Name: ____________________ **Student No:** ____________________

BIOLOGY 3SS3, Version 1

DAY CLASS — Jonathan Dushoff

Test duration: 2 hours — April 2018

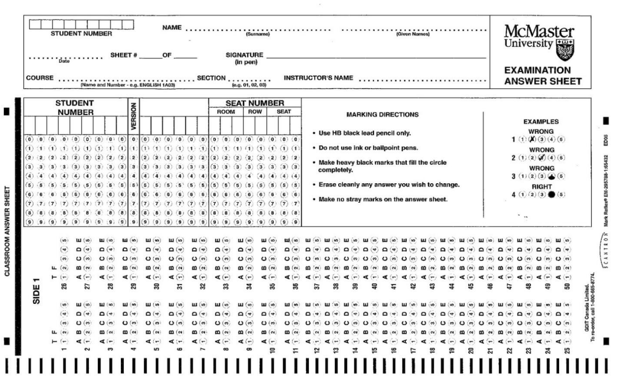
THIS TEST INCLUDES **40 QUESTIONS** and **?? PAGES**. YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR.

- McMaster standard calculator is permitted for this exam.
- Print your name and student number on the front page of this exam paper.
- Answer questions 1-40 on the **optical scan sheets**. Carefully read the following instructions.

SCAN SHEET INSTRUCTIONS: IT IS YOUR RESPONSIBILITY TO ENSURE THAT THE ANSWER SHEET IS PROPERLY COMPLETED. YOUR EXAMINATION RESULT DEPENDS UPON PROPER ATTENTION TO THESE INSTRUCTIONS.

The scanner, which reads the sheets, senses the bubble-shaded areas by their non-reflection of light. A heavy mark must be made, completely filling the circular bubble, with a HB pencil. Marks made with a pen or felt-tip marker will NOT be sensed. Erasures must be thorough or the scanner may still sense a mark. Do NOT use correction fluid on the sheets. Do NOT put any unnecessary marks or writing on the answer sheet.

1. On side 1 (red side) of the form, in the top box, in pen, print your student number (NOTE: 9 digits), name, course name, section number, instructor name and date in the spaces provided. Then you MUST write your signature in the space marked SIGNATURE.
2. In the second box, with a pencil, mark your student number, exam version number, and course section number in the space provided and fill in the corresponding bubble numbers underneath.
3. To indicate your answers, mark only ONE choice from the alternatives (1,2,3,4,5 or A,B,C,D,E) provided for each question. The question number is to the left of the bubbles. Make sure that the number of the question on the scan sheet is the same as the question number on the test paper.
4. Pay particular attention to the Marking Directions on the form.
5. Begin answering questions using the first set of bubbles, marked "1".



Good luck!

Formulas

discrete time growth:

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

continuous time growth:

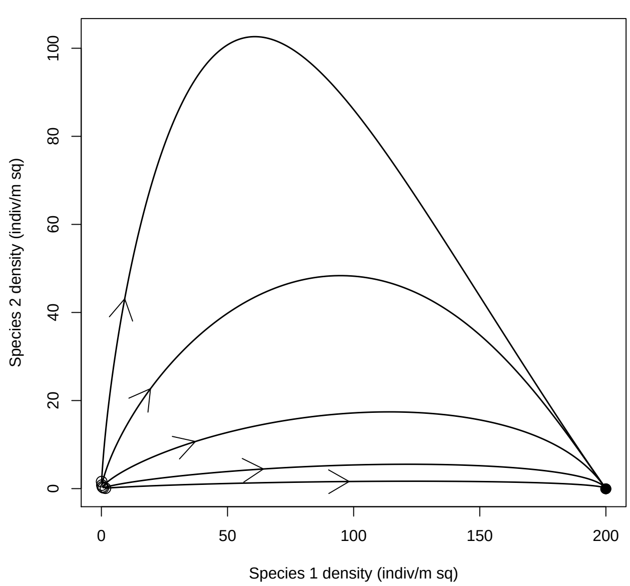
- $N(t) = N(0)\exp(rt)$
- $r = b - d$
- $\mathcal{R} = b/d$

structured growth:

- $\ell_x = p_1 \times p_2 \times \ldots p_{x-1}$
- $\mathcal{R} = \sum \ell_x f_x$
- $\sum \ell_x f_x \lambda^{-x} = 1$
- $\mathrm{SAD}(x) \propto \ell_x \lambda^{-x}$

competition:

