STEM SMART Biology Week 23 - Populations

Patterns of Population Change

Subject & topics

Biology | Ecology | Populations

Status

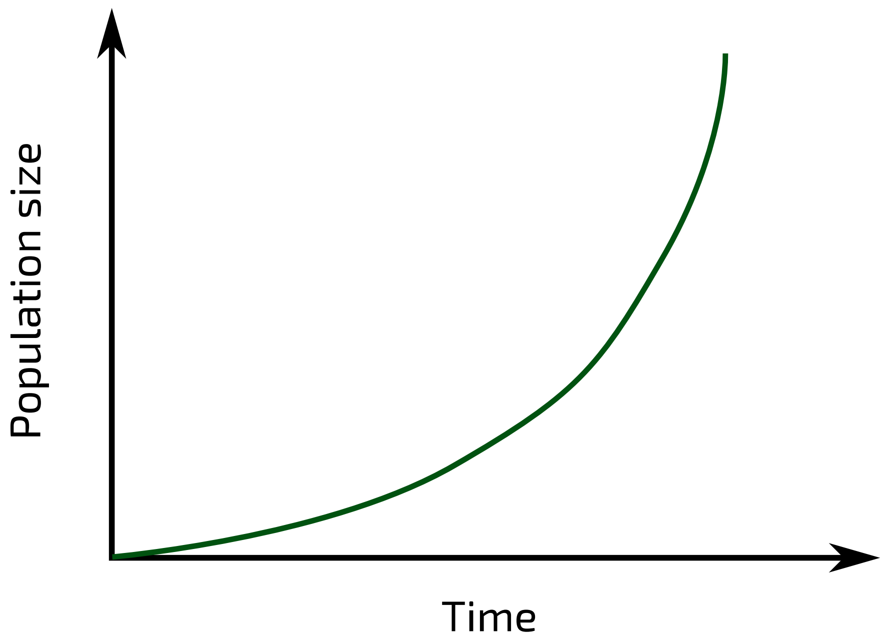
Not started

Stage & difficulty

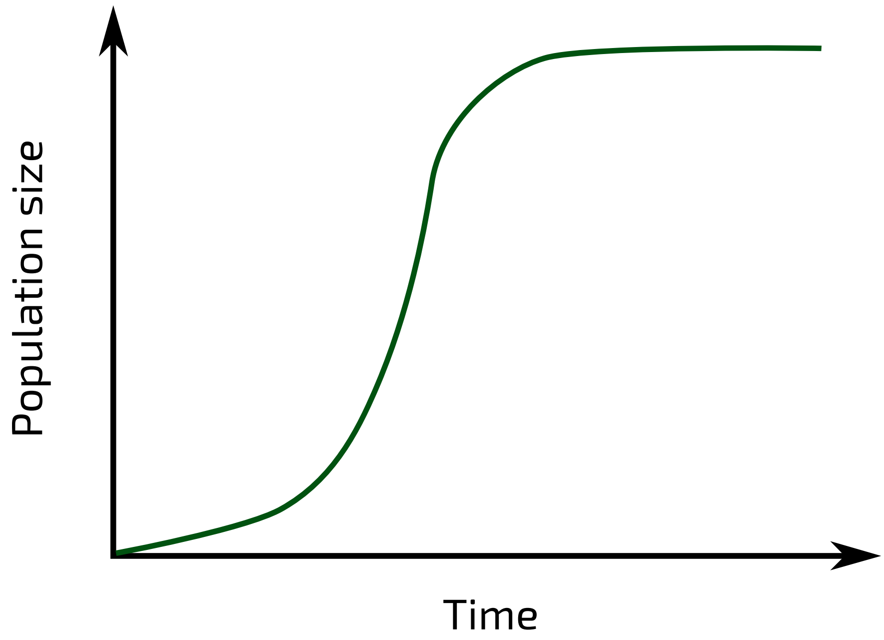
A Level Practice 2

A population's size can change over time. The way in which it changes depends on various environmental factors.

