

# Solutions to 7.014 Problem Set 8

## Question 1

You are studying how the growth of a population of your favorite species of frog, *Xenopus tropicalis*. You construct a massive pond for the frogs and provide them with an unlimited food supply.

a) You begin your experiment with 50 frogs and after 10 months you find 61 frogs in your pond. Assume a continuous growth model for the population.

i) What is the intrinsic rate of increase in units of months<sup>-1</sup> for the frogs (to the nearest hundredth)?

$$\begin{aligned}N_t &= N_0 e^{rt} \\61 &= 50(e^{r(10)}) \\r &= 0.02 \text{ months}^{-1}\end{aligned}$$

ii) How long will it take for your initial population of frogs to double (in months)?

$$\begin{aligned}Td &= \ln 2 / r \\Td &= 0.693 / .02 \\Td &= 34.65 \text{ months}\end{aligned}$$

b) You allow the population of frogs to increase to double the initial population, but then you realize that you don't really have the space or resources to allow the population to continue to grow unchecked. You consider two possible ways to naturally cut the rate of growth of the population.

i) You decide to simply cut the supply of food to the frogs (harsh though this may sound you reason that it will cause a decrease in new breeding and eventually you will reach a steady state population). After another 10 months you find that you have population of 106 frogs. Assuming the value for  $r_{\max}$  is the same as it was in part a, and that population growth is following the logistic equation, estimate what the carrying capacity (in number of frogs) is for your environment.

$$\begin{aligned}N_t &= K / (1 + [(K - N_0) / N_0] e^{-rt}) \\106 &= K / (1 + [(K - 100) / 100] * 0.8187) \\K &= 145\end{aligned}$$

## Question 1, continued

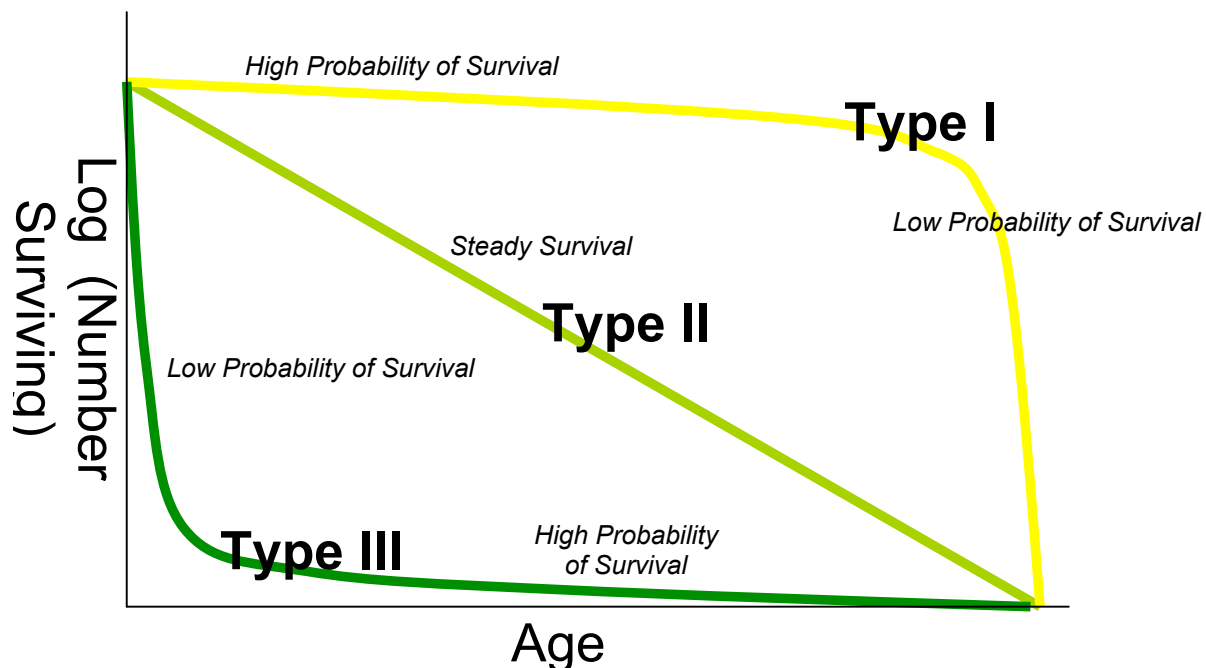
- b) ii) Your second option is to introduce frog-eating snakes into your pond environment. You introduce a small number of snakes into the pond. After a few months you return to your pond and find that the snake population has increased dramatically and that the frog population has decreased equally dramatically. In fact there are now more snakes than frogs present in the pond. Provide two different predictions about what will happen to the populations of snakes and frogs in the long term in your pond environment.

*One prediction would be that the snakes would eat all of the remaining frogs and then lacking a food supply would starve to death. Another prediction would be that the snake population would decline because there is not enough food, and this decline would allow the frog population to rebound. Once the frog population reached a high enough level the snakes would start to increase their population size because of increased food supply. Thus the two populations would oscillate out of phase with each other.*

## Question 2

Survivorship curves allow one to understand a great deal about the survival and reproduction of a species.

- a) Draw three types of survivorship curves (label the axes) and explain what each graph represents.



## Question 2, continued

b) For each of the following groups choose the survivorship curve that best fits with their life cycle and briefly explain why.

i) A group of frogs that reproduce using external fertilization of millions of eggs.