- α_{ij} = effect **of** species i **on** species j
- $C = \alpha_{12}\alpha_{21}$
- $E_{ij} = \alpha_{ij} K_i / K_j$

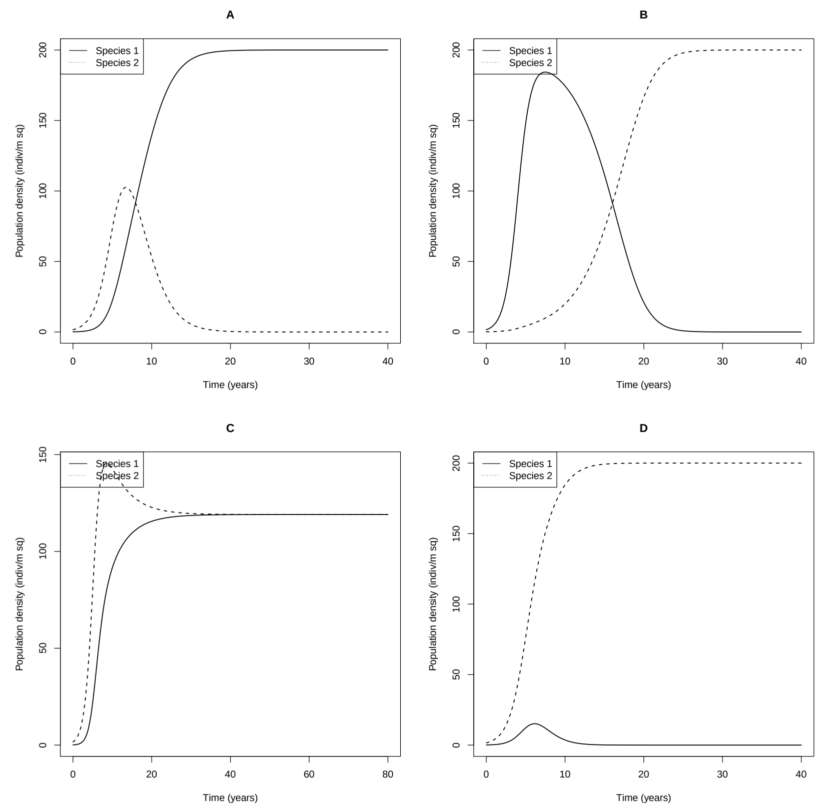


Use the picture above for the next 3 questions. These are plots from a simple model of two competing species.

1. The picture shows:

A. Dominance by species 1
B. Dominance by species 2
C. Mutual exclusion
D. Coexistence

2. Which of the time plots below matches the *upper path* from the phase plot above?



3. If E_{12} is the competitive effect of species 1 on species 2 (and vice verse), what can you say about the values of E in this system?

A. Both E_{12} and E_{21} are > 1.
B. Both E_{12} and E_{21} are < 1.
C. E_{12} but not E_{21} is > 1.
D. E_{21} but not E_{12} is > 1.
E. There is not enough information to choose one of these answers.

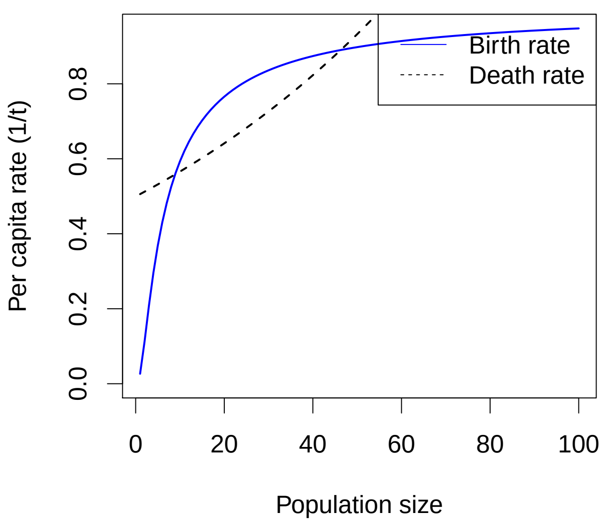
4. Malaria does not persist in Philadelphia because:

A. $r = 0$
B. $0 < r < 1$
C. $\mathcal{R}_0 = 0$
D. $0 < \mathcal{R}_0 < 1$

5. If a resource and exploiter population are under "reciprocal control", then at equilibrium, the equilibrium level of each species is primarily determined by the density that is required to balance:

A. the exploiter species' growth rate
B. the resource species' growth rate
C. its own growth rate
D. the other species' growth rate

Use this picture for the next two questions.

