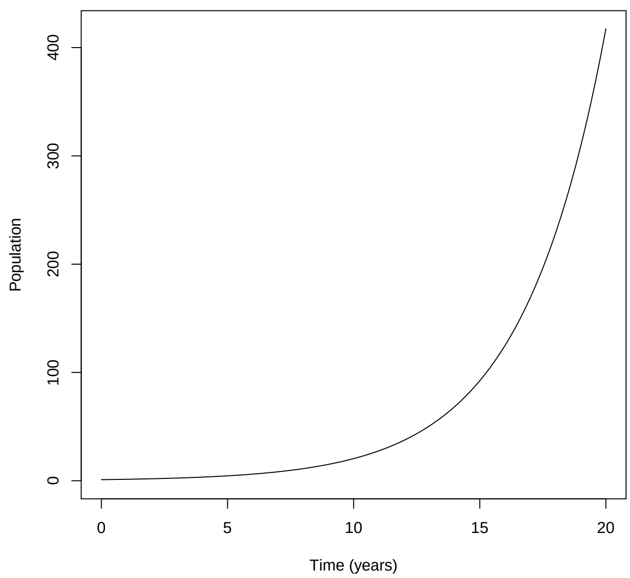
1. This class argues that every population regulates itself:

   A. Directly and immediately
   B. Directly, but not necessarily immediately
   C. Immediately, but not necessarily directly
   D. **Either directly or indirectly and either immediately or with a delay**

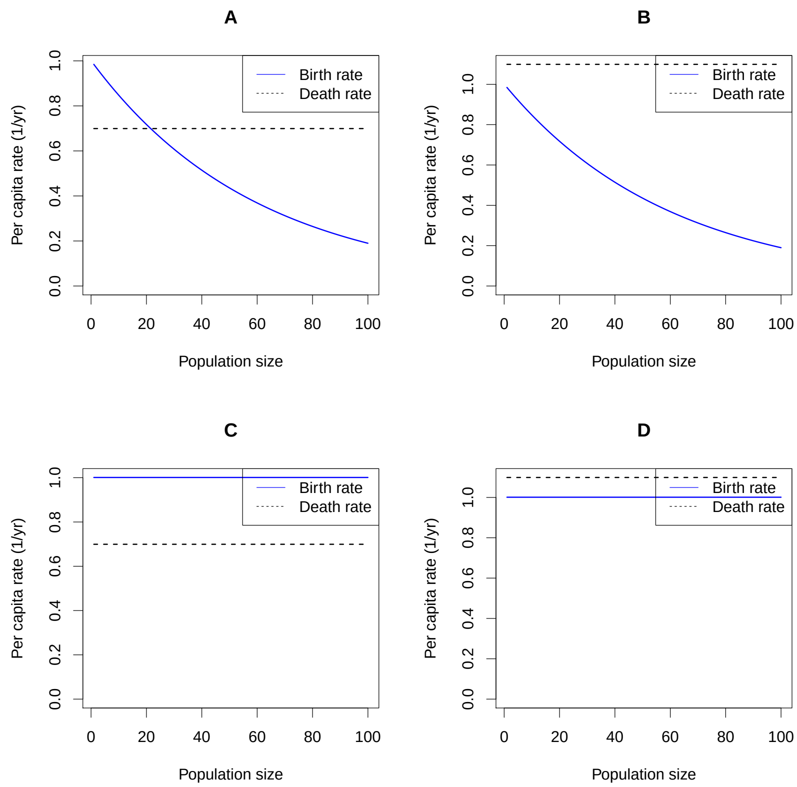
Use the picture below for the next two questions. It shows a time series for a continuous-time birth-death model.



2. This picture shows a population that is:

   A. Increasing arithmetically
   B. **Increasing geometrically**
   C. Increasing arithmetically on the log scale, but geometrically on a linear scale
   D. Increasing geometrically on the log scale, but arithmetically on a linear scale

3. Which of the four pictures below shows the assumptions that generated this time plot?



ANS: C

4. Simple models of continuous-time regulation can be useful, but *cannot* explain:

A. Why exponential growth often occurs at low density
B. Why total population growth is usually highest at intermediate density
C. **Why some populations fluctuate periodically**
D. Why populations may not persist in an area even if they can complete each step of their reproductive cycle

5. A population of shrubs is growing exponentially with a chararacteristic time of 4 yr. Its doubling time will be approximately

A. 0.17 yr
B. 0.36 yr
C. 1 yr
D. **2.8 yr**
E. 5.8 yr

Use this information for the next two questions. A population of small plants has discrete, overlapping generations. Adults survive each year with a probability of 1/2 (and thus they have an average lifespan of two years). Each reproducing adult produces an average of 20 seeds *each year*, of which an average of 10% survive to reproduce in the next year. We model this population using a discrete-time model with time step of 1 year, and we count individuals just before reproduction.