*Type III curve, many eggs are fertilized but very few make it to adulthood.*

ii) A group of prize rose plants (assuming that they have a finite life span).

*Type I curve, these plants are taken care of and so will mostly survive until they die of old age.*

iii) A group of human beings born in England in 1200 A.D.

*Type III, there was very high infant mortality throughout most of human history, despite the investment that parents put into their offspring. (Type I for parental investment would also be ok)*

iv) A group of human beings born in England today.

*Type I, modern medicine has decreased infant mortality a great deal and parents put a huge investment into their children.*

c) Pearl and Reed developed the logistic equation while modeling human population growth. They introduced the concept of  $K$  = carrying capacity. For the United States, Pearl and Reed estimated a carrying capacity of 197 million would be reached in 2300. Today the population of the United States is approaching 300 million.

i) In words, describe what carrying capacity is.

*The maximum population that the system can support.*

ii) It is possible that their model is correct, and that the discrepancy is due to an increased carrying capacity. What are some reasons that the carrying capacity would have increased?

*Increased agriculture, Increased energy into system from mining of fossil fuel.*

iii) It is also possible that their model is correct, but that the discrepancy is due to a time lag. Explain what this would mean for the population in the future.

*It may be that their estimated carrying capacity is real but the time that it is taking humans to respond to the changes in the biosphere is so long. In that case the population has increased beyond the real carrying capacity, and will need to decrease until at carrying capacity.*

### Question 3

Early in the evolution of life on earth, three major branches emerged, the bacteria line, the archaea line and the nuclear line. The endosymbiotic theory proposes that all eukaryotes are derived from the nuclear line.

a) Plants are thought to have evolved from the nuclear line cells that had formed a symbiotic relationship with bacteria.

i) What type of bacteria would have been part of the symbiotic relationship that generated the plants lineage? *cyanobacteria*

ii) What part of the plant cells is the modern day relative of the ancient bacteria?  
*chloroplast*

iii) The cellular process of *photosynthesis* occurs here.

What are the end products of that process?

*You get ATP and NADPH in the light reactions. These are used to make Glucose and O<sub>2</sub> is produce as a waste product.*

b) Other eukaryotes are thought to have evolved from the nuclear line cells that had formed a symbiotic relationship with different bacteria.

i) What type of bacteria would have been part of the symbiotic relationship that generated the non-plant lineage? *A heterotrophic bacteria.*

ii) What part of the non-plant cell is the modern day relative of the ancient bacteria?  
*mitochondria*

iii) The cellular process of *respiration* occurs here.

What are the end products of that process?

*Respiration burns glucose to generate ATP, it also release CO<sub>2</sub>*

c) Molecular evolutionary biologists use DNA as molecular chronometers to determine relatedness of different species. They have data that strongly supports the endosymbiotic theory. Briefly describe what that data is.

*When the DNA in the chloroplasts or mitochondria is compared to all available sequences, it is found to be most highly related to bacterial DNA.*

d) You want to determine the relatedness of the many different bacterial and eukaryotic species of the deep sea vent communities. Which DNA would be the most appropriate for your studies?

DNA encoding an oxygen binding protein.

DNA encoding an enzyme needed for chemosynthesis

DNA encoding an enzyme required for splicing

DNA encoding an enzyme used in glycolysis.

Why? *All organism carry out glycolysis so the sequence for that enzyme should be present in all. The other sequences are not universal to all organisms.*

### Question 3, continued

e) Explain why the DNA sequence encoding a protein and not the protein sequence itself is used for comparison.

*Because structure dictates function, only so much variability is tolerated at the protein level. The genetic code is degenerate, so there is more variability in the DNA than in the protein.*

### Question 4

You are a budding ecologist ready to get your start studying an old growth forest located on the West Coast of the U.S. Just as you are preparing to go out and begin your research, a massive wildfire comes roaring through and destroys the entire forest.

a) You make a trip out to the site a few months later to see what the ecosystem looks like. Expecting to find only a barren charred wasteland, you are shocked to find lots of wildflowers and weeds, along with some insects and birds. What characteristics must these plants have that allows them to grow here?

*They can grow without the presence of other plants, and they can grow in full sunlight.*

b) Twenty years later as a faculty member at a prestigious institution, you return to the site to follow up on your initial characterization of the ecosystem and to pick some of the nice pretty wildflowers. Once again you are shocked to find that site looks nothing like it did when you first arrived. Now you find many young trees and some underbrush along with many small mammals, insects and birds. What made it possible for these new plant species to colonize this location?

*These plants needed the plants that came before them in order to alter the environment so that they could grow.*

c) Now ready to retire, you return to the location 20 years after your previous visit. This time you are not surprised to find that the site looks completely different. Now there are large trees of different varieties than were previously present. You realize that the overall productivity of the site has greatly increased from the time you first visited, forty years earlier. You examine some soil samples, which you collected on each visit, in order to determine if changes in the soil account for this increase in productivity. What would you predict to be different in the soil samples from the original time point and the latest one?

*The soil sample from the final time point should have much more nitrogen than the original. The original plants did not need anything other than the original soil. The secondary plants use what the original plants had provided to grow and also added more nitrogen to the soil. This additional nitrogen was necessary for the final plants to be able to grow.*