 Name__________________

Before starting please **write your name on each page**! Last name, then first name.

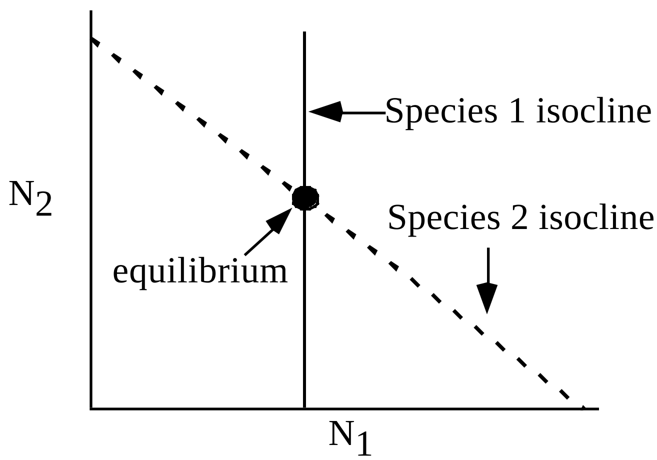
You have tons of time. **Take your time** and **read each question carefully** to ensure you fully understand **exactly** what we are after and **don't jump to conclusions too quickly**.

SCRATCH PAPER. The last page is scratch paper for you to use to organize your thoughts.

We have worked hard to make CHALLENGING questions, not TRICK questions. Good luck

1. The Lotka-Volterra competition model allows for a graphical approach to determining the outcome of competition between two competing species. Below is a graph that needs to be completed for the following specific case: Species 2 does not impact the carrying capacity of Species 1 (this effect is represented by the parameter α). In contrast, Species 1 does affect the carrying capacity of Species 2 (the effect is represented by the parameter β). Despite the competition, both species can coexist.

(a) Fill in the graph below by adding the following: (5 points)
- the isocline for each species, indicating which one is for Species 1 versus Species 2
- the equilibrium point
- label both the x and the y axis (but not specific values of where isoclines intersect axes)



(b) Assuming there is no predator involved here (i.e. just competition) what kind of experimental evidence would indicate that the **specific** outcome outlined above is occurring in nature? Describe both the experiment(s) and the result(s) from the experiment(s) needed to show the specific case shown above. (3 points)

Reciprocal removal experiment:

Remove species 1, density of species 2 should change.
Remove species 2, density of species 1 should not increase.

(Ideally, students should compare densities to a control plot but this may be too picky?)

(c) What is the general equation for change in population size of species 1 in the Lotka-Volterra competition models? (1 point)

$$dN_1/dt = r_1N_1\,(1 - (N_1 + \alpha N_2)/K_1) \quad \text{or} \quad = r_1N_1\,(K_1 - N_1 - \alpha N_2)/K_1$$

2. Each term on the left below has a matching term on right that is directly associated with it. In each space on the left write the letter of the term on the right that is the best match. (10 points).

Virulence __G__

Life history trade-off __E____

Metapopulation __D___

Senescence __L____

$\alpha = \beta$ __K___

K-selected __J____

Competition isocline __A____

Succession __B____

Herbivory __C__

Apparent competition __F___

Mutualism __I___

A. $K_1 = N_1 + \alpha N_2$

B. Inhibition

C. Secondary compound

D. dP/dt = 1 - u/m

E. Size versus number of offspring

F. Indirect effect

G. Transmission vector

H. $\lambda = r$

I. Ant acacia

J. Density dependence

K. Symmetric competition

L. Antagonistic pleiotropy

3. Developers and conservation biologists are fighting over the need to conserve three particular patches of a coastal saltmarsh to save a rare butterfly. The developers claim that these patches are not important to the butterfly because these patches are currently empty of butterflies, and that other patches containing the butterflies have already been preserved. Using the concept of metapopulations, explain why the developers might be wrong with their conclusion that the empty patches are not important to the butterflies. Your answer should explain the basic idea behind metapopulations as well as why reducing the number of patches in a metapopulation could cause global extinction (6 points).

