Topics we will cover over the next 2 classes

Estimating population size at the present and in the future

Size (*N*)

Density (*N*/area)

~~Distribution~~

~~e.g. Uniform, random clumped,~~

POPULATION

And limits to population growth

Growth rate (*r*)

~~Structure~~

~~e.g. age structure, sex ratio~~

Life History Traits

- can affect how populations grow, e.g.

- Age at first reproduction
- Number of offspring
- Likelihood of survival based on age

Pattern of growth

e.g. logistic vs. exponential

Due this Sunday, April 2nd @ 11:59 pm

Group Project

- only one submission per group please
- projects accepted without penalty until Sunday, April 9th @ 11:59 pm
- optional peer evaluation

Quiz 10 – Population Ecology: Population Size and Growth

Quiz 11 – Population Ecology: Life History Traits (covered in Thursday's lecture) – only 4 questions

Worksheet #10 – Spotted Owl – Population Ecology

Note – I will also be opening up Quiz 9 – Species Concepts & Speciation.   Due by the last day of classes.

Midterm #2 will be returned at the end of class

- Answer guide will not be released until Friday, as Brett's teaching team is still marking.

- I will accept any request for regrades after the answer guide has been released. You must drop off your exam to Lynn, and include a note of which question(s) you would like remarked, and why.

- Marks will be posted on Canvas sometime on Wednesday.

A head's up – Rory will be having his office hours on Zoom today

Estimating population size

- In real life it is typically impossible to count every individual in a population.
- So, biologists must estimate abundance via sampling.

https://www.flickr.com/photos/polarguidekeith/6170642611

Two techniques

- The technique used to estimate the population size often depends upon the species being studied.

Quadrat Sampling ← No — Does the organism move? — Yes → Mark-Recapture Techniques

e.g. plants, barnacles, fungi

e.g. reptiles, amphibians, birds, mammals, etc.

Using **mark-recapture** to estimate population size

Visit 1

- Capture individuals
- Count and mark them (**M**)
- Release them

Give marked individuals time to spread out

Visit 2 +

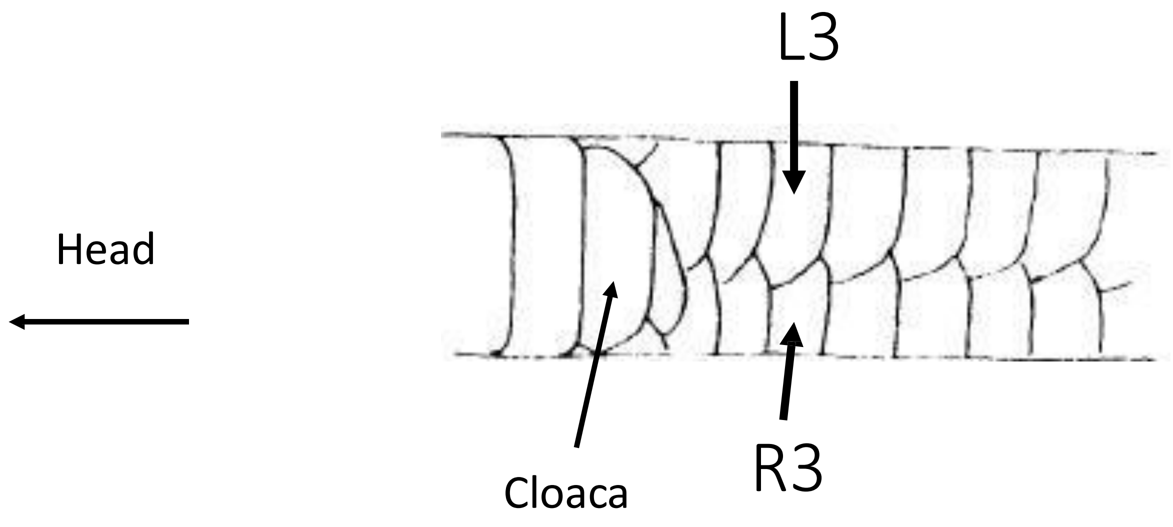
- Capture individuals (**n**)
  - Some will be marked (**m**)
  - Some will be unmarked
- Count them

Mark-recapture techniques - snakes

Not testable

Basic procedure:

- Clip scales on the tail.
- Can give an individual mark (or not).



Manitoba – 10,000 snakes with the R3 mark

Vancouver Island – individual marks, e.g. R3L3, R3L4…..

Lincoln-Peterson method of mark-recapture estimation

Data from 1st visit

$$\frac{M}{\hat{N}} = \frac{m}{n}$$

Data from 2nd visit

M = number of individuals marks on first visit.

.n = number of individuals captured on 2nd visit

.m = number of individuals captured during second visit that were marked

Solve for N̂…

$$\boxed{\hat{N} = \frac{M * n}{m}}$$

I would give you this equation on the exam, but I would not give you a definition of each of the letters.

Lincoln-Peterson method of mark-recapture estimation

Assumes the proportion of **marked/total** in the **second visit** sample is representative of the proportion of **marked/total** in the **population**…

$$\frac{\text{M (\# of individuals marked on visit 1)}}{\hat{N}\ \text{(estimated population size)}} = \frac{\text{m (\# of individuals marked on visit 2)}}{\text{n (total individuals caught on visit 2)}}$$

Some assumptions of the Lincoln-Peterson method

1. The population is closed ($\hat{N}$ does not change between sampling periods)
   - no births, deaths, or movement of individuals in/out of the population

2. Individuals do not differ in their probability of being caught
   - marking does not affect probability of being caught

3. Individuals do not lose marks between sampling periods.

Practice: Lincoln-Peterson method of mark-recapture estimation

You are curious about the number of slugs in Vancouver, so you decide to set up a mark-recapture experiment.

On your first visit, you capture 100 slugs. You mark and release them.

On your second visit, you capture 50 slugs, 15 of which are marked.

What is the estimated population size? Report to the nearest whole number.

$$\hat{N} = \frac{M * n}{m}$$

$\hat{N}$ = estimated population size

M = # individuals marked in first sample

n = total # individuals caught in second sample

m = # marked individuals caught in second sample

Lincoln-Peterson Method - Practice

Based on proportions:

$$\frac{\text{Estimated population size } (\hat{N})}{\text{\# of individuals marked in 1}^{st}\text{ sample (M)}} = \frac{\text{Total \# of individuals captured in 2}^{nd}\text{ sample (n)}}{\text{\# of individuals marked in 2}^{nd}\text{ sample (m)}}$$

$$\frac{\hat{N}}{M} = \frac{n}{m}$$

reorganized: $$\hat{N} = \frac{M*n}{m}$$

100 individuals captured & marked (M)

50 individuals caught in second sample (n)

15 of those 50 individuals are marked (m)

$N = (100 * 50) / 15$

$N = 333$ individuals

iClicker Question

You have been hired to estimate the population size of adult raccoons at UBC. This summer you and a friend place 80 live traps at different locations around campus. You capture 50 raccoons in these traps. You mark the raccoons by spraying pink paint on the tip of their tail and release the raccoons.

One month later, you reopen the traps. You capture 20 raccoons. 4 of these raccoons are marked. What is the estimated population size.

A. 100
B. 150
C. 200
D. 250
E. 500

Answer

You have been hired to estimate the population size of adult raccoons at UBC. This summer you and a friend place 80 live traps at different locations around campus. You capture 50 raccoons in these traps. You mark the raccoons by spraying pink paint on the tip of their tail and release the raccoons.

One month later, you reopen the traps. You capture 20 raccoons. 4 of these raccoons are marked. What is the estimated population size.

A. 100
B. 150
C. 200
D. 250
E. 500

What assumptions do you need to make to have confidence in your estimate?

Learning Objective

If given a scenario, be able to estimate the population size at the present time using the Lincoln-Peterson Index.

Also be able to state some of the assumptions that you are making in order to have confidence in your population estimate.

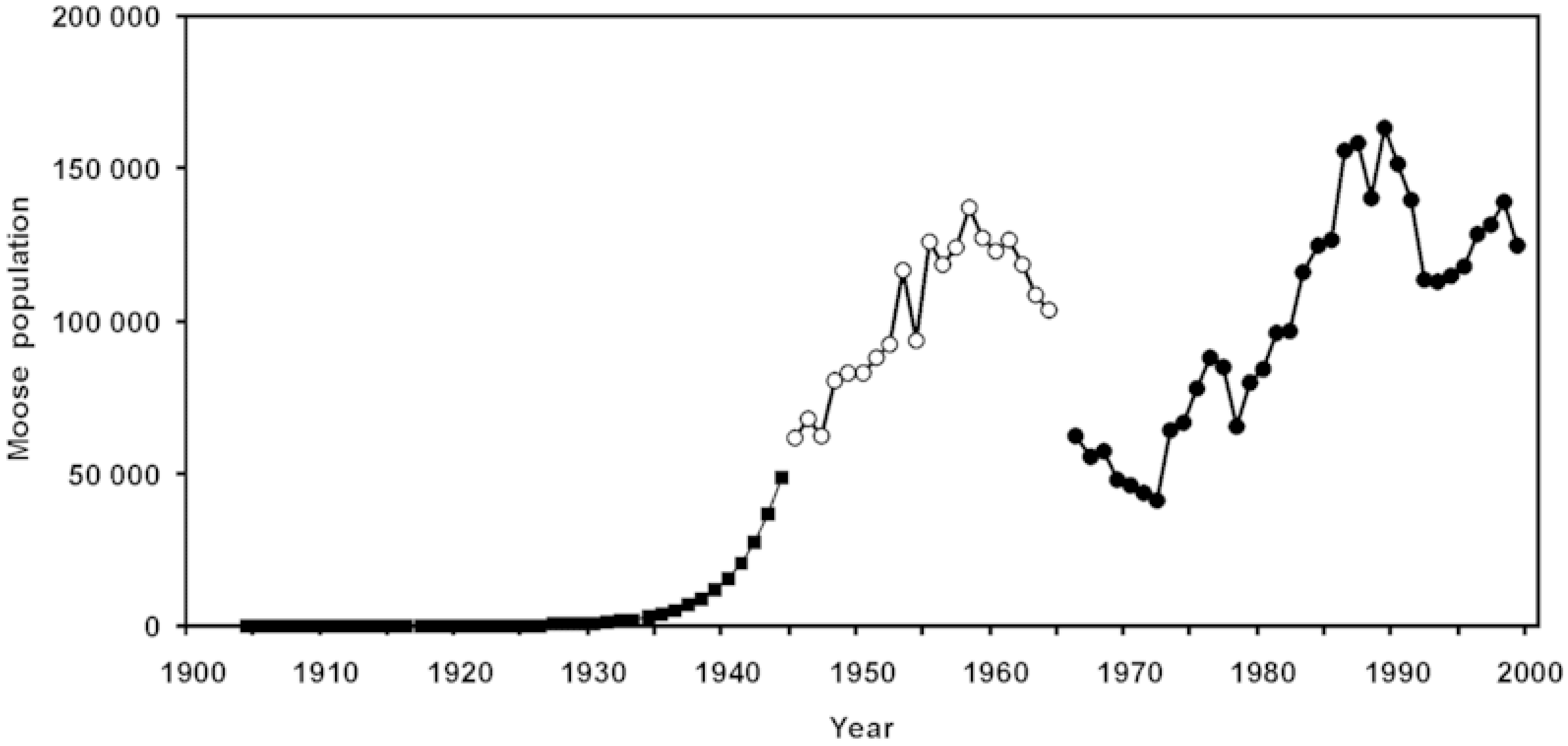
NEW: If given a scenario, be able to estimate the population size in the future using the equation:

$$\mathbf{N_{t+1} = (1 + \boldsymbol{r})\, N_t}$$

- In the following slides, we will work towards this equation.

Population Size (N) varies with time

Moose population size over time in Newfoundland (introduced 1904)



McClaren et al. 2004

iClicker Question

Which variables could cause a population size to increase?

A. Births
B. Deaths
C. Immigration
D. Emigration
E. A and C

iClicker Question

Which variables could cause a population size to increase?

A. Births
B. Deaths
C. Immigration
D. Emigration
E. A and C

Deaths and emigration (individuals leaving a population) can cause population size to decrease

Draw

Estimating population size in the future

We will cover a few equations for calculating population size and different time points.

Size (N)

Density (N/area)

POPULATION

Growth rate (r)

Life history traits

e.g. age specific birth rates, death rate

Pattern of growth

e.g. logistic vs. exponential

Calculating population size at different time points

If you know how many individuals were added/removed from the population over a period of time *t* --> *t + 1*…

$$N_{t+1} = N_t + B - D + I - E$$

N_t = population size (*N*) at time *t*
N_{t+1} = population size (*N*) at time *t + 1*
B = # of new individuals born between *t* and *t + 1*
D = # of individuals that die between *t* and *t + 1*
I = # of individuals immigrating between *t* and *t + 1*
E = # of individuals emigrating between *t* and *t + 1*

This equation is not testable, but one of the steps to getting to the equation that is testable:

$\mathbf{N_{t+1} = (1 + \mathit{r})\ N_t}$

Immigration and emigration not typically include

$$N_{t+1} = N_t + B - D + \underbrace{I - E}$$

Typically not included:

- Difficult to estimate
- Many population models assume no I or E

N_t = population size (*N*) at time *t*

N_{t+1} = population size (*N*) at time *t + 1*

B = # of new individuals born between *t* and *t + 1*

D = # of individuals that die between *t* and *t + 1*

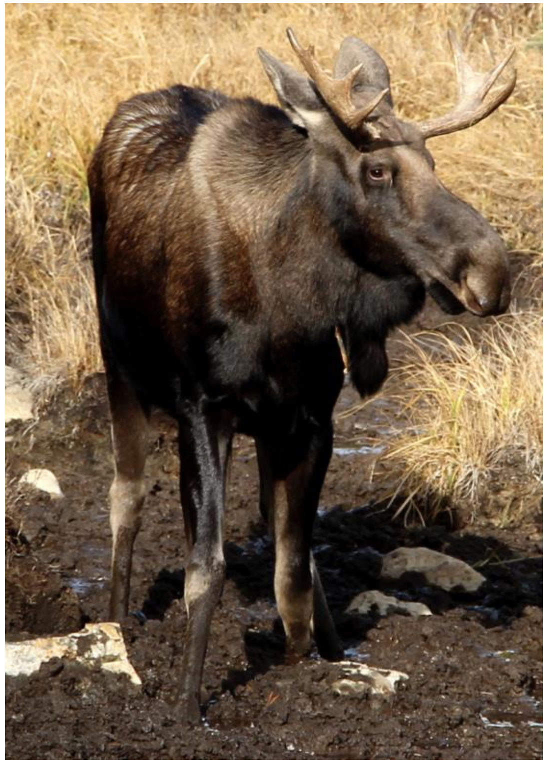
I = # of individuals immigrating between *t* and *t + 1*

E = # of individuals emigrating between *t* and *t + 1*

Example: Calculating population size at different time points

Let’s say we start with a population of 100 moose. Over the course of a year, a total of 10 moose were born and 30 moose died. How large will the population be after one year?

