. Mutualism

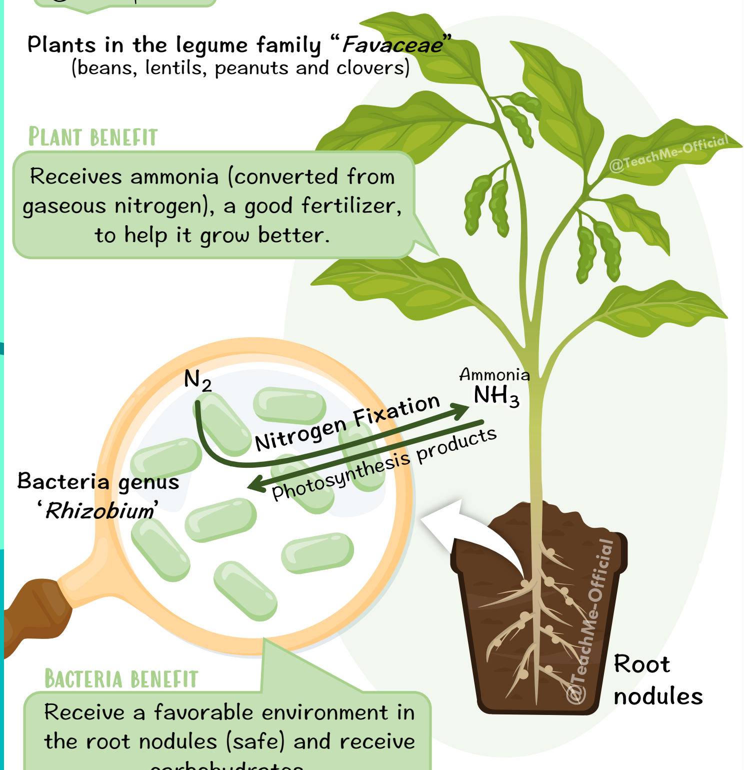
Two different species help each other survive and thrive (WIN/WIN).
Interspecific cooperation that benefits both.

Example 1 Plant root nodules and bacteria

Plants in the legume family "*Favaceae*" (beans, lentils, peanuts and clovers)

Plant benefit

Receives ammonia (converted from gaseous nitrogen), a good fertilizer, to help it grow better.



Bacteria benefit

Receive a favorable environment in the root nodules (safe) and receive carbohydrates.

