Formulas
discrete time growth:

- $N_T = N_0 \lambda^T$
- $\lambda = f + p$
- $\mathcal{R} = f/(1-p)$

continuous time growth:

- $N(t) = N(0)\exp(rt)$
- $r = b - d$
- $\mathcal{R} = b/d$

Use this information for the next two questions. A microbial population grows in a flask with discrete, non-overlapping generations (i.e., survival to next generation $p = 0$), and finite rate of increase $\lambda = 2$. Its generation time is 1 day. The population takes 20 days to fill 100% of the flask.

1. How much of the flask is filled after 19 days?

A. 5%
B. 50%
C. 67%
D. 95%
E. There is not enough information to tell

2. Which of the following *most* accurately describes the instantaneous growth rate r for this population?

A. $r < 0$
B. $r > 0$
C. $0 < r < 1$
D. $r > 1$
E. There is not enough information to tell

3. Which of the following *most* accurately describes the reproductive number $\mathcal{R}$ for this population?

A. $\mathcal{R} > 1$
B. $1 < \mathcal{R} < 2$
C. $\mathcal{R}$=2
D. $\mathcal{R} > 2$
E. There is not enough information to tell

4. The long-term average finite rate of growth λ of a successful species should be:

A. Very close to 0
B. Substantially greater than 0, but substantially less than 1
C. Very close to 1
D. Substantially greater than 1

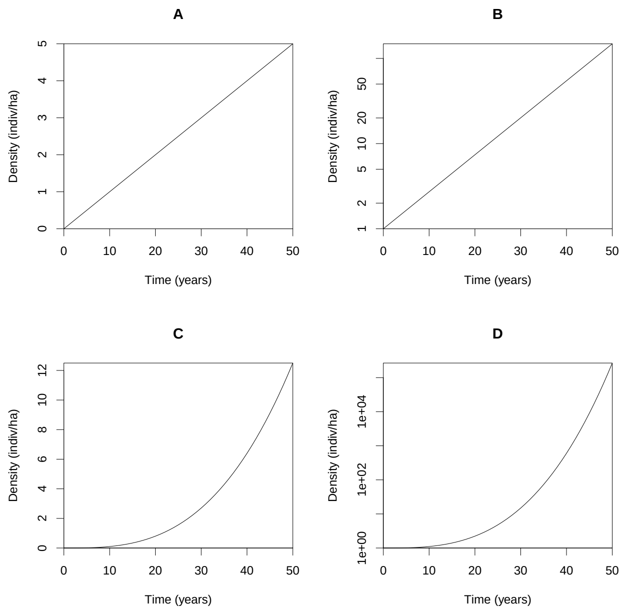
5. An ecologist believes that a population's fecundity decreases when crowded following the equation $f(N) = (N/N_e)^{-k}$. If N is measured in units of indiv/ha, then:

A. N_e and k are also in [indiv/ha]
B. N_e is unitless, and k is in [indiv/ha]
C. N_e is in [indiv/ha], and k is unitless
D. N_e and k are both unitless

6. Which of the following processes is necessary for population cycles?

A. Regulation
B. Allee effects
C. Stochasticity
D. Predator-prey dynamics
E. Age structure

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



Use this information for the following two questions. A population of small plants has discrete, overlapping generations. Adults survive each year with a probability of 3/4 (and thus they have an average lifespan of four years). Each reproducing adult produces an average of 10 seeds *each year*, of which an average of 8% 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.

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

A. $p = 1/4$ and $f = 10$
B. $p = 3/4$ and $f = 10$
C. $p = 1/4$ and $f = 0.8$
D. $p = 3/4$ and $f = 0.8$

9. The reproductive number $\mathcal{R}$ for this population is:

A. 1.05
B. 1.55
C. 3.2
D. 10.25
E. 13.33

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

A. In models where competition is contest-like
B. In models where competition is scramble-like
C. In models without competition
D. We don't see population cycles in simple continuous-time models

11. In this class, the professor argued that populations cannot increase or decline exponentially for long, and that high population densities must:

A. have direct positive effects on their own growth rate
B. have either indirect or direct positive effects on their own growth rate
C. have direct negative effects on their own growth rate
D. have either indirect or direct negative effects on their own growth rate

12. When studying insect populations with non-overlapping generations, researchers often use the time when insects are pupating as their census time because

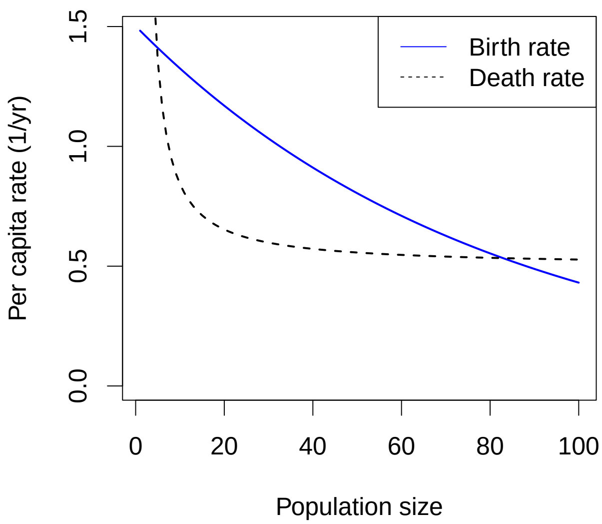
A. pupae are easy to find and count accurately
B. counting just before reproduction gives the most detailed information about the population
C. counting just before reproduction gives the simplest accurate model of the population
D. counting just after reproduction gives the most detailed information about the population
E. counting just after reproduction gives the simplest accurate model of the population

13. Consider a discrete-time, regulated population model with $p = 0$ and $f = f_0 \exp(-N/N_c)$ with $N_c = 50$ indiv/ha and $f_0 = 10$ What is $R(0)$?