$N_{t+1} = N_t + B – D$



Did the population grow or shrink?

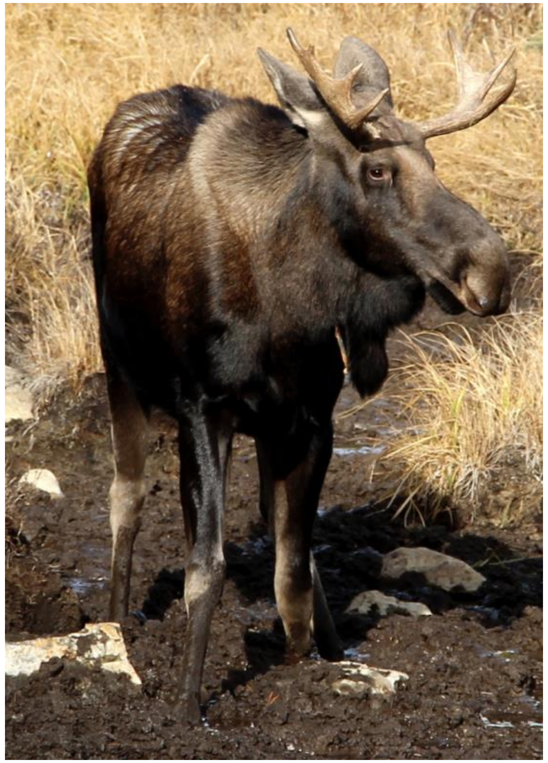
Example: Calculating population size at different time point

Let's say we start with a population of 100 moose. Over the course of a year, a total of 10 moose were born and 30 moose died. How large will the population be after one year?

$N_{t+1} = N_t + B - D$

$N_{t+1} = 100 + 10 - 30$

$N_{t+1} = 80$



Did the population grow or shrink?

$N_{t+1} < N_t$, so the population shrank

per capita birth rates (b) & death rates (d)

Biologists typically calculate population parameters (e.g. birth rates, death rates) on a per capita (or per person/individual) basis.

This allows biologists to compare these parameters across populations of different sizes.

To determine the per capita birth rate(b) or death rate (d)

You just divide the absolute number of births (B) or deaths (D) in a given time period by the population size.

Per capita birth rate: b = B/N

Per capita death rate: d = D/N

b can range from 0 to ∞
d can range from 0 to 1

Calculating *b* & *d*, example

- If the population size (N) was 100 and there were 2 births.

Per capita birth rate (*b*) = B/N   2 /100 = 0.02

- If the population size (N) was 100 and 5 people died:

Per capita death rate (*d*) = D/N   5/100 = 0.05

iClicker Question

If the population size was 200 and there were 10 births, what is the per capita birth rate (*b*)?

A. 0.01

B. 0.02

C. 0.05

D. 0.10

E. I don’t have a calculator.

Answer

If the population size was 200 and there were 10 births, what is the per capita birth rate (*b*)?

A. 0.01

B. 0.02

C. 0.05

D. 0.10

E. I don’t have a calculator.

.b = 10/200

iClicker

If the population size was 250 and there were 5 deaths, what is the per capita death rate (*d*)?

A. 0.01

B. 0.02

C. 0.05

D. 0.10

E. I don't have a calculator.

Answer

If the population size was 250 and there were 5 deaths, what is the per capita death rate (*d*)?

A. 0.01

B. 0.02

C. 0.05

D. 0.10

E. I don't have a calculator.

.$d = 5/250$

Calculating population size at a future point in time using per individual birth and death rates

Another way to think about our population model, if we know the average rate of reproduction and death per individual:

$$N_{t+1} = N_t + b^*N_t - d^*N_t$$

N_t = population size (N) at time t
N_{t+1} = population size (N) at time $t + 1$
b = *per capita** rate of births
d = *per capita* rate of death

This equation is not testable – but I am trying to step you to an equation that is testable

* *per capita* = per individual

$$N_{t+1} = N_t + B - D$$

iClicker Question

Let's say we start with a population of 100 slugs. Over the course of a year, an average slug will have 2 offspring. Each slug also has a 50% chance of dying (or, *per capita*, 0.5 slugs will die in a year). How large will the population be after one year?

$N_{t+1} = N_t + b*N_t - d*N_t$

A. 100

B. 150

C. 200

D. 250

E. Not sure

Answer

Let's say we start with a population of 100 slugs. Over the course of a year, an average slug will have 2 offspring. Each slug also has a 50% chance of dying (or, *per capita*, 0.5 slugs will die in a year). How large will the population be after one year?

$N_{t+1} = N_t + b*N_t - d*N_t$

A. 100

B. 150

C. 200

D. 250

E. Not sure

Answer – with calculations

Let's say we start with a population of 100 slugs. Over the course of a year, an average slug will have 2 offspring. Each slug also has a 50% chance of dying (or, *per capita*, 0.5 slugs will die in a year). How large will the population be after one year?

$N_{t+1} = N_t + b*N_t - d*N_t$

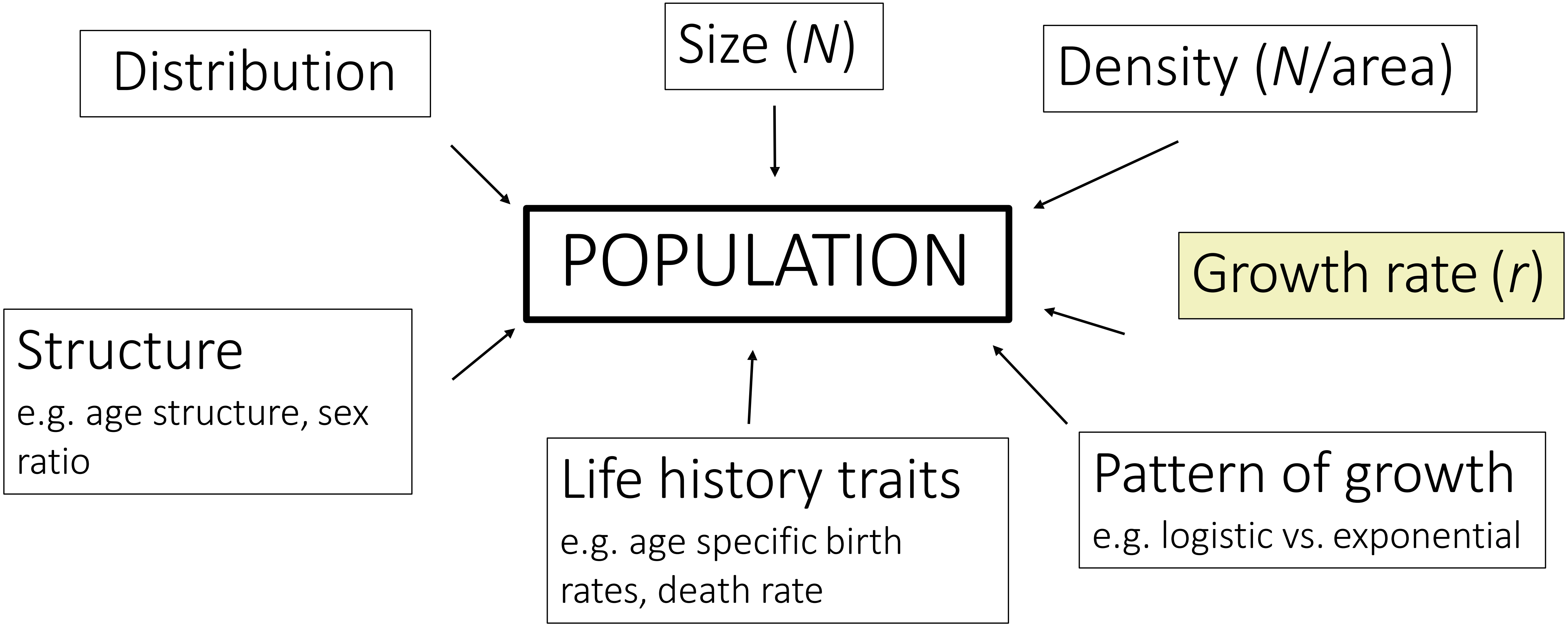
$N_{t+1} = 100 + (2*100) - (0.5*100)$

$N_{t+1} = 100 + 200 - 50$

$N_{t+1} = 250$

$N_{t+1} > N_t$, so the population grew

Population Growth Rate



Calculating population growth rate (r) using b & d

r = per capita growth rate or intrinsic growth rate of the population

$$r = b - d$$

If $b=d$, *then* $r=0$ – population size is not changing

If $b>d$, then $r>0$ – population size is increasing

If $b<d$, then $r<0$ – population size is decreasing

Poll: Calculating *per capita* growth rate

An ecologist studies a population of 10 wolves. Over one year, 1 cub is born, but 3 wolves die. What is the *per capita* growth rate (*r*) for this time period?

A. 0.3
B. 0.1
C. -0.2
D. -2
E. I have no idea how to answer this question.

$\boldsymbol{r = b - d}$

$\boldsymbol{b = B/N_t}$
$\boldsymbol{d = D/N_t}$

Is the population size increasing, decreasing or staying the same?

Answer

An ecologist studies a population of 10 wolves. Over one year, 1 cub is born, but 3 wolves die. What is the *per capita* growth rate (r) for this time period?

A. 0.3
B. 0.1
C. -0.2
D. -2
E. I have no idea how to answer this question.

$b = 1/10 = 0.1$
$d = 3/10 = 0.3$
$r = 0.1 – 0.3 = -0.2$

$\boldsymbol{r = b – d}$

$\boldsymbol{b = B/N_t}$
$\boldsymbol{d = D/N_t}$

Is the population size increasing, decreasing or staying the same? *Decreasing*

Another helpful formula for estimating population size at future time(s) - add *r* to the population growth formula

We know that $r = b - d$...

$$N_{t+1} = N_t + b^*N_t - d^*N_t$$

This is the formula for calculating population growth between two time points for slug question

$$N_{t+1} = N_t + (b - d)^*N_t$$

Factor out b - d

$$N_{t+1} = N_t + r^*N_t$$

Sub in r instead of b - d

This equation is testable.
I won't test you on how to derive this formula. It's just so we understand where N(t+1) = Nt*(1+r) comes from!

$$\boxed{\mathbf{N_{t+1} = (1 + r)\, N_t}}$$

Factor out N_t

iClicker Question - Estimating population size over multiple years

$$N_{t+1} = N_t(1 + r)$$

What is the estimated population size of the pasqueflower population in 2026?

$N_1 = 100$ $r = 0.5$

Year	**Time step**	$\mathbf{N_t}$	***r***
2021	1	$N_1 = 100$	0.5
2022	2	$N_2 = 100(1 + 0.5) = 150$	0.5
2023	3	$N_3 = 150(1 + 0.5) = 225$	0.5
2024	4	$N_4 = 225(1 + 0.5) = 337.5$	0.5
2025	5	$N_5 = 337.5(1 + 0.5) = 506.3$	0.5
2026	6	$N_6 =$	

A. 652.6

B. 681.2

C. 759.4

D. 800.5

E. Unsure

Estimating population size over multiple years

$$N_{t+1} = N_t(1 + r)$$

What is the estimated population size of pasqueflower population in 2026?

$N_1 = 100$ $r = 0.5$

A. 552.6
B. 681.2
C. 759.4
D. 800.5
E. Unsure

Year	Time step	N_t	r
2021	1	$N_1 = 100$	0.5
2022	2	$N_2 = 100(1 + 0.5) = 150$	0.5
2023	3	$N_3 = 150(1 + 0.5) = 225$	0.5
2024	4	$N_4 = 225(1 + 0.5) = 337.5$	0.5
2025	5	$N_5 = 337.5(1 + 0.5) = 506.3$	0.5
2026	6	$N_6 = 506.3(1 + 0.5) = 759.4$	

50 individuals were added since N_1

75 individuals were added since N_2

112.5 individuals were added since N_3

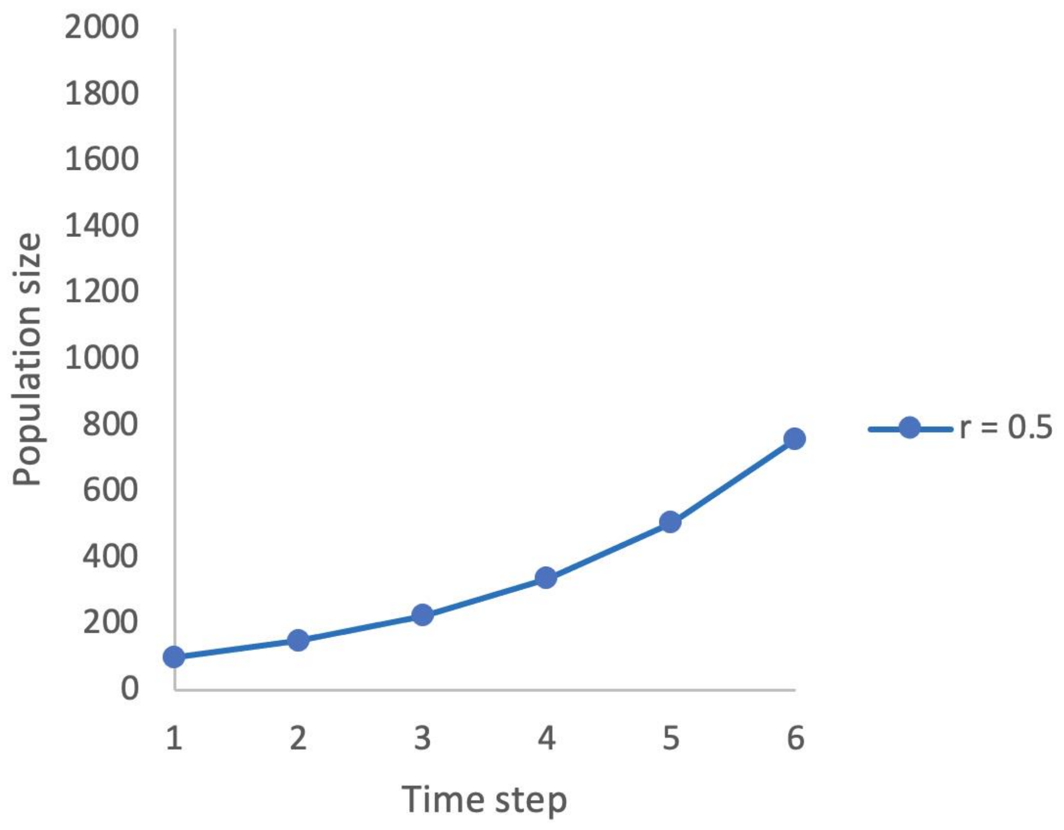
168.8 individuals were added since N_4

253.1 individuals were added since N_5

Note – when r is constant, the number of individuals added to the population gets bigger as population size increase