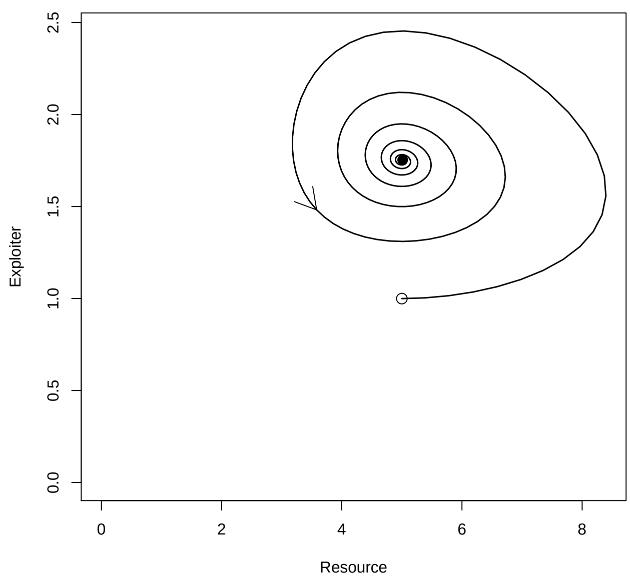


6. The picture above shows:

A. An Allee effect in the birth rate and density dependence in the birth rate
B. An Allee effect in the birth rate and density dependence in the death rate
C. An Allee effect in the death rate and density dependence in the birth rate
D. An Allee effect in the death rate and density dependence in the death rate

7. A population following this conceptual model would:

A. Increase from a low population or decrease from a high population to equilibrium
B. Increase to equilibrium from a low population and from a high population
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



Use the figure above for the next two questions. It shows a simple model of an interaction between an exploiter and a resource species.

8. The figure above shows:

A. Unstable oscillations
B. Neutral oscillations
C. Persistent oscillations
D. Damped oscillations

9. This figure is consistent with a simple model that has:

A. No density dependence and weak predator satiation
B. No density dependence and strong predator satiation
C. Prey density dependence and weak predator satiation
D. Prey density dependence and strong predator satiation

10. If oscillations of the SIR model are analogous to oscillations in a resource-exploiter model, then the resource species is analogous to the ________ individuals, and the exploiter species is analogous to the ________ individuals.

A. susceptible; infectious
B. susceptible; recovered
C. infectious; susceptible
D. infectious; recovered

11. Which of the following does *not* describe a trade-off?

A. Plants that use energy to make fruits for dispersal have less energy to make seeds
B. Aggressive males are more likely to win females, and more likely to be hurt in fights with other males
C. Improved DNA repair systems in bacteria reduce the speed of DNA replication.
D. Cats' sharp claws are used both to catch food and to deter predators.

12. Which of the following changes in a population would be expected to lead to a *smaller* epidemic?

A. An increase in the initial number susceptible
B. An increase in the initial number infected
C. An increase in the birth rate b
D. An increase in the transmission rate β
E. An increase in the recovery rate γ

13. What does β represent in the equation

$$dI/dt = \beta SI/N - \gamma I?$$

A. The rate at which individuals make potentially infectious contacts
B. The average amount of time it takes an individual to make a potentially infectious contact
C. The rate at which individuals leave the infectious class
D. The average amount of time it takes an individual to leave the infectious class

14. If a new disease is introduced to a susceptible population, and $\mathcal{R}_0 > 1$, we expect it to:

A. grow linearly until equilibrium is reached
B. grow exponentially until everyone is infected
C. grow exponentially at first and then grow less than exponentially as susceptibles are depleted
D. grow less than exponentially at first and then exponentially as it becomes established in the population

15. Which of the following populations would be the most likely to require an age- or size-structured population model?

A. Bacteria
B. Semelparous organisms
C. Organisms that are all approximately the same size
D. Large dinosaurs
E. Species that reproduce and die within a single year