A metapopulation is a population of populations, with each populationa living in a discrete patch. Populations (patches) go extinct, but empty patches also get recolonized. Because extinction and recolonization are independent, some patches will always be empty. The metapopulation model seeks to understand the fraction of patches that will be occupied: the fraction of occupied patches dendends on the extinction rate relative to the recolonizatino rate, and persistence of the metapopulation requires that the recolonization rate be higher than the extinction rate. Patches that are empty now will likely be occupied in the future. Removing these patches could cause global extinction for two reasons: (1) the fewer the total patches, the higher the probability that they all go extinct at the same time by chance (e.g. 3 heads in a row in a coin toss is more likely that 6 heads in a row) and (2) if the average distance between patches in increased, colonization rate may decline, and if it declines below extinction rate, the whole system will collapse.

4. You have just completed your study of a cohort of your favorite organism, the Mellow Couchpotato. You began your study by ear-tagging 1000 females, followed the entire cohort until the last one died, and noted the number of babies each female produced, on average, at each age. You then compiled all of your data and found the following: of the original 1000 newborns (age 0) you followed, 500 survived to year 1 where they had (on average) 1 baby each, 250 survived to year 2, where they had 1 baby each, 100 survived to year 3, where they had 3 babies each and none survived to year 4.

Age	Number alive	Babies/ female		
X	s_x	b_x	l_x	$l_x b_x$
0	**1000**	**0**	**1**	**0**
1	**500**	**1**	**.500**	**.5**
2	**250**	**1**	**.250**	**.25**
3	**100**	**3**	**.100**	**.3**
4	**0**	**0**	**0**	**0**

$\mathbf{R_0 = \sum l_x b_x = 1.05}$

(a) Is this population growing, declining or stable? To answer, complete the life table, calculate R_o and explain, based on the value of R_o, what the population is doing. (4 points)

Population is growing because $R_0 > 1$

(b) Why does the value of R_o tell you whether the population is stable, increasing or decreasing? (tell us in words what R_o represents biologically). (2 points)

R_0 is the average number of babies produced over the lifetime of the individualbabies we started with. Therefore, when $R_0 > 1$, each baby more than replaces itself and the population is growing.

(c) Complete the life table that will result in the following: a <u>stable population</u> (i.e. $R_o = 1$) of an <u>annual</u> plant where each female produces <u>10 seeds</u> (seeds for female plants, we ignore males here). Consider seeds as babies (age 0) and start with a cohort of 100 total seeds. Hint: because we are dealing with an annual organism, generation time = 1, hence $R_o = \lambda$. Also, it is helpful to recall our simple life history model of λ for an annual plant. Your table should include the columns used to calculate R_o.(4 points)

Age	Number alive	Babies/ female		
X	s_x	b_x	l_x	$l_x b_x$
0	100	0	1	0
1	10	10	.1	1
2	0	0		

$\mathbf{R_0 = \sum l_x b_x = 1.05}$

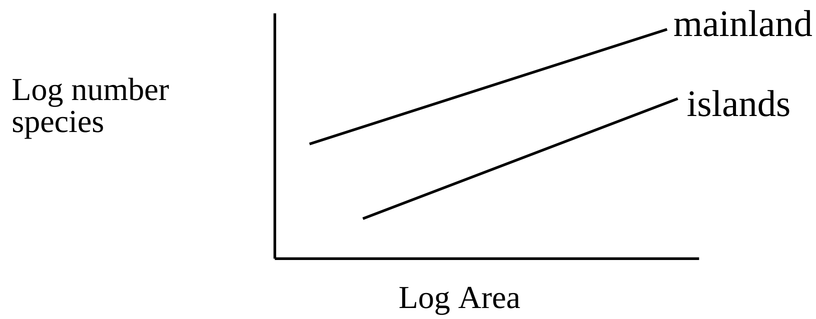
Two ways to figure this out.

(1) Work backwards from R_0 since we know that we start with 100 newborns and each female has 10 babies. This reveals the survival rate of seeds that <u>must be true</u> for the population to be stable: i.e. 0.1).