What does population growth look like over multiple time steps @ $r = 0.5$

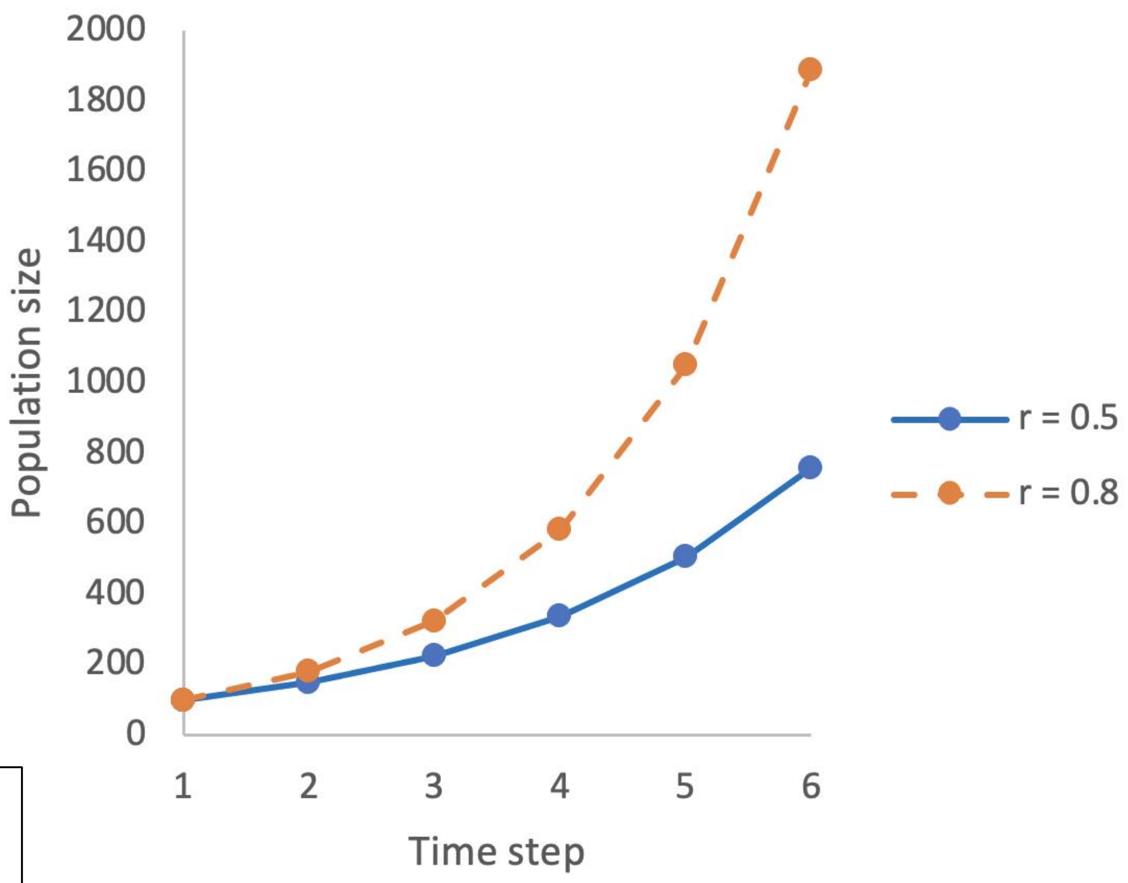
Year	**Time step**	$\mathbf{N_t}$	$\boldsymbol{r}$
2021	1	$N_1 = 100$	0.5
2022	2	$N_2 = 100(1 + 0.5) = 150$	0.5
2023	3	$N_3 = 150(1 + 0.5) = 225$	0.5
2024	4	$N_4 = 225(1 + 0.5) = 337.5$	0.5
2025	5	$N_5 = 337.5(1 + 0.5) = 506.3$	0.5
2026	6	$N_6 = 506.3(1 + 0.5) = 759.4$	



$$\mathbf{N_{t+1} = N_t(1 + \boldsymbol{r})}$$

What does population growth look like over multiple time steps if r = 0.8?

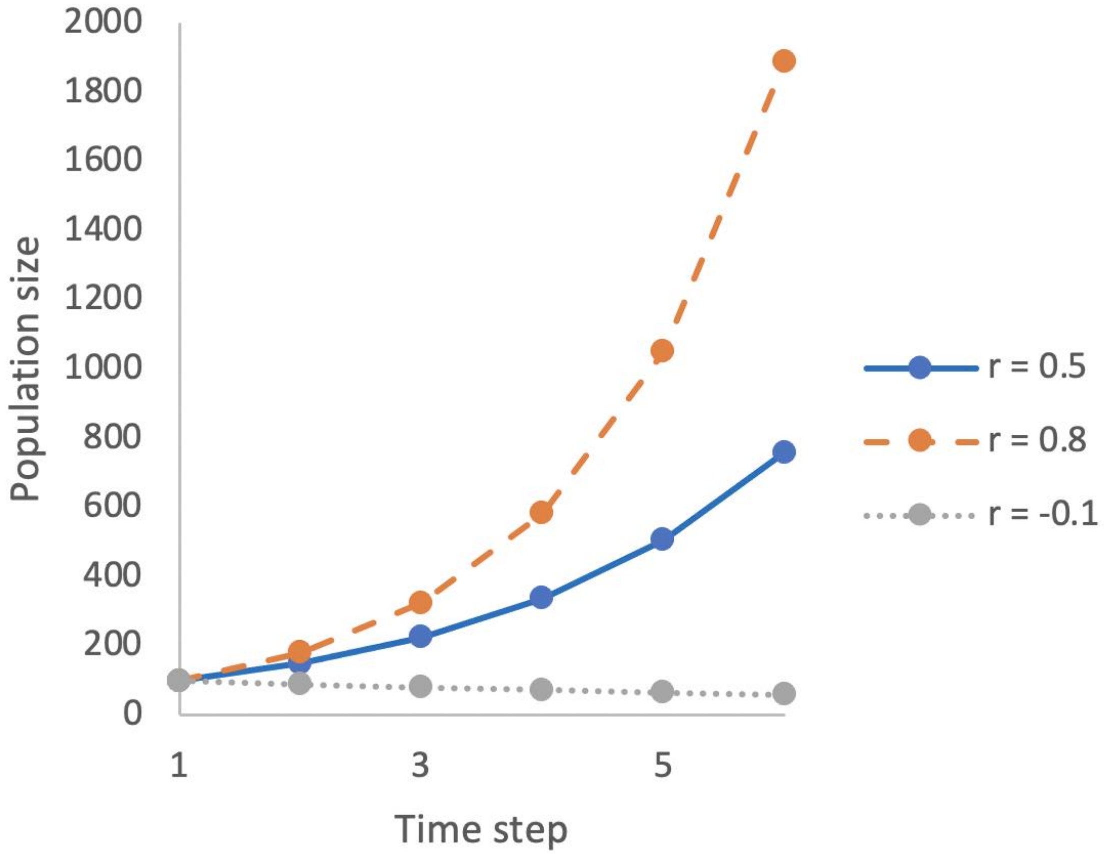
Year	Time step	N_t	r
2021	1	N_1 = 100	0.8
2022	2	N_2 = 100(1 + 0.8) = 180	0.8
2023	3	N_3 = 180(1 + 0.8) = 324	0.8
2024	4	N_4 = 324(1 + 0.8) = 583.2	0.8
2025	5	N_5 = 583.2(1 + 0.8) = 1049.8	0.8
2026	6	N_6 = 1049.8(1 + 0.8) = 1889.6	



The larger the per capita growth rate = the steeper curve, as more individuals are being added to population with each time step

What does population growth look like over multiple time steps if *r* = -0.1?

Year	Time step	N_t	*r*
2021	1	$N_1 = 100$	-0.1
2022	2	$N_2 = 100(1 - 0.1) = 90$	-0.1
2023	3	$N_3 = 90(1 - 0.1) = 81$	-0.1
2024	4	$N_4 = 81(1 - 0.1) = 72.9$	-0.1
2025	5	$N_5 = 72.9(1 - 0.1) = 65.6$	-0.1
2026	6	$N_6 = 65.6(1 - 0.1) = 59.0$	



Per capita growth rate is negative so population size is declining.

Patterns of Population Growth

Two models: Exponential and Logistic

Size (*N*)

Density (*N*/area)

POPULATION

Growth rate (*r*)

Life History Traits

- can affect how populations grow, e.g.

- Age at first reproduction
- Number of offspring
- Likelihood of survival based on age

Patterns of growth

Two simple models:
logistic & exponential

Two types of population growth

Ecologists describe two types of population growth:

Exponential growth – the unrestricted growth of a population that increases at a constant growth rate (*r*).

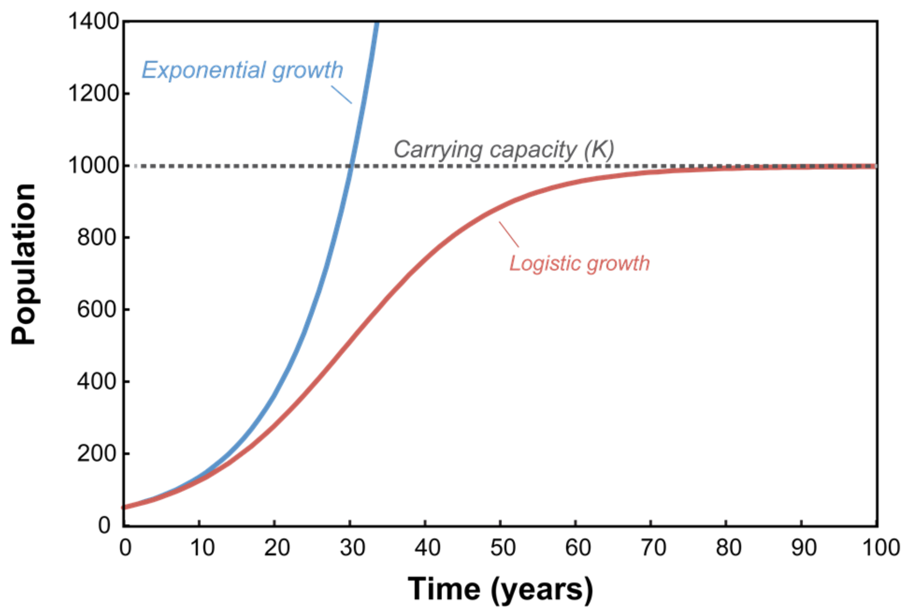
Logistic growth – a pattern of growth that starts fast, but then slows due to limiting factors.

Eventually, the population will stop growing (*r*=0) once it has reached the environment's carrying capacity (or the maximum population size that the environment/habitat can support at a given time).

Population growth – several learning goals

Be able to:

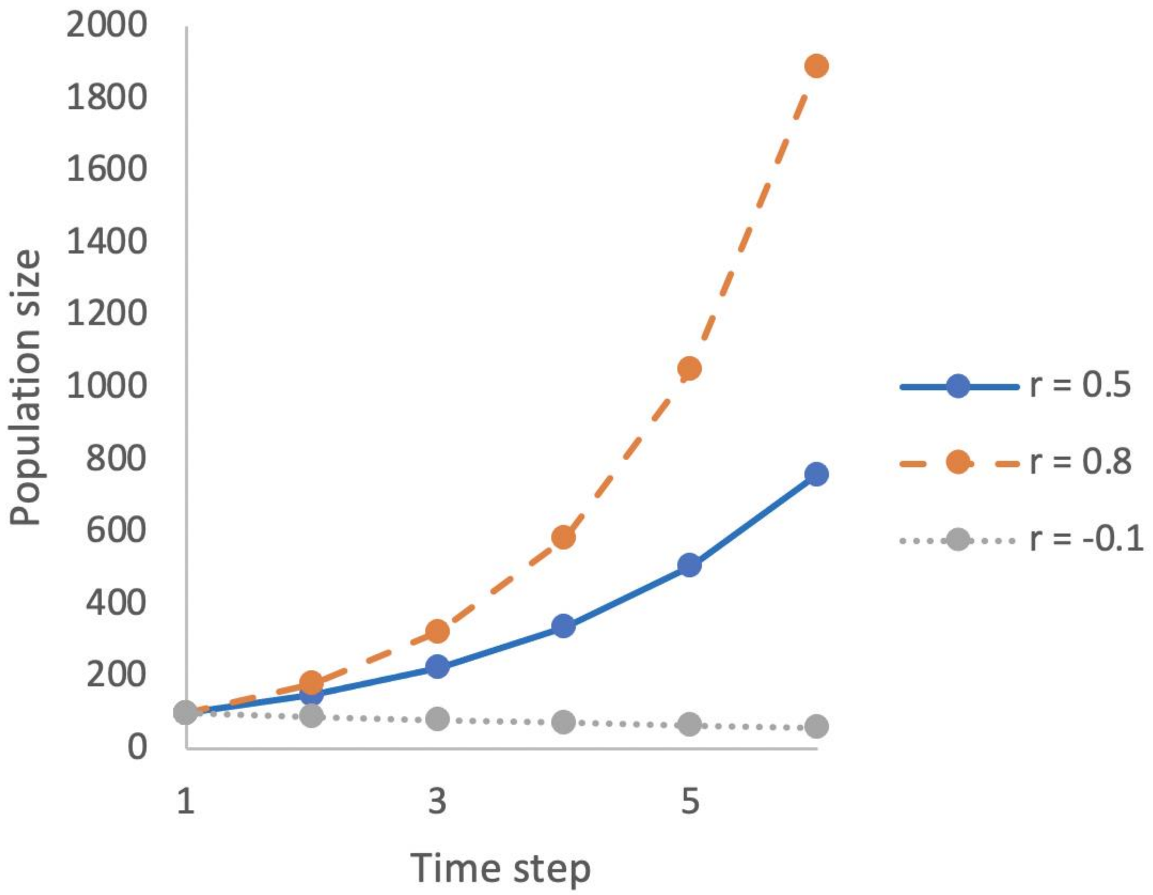
- identify exponential and logistic growth
- describe how the per capita growth rate changes over time or not.
- identify when a population has reached carrying capacity
- explain how density-dependent and density-independent factors affect population growth/size.



