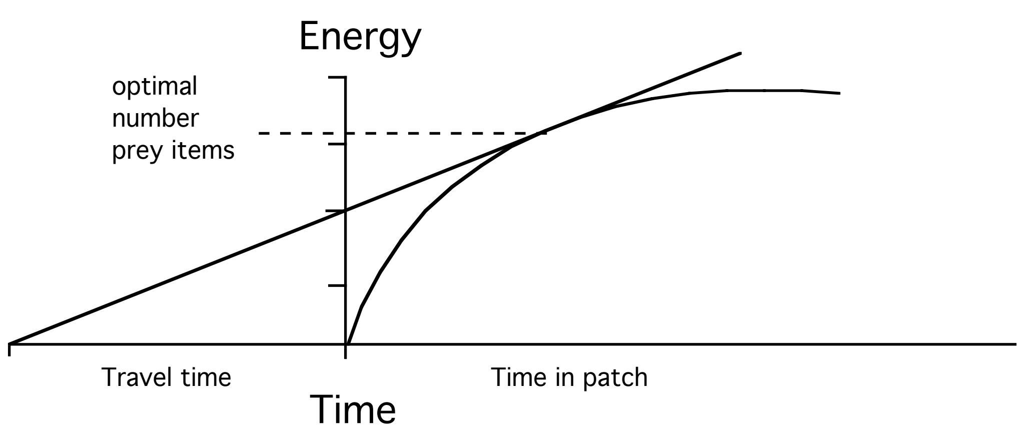
Before you start please write your name on the top each page!

Read each question carefully before answering to ensure that you fully understand what the question is looking for. Answer the questions in sufficient detail to let us know that you fully understand the critical issues. Do not use the shotgun approach of throwing everything under the sun into your answer in the hope that something will hit the target because we will deduct points for statements that are counter to the correct answer. 65 points total.

The last page is scratch paper for organizing your thoughts. Good luck.

1. Graphical models of optimal foraging provide a nice way to examine the foraging decisions of an animal that is repeatedly making trips between foraging patches and a central place, for example a bird that forages for food to feed the chicks in its nest. Below is the skeleton of this graphical model — complete the model as follows:

- Label all axis including the two separate parts of the x axis (2 points)
- Draw the foraging intake curve for rate of energy gathered (prey items) while foraging in the patch (1 point)
- Indicate how we solve for the optimal number of prey items that maximizes the **rate** of prey items returned to the nest (1 point)
- Also indicate the optimal number of prey items the forager should collect (it may not be an even number, don't worry about the tick marks) (1 point)



2. At time zero (t = 0) the population size of the Shrinking Violet is 2. The annual growth rate of the Violet population is λ = 2. What is the population size at time t = 3 years? Show the equation that allowed you to calculate your answer and your calculations. (3 points)

$N_t = N_0\lambda^t$

$2 \times 2^3 = 2 \times 8 = 16$

They get zero if they just write 16 because they likely just copied the answer off a neighbor

3. This question is designed to test your understanding of the process of natural selection as well as the field methods required to show natural selection in a wild population (9 points).

a) Outline the three conditions required for natural selection to occur (the three "ifs" we outlined in class). (3 points)

Condition

1) phenotypic variation in a trait

2) variation (trait) is heritable

3) trait has reproductive and or survival (i.e. fitness) consequences

b) The Feisty Ferret was brought by humans to Disney Island. The ferrets then began eating the native Mickey's Mouse on the island. You suspect that predation by the ferrets on the mice is causing ongoing natural selection for an increase in body in the mice. Outline briefly in point form what you would need to do in a field study to show each of the components of natural selection outlined above: what data you would collect, how you would collect it, and what result would confirm the condition. Your study is an observational study (not experimental) of selection in action (just like the finches) and there is no immigration or emigration of mice (6 points). **Keep in mind** the focus here is simply showing that selection for body size in the mice is occurring (the three parts of selection); the focus is not on figuring out what factor is causing the selection (i.e. you can ignore the ferrets and focus on the mice).

To study this in the mice, we need to capture and mark individuals (so that we can follow the fates of individuals over time). We also need to measure the body sizes of individuals to show that there is variation in body size (part 1 above). We then monitor the survival and reproduction of the individual mice to see who lives and dies — if natural selection favors larger mice, then we should see higher survival and/or higher reproductive output of larger individuals (part 3 above). We also must match specific parents to their offspring to see if body size is heritable. We obtain body size measurements of the kids when they grow up. Showing a positive correlation (relation) between the body size of parents and the body sizes of their adult offspring indicates that the trait is heritable (condition 2 above). If all of this is shown, then natural selection will occur.

