REVISION GUIDE

How many, and *why* not more?

Populations and communities

Nobody counts every buttercup in a meadow or every woodlouse under a log. Estimate them with quadrats and mark and recapture, grow yeast in a flask until it stops, test whether two plants grow together with chi-squared, and watch lynx and hares chase each other's numbers round a ten-year cycle.

9 chapters · a dry lab

The interactive guide, with every animation:

biologybybradford.com/guides/ib-biology-c4-1-populations-and-communities

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By the end you can

- [ ] Describe a population as an interacting, interbreeding group of one species in an area C4.1.1
- [ ] Explain why populations are estimated by random sampling, and what sampling error is C4.1.2
- [ ] Estimate a population of a sessile organism with random quadrats, and read its standard deviation C4.1.3
- [ ] Estimate a population of a motile organism with the Lincoln index, and state its assumptions C4.1.4
- [ ] Define carrying capacity and name resources that limit it C4.1.5
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- [ ] Explain the phases of a population growth curve, and test the exponential phase on a log scale C4.1.7
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- [ ] Compare competition and cooperation within a species, with real examples C4.1.9
- [ ] Describe a community as all the interacting populations in an area C4.1.10
- [ ] Give an example of herbivory, predation, competition, mutualism, parasitism and pathogenicity C4.1.11
- [ ] Explain the benefits to both partners in root nodules, orchid mycorrhizae and coral zooxanthellae C4.1.12
- [ ] Explain how an invasive species can outcompete endemic species for resources C4.1.13
- [ ] Describe experiments and observations that test for interspecific competition C4.1.14
- [ ] Use a chi-squared test for association between two species C4.1.15
- [ ] Explain predator-prey cycles as density-dependent control, with a real case C4.1.16
- [ ] Distinguish top-down from bottom-up control of populations C4.1.17
- [ ] Describe allelopathy and the secretion of antibiotics, with an example of each C4.1.18

Tick each one when you can do it without the book.

C4.1.1 C4.1.2 POPULATIONS AS INTERACTING GROUPS OF ORGANISMS OF THE SAME SPECIES LIVING IN AN AREA ESTIMATION OF POPULATION SIZE BY RANDOM SAMPLING

01 Who counts as *one* population?

A **population** is a group of organisms of one species living in one area, close enough to interact and, normally, to breed with each other. Frogs round one pond are a population. Frogs of the same species round a pond on the far side of a motorway are a different population: they could breed with the first group if they ever met, but the road keeps them reproductively isolated.

Ecologists want to know how big a population is, and whether it is growing or shrinking, to manage a fishery, protect a rare orchid or track a pest. Counting every individual is almost never possible: there are too many, they hide, or counting would damage the habitat. So they take a **sample** and scale it up to an estimate.

The sample must be **random**: every individual, or every spot, must have the same chance of being picked. If you choose where to sample, you drift towards the spots that look interesting, and the estimate is biased. Even a random sample gives an estimate that differs a little from the true size; that difference is the **sampling error**. It shrinks as the sample grows, but never quite vanishes.

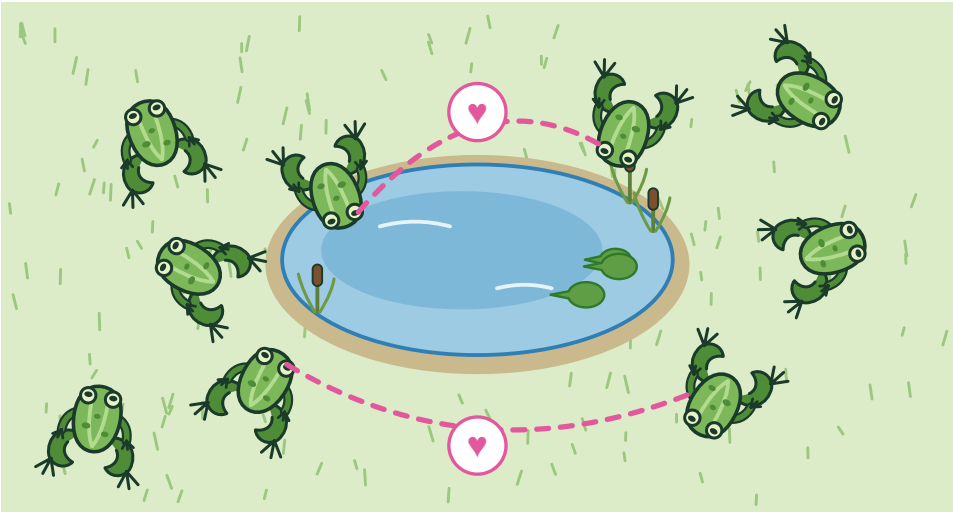
KEY POINTS

- Population: one species, one area, interbreeding.
- Estimate from a random sample; counting all is rarely possible.
- Sampling error: estimate minus true size. Bigger samples, smaller error.

KEY TERMS

population
A group of organisms of the same species living in the same area at the same time, which interact and normally breed with each other.

random
Chosen so that every individual, or every place, has an equal chance of being included, so that the person sampling cannot bias the result.

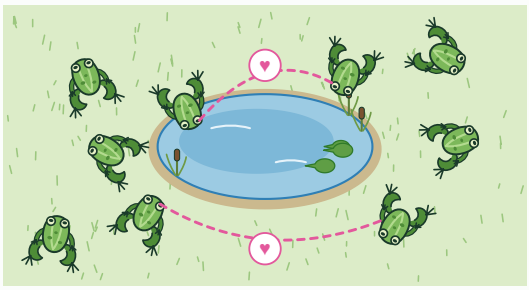


one population: any two can meet and breed

SWITCH IT

2 SETTINGS

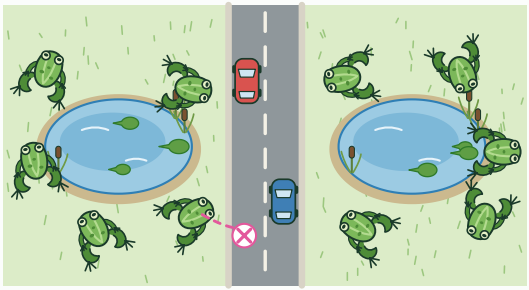
1



one population: any two can meet and breed

One pond

2



two populations: the road keeps them apart

Two ponds and a road

NATURE OF SCIENCE

Random sampling trades certainty for possibility. A sample can never give the true size, only an estimate with an error, but a random one at least makes that error unbiased: as likely to be too high as too low. Scientists report the error with the estimate, so others can judge how far to trust it.

PREDICT

A student estimates the daisies on a field by placing quadrats wherever daisies look thickest. What will the estimate be?

(A) Accurate, because the quadrats were placed where the daisies actually are rather than on bare grass

(B) Too high, because the chosen quadrats hold more daisies than an average square metre of the field

(C) Too low, because daisies in thick patches are harder to count and some will be missed in each quadrat

Decide before you look. Answer on page 30.

02 Throw the *square*

C4.1.3 RANDOM QUADRAT SAMPLING TO ESTIMATE POPULATION SIZE FOR SESSILE ORGANISMS

A **quadrat** is a square frame, often 1 m on each side. It suits **sessile** organisms, ones that stay put: plants, and animals such as barnacles and limpets on a rock.

Lay two tape measures along two edges of the area to make a grid.
Use a random number generator for each pair of coordinates, and put the quadrat there.
Count the individuals inside. Decide a rule for ones on the edge, such as count it if more than half is inside.
Repeat for many quadrats, then work out the mean number per quadrat.
Population estimate = mean per m² × total area in m².

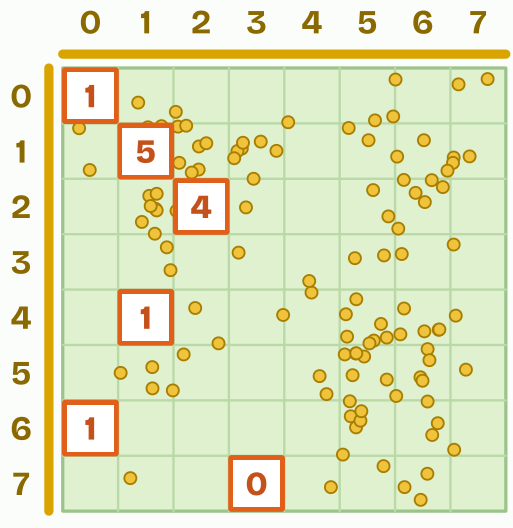
Work out the **standard deviation** of the counts too (a calculator or spreadsheet does it). It measures how much the counts vary round the mean. A small standard deviation means the plants are spread evenly; a large one means they grow in patches, so the estimate is less certain and more quadrats are needed.

KEY POINTS

- Quadrats for sessile organisms; coordinates from random numbers.
- Estimate = mean per m² × area.
- Standard deviation: how spread the counts are; patchy plants give a big one.

