1. An exponentially growing rabbit population takes 5 years to grow from 20 individuals to 100 individuals. If it continues to grow exponentially at the same rate, how long would it take to increase from 100 individuals to 2500 individuals?

A. 5 years
B. **10 years**
C. 20 years
D. 40 years
E. 50 years

2. A population is regulated with a time delay, following the equation:

$$\frac{dN(t)}{dt} = (b(N(t-\tau)) - d(N(t-\tau)))N(t)$$

We expect it to show __________ oscillations when the unitless delay (τ/t_c) is short, and __________ oscillations when the unitless delay is long

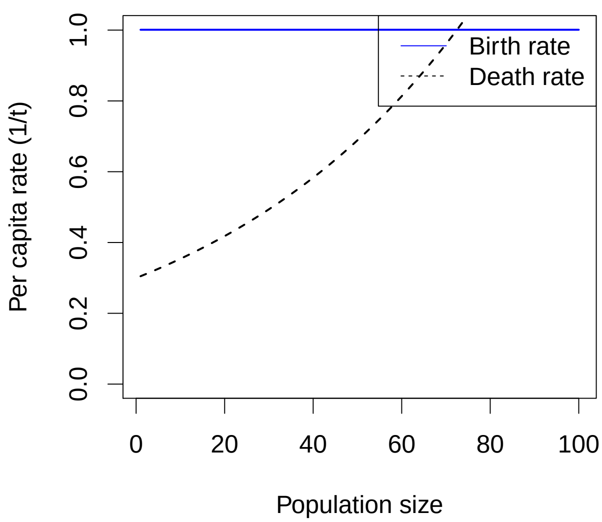
A. no; damped
B. no; persistent
C. damped; damped
D. **damped; persistent**

3. Consider your test paper, the province of Ontario, and the country of Canada. Which two are most similar in area, when considered by absolute difference (linear scale), or by proportional difference (log scale)?

A. The paper is the most different from the other two, on either scale
B. The province is the most different from the other two, on either scale
C. The country is the most different from the other two, on either scale
D. The paper is the most different on the linear scale, and the country is most different on the log scale
E. **The country is the most different on the linear scale, and the paper is most different on the log scale**

4. In a discrete-population model with survival probability p and time step Δt, the average *amount of time* we expect an individual to survive is:

A. $1/p$
B. $1/p \times \Delta t$
C. $1/(1-p)$
D. $1/(1-p) \times \Delta t$
ANS: D



Use the picture above for the next 3 questions.

5. The picture shows:

A. An Allee effect in the birth rate
B. An Allee effect in the death rate
C. Density dependence in the birth rate
D. **Density dependence in the death rate**

6. A population following this conceptual model would:

A. **Increase from a low population or decrease from a high population**
B. Increase exponentially from any starting point
C. Decrease to zero from a low starting population, but increase from an intermediate or high population
D. Increase from an intermediate population, but decrease from a high or low population

7. A population following this conceptual model would have the highest *total* population growth rate at what population size?

A. At very small population sizes
B. **At population sizes intermediate between zero and the carrying capacity**
C. At population sizes near the carrying capacity
D. At very large population sizes
E. The total population growth rate does not depend on the population size

The total growth rate is the per capita growth rate multiplied by the population size: this is very small when the population size is very small, and small again near the equilibrium when the per capita growth rate is small, so it must reach a maximum in between. You can see this on the pictures of total growth rate in your notes.

8. The bacteria you are studying enter a resting state, but only under crowded conditions. If the resting state has lower mortality than the bacteria normally experience when not crowded, we would also expect that, compared to uncrowded conditions, the resting state has ________ birth rates and ________ reproductive number $\mathcal{R}$.