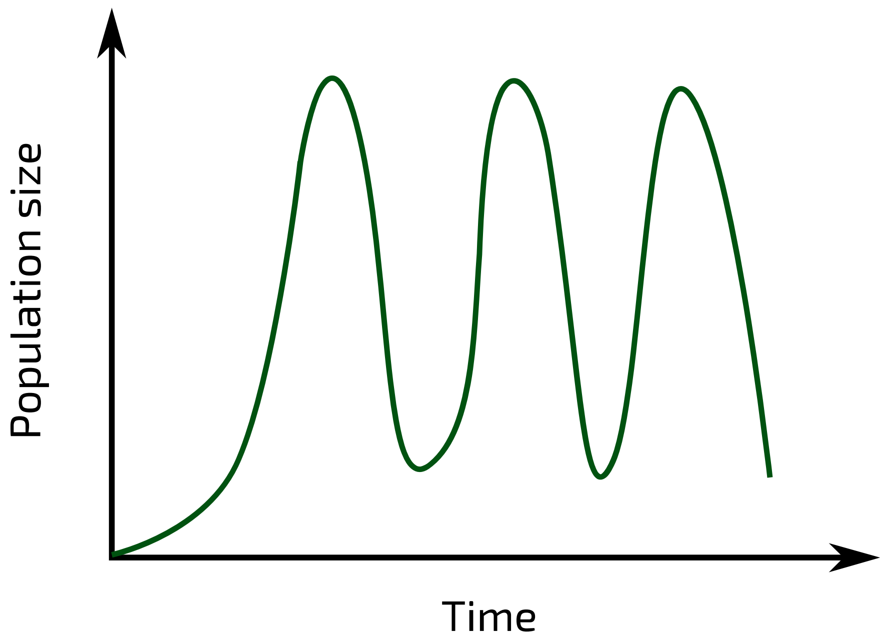
The three graphs below (A, B, C) show different ways in which a population may change over time.



A



B



C

Part A

Types of change

Match the graph to the scenario.

[ ]: A population in a highly stable environment with limiting factors.

[ ]: A population in a highly seasonal environment. Food availability varies greatly between seasons.

[ ]: A population in an environment with no limiting factors. There is unlimited availability of food and no predation on the population.

Items:

A B C

Part B

Common feature

Which of the following features are common to all three graphs?

- the carrying capacity is different at different points in time
- the growth rate initially increases over time
- logistic growth
- the population reaches carrying capacity

Part C

Unrealistic growth

Graph A shows a population undergoing exponential growth. Which of the following factors prevent this from happening indefinitely (forever) in real populations? Select all that apply.

- [ ] a larger population will produce more waste products (e.g. carbon dioxide, ammonia, etc.), which may make the environment less suitable
- [ ] consumers/predators may limit population numbers
- [ ] populations can only grow linearly, not exponentially
- [ ] harmful mutations build up in large populations, which limits population size or causes it to decrease
- [ ] if a population exceeds the carrying capacity, it goes extinct
- [ ] resources (e.g. food, space, etc.) are not unlimited, so there will be a maximum population size that can be sustained in any given environment

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STEM SMART Biology Week 23 - Populations

Collared Doves

Subject & topics

Biology | Ecology | Populations

Status

Not started

Stage & difficulty

A Level Practice 2

The collared dove, *Streptopelia decaocto*, is a recent addition to the British list of breeding birds. At the start of the 20th century, this bird was a rare visitor. It spread across northern Europe and breeding pairs were first seen in Britain in the early 1950s. The collared dove is now widespread throughout Britain.