16. Resource-exploiter systems __________, and competition systems __________, have an intrinsic tendency to oscillate:

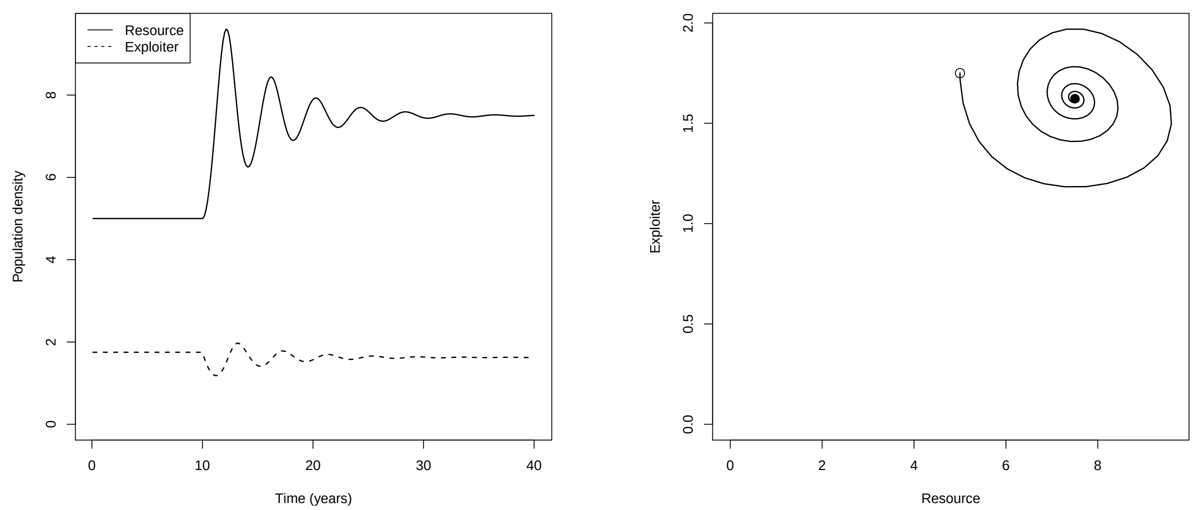
A. do; do
B. do; do not
C. do not; do
D. do not; do not

17. In which of the following circumstances can an older age class have more individuals than a younger age class?

A. This is impossible: older age classes must always be smaller than younger age classes
B. If there has been a temporary increase in fecundity in the recent past
C. If there has been a temporary decrease in juvenile survivorship in the recent past
D. In a stable population
E. In an increasing population

18. My favorite lake has no trout, but nearby lakes with similar conditions and similar weather do. I introduce a pair of adult trout to my lake in a year when the trout in the nearby lakes are doing well, but my trout fail to establish a population (they go locally extinct in my lake). This is likely due to:

- **A.** Allee effects
- **B.** Either Allee effects or environmental stochasticity
- **C.** Either Allee effects or demographic stochasticity
- **D.** Either environmental stochasticity or demographic stochasticity



Use the figure above for the next two questions. It shows a time plot and a phase plot from the *same simulation* of a predator-prey model. We change the parameters at time 10, to reflect a perturbation to the system.

19. At time 10, what changes in our simulation?

- **A.** The removal rate of the predator is increased (e.g., we start catching sharks)
- **B.** The removal rate of the prey is increased (e.g., we start catching fish)
- **C.** The removal rate of both the predator and the prey is increased
- **D.** A predator satiation term is added

20. This model has

- **A.** No reciprocal control or density dependence
- **B.** No reciprocal control and density dependence in the prey
- **C.** Strong reciprocal control and no density dependence
- **D.** Strong reciprocal control and density dependence in the prey

21. An ecologist wants to know what will happen in the short term if an invasive species (species 1) is accidentally introduced into a community where its competitor (species 2) is in equilibrium. The most important quantity to examine is:

A. The individual-level competitive effect of species 1 on species 2 (α_{12})
B. The individual-level competitive effect of species 2 on species 1 (α_{21})
C. The population-level competitive effect of species 1 on species 2 (E_{12})
D. The population-level competitive effect of species 2 on species 1 (E_{21})

22. If K_1 is measured in units of indiv_1, and K_2 is measured in units of indiv_2, what are the units of α_{21}? (see Formulas section if necessary.)

A. indiv_1
B. indiv_2
C. $\text{indiv}_1/\text{indiv}_2$
D. $\text{indiv}_2/\text{indiv}_1$

23. In some areas European polecats and Russian minks compete, and in other areas only one of the two species is found. When people started to harvest Russian minks in large numbers, reducing mink populations, European polecats spread to some areas where minks had been harvested, and polecats hadn't been seen before. A possible explanation for this pattern is that, before people disrupted the system, the realized niche of the __________ was __________ than its fundamental niche.

A. polecat; larger
B. polecat; smaller
C. mink; larger
D. mink; smaller

24. A population of small plants has discrete, overlapping generations. Adults survive each year with a probability of 2/3 (and thus they have an average lifespan of three years). Each reproducing adult produces an average of 10 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. What are the values for survival p and fecundity f for this model?