KEY TERMS

quadrat
A square frame of known area, often 1 m by 1 m or 0.5 m by 0.5 m, placed on the ground to sample the organisms inside it.



a meadow 8 m × 8 m: 64 m²

random coordinates

(0, 6) (1, 4)
(3, 7) (0, 0)
(2, 2) (1, 1)

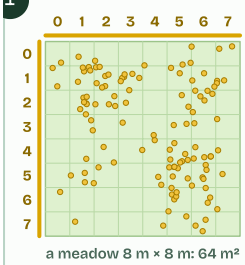
buttercups in each
1, 1, 0, 1, 4, 5

mean = 2.0 per m²
× 64 m² ≈ 128
real number: 120

STEP BY STEP

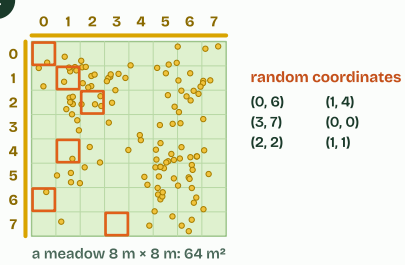
3 STEPS

1



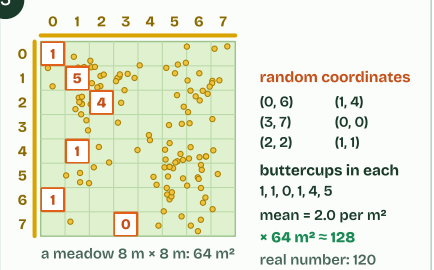
Two tape measures along the edges turn the meadow into a grid of 1 m squares.

2

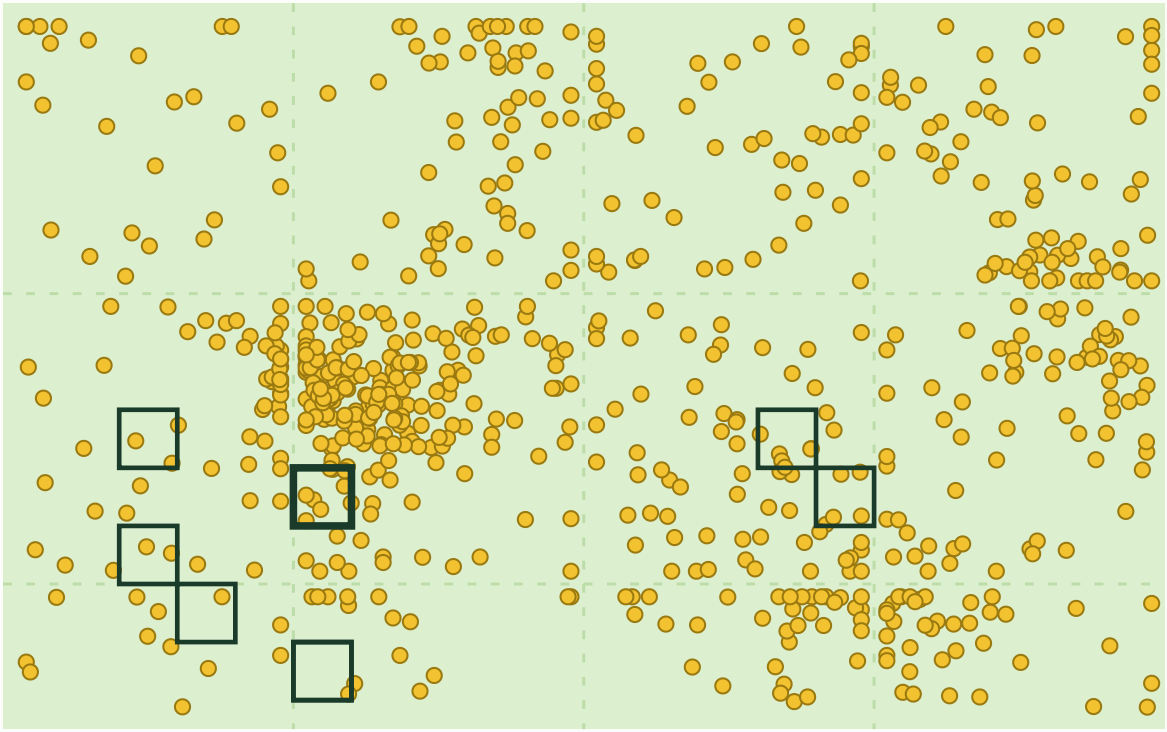


Random numbers give the coordinates; a quadrat goes down at each.

3



Count the buttercups in each, take the mean and multiply by the area: close to the real number.



A meadow of buttercups, sampled by 1 m² quadrats at random coordinates. The mean count per quadrat, times the area, estimates the population.

PREDICT

In the bench below, throw 20 random quadrats, then switch to By eye and place 10 yourself. What do you expect?

(A) The two estimates agree closely, since the same buttercups are being counted in both cases

(B) The by-eye estimate is much higher, because eyes are drawn to the yellow patches

(C) The by-eye estimate is lower, because people avoid placing quadrats in the thick patches

Decide before you look. Answer on page 30.

C4.1.4 CAPTURE-MARK-RELEASE-RECAPTURE AND THE LINCOLN INDEX TO ESTIMATE POPULATION SIZE FOR MOTILE ORGANISMS

03 Mark them, *catch them again*

Animals that move about cannot be counted in a quadrat: they walk out of it. For these **motile** organisms ecologists use capture, mark, release and recapture.

Catch a sample, for example in pitfall traps, and count it: **M**.
Mark each one harmlessly (a dot of paint, a ring, a tag) and release it where it was caught.
Wait long enough for the marked ones to mix back into the population.
Catch a second sample: count all of it, **N**, and the marked ones in it, **R**.

If the marked animals have mixed in evenly, the share of marked ones in the second catch, R ÷ N, should match the share in the whole population, M ÷ population. That gives the **Lincoln index**:

population size ≈ M × N ÷ R

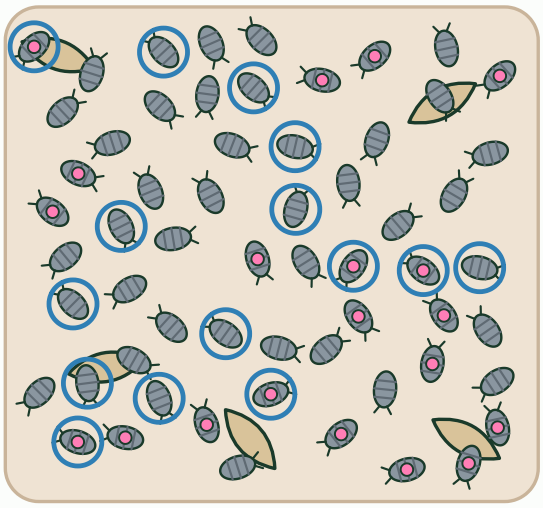
It only works if its **assumptions** hold: marks do not wear off or make animals easier to spot; marked and unmarked animals are equally likely to be caught; they mix fully between the samples; and no births, deaths or migration change the population in between.

KEY POINTS

- For motile animals: catch M, mark, release, recatch N with R marked.
- Population ≈ M × N ÷ R.
- Assumptions: marks last and harm nothing, equal catchability, mixing, closed population.

KEY TERMS

Lincoln index
An estimate of population size from capture-mark-release-recapture: population = M × N ÷ R, where M is the number first caught and marked, N the total in the second catch and R the marked ones in it.



woodlice under the leaf litter

second catch
N = 15

marked in it
R = 5

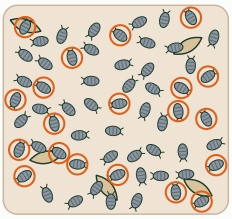
population ≈
M × N ÷ R
= 20 × 15 ÷ 5
= 60

the real number: 60

STEP BY STEP

4 STEPS

1

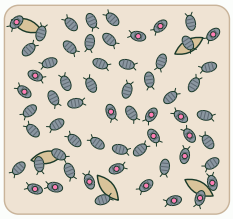


first catch
M = 20
each one marked with a dot of paint

woodlice under the leaf litter

Catch a first sample, **M** = 20, and mark each one with a dot of paint.

2

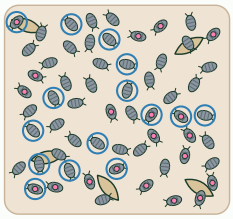


released
they mix back in with the rest

woodlice under the leaf litter

Release them where they were caught, and wait for them to mix back in.

3

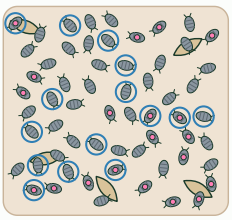


second catch
N = 15
marked in it
R = 5

woodlice under the leaf litter

Catch again: **N** = 15 in the second catch, **R** = 5 of them marked.