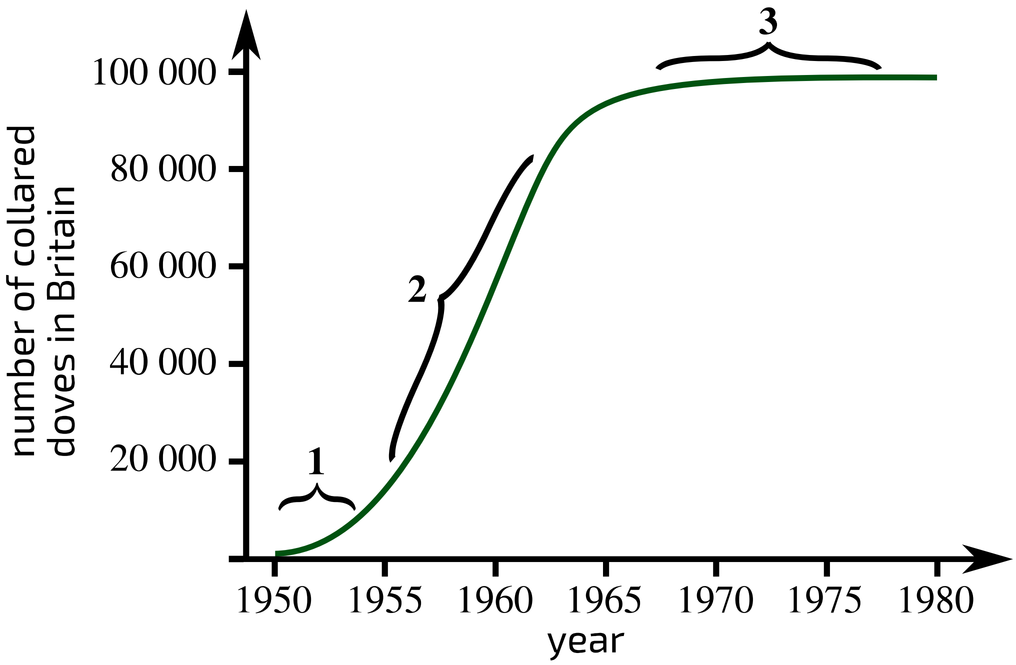

Figure 1: A record of collared dove population growth between 1950 and 1980. Three phases of population change are labelled.

Part A

Phase names

Match the phases to the labelled regions in Figure 1.

- 1:
- 2:
- 3:

Items:

log phase (rapid growth) | lag phase (slow growth) | stationary phase (no growth)

Part B

Phase 1 vs phase 2

Why is growth more rapid in phase 2 than in phase 1?

- The population is more affected by density-dependent limiting factors in phase 1.
- The carrying capacity is higher in phase 2 than in phase 1.
- In phase 1, death rate is higher than birth rate. Whereas in phase 2, birth rate is higher than death rate.
- The larger a population is, the faster it can grow.

Part C
Phase 3

Why does growth slow down and stop in phase 3? Select all that may apply.

- [ ] Collared dove numbers are being limited by predators.
- [ ] Density-independent limiting factors are affecting the population more now.
- [ ] The population has reached extinction
- [ ] The population has reached its carrying capacity.
- [ ] Collared dove death rates are now greater than birth rates.
- [ ] There is only enough food in the ecosystem to support this number of collared doves.

Part D
Carrying capacity

Based on Figure 1, what was the carrying capacity of collared doves in Britain between 1950 and 1980? Give your answer to 1 significant figure.

Part E

Increasing the carrying capacity

Which of the following might **increase** the carrying capacity of collared doves in Britain? Select all that apply.

- [ ] Migration of more collared doves into Britain.
- [ ] A decrease in predator numbers.
- [ ] An increase in food availability.
- [ ] An increase in predator numbers.
- [ ] Emigration of part of the population out of Britain.

Adapted with permission from OCR A Level January 2003, Central Concepts, Question 3

Question deck:

STEM SMART Biology Week 23 - Populations

isaac You work it out.

Algal Population Changes

Subject & topics

Biology | Ecology | Populations

Status

Not started

Stage & difficulty

A Level Practice 2

Not all populations follow sigmoidal growth curves. Some may show large fluctuations, particularly in seasonal environments. **Figure 1** shows one such population.