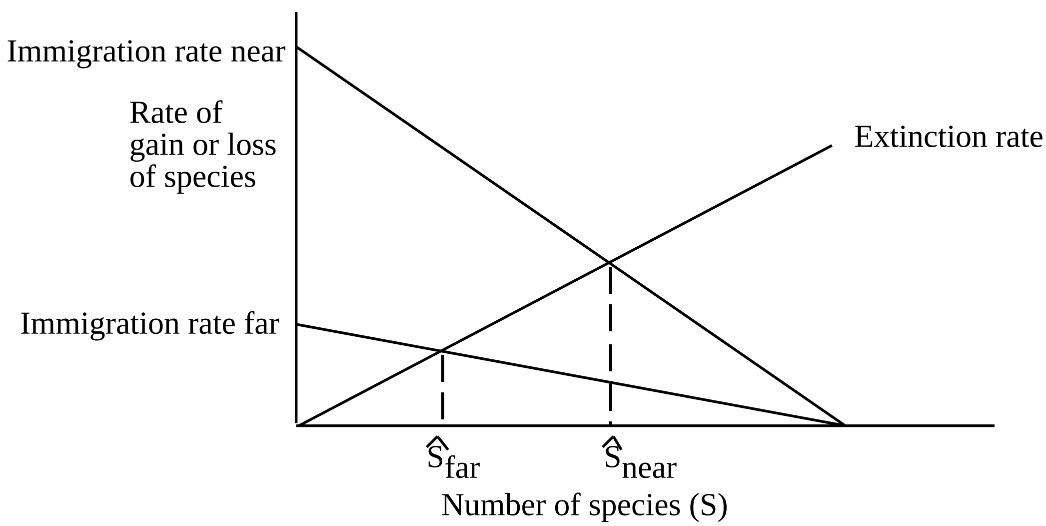
(2) Use the life history model to figure out survival of seed to adulthood ($\lambda = S_o B_o$), rearrange ($S_o = \lambda / B_o$), therefore seedling survival to adulthood (l_1) = 1/10 = 0.1.

5. The Equilibrium Theory of Island Biogeography was developed to explain two interesting relationships: the relation between diversity (number of species) and (i) the size of an island and (b) the distance an island from a mainland source difference in patterns of diversity between mainland areas and islands (including distance between an island and mainland source):

(a) Draw the two species-area relationships that illustrates the two patterns described above and fully label the Y axis. The distance effect can be shown simply by comparing the mainland to islands in general (3 points)



(b) Fill in the graph below to illustrate the how the Theory of Island Biogeography can explain why islands that are farther from the mainland source have fewer species than closer islands. Label the X axis and all of the immigration and extinction lines and be sure to indicate the equilibrium numbers of species on each of the two islands. (6 points)



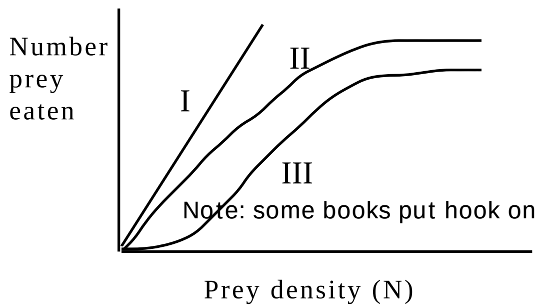
(c) If you surveyed two islands of identical size and equal distance from the mainland, does the theory predict that you will find an identical list of species on two islands? Why or why not? (2 points)

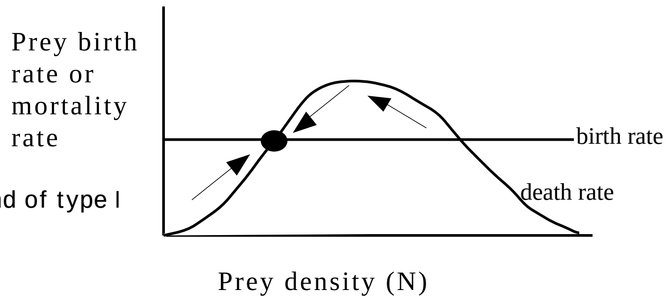
No they would not be identical because of turnover. These islands should on average have the same number of species, but different species colonize each island and different ones go extinct, so the lists of actual species present on each island would differ.