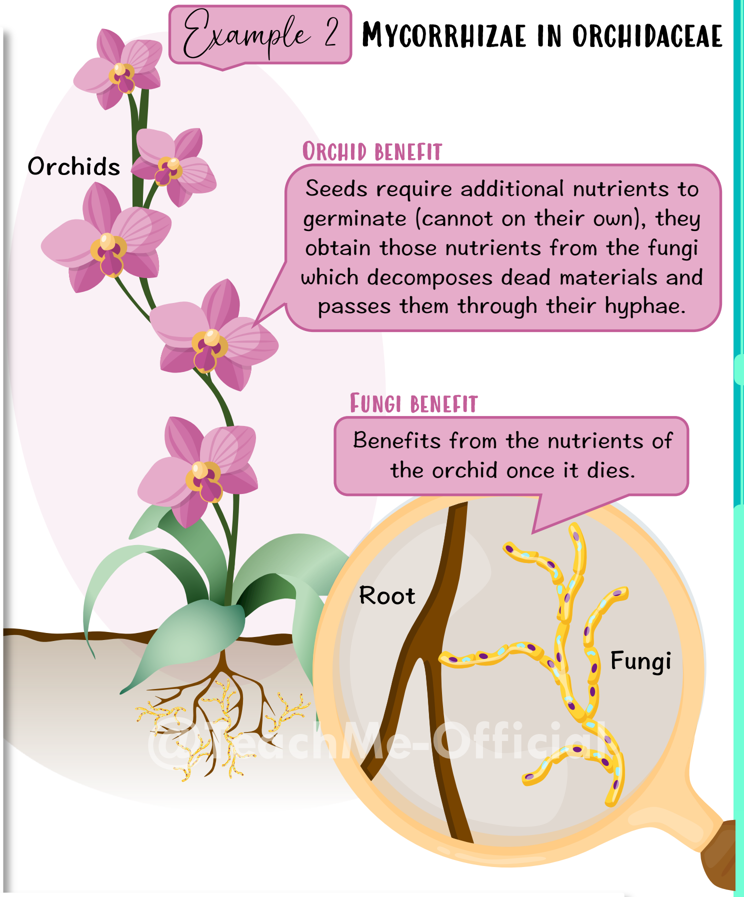
Example 2 Mycorrhizae in Orchidaceae

Orchid benefit

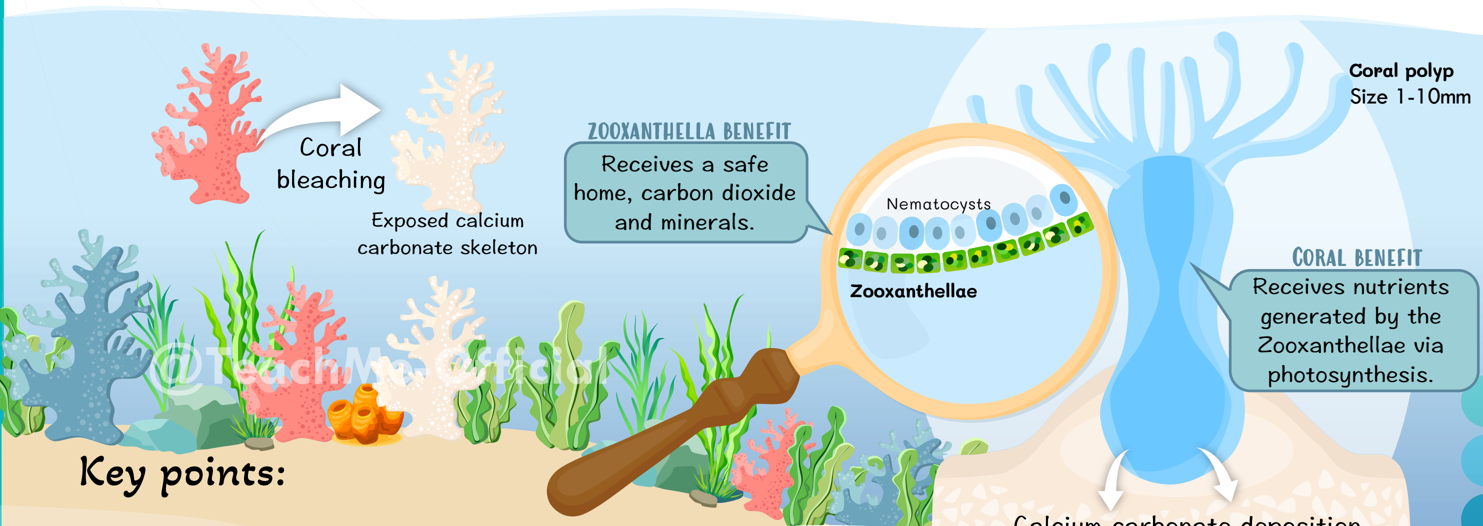
Seeds require additional nutrients to germinate (cannot on their own), they obtain those nutrients from the fungi which decomposes dead materials and passes them through their hyphae.

Fungi benefit

Benefits from the nutrients of the orchid once it dies.



Example 3 Zooxanthellae in hard corals



Zooxanthella benefit

Receives a safe home, carbon dioxide and minerals.

Coral benefit

Receives nutrients generated by the Zooxanthellae via photosynthesis.