4

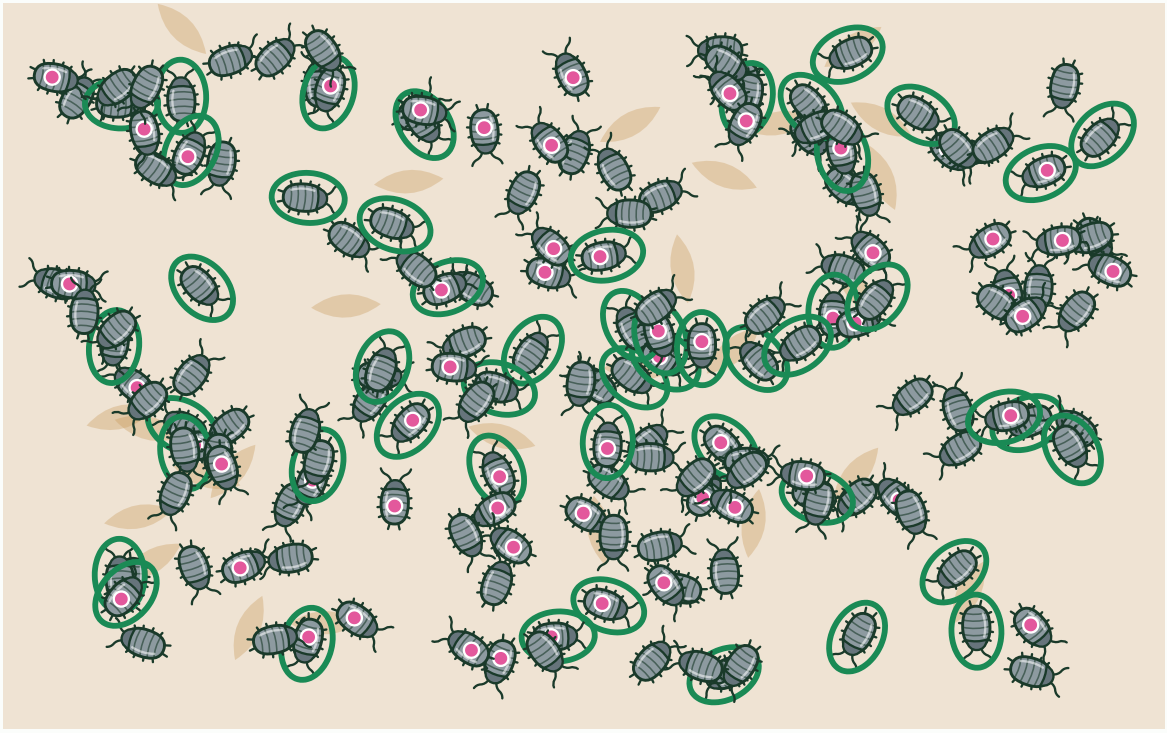


second catch
N = 15
marked in it
R = 5

population ≈
M × N ÷ R
= 20 × 15 ÷ 5
= 60
the real number: 60

woodlice under the leaf litter

Lincoln index: 20 × 15 ÷ 5 = **60**.



Woodlice on a patch of woodland floor. The pink-dotted ones were caught, marked and released; the circled ones are the second catch. The share of marked ones in the second catch estimates the share marked in the whole population.

PREDICT

In the bench, choose Marks wear off and run it. Some marked woodlice lose their paint before the recapture. What happens to the estimate?

(A) It is too low, because the woodlice whose marks wore off are no longer counted in the second catch at all

(B) It is too high, because R is smaller than it should be, and dividing by a smaller R gives a bigger answer

(C) It is unchanged, because the total second catch N stays the same whether or not the marks wear off

Decide before you look. Answer on page 30.

C4.1.5 C4.1.6 C4.1.7 C4.1.8 CARRYING CAPACITY AND COMPETITION FOR LIMITED RESOURCES NEGATIVE FEEDBACK CONTROL OF POPULATION SIZE BY DENSITY-DEPENDENT FACTORS POPULATION GROWTH CURVES MODELLING OF THE SIGMOID POPULATION GROWTH CURVE

04 Room for *so many*

No population grows for ever. The **carrying capacity** (K) is the largest population an environment can support long term. It is set by whatever runs short first: food, water, light, nesting sites, space, or for plants, minerals in the soil. Individuals then **compete** for it.

Some factors hit harder the more crowded the population is. These **density-dependent factors** include competition for resources, predators (more prey makes hunting easier) and pathogens and pests, which spread faster between crowded hosts. They act as **negative feedback**: above K, births fall and deaths rise and the population drops; below K the reverse, and it climbs. **Density-independent** factors, such as a flood, a frost or a fire, kill a share of the population whatever its size, and can knock it away from K, but they do not push it back.

A population introduced into a new area with plenty of resources grows along a **sigmoid** (S-shaped) curve with three phases:

Exponential: resources are plentiful and little limits it, so births far exceed deaths and the population doubles in a fixed time again and again.
Transitional: resources start to run short, density-dependent factors grow, and the rate of growth slows.
Plateau: births plus immigration equal deaths plus emigration, and the population fluctuates around K.

To test whether growth really is exponential, plot the numbers on a **log scale** against time on an ordinary scale: exponential growth is then a straight line. The sigmoid curve is an idealised model. Real populations overshoot, wobble and crash, but the model captures what drives them. Yeast or duckweed in the lab show it within days.

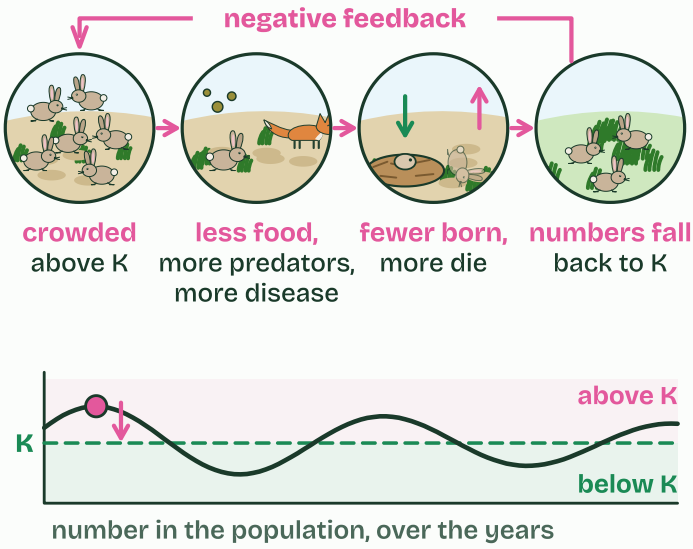
KEY POINTS

- Carrying capacity: the most an environment supports, set by limited resources.
- Density-dependent factors (competition, predation, disease) give negative feedback towards K.
- Sigmoid curve: exponential, transitional, plateau. Exponential is straight on a log scale.

KEY TERMS

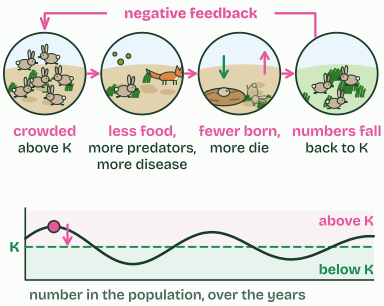
carrying capacity
The maximum population size of a species that an environment can support over a long time, set by the resources it provides.

density-dependent factors
Factors whose effect on a population gets stronger as the population gets denser, such as competition for resources, predation and the spread of disease.



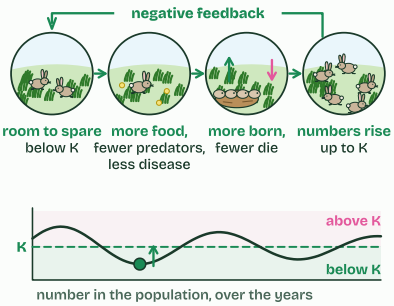
SWITCH IT 2 SETTINGS

1



Above K

2



Below K

WATCH OUT

The IB's sigmoid curve has no lag phase at the start. If you are asked for the phases, give exponential, transitional and plateau.

PREDICT

In the population growth bench (the Dry lab), you double the sugar in the flask. What happens?

(A) The population grows twice as fast from the very start, and then levels off at the same plateau as before

(B) It grows at about the same rate at first, but keeps going for longer and levels off at a higher plateau

(C) Nothing much changes, because the birth rate of the yeast cells, and not the sugar, sets the plateau

Decide before you look. Answer on page 30.

05 Rivals and *allies*

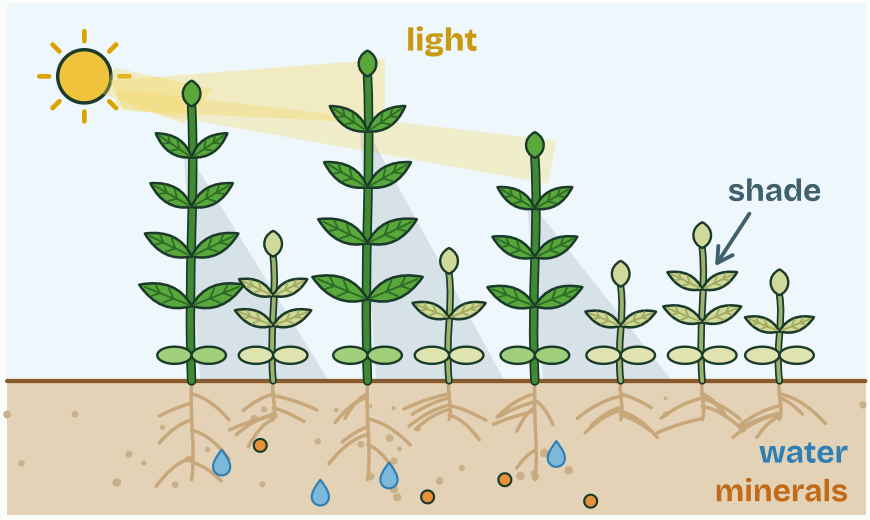
C4.1.9 COMPETITION VERSUS COOPERATION IN INTRASPECIFIC RELATIONSHIPS

Members of one species need exactly the same things, so when something is in short supply they compete for it more fiercely than with any other species. **Intraspecific competition** can be for food, water, light, territory, nest sites or mates. Seedlings of one tree species shade each other out; male red deer fight in the autumn rut for the chance to mate; great tits defend feeding territories in spring, and birds without one often fail to breed.