6. Ecologists have long been interested in the conditions under which predators can stabilize their prey populations (i.e. keep the prey populations in check and from increasing). One aspect of predator behavior of particular interest is the 'functional response'.

(a) On the left graph below, contrast the three types of functional responses in terms of number of prey eaten per predator. (3 points).

(b) One type, in particular, is thought to be able to stabilize prey population growth rate due to density-dependent effects on prey mortality rate. Draw this type of functional response on the graph on the left and, with reference to a line for birth rate, show how this type of predation can stabilize prey populations (i.e., dN/dt of prey = 0). (Hint: pay attention to the Y axis (number or rate) and on the left, draw arrows to show where and why the population is stable). (2 points)





(c) Name one behavioral mechanism that can give rise to this type of functional response that can stabilize prey populations? (2 points)

- limited number of hiding places for prey
- prey switching (search image predation)
- predator satiation (in part)

7. Many infectious diseases show dynamics remarkably like the regular population cycles of mammals. What specifically causes an epidemic to start and what specifically causes the disease to crash or decline? With respect to these causes, why does vaccination cause the disappearance of the cycles? (5 points).

The epidemic starts because births of new babies into the population increases the density of susceptibles above the threshold density required for an epidemic to start.

The decline is caused because once people become sick, they are immune from future infection, and are removed from the population of susceptibles, which causes the density of susceptibles to decline below the threshold density required for an epidemic to continue to spread.

Vaccinations keep the density of susceptibles permanently below the transmission threshold density, so there are never outbreaks.

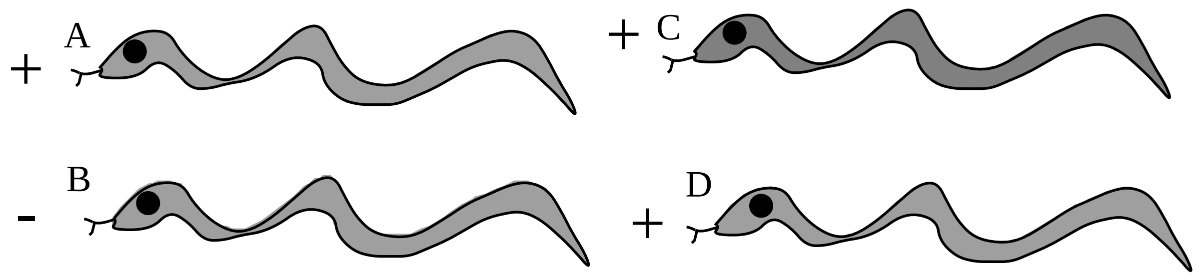
8. Below are shown four species of snakes (each species has a different letter), all brightly colored and patterned. Some snakes vary in their markings, which provide some sort of visual signal, and in their toxicity as well. Snakes with plus signs (+) are poisonous, while snakes with minus signs (-) are harmless. None of these snakes are related, so any resemblance in pattern is due to convergence, not common ancestry.

(a) Identify one species of snake that fit each of the following descriptions by filling in a letter next to each description (3 points):

Mullerian mimic ______**A or D**______

Batesian mimic ______**B**__________

Aposomatic coloration ______**A, C, D**__ (not B, it has fake warning color)



(b) Why does aposomatic coloration evolve? (2 points)

It reduces the predation rate on the animal with the aposomatic colors or warning colors, because predators with previous experience with the colorful prey will not attack it.