4. The population growth rate per individual, r, is a very useful population parameter that is used in many population models. However, the value of r depends on the time scale used. If r per day is 1, what is r per week? (1 point)

r = ***7/week***

5. You are one of the biologists in charge of conserving the relatively small population of grizzly bears in Yellowstone Park. On your annual bear counts, you notice that the population size fluctuates, and this is also reflected in your estimates of λ, a measure of per individual population growth rate or decline across years. In good years $\lambda = 4.0$, in bad years $\lambda = 0.2$, and good and bad years occur with equal frequency. Your colleague insists that the bear population is in fine shape because the arithmetic mean of λ is 2.1 and plugging this value into the deterministic population model shows that the population will grow over the long-term. Being a well-trained ecologist, you correct them and insist that a stochastic population model is needed here.

a) What is the fundamental difference between stochastic population model and deterministic population models? (2 points).

Stochastic models have chance or random influences on the value of variables, whereas deterministic models do not.

b) Even without running any model you can do a quick calculation with the above λ values to obtain the appropriate estimate of some sort of 'average' λ value that accurately predicts long-term prospects for the bear population. What is the name of the average needed to predict long-term population trajectory? Show the calculation that allows you to see what the population is doing. Is the population growing, stable or declining over the long-term? Explain. (3 points).

Declining. Geometric mean lambda indicates long-term population growth. Since good and bad years occur with equal frequency, the geometric mean is just the square root of the product of the two lambdas (ie. square root of 2 times 0.4 or square root of 0.8). Square root of any number less than one is also less than one. Therefore geometric mean l < 1, and population is declining.

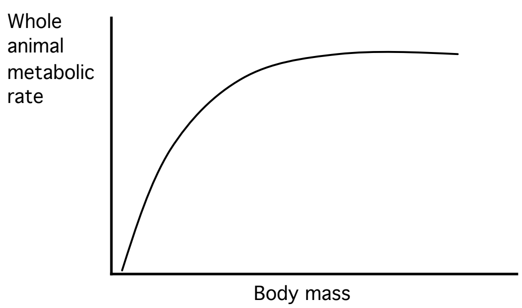
6. According to population models, the density-dependent effects of intraspecific competition can have very different and interesting consequences for the population dynamics of populations with discrete breeding seasons compared to populations with continuous breeding. These consequences are best illustrated by contrasting the population dynamics (changes in N over time) predicted by the continuous logistic ($dN/dt = rN(1-N/K)$) versus the discrete logistic model ($N_{t+1} = N_t + r_d N_t(1-N_t/K)$).

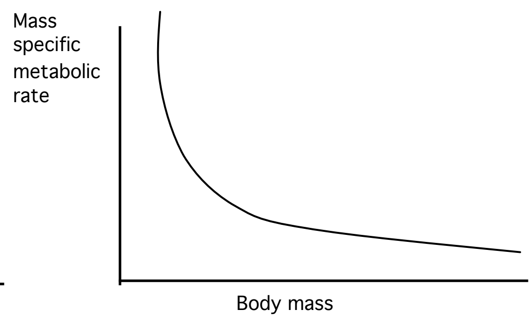
a) What is the major difference between these models in terms of the population dynamics each model predicts when r is very high? You can describe in words or you draw a couple of graphs (2 points)
The continuous logistic shows a smooth increase to carrying capacity (K) and then the population stays exactly at K. The discrete logistic increases to K but then overshoots and undershoots, either showing stable limit cycles or if r is very high, chaos.

b) Why specifically do these two models produce such different outcomes? (2 points)
Time lags due to discreteness. ***Due to discreteness there is a time lag between current population size and timing of when density dependence actually kicks in. Time lags plus high r gives rise to strong changes in population above and below K and the population cannot settle on K. With continuous, population is adjusted instantaneously and K is reached smoothly.***

7. Allometry is the study of how traits or factors change in relation to body size. The relation between metabolic rate and body mass, in particular, has been the focus of intense interest and a couple of key patterns have been discovered.

a) Fill in the graphs below with a line or curve to show the relation between whole animal metabolic rate (Kcal/unit time) and body mass (left) and mass specific metabolic rate (Kcal/gram/unit time) and body mass (right). Graphs are arithmetic, not logarithmic (2 points)





b) Two new mammals have just been discovered in Siberia, a cow-sized beast and a tiny shrew-sized creature. Based on what you know about the physiological consequences of body size, speculate about (i) the expected diet differences between these two species (what they eat) and (ii) the risk that a three-day cold period without food poses to each. Justify your speculation with reference to the graphs. (4 points)

- mass specific metabolic rate huge for the tiny mammal, small for the huge animal
- thus, small animal eats energy rich food (nectar, insects); large eats low quality food (herbivore)
- endurance increases with size, tiny animal cannot last cold period without dropping metabolic rate (torpor), cold period is a piece of cake for the big animal
(stating that big animals store more fat is not correct: need to mention efficiency or endurance)

8. Darwin's finches on the Galapagos Island archipelago are a classic example of an adaptive radiation. However one species of Darwin's finches, the Cocos Finch, made it to Cocos Island (a lone island by itself) near Costa Rica. Clearly all of these finches are close relatives phylogenetically, but the pattern of evolution in these two locations is very different. With reference to adaptive radiation, speciation and ecological specialization, compare and contrast the Darwin's finches in the Galapagos and the Coco's finch. (4 points).