6. What are the values for survival p and fecundity f for this model?

A. $p = 1/4$ and $f = 1$
B. $p = 1/2$ and $f = 1$
C. $p = 1/4$ and $f = 2$
D. $p = 1/2$ **and** $f = 2$

7. What can you say about the finite rate of increase λ and the reproductive number $\mathcal{R}$ for this population?

A. $\mathcal{R}$ and λ both $= p + f$
B. $\mathcal{R}$ and λ are both $> p + f$
C. $\mathcal{R} = p + f$, but λ is larger
D. $\lambda = p + f$**, but** $\mathcal{R}$ **is larger**

8. Which of the following is the *least* likely scenario for a density-dependent per capita response? As population density goes up:

A. Birth rate goes down and death rate goes up
B. **Birth rate goes down and death rate goes down faster**
C. Birth rate goes up and death rate goes up faster

9. Modern humans have been very successful over the last 100 kiloyears. Considering the lifespan of a single human, it would be most accurate to say that the instantaneous rate of increase r has been:

A. **A little greater than zero**
B. Much greater than zero
C. A little greater than one
D. Much greater than one

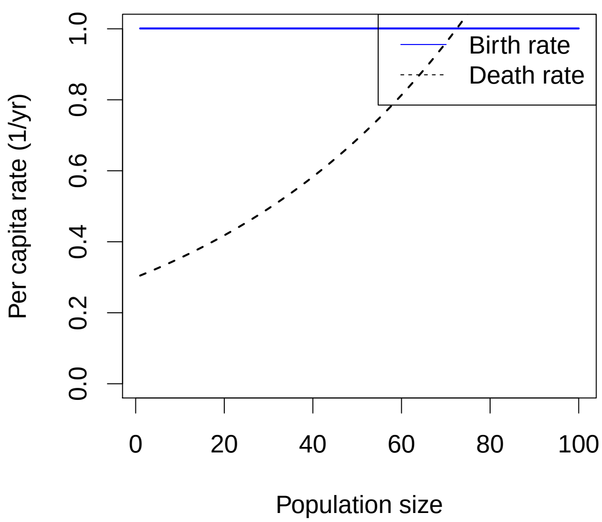
10. Choose the most precise correct answer. A gypsy moth population grew from 100 pupae/hectare to 2000 pupae/hectare in 2008, and then to 5000 pupae/hectare in 2009. The 2009 change was larger than the 2008 change:

A. **On the linear scale**
B. On the log scale
C. On both scales
D. On neither scale

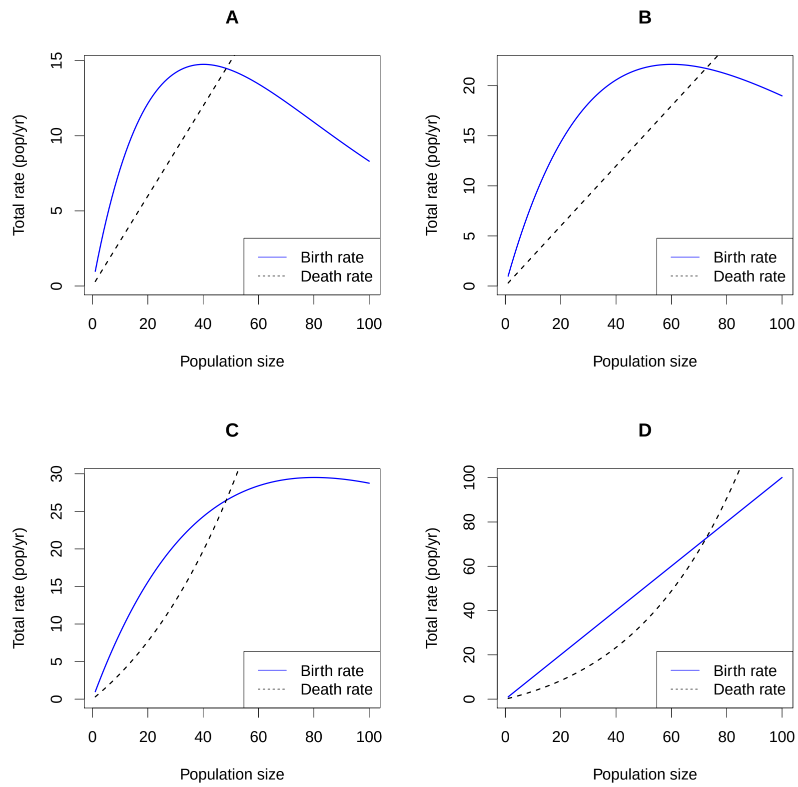
11. All of the following mechanisms can change gypsy moth population growth rates. Which of the following is *least* like to *regulate* growth rate in the sense discussed in class?