Members of a species also **cooperate**, when working together gains each one more than it costs. Emperor penguins huddle through the Antarctic winter in thousands, shuffling so that each takes a turn on the cold outside. Wolves hunt large prey in packs. Meerkats take turns on sentry duty and call when they see a predator. Honeybee workers raise their sisters rather than breeding themselves.

KEY POINTS

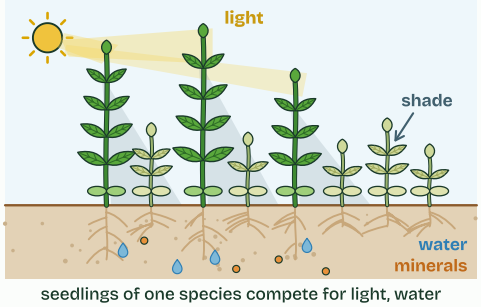
- Competition within a species: for food, water, light, space, mates.
- Cooperation: huddling, group hunting, sentries, shared care of young.
- Both happen in most populations; which wins depends on the resource and the situation.



seedlings of one species compete for light, water and minerals: the tallest shade the rest

SWITCH IT 2 SETTINGS

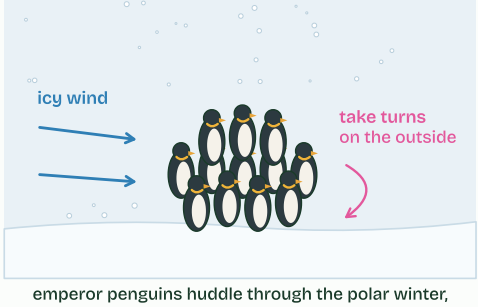
1



seedlings of one species compete for light, water and minerals: the tallest shade the rest

Competition

2



emperor penguins huddle through the polar winter, sharing warmth: cooperation within a species

Cooperation

PREDICT

Why is competition usually fiercer within a species than between two different species?

(A) Members of one species are always more aggressive to their own kind than to any other animal

(B) Members of one species need exactly the same resources, so every one of them is a rival for all of it

(C) Different species cannot use the same resources at all, so they never compete with each other

Decide before you look. Answer on page 30.

C4.1.10 C4.1.11 C4.1.12 A COMMUNITY AS ALL OF THE INTERACTING ORGANISMS IN AN ECOSYSTEM HERBIVORY, PREDATION, INTERSPECIFIC COMPETITION, MUTUALISM, PARASITISM AND PATHOGENICITY AS CATEGORIES OF INTERSPECIFIC RELATIONSHIP WITHIN COMMUNITIES MUTUALISM AS AN INTERSPECIFIC RELATIONSHIP THAT BENEFITS BOTH SPECIES

06 Six ways to *get along*

A **community** is every population living in an area together: the plants, animals, fungi and bacteria, all interacting. Those interactions between species fall into six kinds, each marked by whether it helps (+), harms (–) or does nothing (0) to each species.

One deserves a closer look. In **mutualism** both species benefit:

Root nodules in legumes (beans, peas, clover): *Rhizobium* bacteria in the nodules fix nitrogen from the air into ammonium that the plant uses for amino acids; the plant gives them sugars and a low-oxygen home.
Mycorrhizae in orchids: orchid seeds are dust-like, with almost no food store, and germinate only when a fungus infects them and supplies sugars and minerals. Many adult orchids pass sugars back to the fungus.
Zooxanthellae in hard corals: these algae live inside the coral's cells and give it most of its food, sugars and oxygen from photosynthesis; the coral gives them shelter in clear sunlit water, carbon dioxide and nitrogen compounds from its waste.

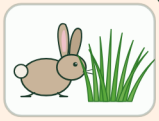
KEY POINTS

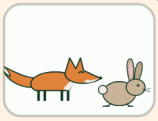
- Community: all the populations in an area.
- Herbivory, predation, parasitism, pathogenicity (+/–); competition (–/–); mutualism (+/+).
- Mutualism examples: legume nodules, orchid mycorrhizae, coral zooxanthellae.

KEY TERMS

community
All the populations of all the species living and interacting in an area: plants, animals, fungi, protists and bacteria.

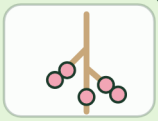
mutualism
A close relationship between two species in which both benefit.

herbivory
rabbits graze grass

+ / –

predation
a fox kills a rabbit

+ / –

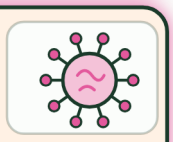
competition
red and grey squirrels

– / –

mutualism
beans and Rhizobium

+ / +

parasitism
a tick on a deer

+ / –

pathogenicity
a virus infects a host

+ / –

Herbivory: an animal eats a plant (or alga). The herbivore gains (+), the plant loses tissue (–). Example: rabbits grazing grass.

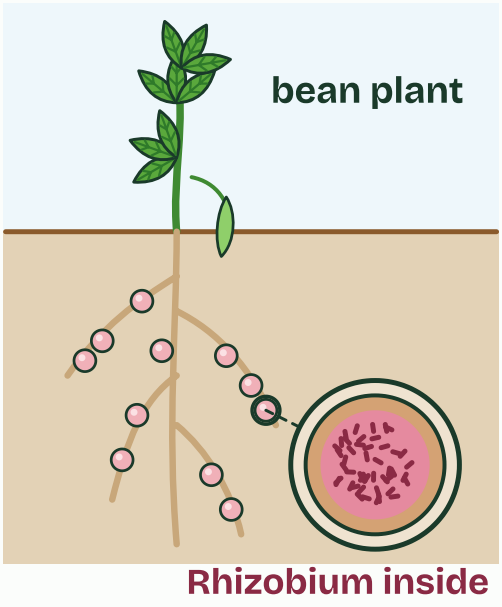
Interspecific competition: two species use the same limited resource, so each has less (– for both). Example: grey and red squirrels competing for seeds in British woods.

Parasitism: a parasite lives on or in a host and feeds on it, usually without killing it. The parasite gains (+), the host is harmed (–). Example: a tick sucking a deer's blood.

Predation: a predator kills and eats its prey. The predator gains (+), the prey dies (–). Examples: a fox and a rabbit; the lynx and the snowshoe hare.

Mutualism: both species benefit (+ / +). Example: Rhizobium bacteria in the root nodules of a bean plant fix nitrogen for it and get sugars in return.

Pathogenicity: a pathogen (a virus, bacterium, fungus or protist) causes disease in its host. The pathogen gains (+), the host is harmed (–). Example: the chytrid fungus killing frogs.

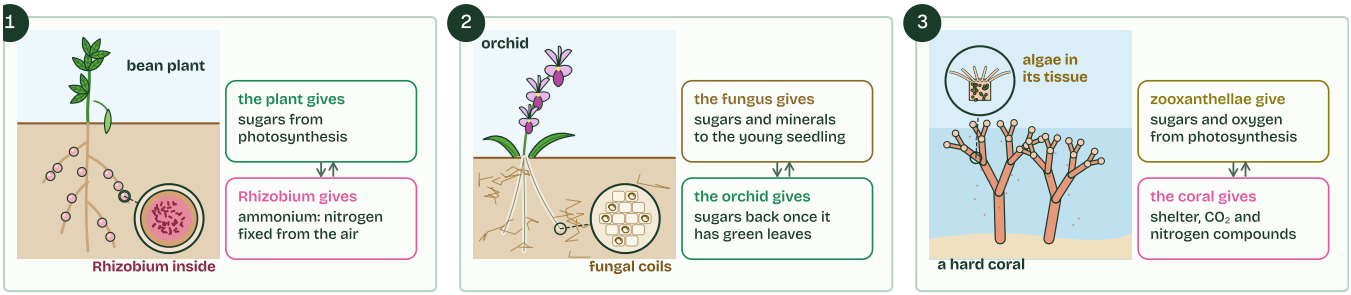


the plant gives
sugars from photosynthesis

Rhizobium gives
ammonium: nitrogen fixed from the air

SWITCH IT

3 SETTINGS



Root nodules | **Orchid mycorrhiza** | **Coral zooxanthellae**

PREDICT

Sea water warms and corals expel their zooxanthellae ("bleaching"). Why do bleached corals often die?

(A) The warm water itself is poisonous to coral tissue, whether or not the algae are still inside the cells

(B) The coral loses the sugars the algae made, which were most of its food, and starves if they do not return

(C) Without the algae the coral's skeleton dissolves away, because the algae were what built the skeleton

Decide before you look. Answer on page 30.

C4.1.13 C4.1.14 RESOURCE COMPETITION BETWEEN ENDEMIC AND INVASIVE SPECIES TESTS FOR INTERSPECIFIC COMPETITION

07 Newcomers and *tests*

An **endemic** species is native to a place. An **invasive species** has been brought in from elsewhere, spreads, and harms what was there. Often it wins because it takes a shared resource more efficiently. Grey squirrels, brought to Britain from North America in the 1800s, can digest acorns while they are still full of tannins, which red squirrels cannot. In oak woods the greys get to the food first, and the reds have largely disappeared from England and Wales. Cane toads, released in Australia in 1935 to eat beetles in sugar cane, ate the insects native frogs and lizards needed, bred fast in the same ponds, and have no natural predators there that can survive their poison.