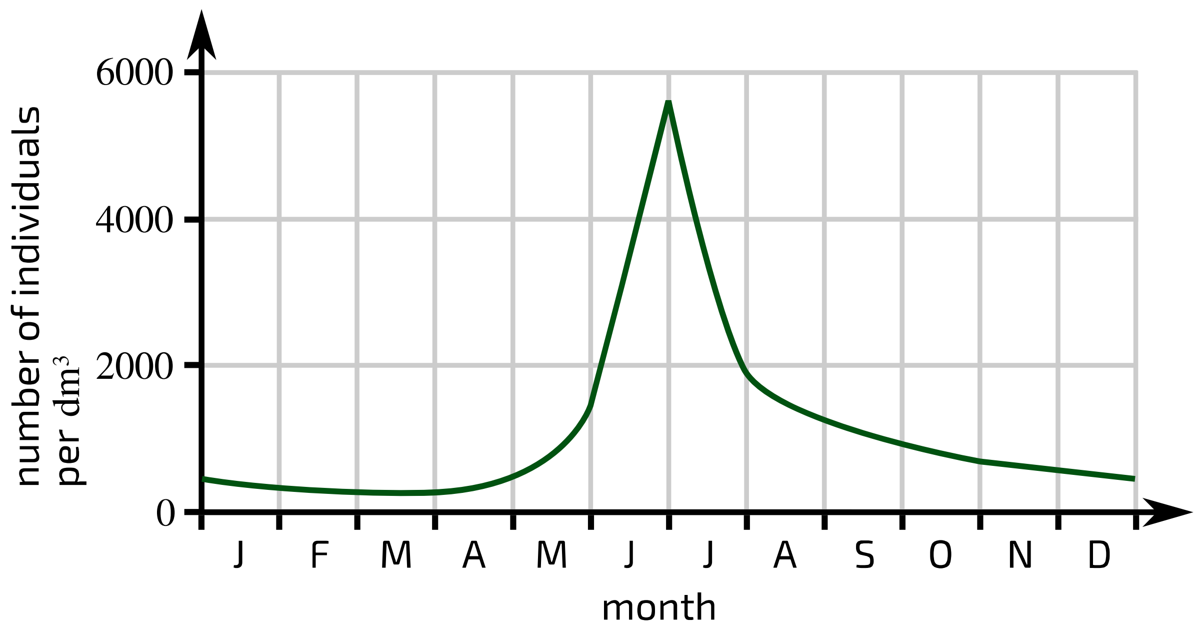

Figure 1: The population curve of an algal species in a freshwater lake in southern England.

Part A

Population increase

Which of the following may explain the rapid population growth from May to July? Select all that apply.

- [ ] increasing temperature
- [ ] increasing day length
- [ ] decreasing temperature
- [ ] decreasing nutrient availability
- [ ] increasing water availability in the soil
- [ ] decreasing day length
- [ ] an increase in the number of consumers

Part B

Population decrease

Which of the following may explain the rapid population decrease from July to September? Select all that apply.

- [ ] increasing temperature
- [ ] decreasing nutrient availability
- [ ] decreasing day length
- [ ] an increase in the number of consumers
- [ ] increasing day length
- [ ] decreasing temperature
- [ ] increasing water availability in the soil

Part C

Carrying capacity statements

Which of the following statements are correct? Select all that apply.

- The reason that this population does not follow a sigmoidal growth curve is that its carrying capacity is **lower** in the summer than in the other seasons.
- The carrying capacity in the summer must be the same as (or greater than) the maximum population size reached.
- The carrying capacity in the summer may be lower than the maximum population size reached, and this could account for the dramatic population decrease in July.
- The carrying capacity of this population is the same all year, because carrying capacities do not change.
- The reason that this population does not follow a sigmoidal growth curve is that its carrying capacity is **higher** in the summer than in the other seasons.

Adapted with permission from OCR A Level January 2003, Central Concepts, Question 3

Question deck:

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Predatory Mites

Subject & topics

Biology | Ecology | Populations

Status

Not started

Stage & difficulty

A Level Practice 2

Two species of mite were kept in a laboratory. One species (the prey species) feeds on oranges, and other is a predator of the first species.

Figure 1 shows the changes in the populations of these two species over time in a particular experiment.