Key points:

- Zooxanthellae (phylum Dinoflagellates) are pigmented (gives the coral color) and do photosynthesis.
- Nematocysts cause stinging to deter predators.
- Coral polyps obtain nutrients in two manners: eating (zooplankton) and with help of zooxanthellae (major contribution).
- Coral bleaching is a phenomenon that happens when the zooxanthellae leave or die.

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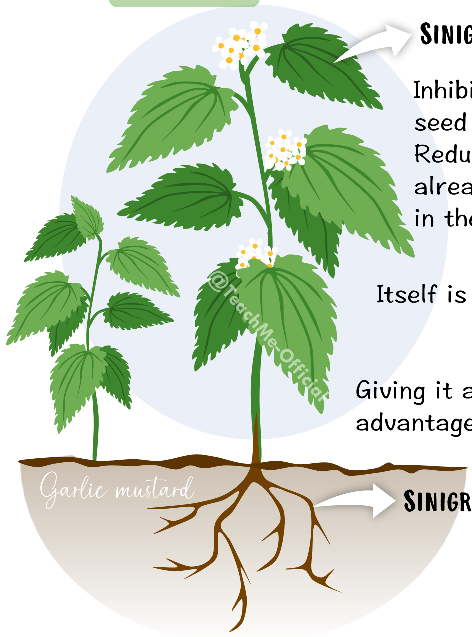
3. Allelopathy

A phenomenon by which one organism produces metabolites that influence the growth, and success of other organisms.

- **Primary metabolites** – Involved in normal growth.
- **Secondary metabolites** – Made to impede or kill.

In Plants



SINIGRIN

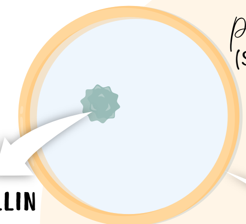
Inhibit OTHER plant seed germination, Reduce root growth of already growing plants in the area.

Itself is not affected.

Giving it a competitive advantage.

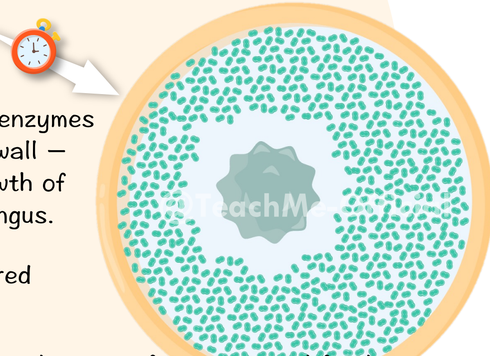
SINIGRIN

In Microbes



Penicillium rubens (Single-celled fungus)

PENICILLIN



Penicillin blocks bacterial enzymes involved in building cell wall – thus preventing the growth of bacteria around the fungus.

Penicillin is considered as an antibiotic.

Competitive advantage for space and food. Also allow their own colonies to spread while inhibiting the spread of competing colonies.

4. Investigating Interspecific Competition

METHOD ONE: Field observation

Presence-absence matrix: Presence of a species in a zone = 1; Absence of a species in a zone = 0