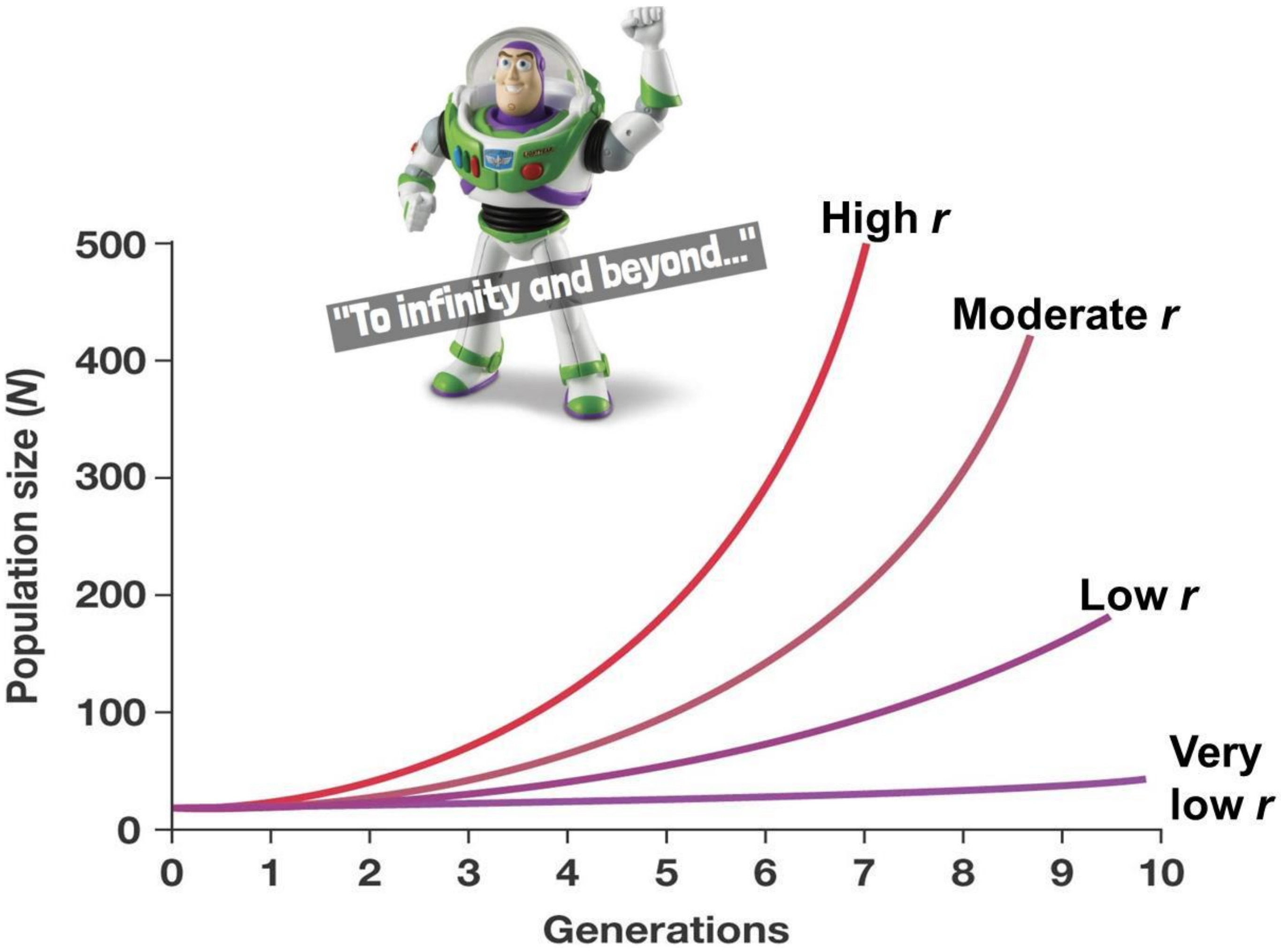
Exponential growth

J-shaped curve

- *r* is **density-independent** under exponential growth
  - In other words – ***r* won't change**, no matter how big or small the population gets



Exponential population growth - equation



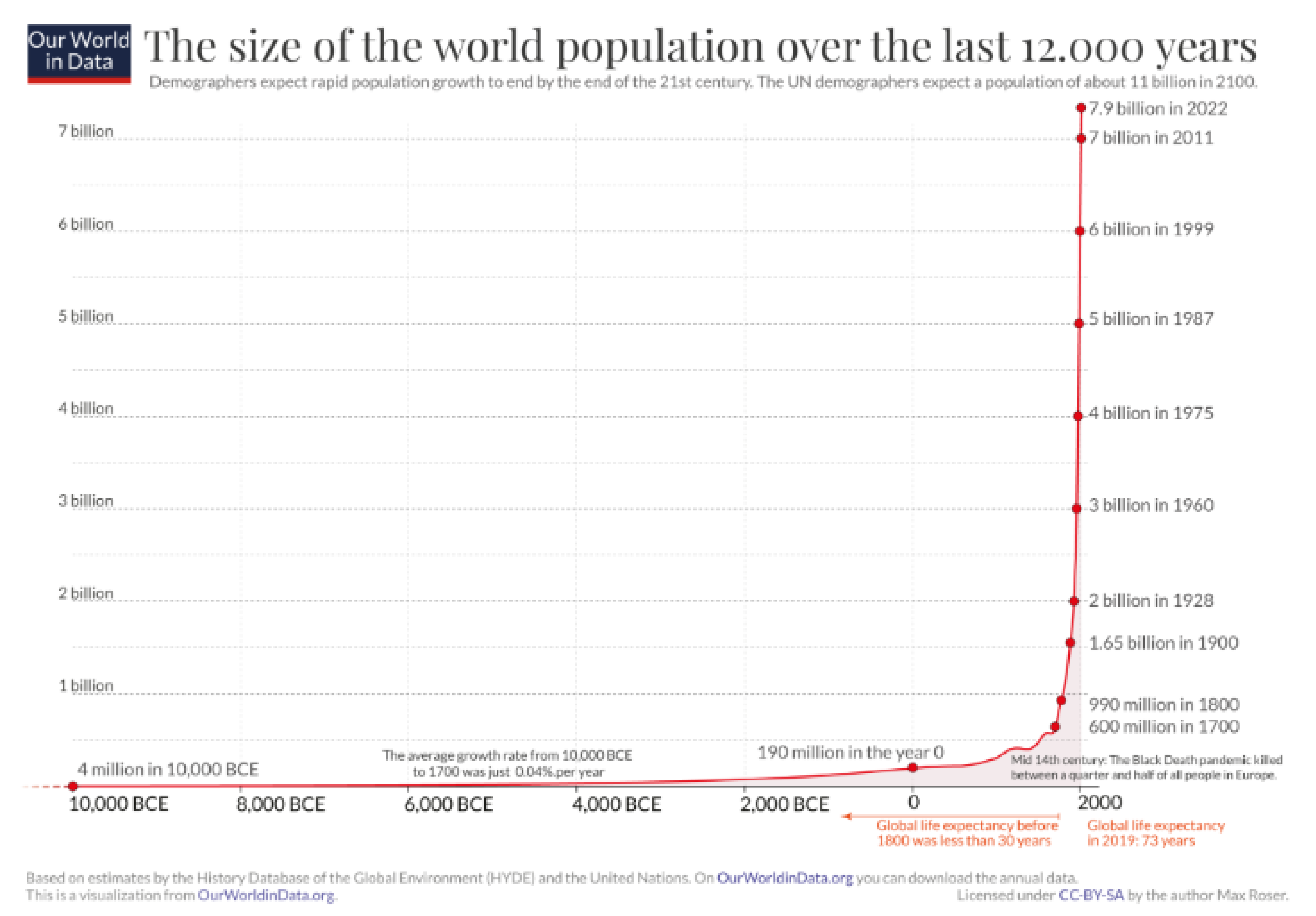
$$\frac{dN}{dt} = rN$$

dN/dt = **instantaneous* rate of change of N over time** (*not over time steps)

You don't need to be able to use this equation.

Notice how the larger the per capita growth rate (*r*) the steeper the curve.

The larger a population gets the more individuals get added to the population with time.



https://ourworldindata.org/world-population-growth

It took all of human history up until the early 1800’s for the population size to reach 1 billion people.

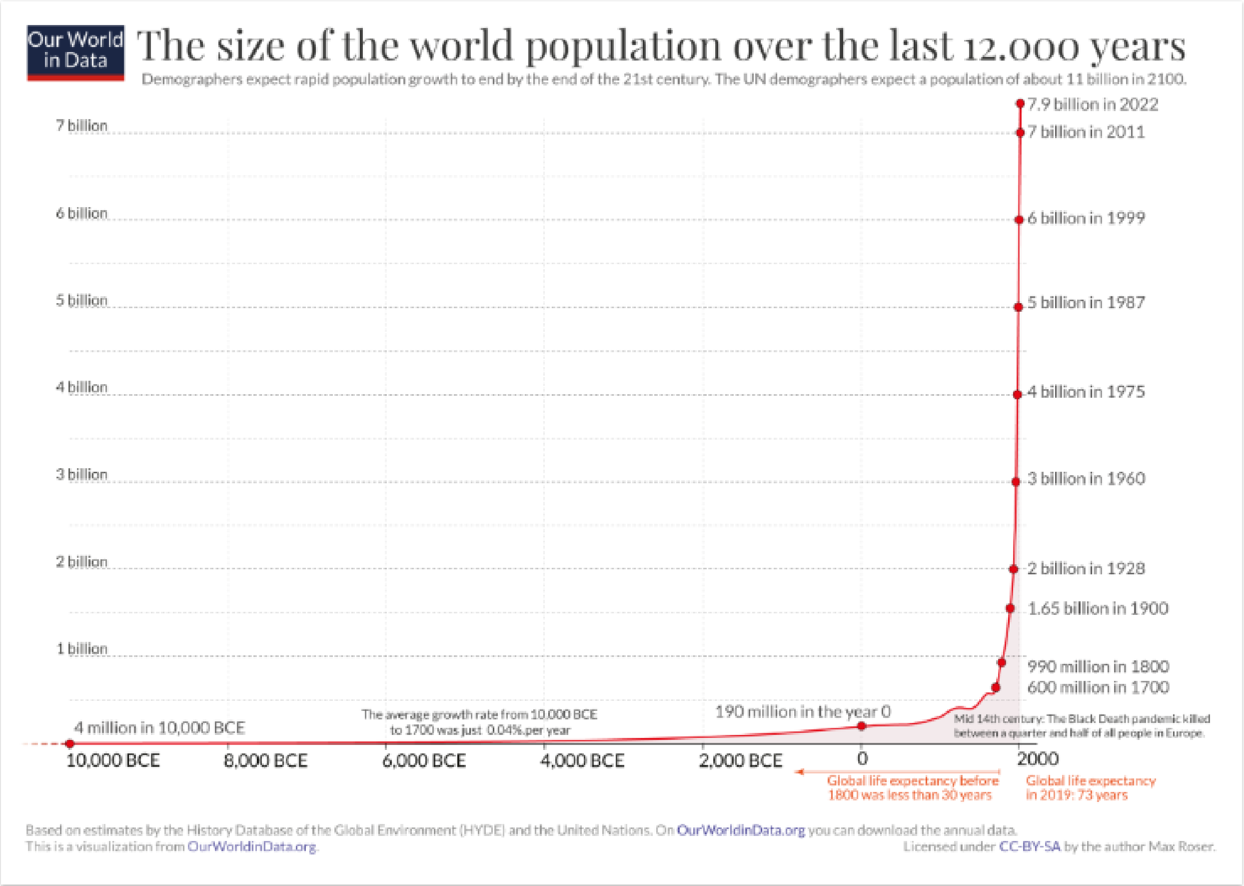
1930 - 2 billion people (it had only taken ~**126 years** to add 1 billion people)

1960 – 3 billion people (it took ~**30 years** to add 1 billion people)

1974 - 4 billion years (it took ~**14 years** to add 1 a billion people)

......

2022 - 8 billion people (it took ~**12 years** to add 1 billion people)



$$\frac{dN}{dt}=rN$$

https://ourworldindata.org/world-population-growth

Under what conditions can we realistically expect **exponential growth** to occur?

When:

- **Resources** are close to **unlimited,** and
- Population **sizes** are relatively **small**

For example – exponential growth can occur when:

- A few individuals colonize a new area with few competitors and resources are plentiful

- Population is recovering from a bottleneck and resources are plentiful

- so, no competition for limited resources that would negatively affect the per capita birth or death rates.

Exponential growth cannot continue forever…

https://www.nationalgeographic.org/encyclopedia/limiting-factors/

…otherwise, the earth would be covered in, e.g. rabbits!

At some point, **resources (e.g. food, shelter, mates) become limiting**.