Showing that two species compete is harder than it looks. There are three approaches:

Laboratory experiments: grow two species alone and together under controlled conditions. Gause's two *Paramecium* species each thrived alone; together, one always died out.
Field observations: random sampling shows whether two species are found together less often than chance would predict (the chi-squared test, chapter 8).
Field manipulation: remove one species from plots and see whether the other does better. Joseph Connell scraped the large barnacle *Balanus* off rocks in Scotland, and the small barnacle *Chthamalus* then lived lower on the shore than before.

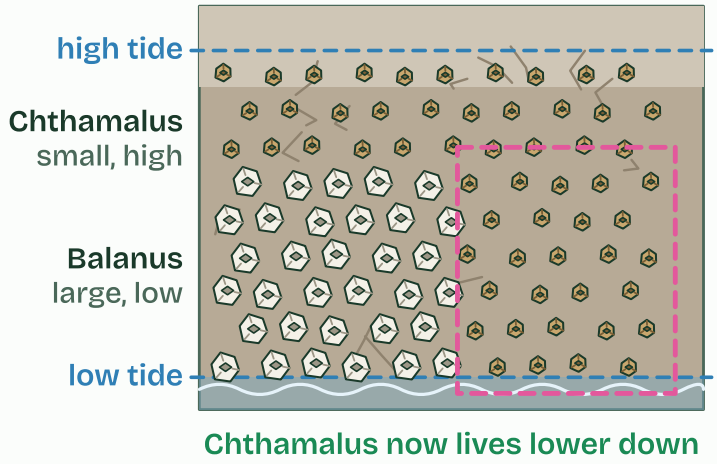
Each gives evidence, not proof. If one species does better when another is absent, competition is **indicated**, but something else, such as a different predator or a difference in the soil, might explain it.

KEY POINTS

- Invasive species often win by taking a shared resource more efficiently.
- Tests: lab experiments, field observations, removal from plots.
- Better without the other species indicates competition but does not prove it.

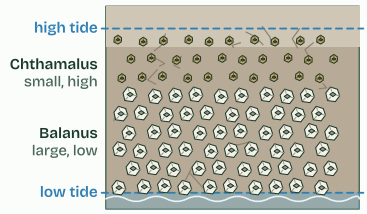
KEY TERMS

invasive species
A species introduced by humans to an area outside its natural range, which spreads and harms the native species or ecosystem.



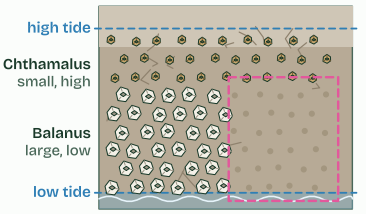
STEP BY STEP 3 STEPS

1



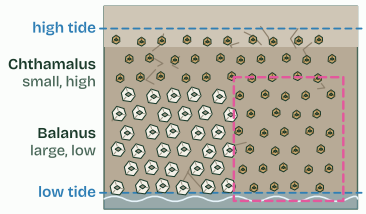
On the shore, small **Chthamalus** lives high up and larger **Balanus** lower down.

2



Connell scraped **Balanus** off patches of rock.

3



There **Chthamalus** grew lower than before: *Balanus* had been keeping it out.

NATURE OF SCIENCE

Hypotheses can be tested by experiments and by observations. In an experiment the scientist changes one factor (removing *Balanus*) and controls others; in an observation they record what happens naturally (which quadrats hold both species). Experiments show cause more clearly; observations show what happens in real, uncontrolled communities.

PREDICT

In Connell's experiment, what was the purpose of leaving some plots with *Balanus* untouched?

(A) To give the Balanus barnacles a safe place to keep breeding until the scraped plots could be restocked

(B) As a control, to show that Chthamalus did not move lower anyway, for a reason other than losing its competitor

(C) To count how many Chthamalus larvae drifted across from the scraped plots onto the rocks next to them

Decide before you look. Answer on page 30.

C4.1.15 USE OF THE CHI-SQUARED TEST FOR ASSOCIATION BETWEEN TWO SPECIES

08 Together, apart, or *chance*?

Throw quadrats at random and record whether each of two species is present. If they grow together more often than chance predicts, there is a **positive association**: perhaps they need the same conditions, or one helps the other. If they occur together less often, a **negative association**: perhaps they need different conditions, or they compete. The **chi-squared test** tells you whether the difference from chance is big enough to be real.

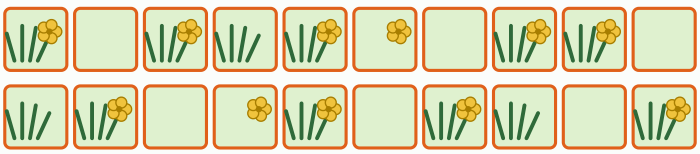
State the hypotheses. H_0: the two species are distributed independently. H_1: they are associated.
Make a 2 × 2 table of observed counts: both present, A only, B only, neither.
Work out each expected value: row total × column total ÷ grand total.
$\chi^2 = \Sigma (O - E)^2 \div E$, over all four cells.
Degrees of freedom = (rows − 1) × (columns − 1) = 1. The critical value at p = 0.05 is 3.84.
If χ^2 is larger than 3.84, reject H_0: the association is significant. Compare O with E for "both present" to see whether it is positive or negative.

KEY POINTS

- Presence and absence in random quadrats, then a 2 × 2 table.
- Expected = row total × column total ÷ grand total.
- $\chi^2 > 3.84$ (1 df, p = 0.05): significant association.

KEY TERMS

chi-squared test
A statistical test of whether observed frequencies differ significantly from those expected; for two species it tests whether they are associated.



soft rush creeping buttercup

	buttercup		no buttercup	
rush	9	(6.6)	3	(5.4)
no rush	2	(4.4)	6	(3.6)
total	11		9	

$\chi^2 = 4.85 > 3.84$: a significant positive association

STEP BY STEP

3 STEPS

1



Twenty random quadrats in a wet meadow: is soft rush there, is creeping buttercup there?

2



	buttercup	no buttercup
rush	9	3
no rush	2	6
total	11	9

The **observed** counts go in a 2 × 2 table.

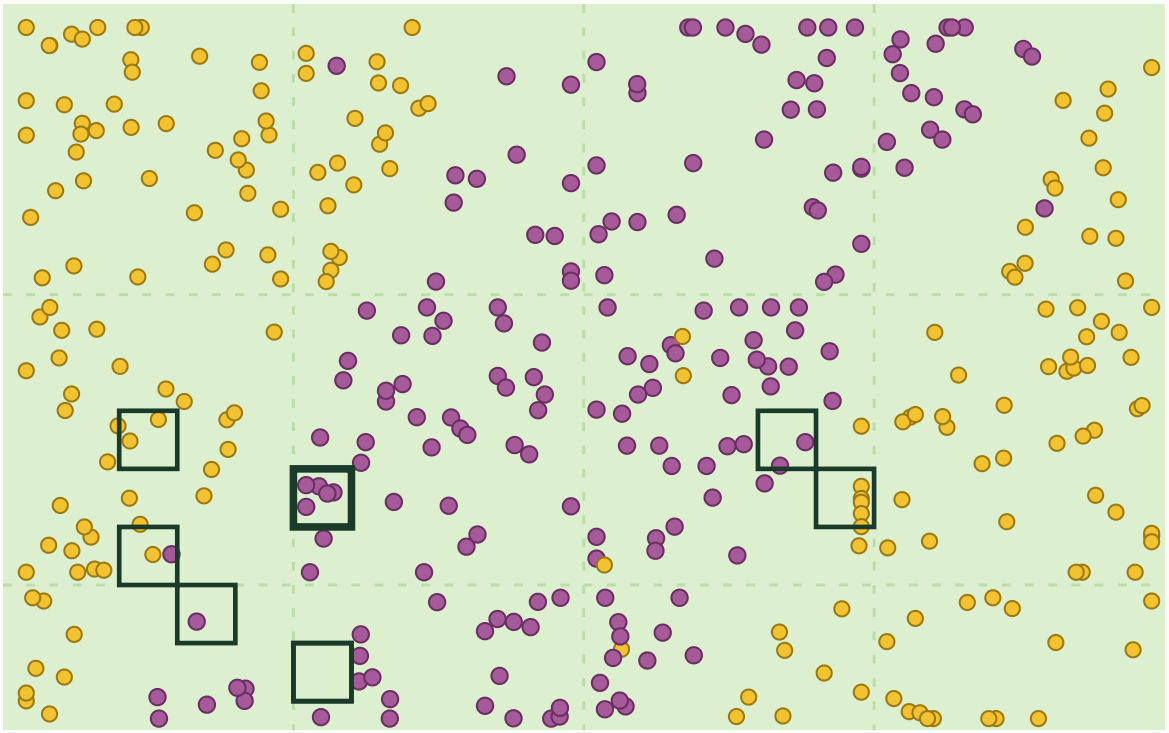
3



	buttercup	no buttercup
rush	9 (6.6)	3 (5.4)
no rush	2 (4.4)	6 (3.6)
total	11	9

$\chi^2 = 4.85 > 3.84$: a significant positive association

The **expected** counts come from the totals. $\chi^2 = 4.85$, above 3.84: the two grow together more than chance predicts.