Sites

Species	A	B	C	D	E
1	1	1	0	0	0
2	0	1	1	1	1

1 – *Chthamalus* barnacles
2 – *Semibalanus* barnacles

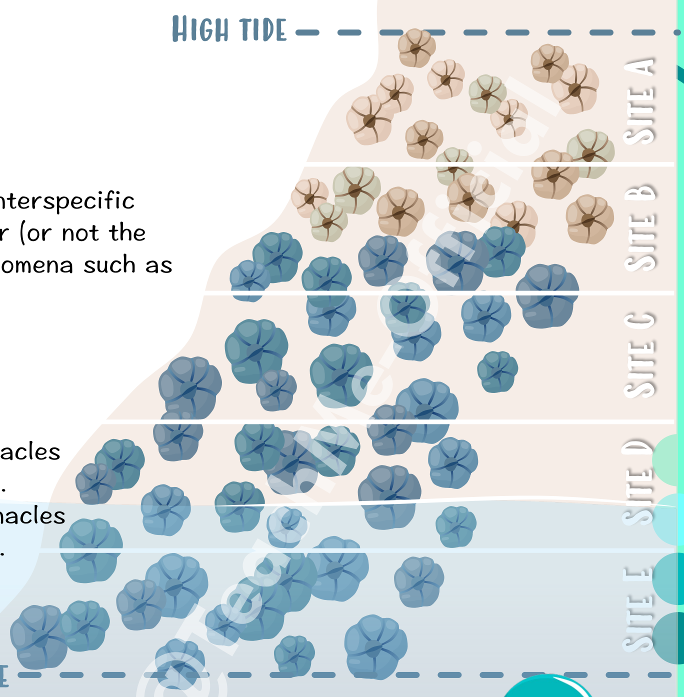
Although through observation, we may conclude the presence of interspecific competition to explain the results. But it is not always the answer (or not the only one). In science, to find an answer related to ecological phenomena such as competition, we use multiple techniques including:

METHOD TWO: Field manipulation

- when the **CHTHAMALUS** barnacles are removed, the **SEMIBALANUS** barnacles do **not** take over the area (suggested no interspecific competition).
- when the **SEMIBALANUS** barnacles are removed, the **CHTHAMALUS** barnacles take over their area (showing there was interspecific competition).

Watch the video to see the animated version of this method

METHOD THREE: Laboratory experiments



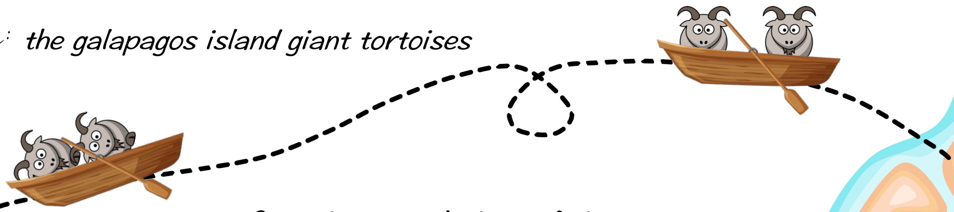
Populations & Communities

5 ENDEMIC AND INVASIVE SPECIES

Endemic: Only found there and nowhere else.

Invasive: One that is non-native, and when introduced into this new area starts to cause problem for the species that are already living there.

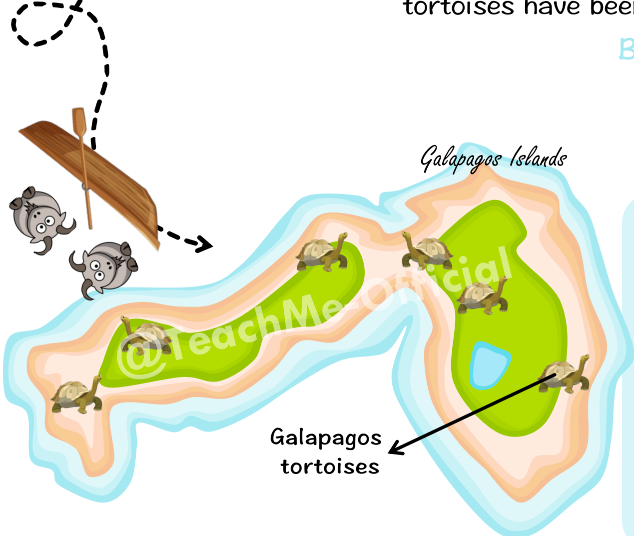
Example: *the galapagos island giant tortoises*



Over time, populations of giant tortoises have been decimated.

But why?

(1) Humans eating them
(2) Competition with **invasive species** (goats)



Humans brought goats to the islands to breed as a supply of meat.

↓

Some escaped and formed feral populations.

↓

Goats compete with tortoises for grazing space. More rapid, and less predators.

↓

To fix this, culling and eradication programs have been implemented over several decades.