Individuals start to compete with each other and *per capita* growth rates begin to get smaller because

- *Per capita* birth rates decrease
- *Per capita* death rates increase
  - So population, growth slows.
- Eventually, *r* approaches 0 and the population will have reached a stable size or carrying capacity (K).

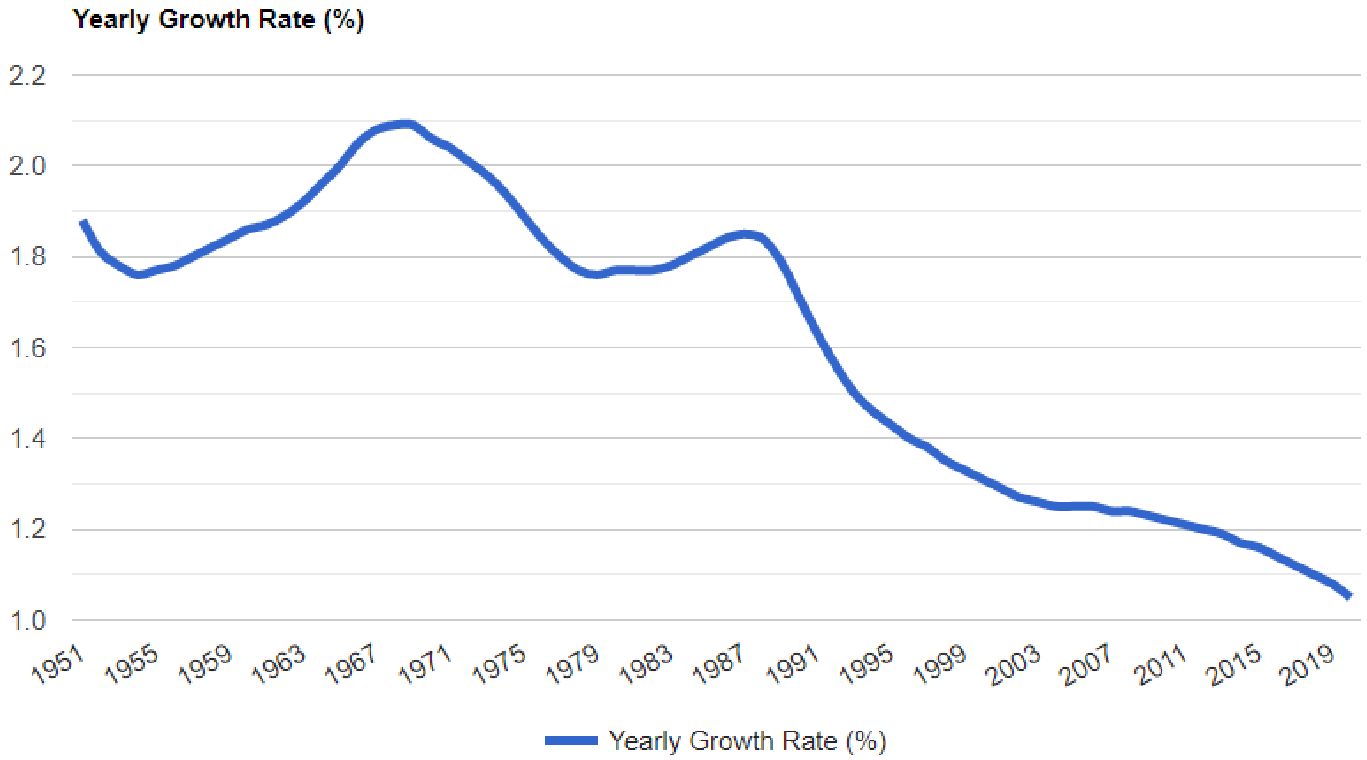
Our growth rate is getting smaller..

Our growth rate peaked in the 1960's when r = ~2.0

Today, r = ~0.84

It is estimated that the human population size will reach:

- 9 billion in 2037 (15 years)
- 10 billion in 2057 (20 years)



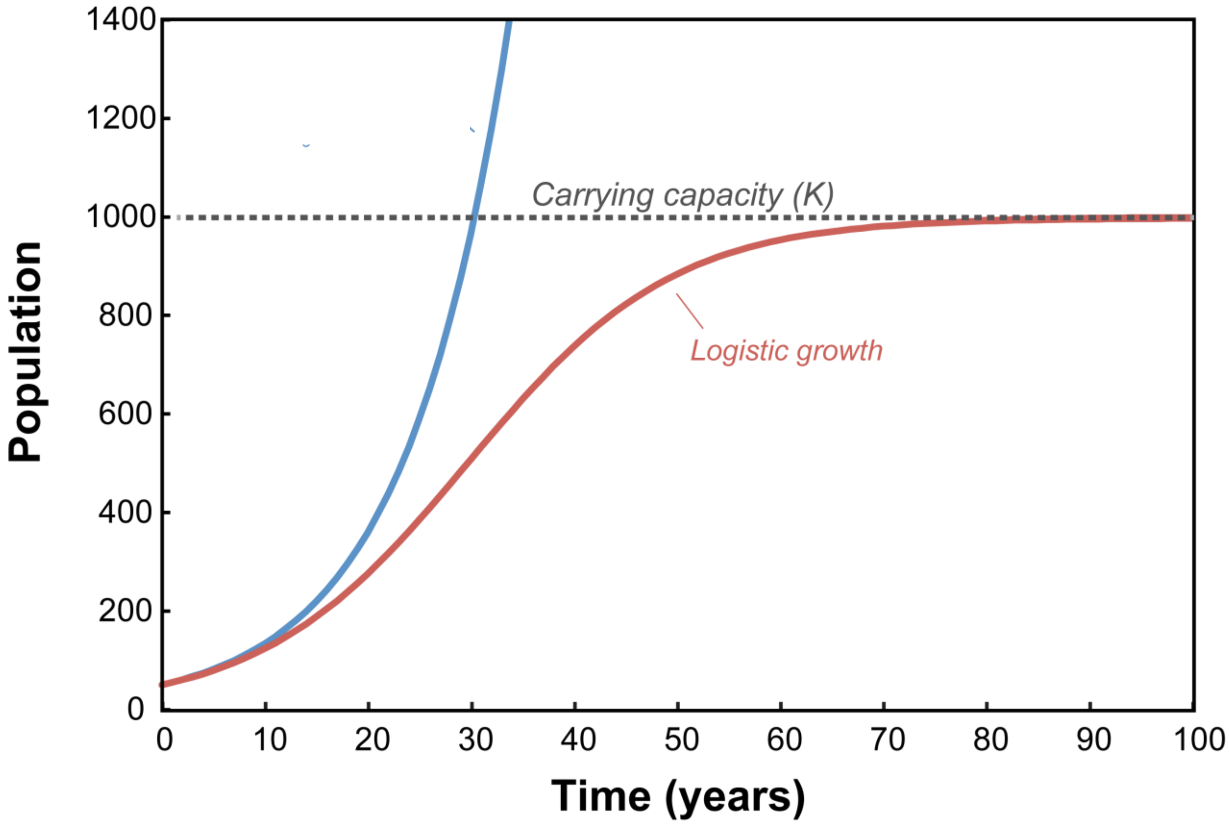
https://www.worldometers.info/world-population/

Logistic growth – a more realistic model

S-shaped Curve (red) - *contrast with blue curve*

r is <u>density-dependent</u> under logistic growth

In other words – ***r* will decrease** as the population gets bigger and uses more resources



https://serc.carleton.edu/details/images/56878.html

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

You do not need to know this formula.

Formula now incorporates the concept of a <u>carrying capacity (K)</u> into the equation.

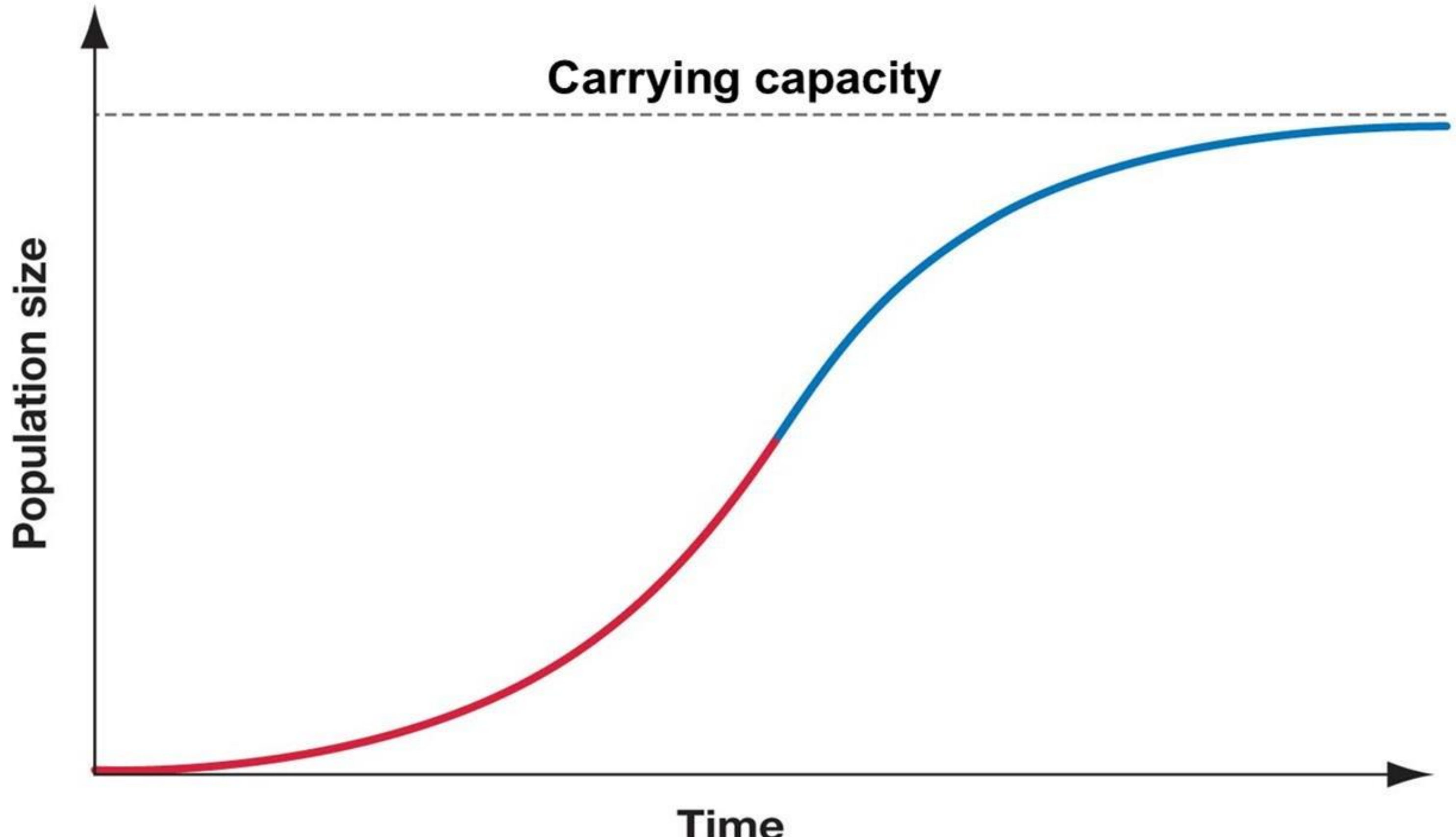
<u>Think of [(K-N)/K] as modifier of *r*</u>

Carrying Capacity (K)

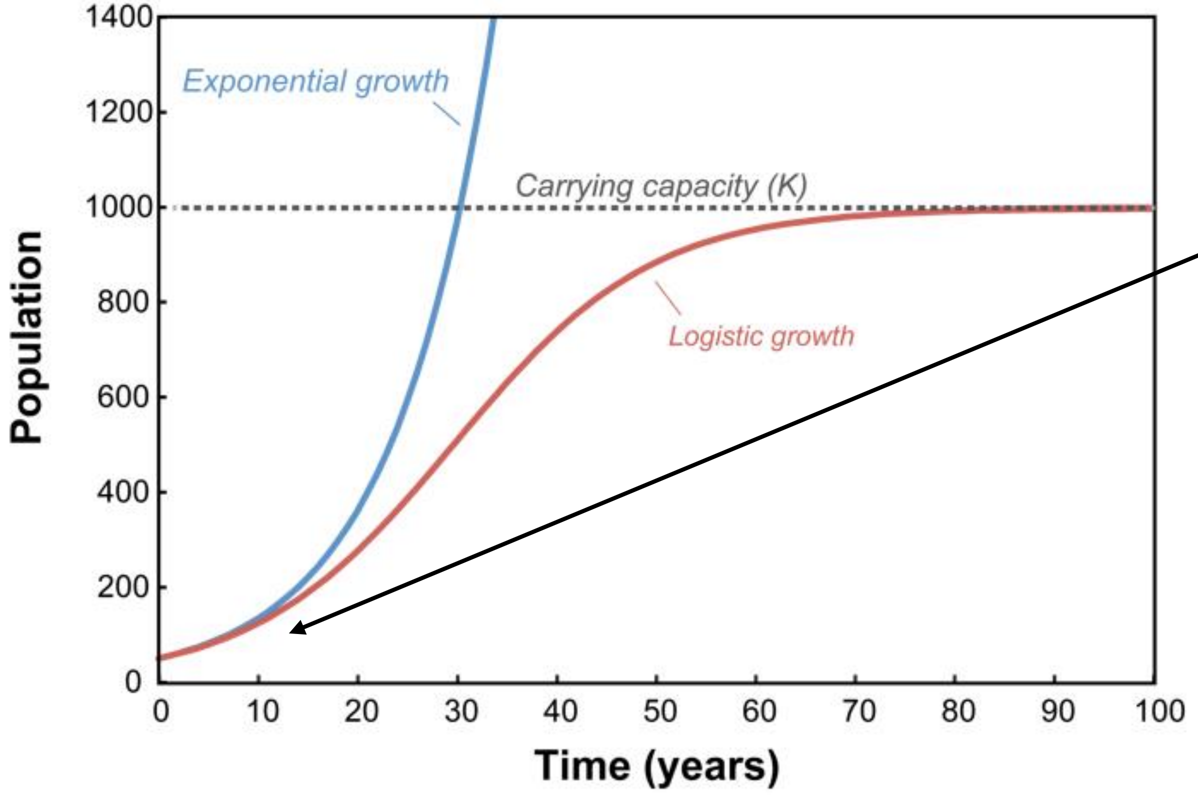
Carrying capacity (K) refers to the maximum number of individuals of a species that the environment can support at a specific time.