Two species on a hillside, sampled by random quadrats: each quadrat records whether each species is present.

WATCH OUT

A significant negative association does not prove competition. Two species might simply need different soils, as heather and creeping buttercup do. It is a clue, to be tested with a removal experiment.

PREDICT

On the Hillside in the bench, heather and creeping buttercup are found together in fewer quadrats than expected, and $\chi^2 = 11.2$. What should you conclude?

(A) There is no association, because 11.2 is much higher than the critical value for the test of 3.84

(B) There is a significant negative association: the two are found together less often than chance predicts

(C) Heather is proven to outcompete buttercup, because the two species are almost never found together

Decide before you look. Answer on page 30.

C4.1.16 C4.1.17 C4.1.18 PREDATOR-PREY RELATIONSHIPS AS AN EXAMPLE OF DENSITY-DEPENDENT CONTROL OF ANIMAL POPULATIONS TOP-DOWN AND BOTTOM-UP CONTROL OF POPULATIONS IN COMMUNITIES ALLELOPATHY AND SECRETION OF ANTIBIOTICS

09 Held in *check*

For nearly a century the Hudson's Bay Company bought furs from trappers across Canada, and its records show snowshoe hares and the Canada lynx that hunt them rising and falling together, about every ten years, the lynx a year or two behind. When hares are plentiful, lynx catch more and rear more kittens. As lynx increase, they eat hares faster than hares breed, and the hares crash. Then the lynx starve, and with few lynx the hares recover. Predation is **density-dependent**: the more hares there are, the more are eaten, which pulls their numbers back.

A population can be held back from above or from below. **Top-down control** comes from predators; **bottom-up control** comes from the food, nutrients and producers below. Both act in most communities, but one usually dominates. When sea otters were hunted out along the Pacific coast, sea urchins (their prey) multiplied and grazed kelp forests to bare rock: top-down. When fertiliser washes into a lake, the algae bloom, and everything above them changes: bottom-up.

Some organisms fight competitors with chemicals. In **allelopathy** a plant releases substances that stop others growing near it: black walnut trees release juglone from their roots, leaves and nut husks, and many plants wilt and die near them. Microorganisms secrete **antibiotics**: the mould *Penicillium* secretes penicillin, which kills bacteria competing with it for the same food.

KEY POINTS

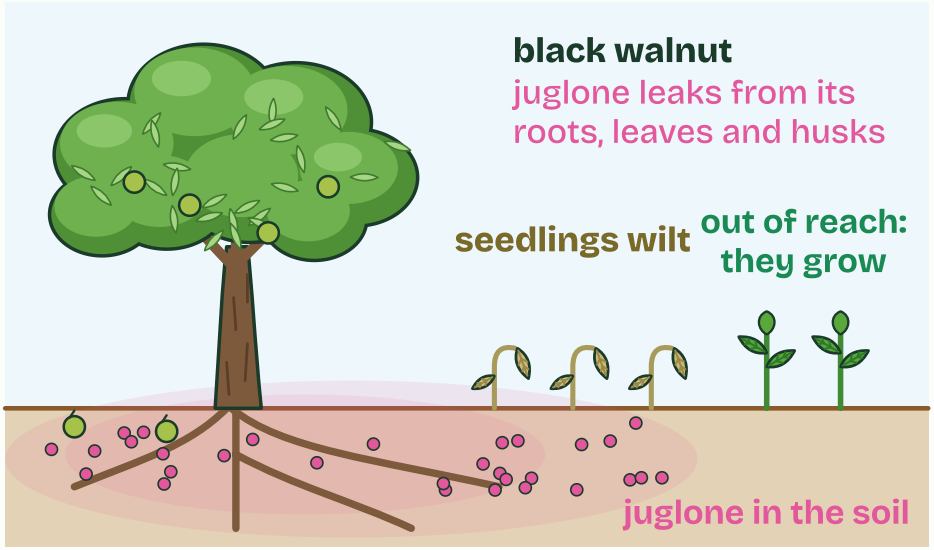
- Predator-prey cycles: lynx and hare, about ten years, predators lag behind.
- Top-down (predators) and bottom-up (resources); one usually dominates.
- Allelopathy (black walnut, juglone) and antibiotics (Penicillium, penicillin) deter competitors.

KEY TERMS

Top-down control
Control of a population by the trophic level above it: its predators, herbivores or parasites.

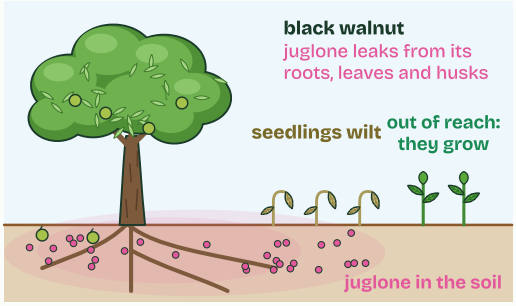
bottom-up control
Control of a population by the resources below it: the food, nutrients or producers it depends on.

allelopathy
The release by a plant of chemicals into the environment that inhibit the germination or growth of other plants nearby.



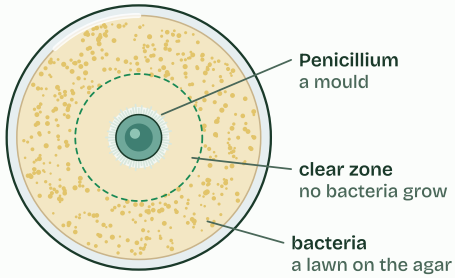
SWITCH IT 2 SETTINGS

1



Black walnut

2

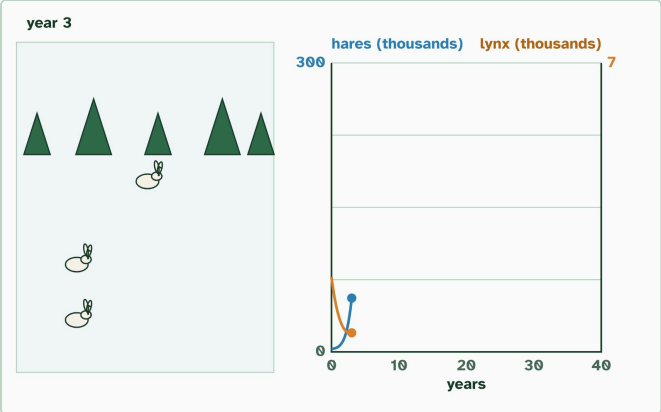


Penicillium

ANIMATION · WATCH IT HAPPEN: LYNX AND HARES

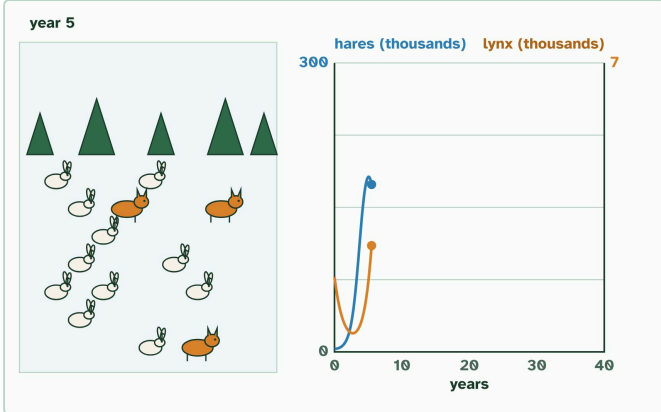
6 MOMENTS

1 YEAR 3



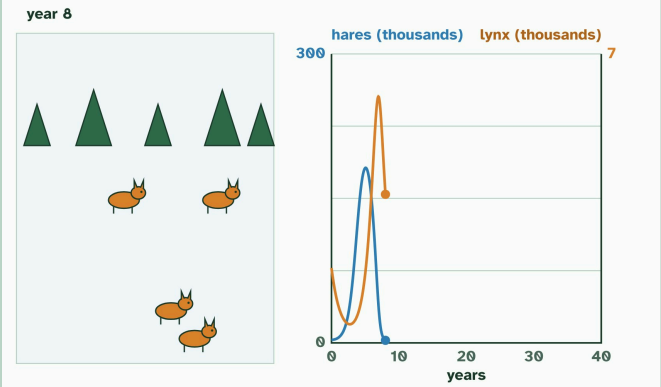
Snowshoe hares breed fast. With plenty of food and few lynx, their numbers climb.