A. **lower; lower**
B. lower; higher
C. higher; lower
D. higher; higher

9. Which of the following would *not* be expected to lead to Allee effects?

A. Individuals co-operating to find food
B. Individuals having difficulty finding mates
C. **Individuals competing for breeding sites**
D. Individuals co-operating to look out for predators

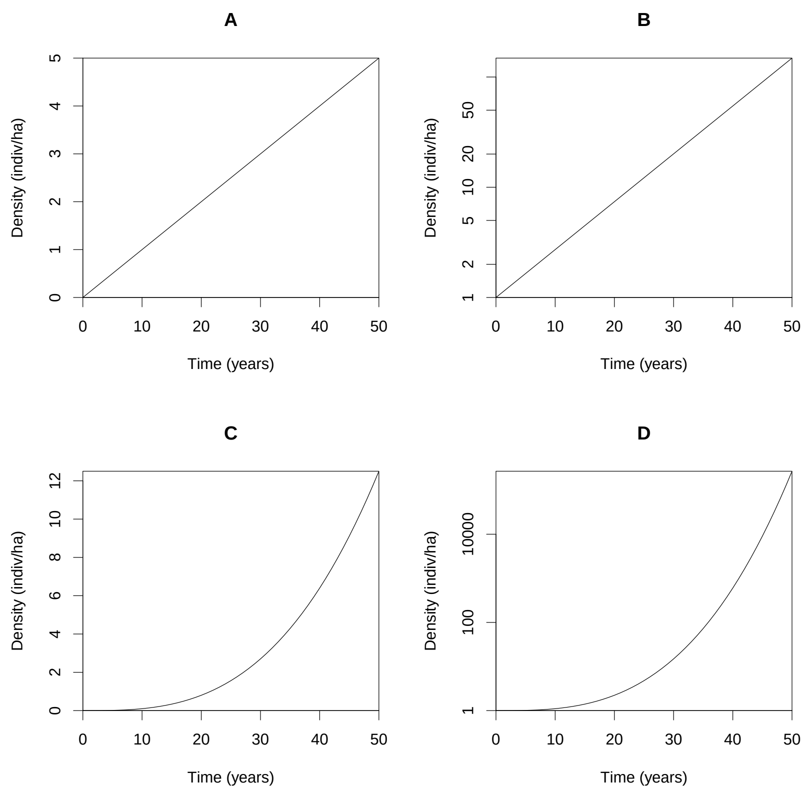
10. If a simple model assumes individuals are independent of each other, then ________ death rates should ________ the size of the population.

A. **per capita; not be affected by**
B. per capita; decrease with
C. total; not be affected by
D. total; decrease with

11. In simple, discrete-time models of a single species competing for resources, we often see population cycles:

A. In models without resource depletion
B. **In models with resource depletion**
C. In models with or without resource depletion
D. We don't see population cycles in discrete-time models

12. *One* of the four pictures below shows a population growing exponentially – which one?



ANS: B

13. In a linear population model, we expect:

A. The reproductive number $\mathcal{R}$ is always > 1
B. The instantaneous growth rate r is always > 1
C. The finite growth rate λ is always > 1
D. $\mathcal{R} > 1$ exactly when $r > 1$
E. $\mathcal{R} > 1$ **exactly when** $\lambda > 1$

14. Researchers studying a gypsy moth population make the following estimates: The average reproductive female lays 400 eggs; 10% of eggs hatch into larvae; 20% of larvae mature into pupae; 50% of pupae mature into adults; 60% of adults survive to reproduce. What is the correct value of fecundity f for this population?

A. 1.2
B. 2.4
C. 1.2 moths/year
D. 2.4 moths/year
E. **There is not enough information to answer this question**

15. In a simple model of population regulation, where the only effect of population size is crowding, we would expect __________ to always go down __________.

A. The birth rate; through time
B. The birth rate; as population increases
C. The reproductive number $\mathcal{R}$; through time
D. **The reproductive number $\mathcal{R}$; as population increases**

16. If I say a population is changing exponentially, I mean that

A. It is changing faster and faster
B. It is changing at a constant rate
C. **It is changing at a rate proportional to its own size**
D. It is changing at a rate proportional to the time that has elapsed

17. A population is changing in continuous time, according to the equation $dN/dt = r(N)N$. What are the conditions for this population to be in equilibrium?