A. Conflict between gypsy-moth caterpillars
B. Viral diseases
C. Gypsy-moth damage to the trees
D. **Drought damage to the trees**

Use the picture below for the next three questions. It shows the assumptions made for a continuous-time birth-death model.



12. Which of the four pictures below could be generated by the same model as the picture above?



ANS: D

13. The highest *total population* net growth rate (dN/dt) in this model is seen:

A. When the population is very small
B. **When the population is between the two equilibria**
C. When the population is at the nonzero equilibrium
D. When the population is very large

14. The model illustrated above predicts that the population will decrease:

A. When the population is very small (only)
B. **When the population is very large (only)**
C. When the population is very small or very large
D. When the population is between the two equilibria
E. When the population is at the nonzero equilibrium

15. If a simple model assumes individuals are independent of each other, then __________ death rates should __________ with the size of the population.

A. per capita; increase
B. per capita; decrease
C. **total; increase**
D. total; decrease

16. If we are modeling the spread of coronavirus with one of our population models, then a "death" would correspond to a person:

A. Catching the disease
B. Either catching the disease or recovering
C. Dying from the disease
D. **Either dying from the disease or recovering**

17. Which of these is *not* a likely mechanism for the population of coronavirus to regulate itself?

A. People recovering from the disease and becoming immune
B. People changing behaviour in response to the disease
C. **Viral evolution**
D. A vaccination campaign

18. (4 points) Imagine some bacteria in a favorable environment. They are continuously reproducing at a constant per-capita rate of 0.4 new indiv per indiv per day and continuously dying at a constant per-capita rate of 0.1 per day. We start with a density of 3 indiv/ml.

a) Write an equation describing our *assumptions* about how this population changes through time (not the result).

$dN/dt = rN$ or $dN/dt = (b - d)N$

b) What are the birth rate b, death rate d and growth rate r?

$b = 0.4/\text{day}$, $d = 0.1/\text{day}$, $r = 0.3/\text{day}$.
Half off for no units, or wrong units. Half off if there's clearly only one mistake.

c) How many bacteria do we expect to see after a day?

$3 \text{ indiv/ml} * \exp(1\text{day} * 0.3/\text{day}) = 4.05 \text{ indiv/ml}$.
Half off for wrong units or no units.

d) How many bacteria do we expect to see after a week?

$3 \text{ indiv/ml} * \exp(1\text{week} * 0.3/\text{day}) = 3\exp(2.1) \text{ indiv/ml.} = 24.5 \text{ indiv/ml}$.
As above

19. A car uses 6L of gasoline per 100km.

a) (2 points) How far can the car go on 10L of gasoline? Show work with units.

Put km on top, because we want an answer in km:

$$\frac{100\text{km}}{6\text{L}} \times 10\text{L} = 166.67\text{km}$$

b) (2 points) If $1\text{L} = 1\text{m}^3$ and $1\text{km} = 1000\text{m}$, write the fuel consumption of the car in the simplest form (consumption should be higher if the car uses more gas for a given distance).

This is terrible! $1000\text{L} = 1\text{m}^3$ and I can't believe I told you otherwise. I'll solve the problem using the wrong information here, though.

Fuel consumption of the car is the general value 6L of gasoline per 100km.

We write

$$\frac{6\text{L}}{100\text{km}} \times \frac{\text{km}}{1000\text{m}} \times \frac{1\text{m}^3}{\text{L}} = 6 \times 10^{-5}\text{m}^2$$

The correct conversion would have given

$$\frac{6\text{L}}{100\text{km}} \times \frac{\text{km}}{1000\text{m}} \times \frac{1\text{m}^3}{1000\text{L}} = 6 \times 10^{-8}\text{m}^2$$

c) (1 point, extra credit). Can you find a clear explanation for the simplest units of fuel consumption?

The units of fuel consumption are area! The explanation is that if you put the fuel in a tube that is as long as your journey, fuel consumption can be expressed as the cross-sectional area of that tube.