2 YEAR 5



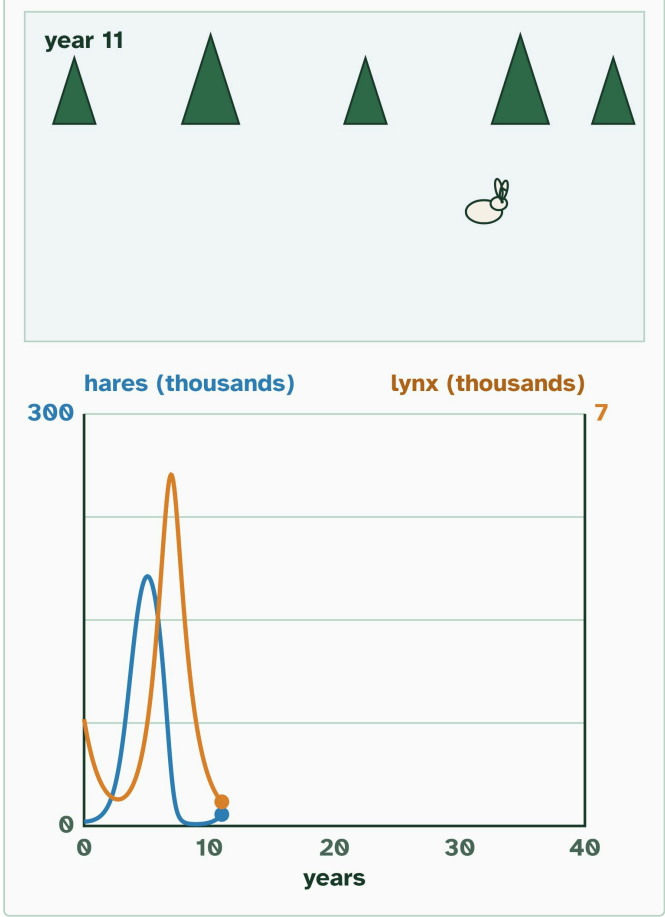
More hares means more food for the lynx. More lynx kittens survive, so the lynx rise too, a year or two behind.

3 YEAR 8



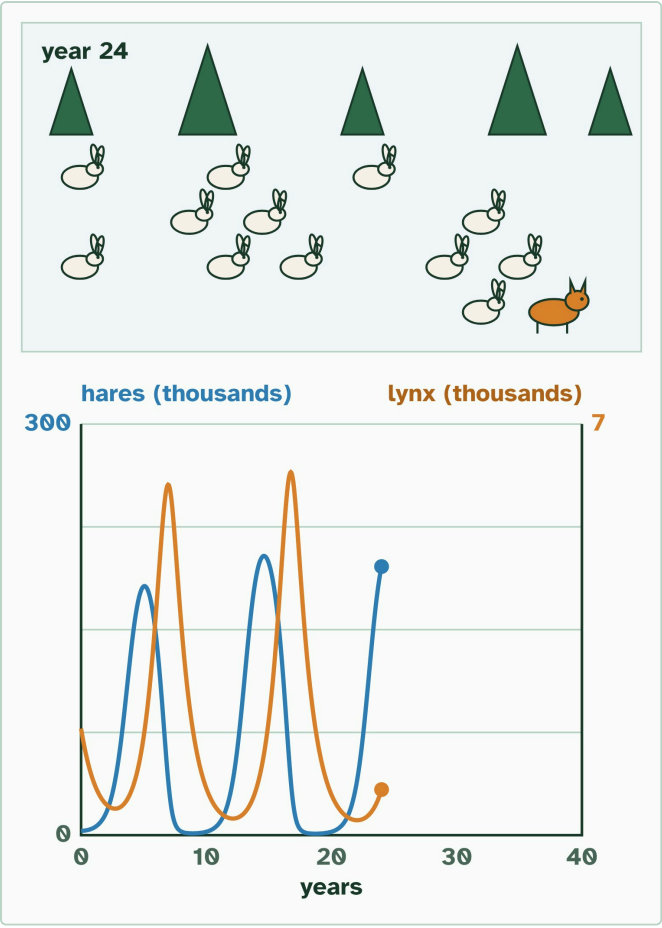
Now the lynx eat hares faster than hares are born: the hares crash. Predation is **density-dependent**: the more hares there are, the more are caught.

4 YEAR 11



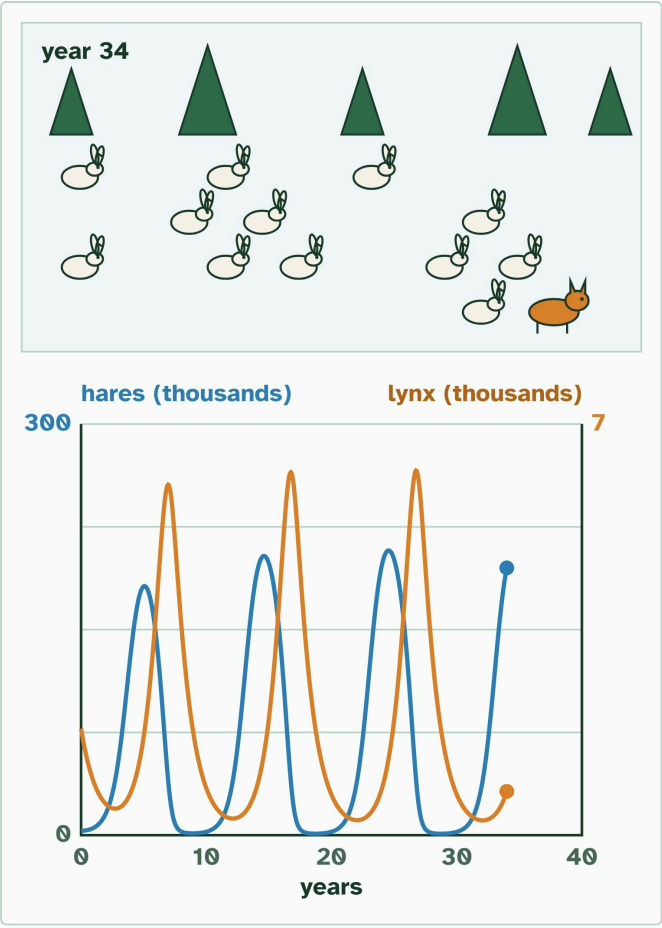
With few hares left the lynx starve and fall. With few lynx the hares recover, and the cycle starts again, about every ten years.

5 YEAR 24



The same cycle again. Neither population runs away: each one's growth is held back by the other, a negative feedback with a lag.

6 YEAR 34



Real hare cycles are pushed by both: lynx from above (**top-down**) and the hares' winter food from below (**bottom-up**).

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-c4-1-populations-and-communities#control

PREDICT

In the film, choose Lynx trapped out. What happens to the hares after year 20?

(A) They keep cycling exactly as before, because the hare cycle is driven entirely by their winter food supply

(B) They grow without limit, because with no predators left there is nothing at all to slow their growth

(C) They rise far above their old peaks, then level off where their food limits them: bottom-up control takes over

Decide before you look. Answer on page 31.

Key terms

Every term this guide defines, A to Z, with the chapter it is in. Cover the right-hand side and test yourself.

allelopathy 09
The release by a plant of chemicals into the environment that inhibit the germination or growth of other plants nearby.

bottom-up control 09
Control of a population by the resources below it: the food, nutrients or producers it depends on.

carrying capacity 04
The maximum population size of a species that an environment can support over a long time, set by the resources it provides.

chi-squared test 08
A statistical test of whether observed frequencies differ significantly from those expected; for two species it tests whether they are associated.

community 06
All the populations of all the species living and interacting in an area: plants, animals, fungi, protists and bacteria.

density-dependent factors 04
Factors whose effect on a population gets stronger as the population gets denser, such as competition for resources, predation and the spread of disease.

invasive species 07
A species introduced by humans to an area outside its natural range, which spreads and harms the native species or ecosystem.

Lincoln index 03
An estimate of population size from capture-mark-release-recapture: population = M × N ÷ R, where M is the number first caught and marked, N the total in the second catch and R the marked ones in it.

mutualism 06
A close relationship between two species in which both benefit.

population 01
A group of organisms of the same species living in the same area at the same time, which interact and normally breed with each other.

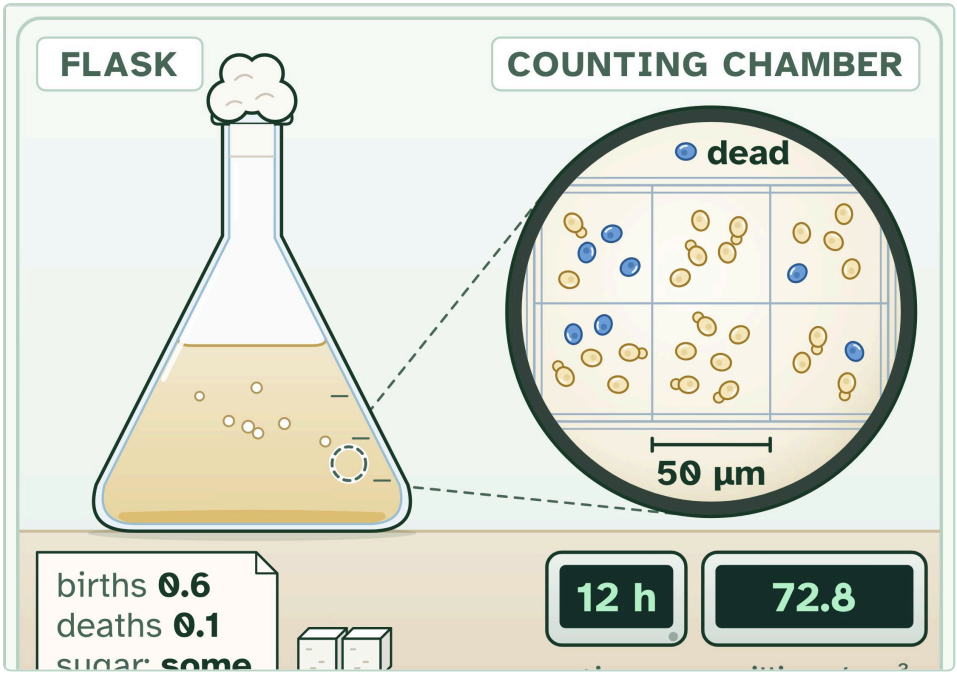
quadrat 02
A square frame of known area, often 1 m by 1 m or 0.5 m by 0.5 m, placed on the ground to sample the organisms inside it.

random 01
Chosen so that every individual, or every place, has an equal chance of being included, so that the person sampling cannot bias the result.