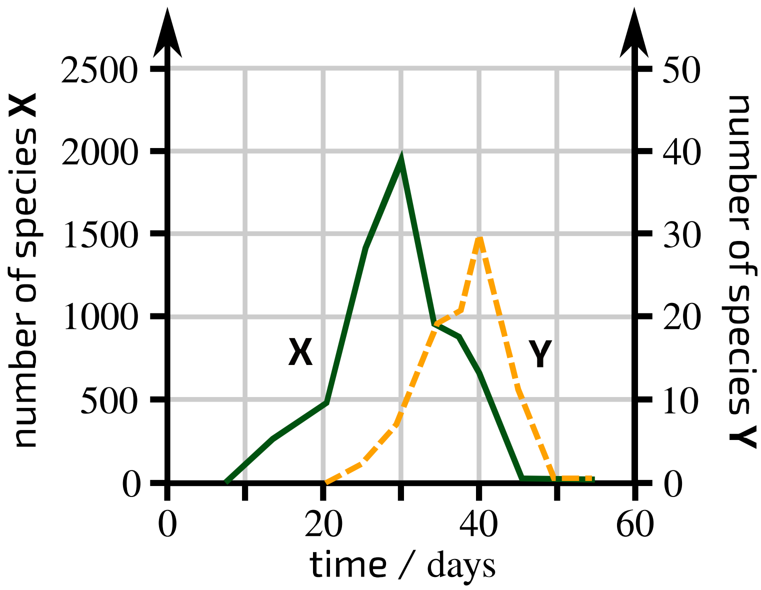

Figure 1: Population changes of species **X** and **Y** over the course of a 60-day experiment.

Part A

Identify the prey

Which species in **Figure 1** is the **prey** species?

- X
- Y

Which of the following statements support your answer above?

- The population of **Y** is always lower than the population of **X**, which suggests that species **Y** occupies a ***lower*** trophic level.
- The population of **Y** is always lower than the population of **X**, which suggests that species **Y** occupies a ***higher*** trophic level.
- When the population of **X** decreases, the population of **Y** decreases soon after, which suggests that species **Y** is dependent on species **X**.
- From day 30 to day 40, the population of **X** decreases while the population of **Y** increases, which suggests that species **Y** is negatively affected by species **X**
- When the population of **Y** increases, the population of **X** decreases, which suggests that species **X** is negatively affected by species **Y**.
- From day 40 onwards, the population of **Y** is decreasing, and the population of **X** is also decreasing, which suggests that species **X** is dependent on species **Y**.

Part B

Population maximum of X

What is the maximum population size of **X**? Give your answer to two significant figures.

On what day does population **X** reach its maximum size?

Part C

Population maximum of Y

What is the maximum population size of **Y**? Give your answer to one significant figure.

On what day does population **Y** reach its maximum size?

Adapted with permission from OCR A Level June 2003, Central Concepts, Question 7

Question deck:

STEM SMART Biology Week 23 - Populations

STEM SMART Biology Week 23 - Populations

Plotting Exponential Growth

Subject & topics

Biology | Ecology | Populations

Status

Not started

Stage & difficulty

A Level Challenge 1

A student plotted their prediction of the exponential growth of a bacterial population over 24 hours. Their graph is shown below.