Populations & Communities

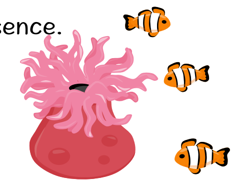
CHI SQUARED TEST (Test of association / Test of independence)

[A test used to measure how **EXPECTATIONS** compare to actual **OBSERVED** data]

This concept will be explained using an example:

Example - **The association between anemones and clown fish.**

Step 1 I want to investigate wether or not the presence of clown fish is dependent on anemone presence. For this I first need to set up my hypotheses:

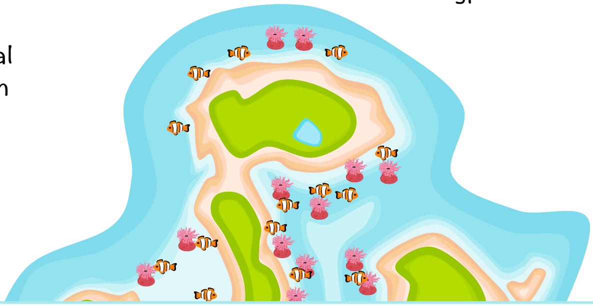


Null Hypothesis (H_0) — Clown fish presence is **independent** of anemone presence.

Alternative Hypothesis (H_1) — Clown fish presence is NOT **independent** of anemone presence.

By calculating the **Chi Squared test** value, I will determine whether I can **ACCEPT** or **REJECT** the alternative hypothesis.

Step 2 I then conduct my experiment by placing quadrats in a coral reef habitat 50 times and recording each quadrat based on whether clown fish and anemone are present or absent. I organize my data in a table as such:



Observed values:

	Clown fish present	Clown fish absent	Total
Anemone present	28	2	30
Anemone absent	7	13	20
Total	35	15	50

Example to illustate the meaning of expected value:

If you can throw a 6 on a die and a head on a coin you, get $1000

What is the odds of succeeding?

$$\frac{1}{6} \times \frac{1}{2} = \frac{1}{12}$$

Step 3 From this table I can now calculate the **EXPECTED VALUE** for each cell and organize them into a table:

Full working for: Both clown fish and anemone present:

$$\frac{30}{50} \times \frac{35}{50} \times 50 = \frac{1050}{2500} \times 50 = 0.42 \times 50 = 21$$

$\frac{\text{total of anemone present}}{\text{total}}$

$\frac{\text{total of clown fish present}}{\text{total}}$

total

odds/frequency

Expected values:

	Clown fish present	Clown fish absent	Total
Anemone present	21	9	30
Anemone absent	14	6	20
Total	35	15	50

Step 4 Using the observed values and expected values, I can now calculate the Chi-squared value for my data using the following equation:

$$\chi^2 = \sum \left(\frac{(O - E)^2}{E} \right)$$

Chi-squared

Observed

Expected

SUM

$$X^2 = \frac{(28 - 21)^2}{21} + \frac{(2 - 9)^2}{9} + \frac{(7 - 14)^2}{14} + \frac{(13 - 6)^2}{6} = \mathbf{19.44}$$

Step 5 Now that I have the X^2 value, I need to interpret it (see next page):

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Step 5 Now that I have the X^2 value, I need to interpret it by capering my value to a critical value table (this table doesn't need to be memorized, it would be given to you in an exam).

Degrees of freedom (d.f.)	Probability values				
	0.1	0.05	0.025	0.01	0.005
1	2.706	3.841	5.024	6.635	7.879
2	4.605	5.991	7.378	9.21	10.597
3	6.251	7.815	9.378	11.345	12.838
4	7.779	9.488	11.143	13.277	14.86
5	9.236	11.07	12.833	15.086	16.75

This is calculated with;
(row-1)(column-1) = 1

Compare the χ^2 value to the critical value table.

$$19.44 > 3.84$$

We reject the **NULL HYPOTHESIS**, and accept alternative hypothesis. Clown fish presence is NOT independent of anemone presence.

notes