It is the population size at which growth stops.

Birth rates are now equal to death rates – so in this model: *b*=*d*, *r*=0, dN/dt=0.



Logistic growth



Initially, when the population is very small, logistic growth closely <u>**resembles**</u> exponential growth.

Resources are still plentiful; so little to no competition that will negatively affect survival/reproduction.

Example #1 – at a very small population size, logistic growth resembles exponential growth

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

When N is small, $\left(\frac{K-N}{K}\right)$ is close to 1 ------> *r* is mostly unmodified

- For example, imagine a population:
  N = 10
  K = 1000
  r = 0.2

dN/dt = rN*[(1000-10)/1000]

dN/dt = rN*0.99

dN/dt = (0.2*10)*.99 = **1.98**

Compare to exponential growth:
dN/dt = rN
dN/dt = .2*10 = **2.00**

As the population size gets bigger… (now 500 individuals)

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

- When N gets bigger, $\left(\frac{K-N}{K}\right)$ gets smaller (<<1) - - - *r* is modified more

For example, N is larger (500 individuals):

N = 500

K = 1000 (no change)

r = 0.2 (no change)

dN/dt = rN*[(1000-500)/1000]

dN/dt = rN * 0.5

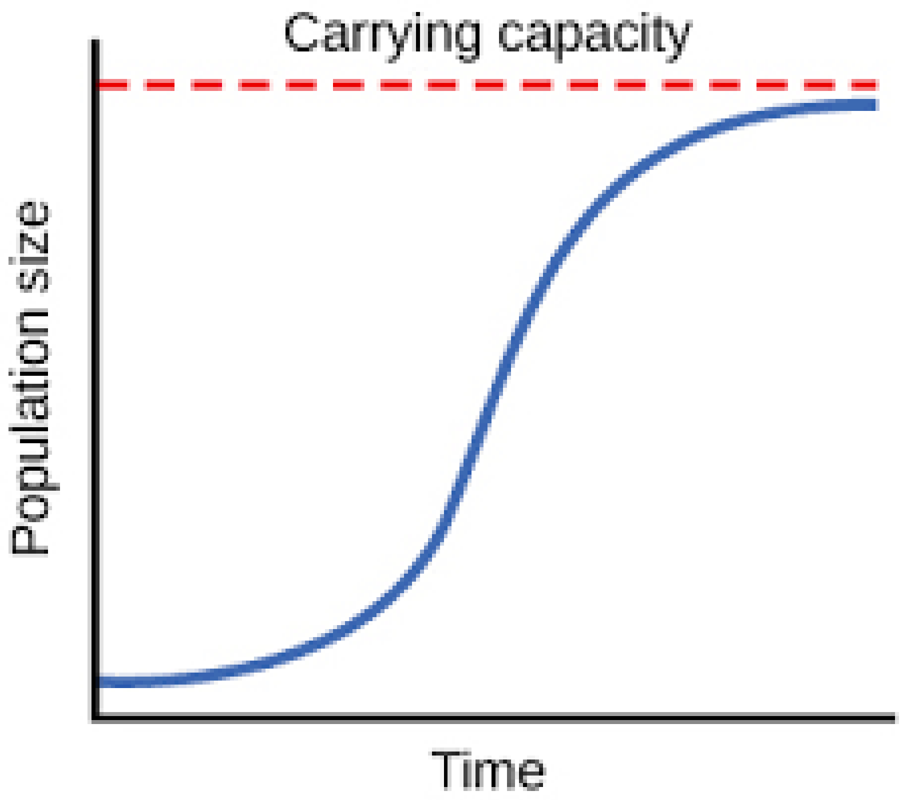
dN/dt = (0.2*500)*0.5

dN/dt = 100 * 0.5 = 50

Compare to exponential growth:

dN/dt = rN = 0.2 * 500 = 100

Per capita growth rate (r) gets smaller until K



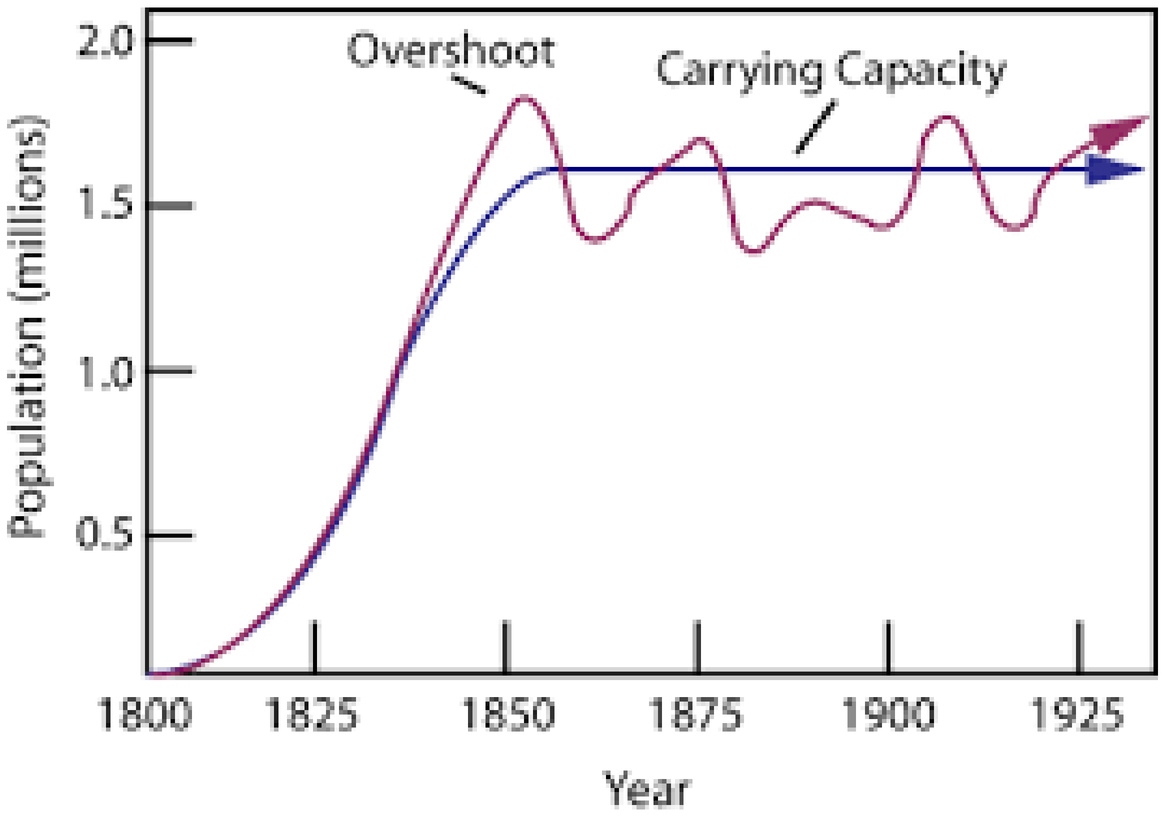
dN/dt = rN*[(1000-1000)/1000]
dN/dt = rN * 0
dN/dt = (0.2*1000)*0
dN/dt = 0

As the population increases in size, critical resources become limited (e.g., food, shelter, mates) and individuals compete with each other for those resources

The competition becomes more intense as the population size grows

- The per capita growth rate (*r*) gets smaller (*b* decreases and *d* increases)
- Population growth stops at the carrying capacity (K). **Birth rates are now equal to death rates – so in this model: *b=d, r*=0, dN/dt=0**

In real life populations fluctuate around K



https://socratic.org/questions/what-is-the-relationship-between-carrying-capacity-and-population-size

- If population exceeds K, per capita growth rate (*r*) becomes negative, and population size decreases
- If population falls below K, per capita growth rate becomes positive and population grows

Carrying Capacity (K) for a particular species is not constant - can change over time

e.g.,

- Available space changes
- Water availability changes

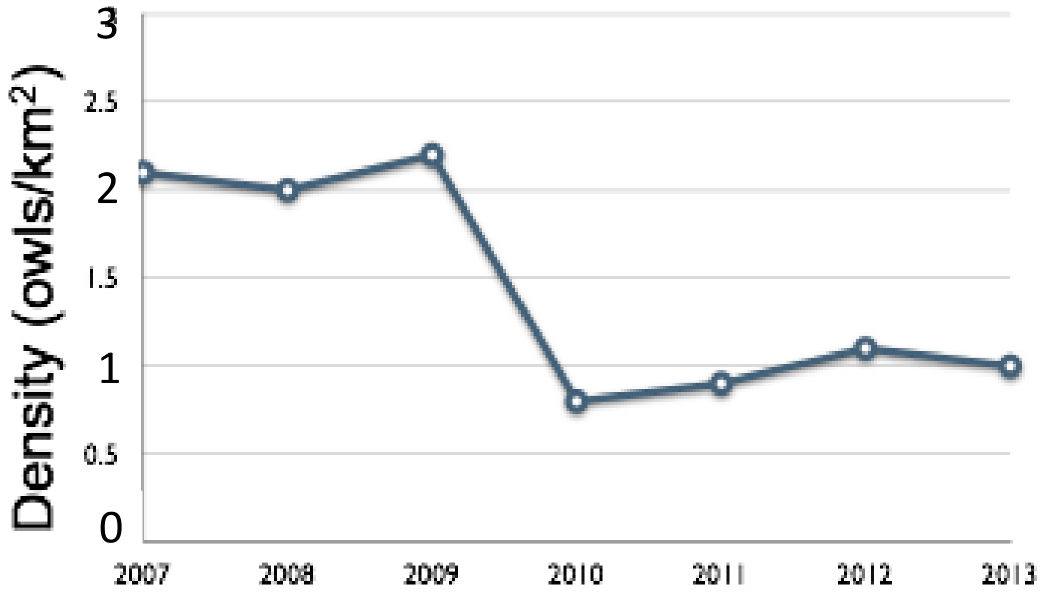
https://thenarwhal.ca/bc-old-growth-forest-deferrals-scientists-2021/

https://site.extension.uga.edu/climate/2018/03/kenyan-droughts-are-getting-worse-affecting-livestock-producers-there/