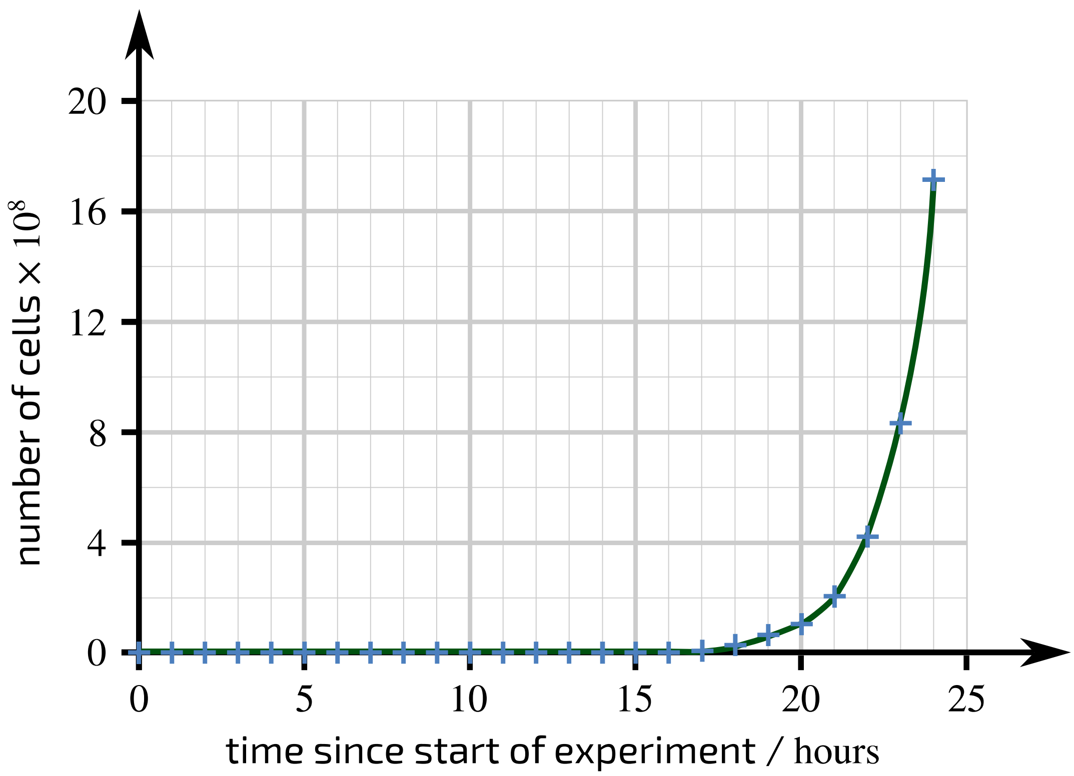

Figure 1: A student's graph showing their prediction of the exponential growth of a bacterial population over 24 hours.

Part A

Plotting problem

What is the problem with plotting exponential growth as the student has done in **Figure 1**?

- The graph shows logistic growth, not exponential growth.
- The y-axis is too small, which makes it hard to read the smaller values.
- In order to fit the larger y-axis values on the graph, the scale must be so large that smaller values cannot be read.
- The x-axis should start at 15 rather than at 0, because there is no growth from 0 hours to 15 hours.

Part B

Plotting solution

What change could the student make to fix the problem identified in the previous section?

- Plot the logarithm of time on the x-axis
- Plot the logarithm of cell number on the y-axis
- Plot the logarithm of time on the x-axis **and** plot the logarithm of cell number on the y-axis.
- Remove the later values from the graph.

Part C

An improved graph

The student recreated their graph by plotting the logarithm of cell number on the y-axis, as shown below.