Top-down control 09
Control of a population by the trophic level above it: its predators, herbivores or parasites.

Dry lab: *The population growth bench*

Grow yeast in a flask of sugar solution and count it every two hours. Change the birth rate, the death rate and the sugar, add a cold shock, and watch the J curve bend into an S.



Run it online: change the variables, run the trials, and the table and graph fill in as you go. biologybybradford.com/guides/ib-biology-c4-1-populations-and-communities#lab

Your question

How does a population of yeast grow in a flask, and what makes it stop? Predict first: if you double the sugar, will the population grow faster at the start, level off higher, or both?

What you can change

Births per cell per hour, deaths per cell per hour, and the sugar in the flask, which sets the carrying capacity. You can also chill the flask at 14 hours, a density-independent knock.

What to record

The count every two hours, the hour each phase begins, and the plateau. Plot the counts on a normal scale and on a log scale. The yeast is a model with invented numbers; the pattern is what real yeast and duckweed cultures show.

Find out

- **The S curve.** Run 30 hours with the middle settings. Turn on Show the phases and name each one: where is the population growing fastest, and where has it stopped?
- **Births and deaths.** Open Births and deaths. At what population do the two lines cross, and how does that number compare with the carrying capacity line?
- **Food sets the ceiling.** Run Little, Some and Lots of sugar. Does the carrying capacity change, the speed of growth, or both?
- **The birth rate.** Keep the sugar the same and try each birth rate. Which part of the curve moves, and which stays put?
- **A cold shock.** Add the cold shock at 14 hours. Is the cold density dependent or density independent? How long does the flask take to get back to the plateau?
- **Log scale.** Switch it on. Which phase becomes a straight line, and why?
- **Back to biology.** Using your results, explain why the population follows an S curve, and what decides the level it holds at.

Record

- A table of the carrying capacity and the time to reach half of it for each amount of sugar.
- A sketch of one S curve with the exponential, transitional and plateau phases labelled.
- For the cold shock: the number before and after it, and the time to recover.
- Download the CSV to keep every reading.

Your question How does a population of yeast grow in a flask, and what makes it stop? Predict first: if you double the sugar, will the population grow faster at the start, level off higher, or both?**What you can change**Births per cell per hour, deaths per cell per hour, and the sugar in the flask, which sets the carrying capacity. You can also chill the flask at 14 hours, a density-independent knock.**What to record**The count every two hours, the hour each phase begins, and the plateau. Plot the counts on a normal scale and on a log scale. The yeast is a model with invented numbers; the pattern is what real yeast and duckweed cultures show.

Back to biology

Using your results, explain why the yeast population followed an S-shaped curve, and what decides the level it finally holds at.

QUESTIONS ON THE LAB

QUESTION 1

The yeast in the flask has reached its plateau. A student says the cells have stopped reproducing. Are they right?

(A) Yes: once the sugar runs low every cell stops dividing, so no new cells are added at all

(B) No: cells are still being born, but at the same rate as others die, so the number holds steady

(C) No: the cells reproduce faster than ever, but the new ones are too small to be counted

Answer on page 31.

QUESTION 2

Raising the sugar from Little to Lots, what happens to the plateau?

(A) It rises: more food lets the flask support more cells before competition balances births and deaths

(B) It stays the same: the carrying capacity is set by the species, not by the food it is given

(C) It falls: the extra sugar makes the cells grow so fast that they use up all the oxygen early

Answer on page 31.

QUESTION 3

The cold shock kills 60% of the cells whatever the population. What kind of factor is it?

(A) Density dependent: it kills more cells when there are more cells in the flask to be killed

(B) Density dependent: the cells that survive then have more sugar each, so they grow back faster

(C) Density independent: it kills the same share of the cells however crowded the flask is

Answer on page 31.

Check yourself

The check for this guide is online: a fresh paper of past-paper style questions from the exam bank on C4.1 each time, marked as you go, and saved to your Exam practice progress when you are signed in. Scan the code, or type the link.

biologybybradford.com/exam-maker/sit?topics=C4.1&level=SL&paper=quiz&marks=15&src=ep

Answers

PREDICTIONS IN THE CHAPTERS

01 A student estimates the daisies on a field by placing quadrats wherever daisies look thickest. What will the estimate be?

B **Too high, because the chosen quadrats hold more daisies than an average square metre of the field**

Choosing the thickest patches biases the sample upwards: the mean per quadrat is higher than the true mean, so the estimate for the whole field is too high. Random coordinates remove the choice.

02 In the bench below, throw 20 random quadrats, then switch to By eye and place 10 yourself. What do you expect?

B **The by-eye estimate is much higher, because eyes are drawn to the yellow patches**

Almost everyone places quadrats on the buttercups, so the by-eye mean, and the estimate, come out far too high. Then press Count every buttercup and see how close the random estimate was.

03 In the bench, choose Marks wear off and run it. Some marked woodlice lose their paint before the recapture. What happens to the estimate?

B **It is too high, because R is smaller than it should be, and dividing by a smaller R gives a bigger answer**

Lost marks make marked woodlice look unmarked, so R falls while N stays the same, and M × N ÷ R rises. Trap-happy animals do the opposite: more marked ones are recaught, R rises, and the estimate falls.

04 In the population growth bench (the Dry lab), you double the sugar in the flask. What happens?

B **It grows at about the same rate at first, but keeps going for longer and levels off at a higher plateau**

Early on the yeast has more sugar than it can use, so extra sugar changes little. It raises the carrying capacity: the population keeps growing longer before competition slows it, and levels off higher.

05 Why is competition usually fiercer within a species than between two different species?

B **Members of one species need exactly the same resources, so every one of them is a rival for all of it**

Two species overlap in only some of their needs, but two individuals of one species overlap in all of them: same food, same nest sites, same mates. So the competition is complete.

06 Sea water warms and corals expel their zooxanthellae ("bleaching"). Why do bleached corals often die?

B **The coral loses the sugars the algae made, which were most of its food, and starves if they do not return**

Most of a reef-building coral's food comes from its zooxanthellae. Without them it can survive a few weeks on what it catches, but if the water stays warm and they do not return, it starves.

07 In Connell's experiment, what was the purpose of leaving some plots with *Balanus* untouched?

B **As a control, to show that Chthamalus did not move lower anyway, for a reason other than losing its competitor**

The untouched plots are the control. Only if *Chthamalus* spreads lower where *Balanus* was removed, and not where it was left, does the change point to competition with *Balanus*.

08 On the Hillside in the bench, heather and creeping buttercup are found together in fewer quadrats than expected, and $\chi^2 = 11.2$. What should you conclude?

B **There is a significant negative association: the two are found together less often than chance predicts**

11.2 is above 3.84, so H_0 is rejected: the association is significant, and because "both present" is below its expected value it is negative. It does not prove competition: heather grows on the dry ridge and buttercup in the damp hollows.

09 In the film, choose Lynx trapped out. What happens to the hares after year 20?

C **They rise far above their old peaks, then level off where their food limits them: bottom-up control takes over**

With the top-down control gone, the hares climb until competition for food stops them, at the carrying capacity. Nothing grows without limit; the control just passes to the level below.

QUESTIONS ON THE DRY LAB

Q1 The yeast in the flask has reached its plateau. A student says the cells have stopped reproducing. Are they right?

B **No: cells are still being born, but at the same rate as others die, so the number holds steady**

A plateau is a balance, not a stop. Open Births and deaths: the two rates meet at the carrying capacity, so for every cell that buds off another dies.

Q2 Raising the sugar from Little to Lots, what happens to the plateau?

A **It rises: more food lets the flask support more cells before competition balances births and deaths**

The carrying capacity belongs to the environment, not the species. More of the limiting resource raises it; the shape of the curve stays an S.

Q3 The cold shock kills 60% of the cells whatever the population. What kind of factor is it?

C **Density independent: it kills the same share of the cells however crowded the flask is**

A density-dependent factor hits harder as the population grows: competition for sugar, waste, disease. The cold takes the same fraction at any density. The faster regrowth afterwards is density dependence at work, but it is not the cold.

How this was made. The course structure, the activities and the teaching choices come from my own classroom, my presentations and my years of teaching IB and AP Biology. I use Claude, an AI, to help write and build the interactive guides, lesson plans, slides and practice questions, and to draw the diagrams and code the interactives. I direct the work and review it against the IB and AP specifications before it goes live.

Written and drawn for Biology by Bradford, biologybybradford.com. Free to print and share with a class.