A. 5
B. 10
C. $\exp(-5)$
D. $10 * \exp(-5)$
E. $5 * \exp(-10)$

14. Plotting how population changes through time *on a log scale* reflects a(n) __________ perspective, because __________ changes through time reflect __________ rates of birth and death

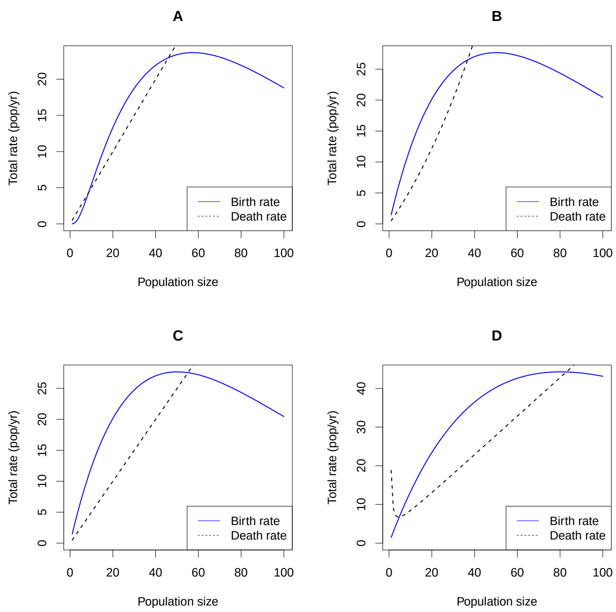
A. individual; additive; per capita
B. individual; multiplicative; per capita
C. population; additive; total
D. population; multiplicative; total



15. The figure above shows __________ in the birth rate and __________ in the death rate

A. density dependence; density dependence
B. Allee effects; density dependence
C. Allee effects; Allee effects
D. density dependence; Allee effects

16. Which of the four pictures below was generated by the same model as the large picture?



A. A
B. B
C. C
D. D

17. This population has a(n) __________ equilibrium at 0 individuals and a(n) __________ equilibrium at 80 individuals

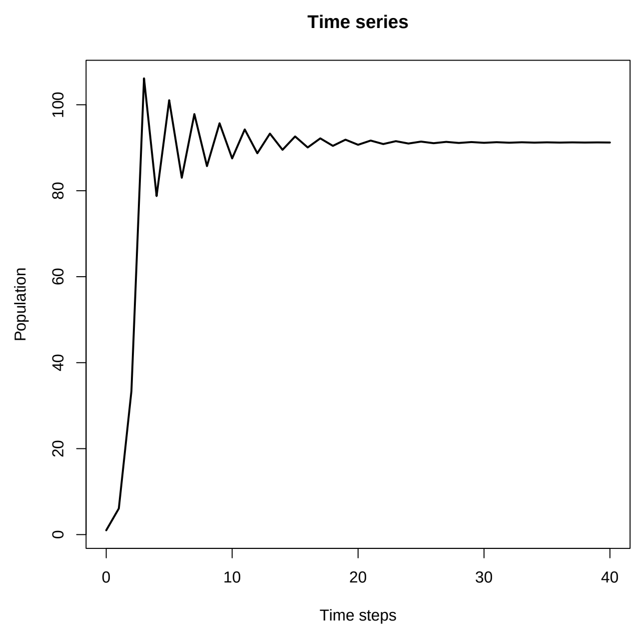
A. stable; stable
B. stable; unstable
C. unstable; stable
D. unstable; unstable

18. 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 at a non-zero value?

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

19. 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



20. The picture above illustrates a time series that is:

A. Converging smoothly to a stable equilibrium
B. Converging with oscillations to a stable equilibrium
C. Converging with oscillations to an unstable equilibrium
D. Oscillating without convergence around an unstable equilibrium

Name ____________ **Macid** ____________**Tutorial section** ______**Version 2**

Short-answer questions

Answer questions *in pen.* *Briefly* show necessary work and equations. Points may be *deducted* for wrong information, even when the correct information is also there.

21. (4 points) A population of sea turtles was observed to decline from 1300 breeding females in the year 2007 to 1000 in 2020. The instantaneous death rate d was estimated at 0.035/year. The sea turtle population has a 1:1 sex ratio. For the purposes of this question, assume the population is changing exponentially, on average.

a) Why does d have units of [1/year] only (no turtles)?

b) What is the instantaneous rate of change r for this population?

c) What is the instantaneous birth rate b?

d) What is the lifetime reproductive number $\mathcal{R}$?

22. Give one plausible reason for density dependence in a population of seed-eating birds