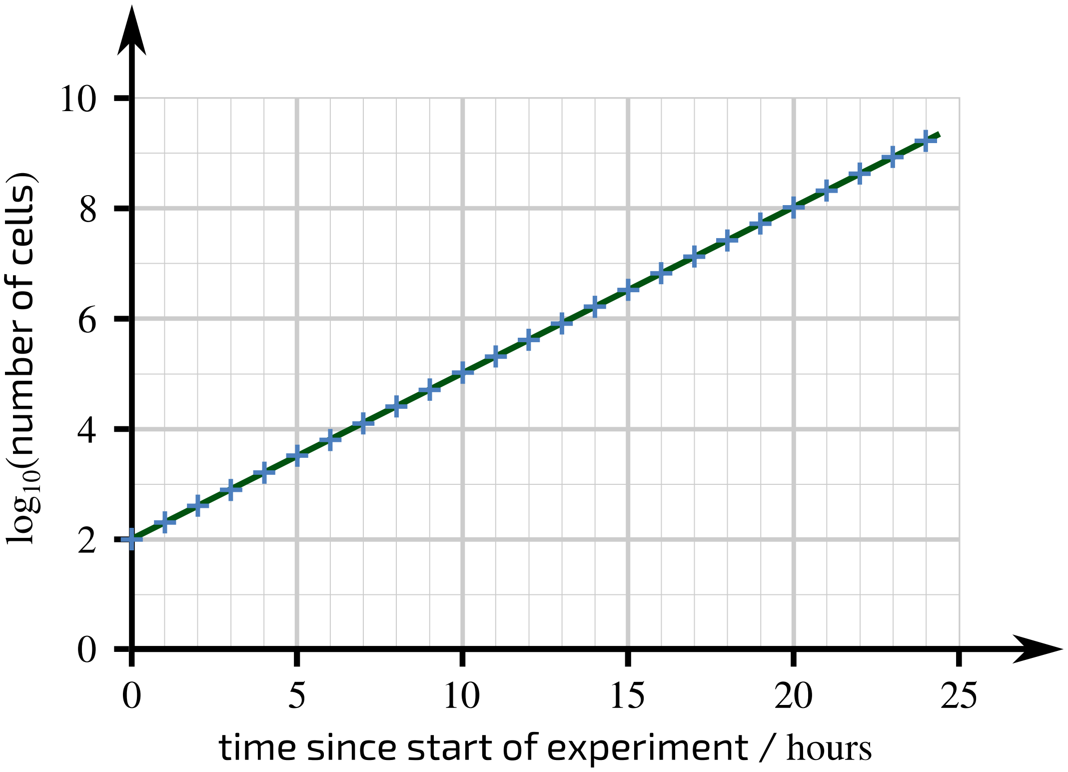

Figure 2: The student's graph showing their prediction of the exponential growth of a bacterial population over 24 hours, showing the logarithm of cell number on the y-axis.

Estimate the number of cells at each timepoint below, using **Figure 2**. Give your answers to 1 sf.

0 hours:

10 hours:

20 hours:

Part D

Growth equation

The student's prediction was that the number of cells would double every hour.

Use this information and your first answer in the previous section (your $0\ \mathrm{hours}$ value) to give the student's formula for the number of cells over time, where y is the number of cells and x is the time in hours.

The following symbols may be useful: x, y

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Question deck:

STEM SMART Biology Week 23 - Populations

STEM SMART Biology Week 23 - Populations

Exponential Population Growth

Subject & topics

Biology | Ecology | Populations

Status

Not started

Stage & difficulty

A Level Challenge 3

Further A Practice 3

*This question involves using **exponentials and logarithms** and **differentiation**, which are part of A Level Maths. For more information please check with your teacher.*

Mathematical models allow us to predict how a population will grow over time. Two commonly-used mathematical models of population growth are exponential growth and logistic growth. Both of these models assume that population growth is continuous rather than discrete.

Exponential growth is the simpler of the two models. In this model, a population's growth can be described by the following equation

$$N = N_0 e^{rt}$$

where N is the population size at time, t; N_0 is the initial population size; and r is the per capita growth rate (the population growth rate per individual per unit time).

Part A

Find N

A particular population has an initial size of 50 individuals. The per capita growth rate, r, is estimated to be $0.40\,\mathrm{year}^{-1}$.

What size would we predict the population to be after 5, 10, and 15 years, if we use the exponential growth model? Give your answers to 2 sf.

5 years: [ ] individuals

10 years: [ ] individuals

15 years: [ ] individuals

Part B

Find N_0

Another population has a current size of $17\,860$ individuals. The per capita growth rate, r, is estimated to be $0.30\,\mathrm{year}^{-1}$.

Use the exponential growth model to calculate the size that the population was $9\,\mathrm{years}$ ago. Give your answer to 2 sf.

Part C

Find t

A population of unicellular organisms has a current size of 1.0×10^8 cells. The initial population consisted of 20 cells. The per capita growth rate, r, is estimated to be $1.1\,\mathrm{day}^{-1}$.

Use the exponential growth model to calculate how much time has passed since the population was founded. Give your answer to 2 sf.

Part D

Find r

Another population started with an initial size of 150 individuals. After $25 \, \mathrm{months}$ the population has a size of 200 individuals.

Use the exponential growth model to calculate r. Give your answer to 2 sf.

Part E

Rate of change

We can differentiate the exponential growth equation to find the rate of change (i.e. the population growth rate) at any particular timepoint. This helps us understand how the population growth rate changes over time.