A. $r(N) = 0$
B. $0 < r(N) < 1/\text{yr}$
C. $r(N) = 1/\text{yr}$
D. $r(N) = 1$
ANS: A

18. (4 points) The University of Victoria has a problem with rabbits. There are estimated to be about 80 rabbits on campus. Suppose that the rabbits are not yet experiencing any decrease in growth rate or increase in death rate due to crowding. Suppose a female rabbit can produce 4 offspring in a year, that there is a 1:1 sex ratio, and that rabbits survive for 2 years on average. Ignoring winters (it's Victoria), suppose that rabbits can breed continuously all year, and pretend that baby rabbits instantaneously mature and begin breeding themselves.

a) How would you model the assumptions described here? What are the key parameters?

Since we are told to assume continuous breeding and instantaneous maturation, we should use a simple continuous-time model. The key parameters are the birth rate and death rate. The birth rate is given as total offspring per female, so we need to multiply by the proportion female (1/2) to close the loop and get a unitless birth rate (units of females per female) $b = 2/\mathrm{yr}$. The death rate should be the reciprocal of the average life span: $d = 1/(2\mathrm{yr}) = 0.5/\mathrm{yr}$.The key parameters are the birth rate $b = 2/\mathrm{yr}$ and the death rate $d = 1/(2\mathrm{yr}) = 0.5/\mathrm{yr}$.

b) What is the characteristic time of your modeled population, in days?

The instantaneous rate of growth is $r = b - d = 1.5/\mathrm{yr}$, so the characteristic time is $1/(1.5/\mathrm{yr}) = 0.67\mathrm{yr}$. Multiplying by $365\mathrm{day}/\mathrm{yr}$, we get $243.33\mathrm{day}$.

c) Ignoring density-dependent effects, how long will it take until the population reaches 1000?

The population will follow the equation $N = N_0 \exp(rt)$. We can solve by dividing by N_0, taking the log and then dividing by r:

$t = \log(N/N_0)/r = 1.68\mathrm{yr}$

19. (4 points) A population of mayapple plants reproduces once per year, and are censused before reproduction. Adults which are observed one year have a probability 0.8 of being observed the next year. They produce 100 seeds on average. The seed survival probability is given by $p_s = 0.012 \exp(-N/N_f)$, where N is the size of the previously censused population.

a) What is the value of λ in the population, at the limit where there is no crowding (λ_0)?

$\lambda = f + p$, where $p = 0.8$ is the probability of an organism that is censused being censused again the next time. We calculate f by going around the loop: adults produce 100 seeds, and they survive with probability $0.012 \exp(-N/N_f)$, so the value of f is the product. When the mayapples aren't crowded, the exponential term goes to 1, and f becomes $100 \times 0.012 = 1.2$. So $\lambda_0 = 1.2 + 0.8 = 2$

b) What is the value of $\mathcal{R}_0$ in this population?

We also calculate $\mathcal{R}_0$ from the uncrowded values $f = 1.2$, $p = 0.8$. In this case, the average lifespan is going to be $L = 1/(1-p) = 5$, so the expected lifetime reproduction (when not crowded) is $1.2 \times 5 = 6$

c) The estimated equilibrium density (carrying capacity) of the population is 6 plants/m^2. What is your estimate for the parameter N_f?

The mayapples will reach equilibrium when $\lambda = 1$. This will happen when the population increases to a level where f goes down to $1 - p$ (so that $f + p = 1$). This means that $1.2 \exp(-(6\mathrm{plant/m^2})/N_f) = 0.2$.

Thus $N_f = -(6\mathrm{plant/m^2})/\log_e(0.2/1.2) = 3.35\mathrm{plant/m^2}$