9. At times, it can be difficult to distinguish predation (and other harmful interactions) from mutualism. Show that this is so by describing predation on conifer seeds by birds that cache the seeds for the future (i.e. smart birds like jays bury the seeds and return to find them at a later date). What observations or data would you need to distinguish between the predation and mutualism hypotheses? (6 points)

The birds are eating seeds, which are baby plants. On the face of it, this looks like predation. However, before eating the seeds, the birds bury them in the soil, which is a fine place for a seed to germinate. The jays bury enormous numbers of seeds (30,000) but only eat a fraction of these. So the cost to the plant is the lost seeds eaten by the birds, while the benefit is some high quality seed dispersal. The key issue is whether the benefit from enhanced seed dispersal outweigh the fitness losses the the plant suffers due to seed predation. This could be approached in a couple of ways. First, see if these pines have any traits (adaptations) that make it easier for jays to find and collect their seeds, say perhaps their cone structure might differ compared to pines where jays do not collect seeds. Evidence that the tree has traits to encourage seed gathering would strongly suggest this is a mutualistic relationship. Second, assuming you have unlimited money and assistence for experiments, experimentally prevent jays from taking seeds and compare the number of seedlings produced by trees with jays and without jays.

 Name__________________

10. Succession is the change in community composition over time after a disturbance. The graph below shows the relative photosynthetic rates of three species of plants, and these rates predict the relative competitive abilities between the species, for each given light intensity (i.e. the plant with the highest photosynthetic rate under the existing light conditions beats out the other species).

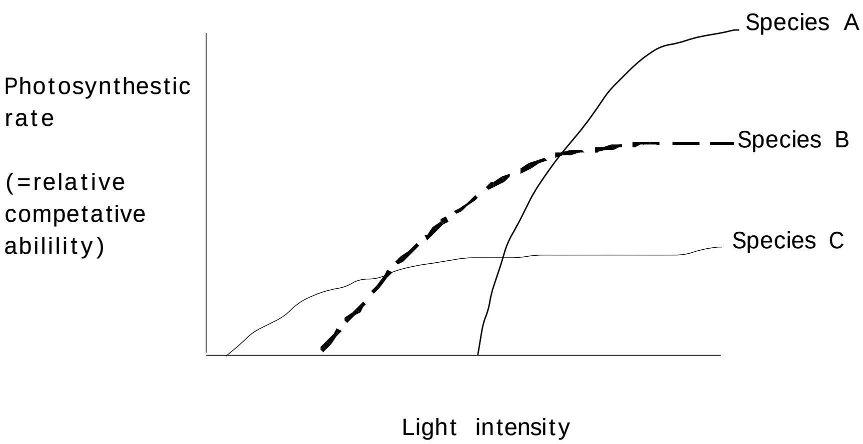
(a) What will be the order of succession (which species grows first, which second, and which third) after a disturbance, given that light levels are high immediately after a disturbance but then light levels continually decrease over time as plant grow and provide shade? (3 points)

____**A**____ is first

____**B**____is second

____**C**____ is third

(b) From the curves, draw lines down to the x axis to show the light intensities where we will see species change in the community. (2 points)



11. The following experiment is performed to assess the nature of the food web and trophic cascades in a lake. Before the experiment, the lake is crystal clear. Then, when you experimentally remove all of the individuals of one species, the Tanned Sunfish, the lake progressively gets green and scummy because of a huge buildup of phytoplankton. Previous studies showed that the Tanned Sunfish does not have any predators in the lake, and it is not a herbivore. Based on the result of the experiment, draw the food web for this lake, and indicate what trophic level the Sunfish is on and how many trophic levels were below it. Explain briefly in words how you know this (i.e., why would the number of trophic levels affect how green this this lake is? (6 points)

Tanned Sunfish
↓
Primary predator
↓
Herbivore
↓
Plants (Algae)

This was a four trophic level system, with the tanned sunfish eating primary predators. When the Tanned Sunfish was present, it kept the primary predators in check. Low numbers of primary predators means lots of herbivores, wh clear. Removing the Tanned Sunfish turned what had been a into a three trophic level system (even). Without the sunfi increased until limited from their food supply, the herbivor populations. Lack of herbivory freed up the bottom trophic numbers and turned the lake green and scummy. Odd numbe even numbers of trophic levels produce less green worlds.