Example of carrying capacity changing over time

of individuals the environment supports can change over time

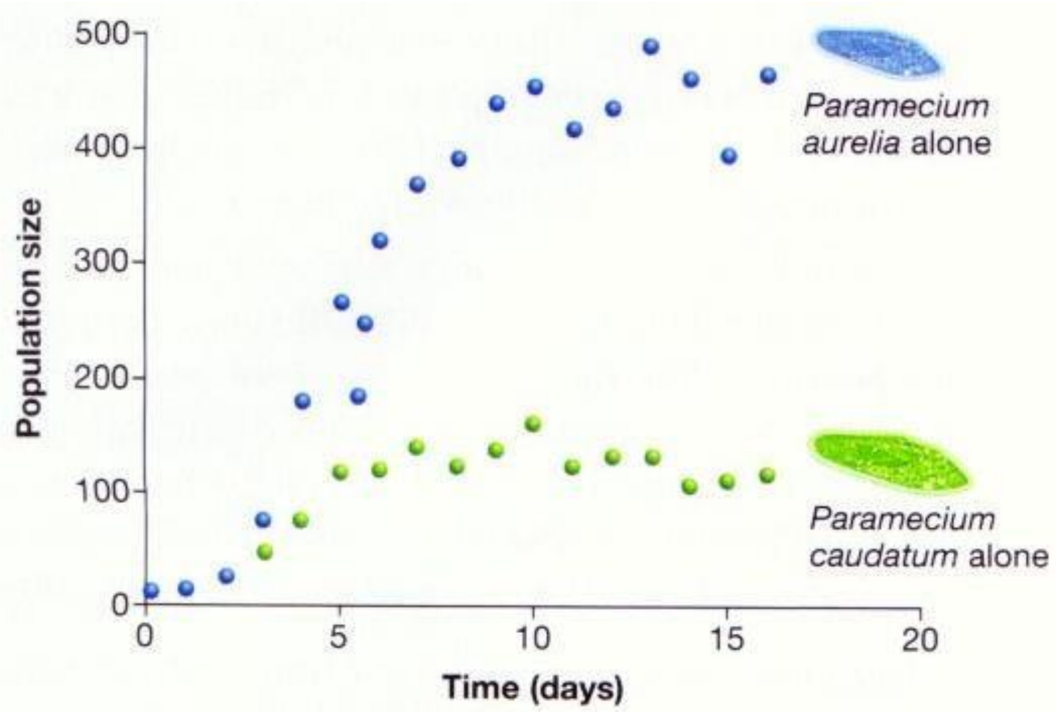
- e.g. available space may change



Carrying capacity (K) can differ between species

Different species have different requirements for survival/reproduction

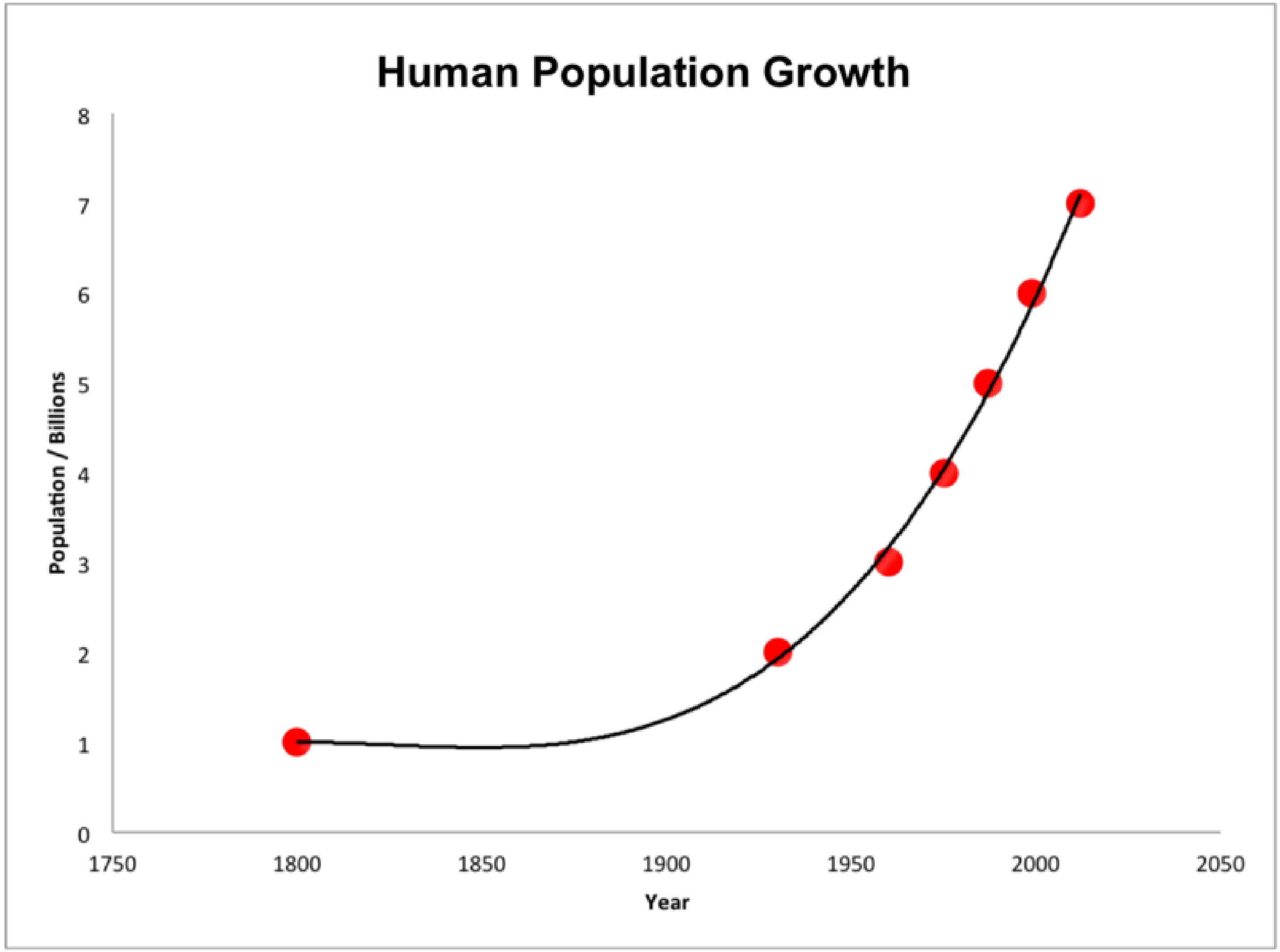
- e.g. *Paramecium caudatum* is a larger organism that needs more resources and space



iClicker Question

If human population growth was still exponential, where is the per capita growth rate (“*r*”) the greatest on this curve?

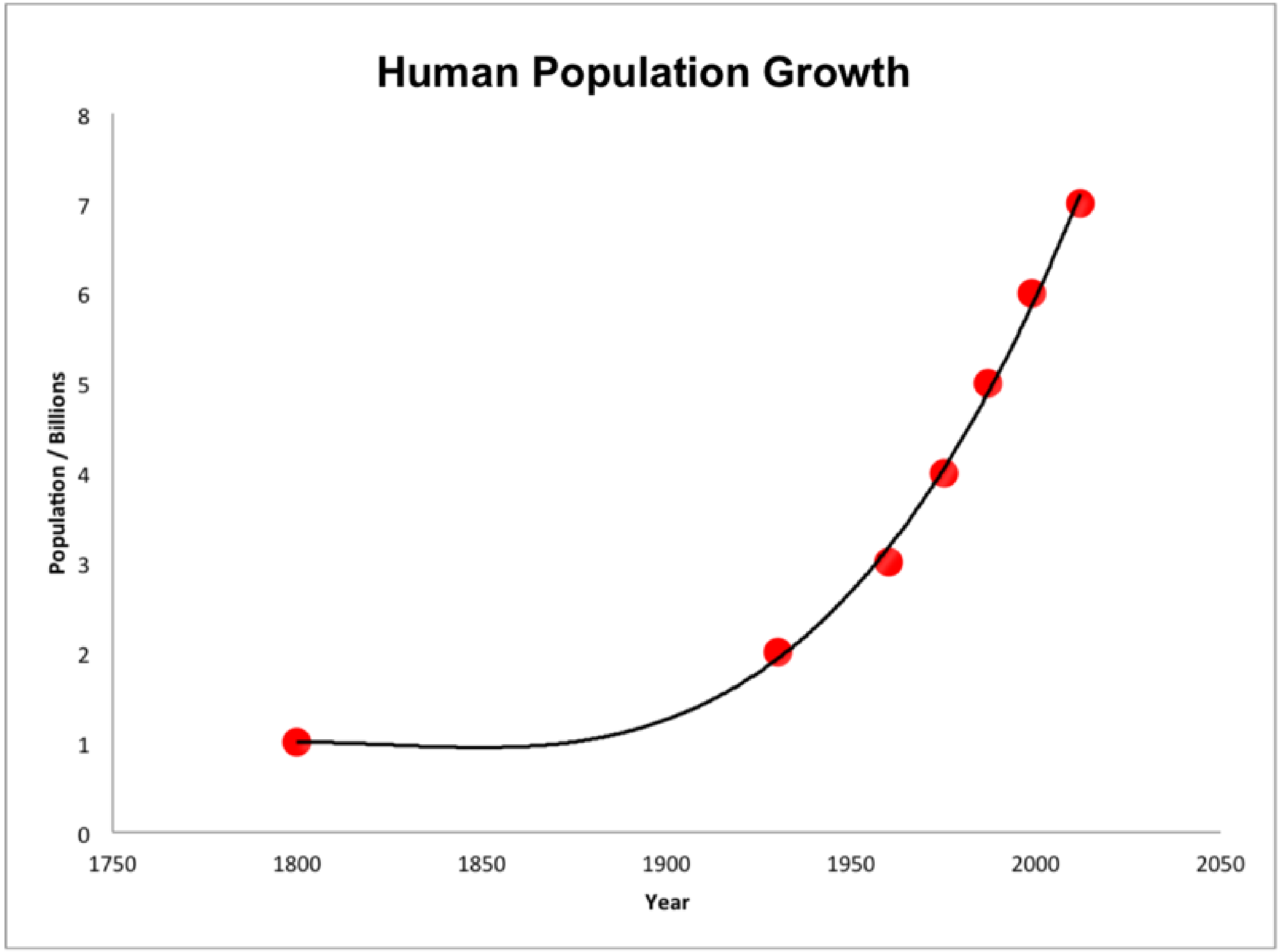
A. ~1940
B. ~1980
C. ~2000
D. ~2020
E. .*r* is constant



Answer

If human population growth was still exponential, where is the per capita growth rate ("*r*") the greatest on this curve?

A. ~1940
B. ~1980
C. ~2000
D. ~2020
E. .r is constant

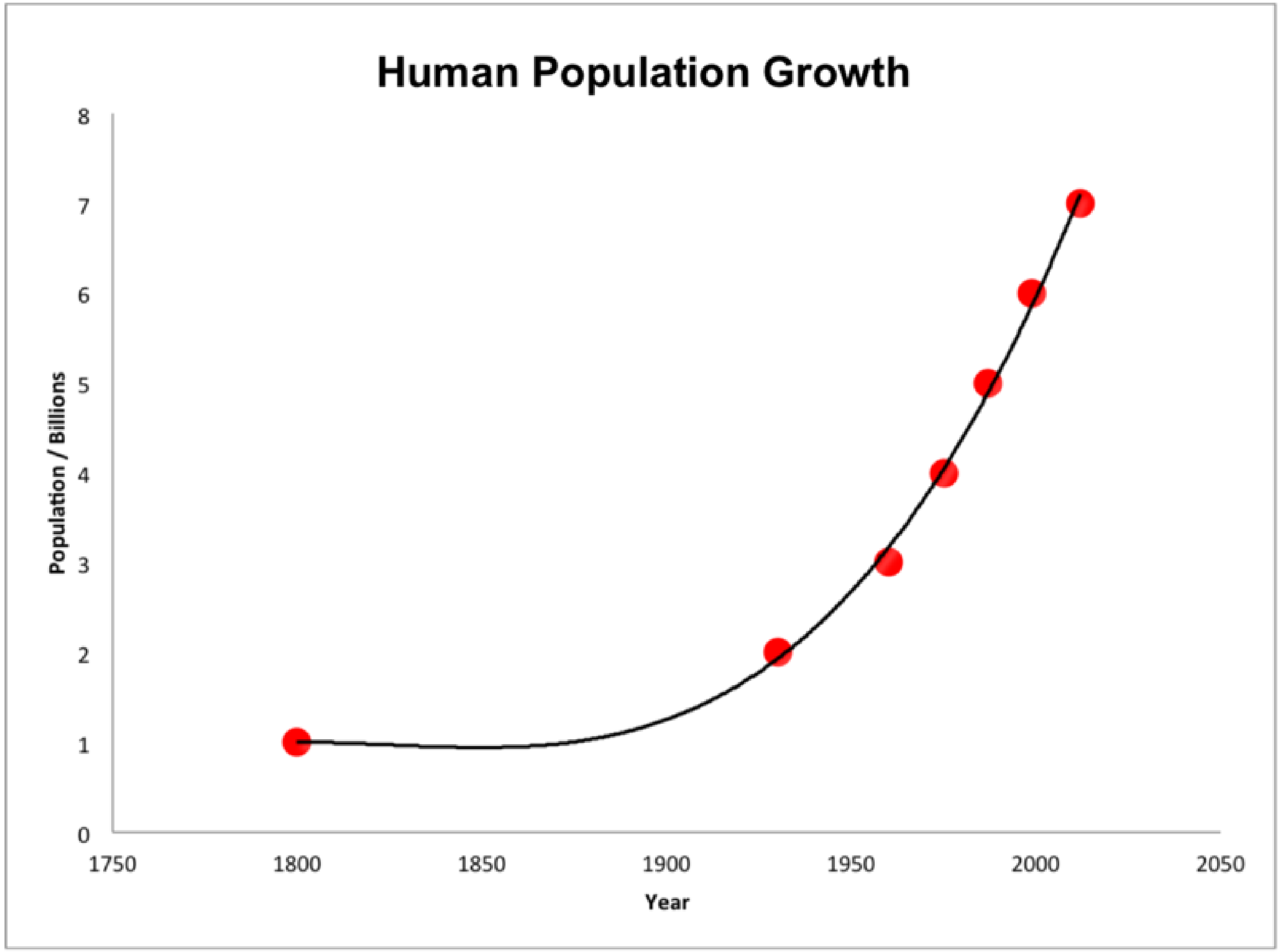


iClicker Question

In which year will the greatest number of individuals being added to the population?

A. ~1800
B. ~1940
C. ~2000
D. ~2050
E. Numbers are constant

$$\frac{dN}{dt} = rN$$



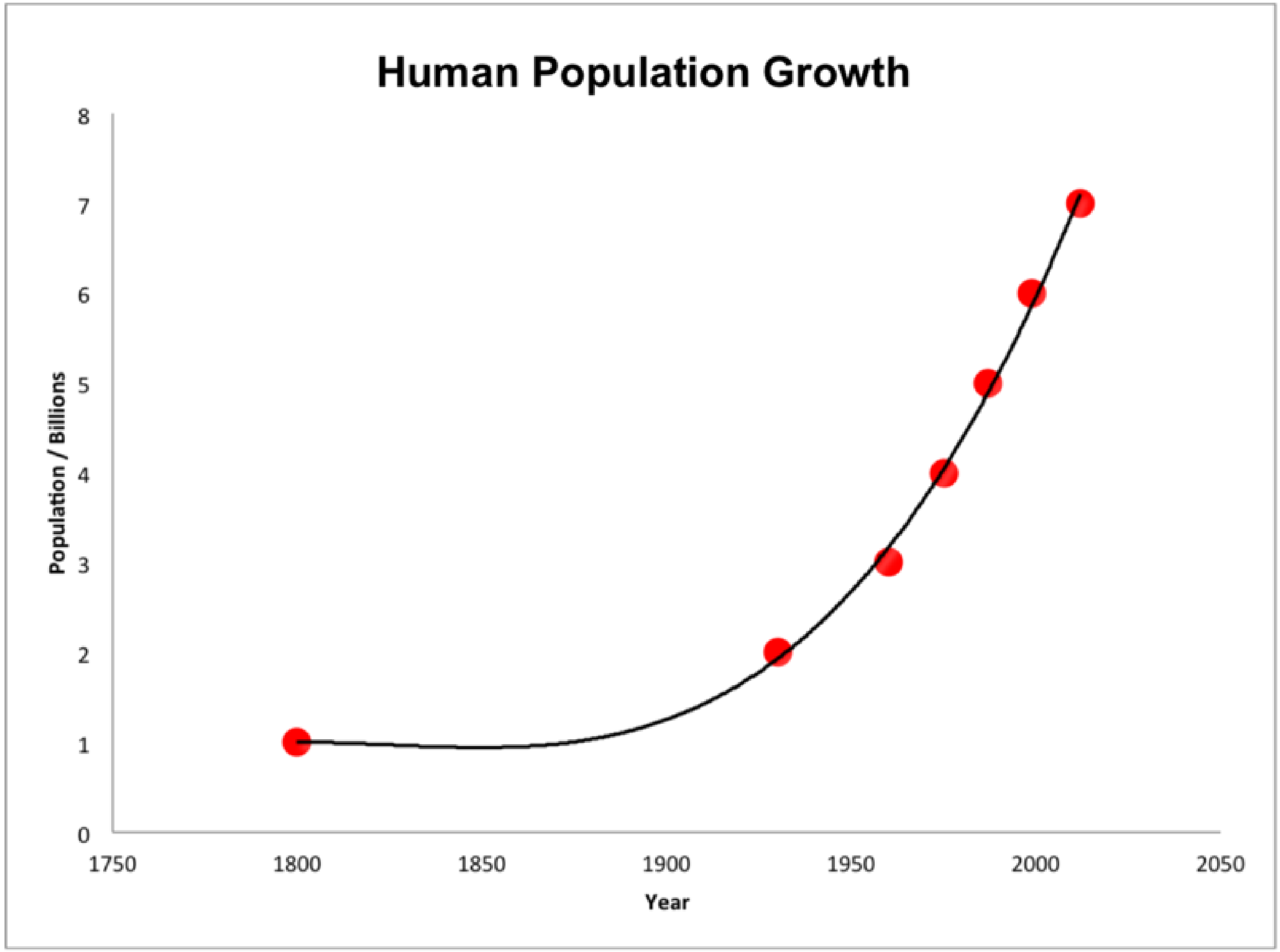
Answer

In which year will the greatest number of individuals be added to the population?