A. $p = 1/3$ and $f = 1$
B. $p = 2/3$ and $f = 1$
C. $p = 1/3$ and $f = 2$
D. $p = 2/3$ and $f = 2$

25. Which of the following is *not* a 'bet-hedging' adaptation that allows organisms to average over risk within a generation?

A. Long-distance seed dispersal
B. Semelparity
C. Delayed germination of seeds (seed dormancy)
D. Occasional migration behavior (like lemmings who seek new habitats when overcrowded)

x	f_x	p_x
1	0	0.8
2	1	0.5
3	4	0

Use the life table above for the following three questions.

26. What is ℓ_1 for this population?

A. 0.4
B. 0.5
C. 0.8
D. 1
E. 1.3

27. What is R for the population described above?

A. 2.0
B. 2.4
C. 2.8
D. 3.2
E. 3.6

28. What can you say about the instantaneous growth rate λ for the population described above?

A. $\lambda < 1$
B. $\lambda = 1$
C. $1 < \lambda < \mathcal{R}$
D. $\lambda = \mathcal{R}$
E. $\lambda > \mathcal{R}$

Use this information for the next two questions. In a population of beetles, all reproduction is sexual. Females in this population produce many fewer male than female offspring.

29. What can you say about the relative fitness at birth of females and males in this population?

A. Females have higher fitness per individual
B. Males have higher fitness per individual
C. Both sexes have equal fitness per individual
D. There is not enough information to tell

30. Based on the balance argument, we would expect to find that in this population:

A. Males are less likely than females to survive to reproduce
B. Males are more likely than females to survive to reproduce
C. Females use more resources for each individual female offspring than for male offspring
D. Females use less resources for each individual female offspring than for male offspring

31. Under which of the following circumstances can competitive outcomes depend on the starting population densities?

A. When $C < 1$
B. When $C = 1$
C. When $C > 1$
D. When competition is balanced
E. When intraspecific competition is greater than interspecific competition

32. Which of the following equilibria is usually *not* relevant in a system with one exploiter e and one resource species f?

A. $r_e = r_f = 0$
B. $r_e = N_f = 0$
C. $N_e = r_f = 0$
D. $N_e = N_f = 0$

33. 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

34. An exponentially growing rabbit population takes 10 years to grow from 20 individuals to 500 individuals. If it continues to grow exponentially at the same rate, how long would it take to increase from 500 individuals to 2500 individuals?

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

35. Two species are coexisting stably. Based on this information, what is the strongest correct statement you can make about the individual-level competitive effects α?

A. Both must be < 1
B. Both must be > 1
C. At least one must be < 1
D. At least one must be > 1
E. None of the above

36. Species face a tradeoff between $r_{\max}$ and K in their life-history strategies. Some species adopt strategies that put more emphasis on one or the other. In the long term, we would expect species which emphasize __________ to do better in stable environments, and species which emphasize __________ to do better in highly disturbed environments

A. $r_{\max}$; $r_{\max}$
B. $r_{\max}$; K
C. K; $r_{\max}$
D. K; K

37. $r_f(N_f, N_e)$ and $r_e(N_f, N_e)$ represent the *per capita* growth rates of a resource and exploiter species respectively, which of the following is definitely true?

A. $r_e(5, 5) > r_f(5, 5)$
B. $r_e(10, 5) > r_e(5, 5)$
C. $r_e(5, 10) > r_e(5, 5)$
D. $r_f(10, 5) > r_f(5, 5)$
E. $r_f(5, 5) > r_f(5, 10)$

38. We expect coexistence to occur when

A. Each species does better in an environment dominated by conspecifics than it does in an environment dominated by the other species
B. Each species does better in an environment dominated by the other species than it does in an environment dominated by conspecifics
C. One species does relatively better in an environment dominated by conspecifics, while the other does relatively better in an environment dominated by the other species
D. One species does better than the other in any environment

39. In a certain environment, algal species compete primarily for light in small pools, which may be disturbed. If the disturbance rate is very low, which species would we expect to dominate?

A. The species with the highest growth rate at high light (r_{max})
B. The species with the lowest r_{max}
C. The species with the highest light level at which it reaches equilibrium
D. The species with the lowest light level at which it reaches equilibrium

40. Compared to the instantaneous rate 0.05/day, the instantaneous rate 1.2/hr:

A. Means exactly the same thing
B. Is not directly comparable, because they refer to different time steps
C. Is comparable, and refers to a larger (faster) rate
D. Is comparable, and refers to a smaller (slower) rate