Differentiate N with respect to t to find the rate of change.

The following symbols may be useful: `Derivative(_, t), N, N_0, e, r, t`

Part F

Exponential growth behaviour

Which of the following statements about exponential growth are correct? Select all that apply.

You may find it helpful to refer to your answer to part E.

- [ ] As population size increases, the population growth rate **increases.**
- [ ] As population size increases, the population growth rate **decreases**.
- [ ] As population size increases, r **increases**.
- [ ] As population size increases, r **decreases**.
- [ ] Initially, as population size increases, the population growth rate **increases**. However, the population growth rate **decreases** as the population size approaches a maximum limit.

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Question deck:
STEM SMART Biology Week 23 - Populations

STEM SMART Biology Week 23 - Populations

Logistic Population Growth

Subject & topics

Biology | Ecology | Populations

Status

Not started

Stage & difficulty

A Level Challenge 3
Further A Practice 3

*This question involves using **exponentials and logarithms** and **differentiation**, which are part of A Level Maths. For more information please check with your teacher.*

Mathematical models allow us to predict how a population will grow over time. Two commonly-used mathematical models of population growth are exponential growth and logistic growth. Both of these models assume that population growth is continuous rather than discrete.

Logistic growth is the more complex of the two models. It is sometimes called sigmoidal growth because the graph of population size over time produces an S-shaped curve. In this model, a population's growth can be described by the following equation

$$N = \frac{K}{1 + \left(\frac{K}{N_0} - 1\right) e^{-rt}}$$

where N is the population size at time, t; K is the carrying capacity; N_0 is the initial population size; and r is the per capita growth rate (the population growth rate per individual per unit time).

Part A

Find N

A particular population has an initial size of 50 individuals. The per capita growth rate, r, is estimated to be $0.40\,\mathrm{year}^{-1}$. The carrying capacity is estimated to be $25\,000$ individuals.

What size would we predict the population to be after 5, 10, 15, 20, and 25 years, if we use the logistic growth model? Give your answers to 2 sf.

5 years: individuals

10 years: individuals

15 years: individuals

20 years: individuals

25 years: individuals

Part B

Find K

Another population has a current size of 5000 individuals. 11 years years ago, the population consisted of 3800 individuals. The per capita growth rate, r, is estimated to be $0.15\,\mathrm{year}^{-1}$.

Use the logistic growth model to predict the carrying capacity of this population. Give your answer to 2 sf.

Part C

Rate of change

We can differentiate the logistic growth equation to find the rate of change (i.e. the population growth rate) at any particular timepoint. This helps us understand how the population growth rate changes over time.

Differentiate N with respect to t to find the rate of change.

Part D

No change

Use the answer to part C to identify the value(s) of N for which there will be no population growth. Assume that r is positive. Select all that apply.

- [ ] $N = 0$
- [ ] $N = 1$
- [ ] $N = 1 - K$
- [ ] $N = K$
- [ ] $N = rK$
- [ ] $N = \frac{K}{2}$
- [ ] $N = \frac{K}{r}$

Part E

Maximum rate of change

We can find the value of N for which the population growth is at its maximum by differentiating the growth rate $\frac{dN}{dt}$ with respect to N and setting this derivative equal to zero.

Differentiate $\frac{dN}{dt}$ with respect to N.

Use the answer above to find the value of N for which population growth will be at its maximum. Assume that r is positive.

The following symbols may be useful: `K`, `N`, `r`

Part F

Logistic growth behaviour

Which of the following statements about logistic growth are correct? Select all that apply.

- [ ] When the population size is **greater than** half the carrying capacity, as population size increases, the population growth rate **increases**.
- [ ] When the population size is **less than** half the carrying capacity, as population size increases, the population growth rate **decreases**.
- [ ] For any population size, as population size increases, the population growth rate **increases**.
- [ ] When the population size is **greater than** half the carrying capacity, as population size increases, the population growth rate **decreases.**
- [ ] For any population size, as population size increases, the population growth rate **decreases**.
- [ ] When the population size is **less than** half the carrying capacity, as population size increases, the population growth rate **increases**.