A. ~1800
B. ~1940
C. ~2000
D. ~2050
E. Numbers are constant

The bigger the population size the more individuals added to the population each generation

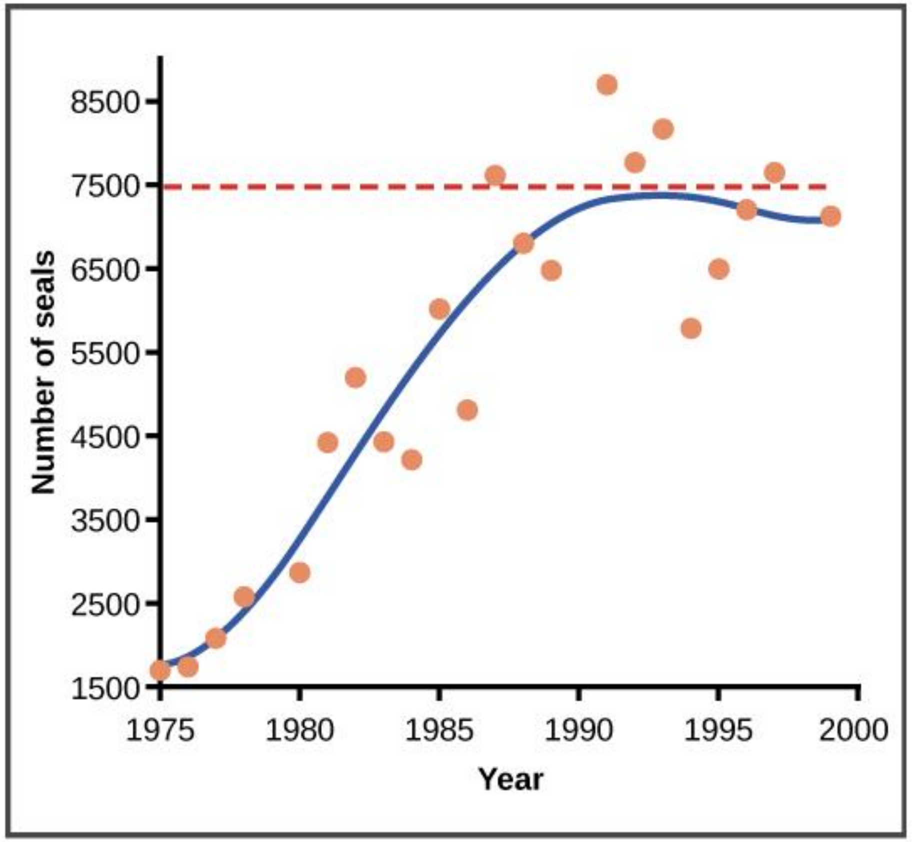
$$\frac{dN}{dt} = rN$$



iClicker Question

In ~ what year was the per capita growth rate (*r*) for the seal population likely the greatest?

A. 1980
B. 1985
C. 1990
D. 1995
E. 2000

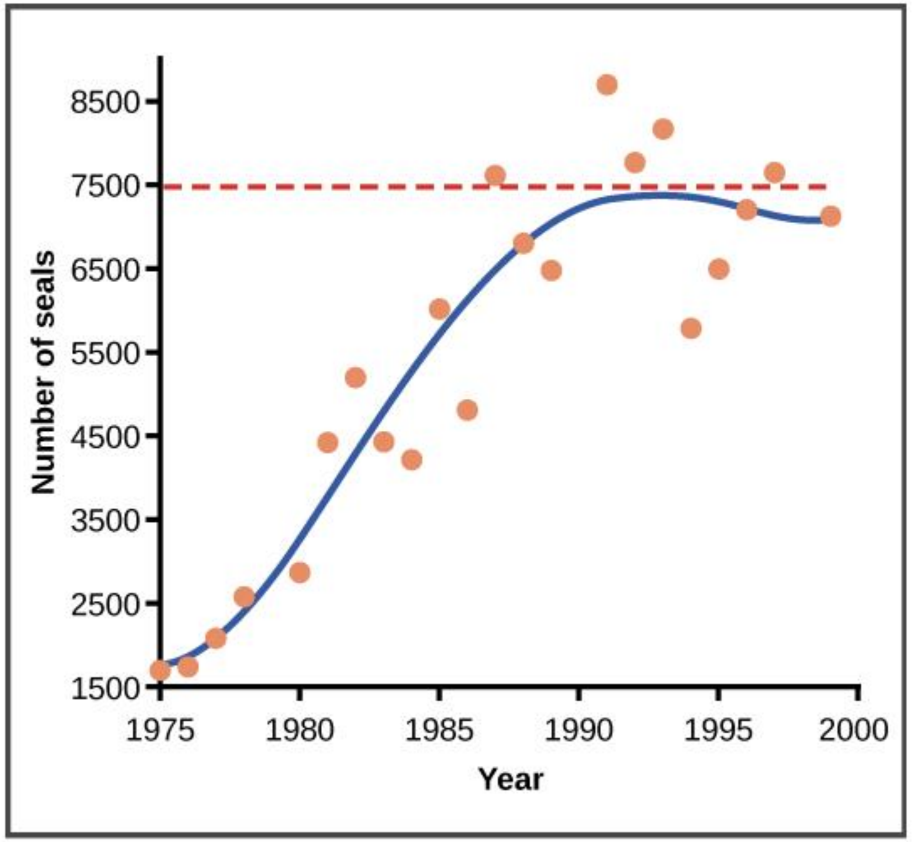


Source: Khan Academy

Answer

In ~ what year was the per capita growth rate for the seal population likely the greatest?

A. 1980
B. 1985
C. 1990
D. 1995
E. 2000



As population size increased, *r* becomes increasingly smaller.

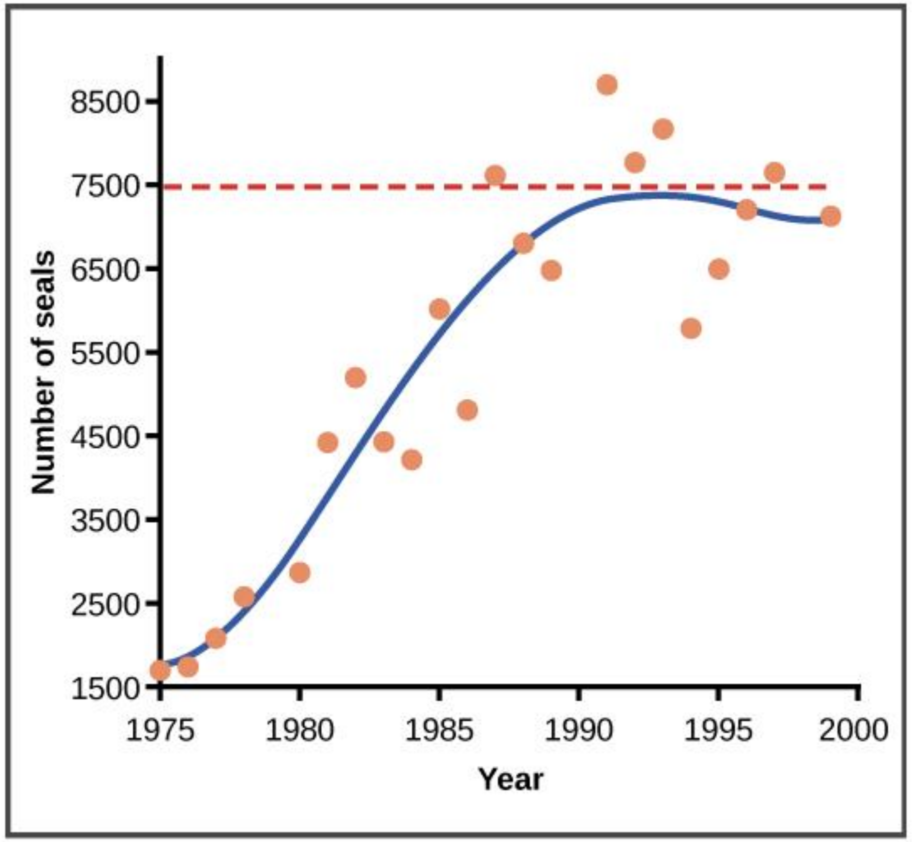
$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

Source: Khan Academy

iClicker Question

In ~ what year was the greatest number of individuals added to the population?

A. 1980
B. 1985
C. 1990
D. 1995
E. 2000



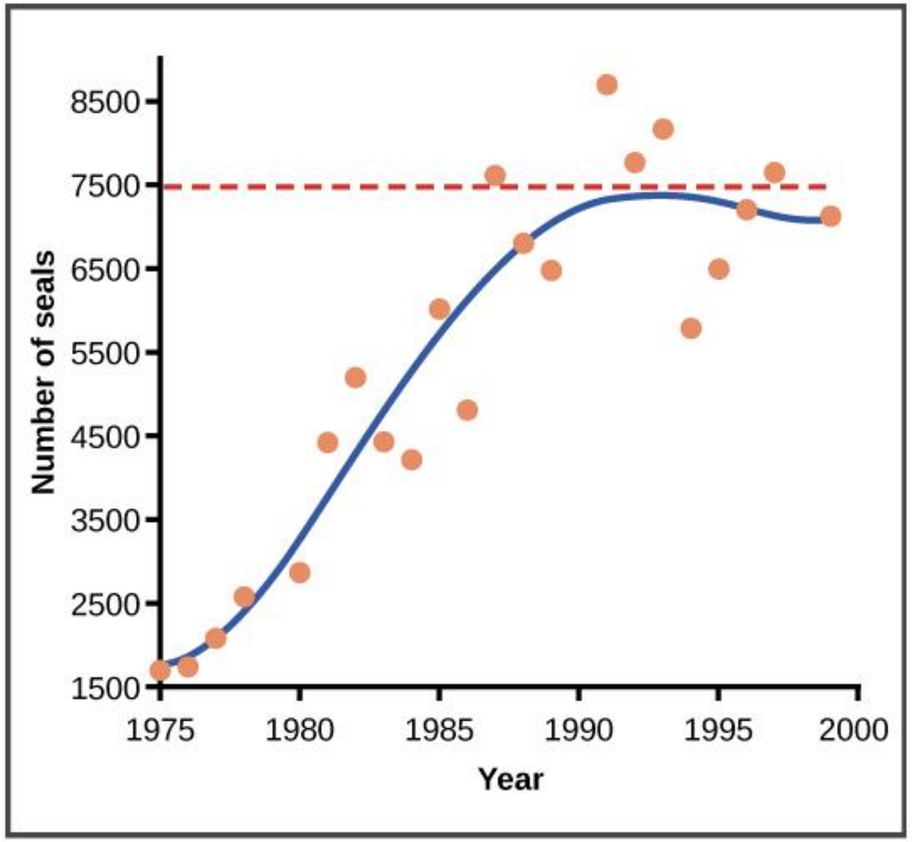
$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

Source: Khan Academy

iClicker Question

In ~ what year was the greatest number of individuals added to the population?

A. 1980
B. 1985 (around the inflection point
C. 1990
D. 1995
E. 2000



$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

Source: Khan Academy

Year	N	r	Modifier [(K-N)/K]	modified r	dN/dt=rN(Modifier)
1975	1700	0.2	0.773	0.155	262.933
1976	1962.9	0.2	0.738	0.148	289.837
1977	2252.8	0.2	0.700	0.140	315.221
1978	2568.0	0.2	0.658	0.132	337.743
1979	2905.7	0.2	0.613	0.123	355.992
1980	3261.7	0.2	0.565	0.113	368.642
1981	3630.4	0.2	0.516	0.103	374.618
1982	4005.0	0.2	0.466	0.093	373.266
1983	4378.3	0.2	0.416	0.083	364.475
1984	4742.7	0.2	0.368	0.074	348.720
1985	5091.4	0.2	0.321	0.064	327.014
1986	5418.5	0.2	0.278	0.056	300.766
1987	5719.2	0.2	0.237	0.047	271.590
1988	5990.8	0.2	0.201	0.040	241.099
1999	6231.9	0.2	0.169	0.034	210.736
2000	6442.7	0.2	0.141	0.028	181.656
2001	6624.3	0.2	0.117	0.023	154.689
2002	6779.0	0.2	0.096	0.019	130.338
2003	6909.3	0.2	0.079	0.016	108.829
2004	7018.2	0.2	0.064	0.013	90.176
2005	7108.3	0.2	0.052	0.010	74.241

Note - per capita growth rate is greatest in 1975. But, number of individuals added to the population is greatest in 1981.

This is because the number of individuals being added to the population is a function of both per capita growth rate and population size

dN/dt = rN[(K-N/K]

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

Summary - Learning goals for population ecology

- Understand the difference between population size and population density.

Be able to:

- Estimate population size using Lincoln-Peterson Index. Know the assumptions of this index
- Estimate per capita birth and death rates, and the per capita growth rate a population (*r*).
- Estimate population size at a future point using per capita growth rate (*r*)
- Explain how the difference between exponential growth and logistic growth
  - How the pattern of growth is related to the per capita growth rate (*r*) and the
  - environment's carrying capacity (K)
- Identify or describe density-dependent and/or density dependent factors and their effects on population size and/or per capita growth rates
- Know life history traits are (e.g., survivorship and fecundity)
- How to interpret survivorship curves
- What are the characteristics of r- and k-selected species.
  - In what environments/situations would you expect to find r-selected species? k-selected species? (To be covered in more detail in Community Ecology – Succession)
- Be able to apply your knowledge to new scenarios.

Next class

- Population Ecology III – Density-Dependent and Density-Independent Factors, and Life history traits
- Start Community Ecology
  - Introduction and Overview