Darwin's finches on Galapagos — many species; speciation possible because are many islands far enough for infrequent colonization and this isolation (allopatry) permits speciation and ecological specialization on different food resources through species differences in morphology (beak structure)

Coco's Finch— one island, therefore isolation and no speciation and only one species; get ecological specialization through individual behavioral specialization on different food resources.

9. Match each term on the left with one term on the right that is the BEST match and write the letter of the term in the space provided (5 points).

1. increased female body size — **A**	A. fecundity selection
2. risk sensitive foraging — **F**	B. continental drift
3. Arctic Circle — **C**	C. summer solstice
4. Wallace's line — **B**	D deterministic
5. pygmy deer & giant squirrels — **G**	E. speciation + ecological specialization
	F. variability in food supply
	G. Island Rule

10. The "ideal free distribution" is a theory that predicts how foraging animals will distribute themselves among feeding patches of different intrinsic quality (where quality is based on the total amount of food in patch or the rate at which food is produced). The theory is easily tested with a school of fish in an aquarium and two separate food dispensers that differ in the rate at which they dispense food. (3 points)

a) A test of the ideal free distribution is conducted in a tank with 40 fish. There are two feeding stations. Station A dispenses 3 fish pellets per minute, while Station B dispenses 1 fish pellet per minute. If these fish show a perfect ideal free distribution:

How many individuals will be at Station A? (1 point) **30 fish at station A**

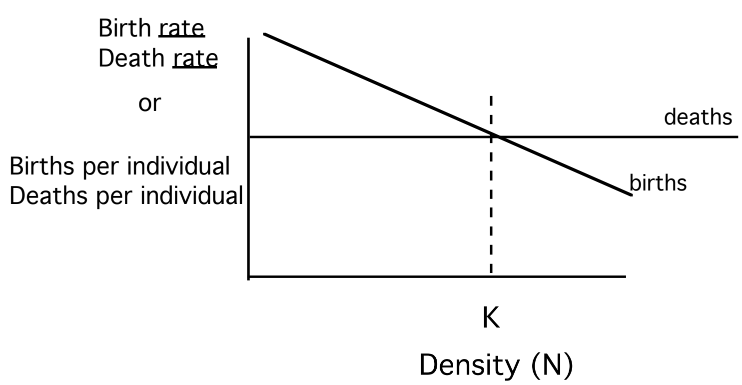
b) What are the two key features of this system that are critical for producing the ideal free distribution? (2 points)

animals free to move around
animals can assess
animals seek to maximize food intake rate
no territoriality or aggressive control of resources

11. Density-dependence is of special interest to ecologists because it can potentially explain what limits population growth in some species.

a) List two mechanisms that can cause density-dependence. (2 points)
space depletion, territories, safe hiding spots, resource depletion (intra or intersp), intraspecific predation (cannibalism), parasitism, disease, search image predation, Allee effect, and anything else that seems reasonable)

b) Use the graph below to illustrate how a density-dependent birth rate and/or a density-dependent death rate can "regulate" a population so that it will be stable. Label each axis, all lines and indicate with a dashed line that drops to the X axis where the population is stable. Also, explain clearly in words why the population will be stable in terms of population growth rate parameter r. NOTE: this is general density-dependence, not the logistic model due to intraspecific competition. (3 points)



b- d = r, there can see where pop grows , shrinks or is stable

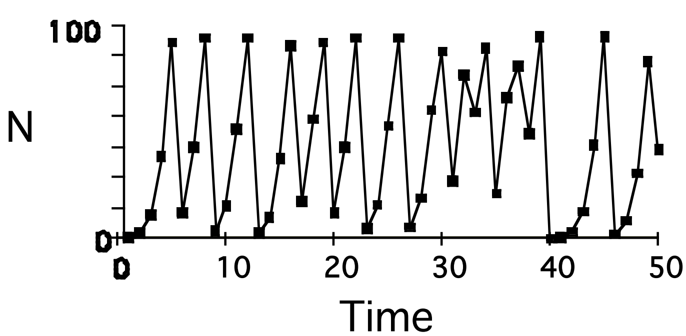
Above K: b - d < 0, pop srhinks

Below K: b - d > 0, pop grows

At K: b - d = 0, pop is stable

(any configuration of b and d line crossing where b higher at low density is fine)

12. The graph below shows the population dynamics for the Frenetic Fritillary, a butterfly famous for its fluctuating population dynamics. These dynamics can be produced by two very different types of models, each of which addresses a very different biological mechanism. Outline these two different mechanisms and identify the <u>specific factor</u> that causes the population fluctuations. (4 points)



The first model (or mechanism) is one where stochastic (random) effects influence the population growth rate, such as weather.

The second model is a discrete logistic model, where density dependence, time lags and high population growth rates can lead to chaos.
NOTE: CHAOS IS NOT A MODEL OR A MECHANISM BUT A PATTERN. THE MECHANISM IS DENSITY DEPENDENCE WITH TIME LAGS!

13. Match each biome on the left with the description on the right that best applies to it and write the letter of the description in the space provided (5 points)

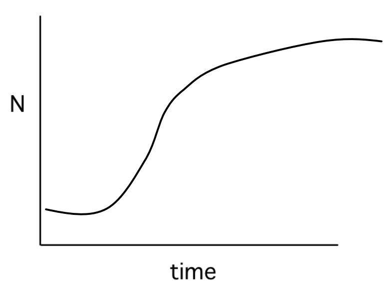
1. Tropical rainforest— **B**
2. Grassland — **G**
3. Northern coniferous forest — **A**
4. Temperate deciduous forest — **D**
5. Desert — **F**

A. dramatic population cycles of mammals
B. extreme biodiversity
C. most extreme seasonality of any biome
D. spring ephemeral flowers
E. wet, warm, coniferous trees
F. concentrated at 30° N and S latitude
G. fire maintains boundary in some regions

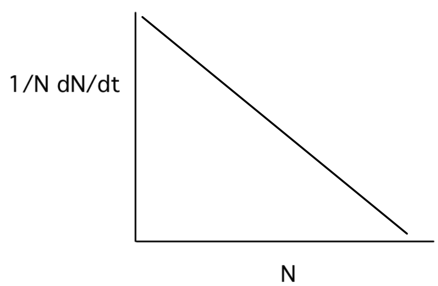
14. Fill in each graph below with the curves or lines predicted by the equation or phrase at the top of the graph beside the large letters. Read the x and y axes carefully: don't jump to conclusions (6 points)

A $dN/dt = rN(1-N/K)$ (where $r > 0$)

Must be sigmoidal

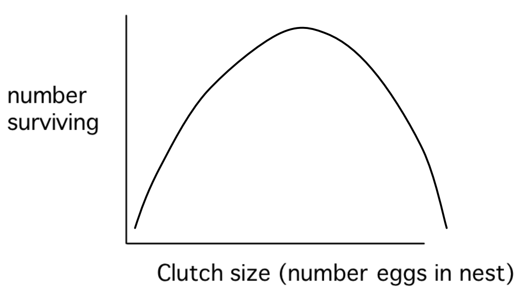


B $dN/dt = rN(1-N/K)$ ($r > 0$)

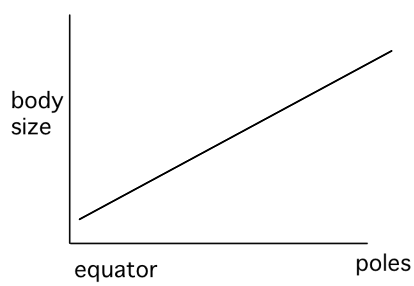


Straight

C The Lack Clutch size

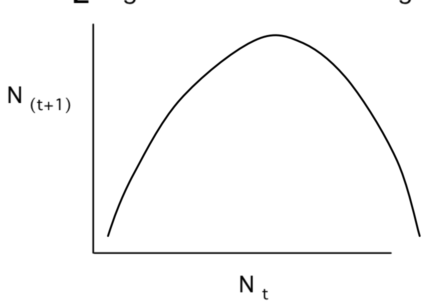


D Bergmann's Rule

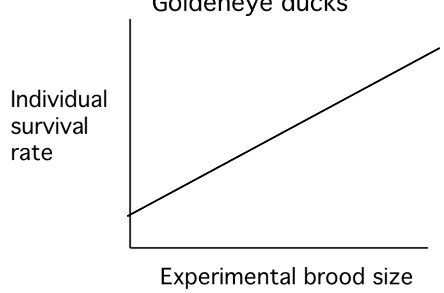


Straight or curved; must go up

E Signature of chaos: strange attractor



F Safety in numbers hypothesis for Goldeneye ducks



Straight or curved up