Lab 13 Natural Selection

(June 2014)

Section 1 – Significance of Natural Selection to Biology

[2] Well look who survived Bio 3! Here we are at the last lab and I know you've learned quite a lot of biology if you've made it to this point. Congratulations! Just one more topic to go and it's a very important one to biologists – evolution.

[3] Have you ever heard anyone say that evolution is "just a theory"? Well that doesn't make too much sense because a theory is one of the most powerful ideas in science. A theory is an idea that explains a wide range of natural phenomena. Evolution is the explanation for why all species on earth use similar chemical reactions to stay alive, why the fossil record shows development through the millions of years that life has been on earth, and how we see species adapt to changing environmental conditions.

[4] In your lecture, you may have learned about some remarkable things we can do in a laboratory like putting jellyfish genes into a mouse, making them glow in the dark, just like a jellyfish. Think about why this jellyfish gene can work in a mouse – the molecule that contains the instructions is the same for these two organisms – DNA. This is powerful evidence that all life on earth is related and we all must share a chemical ancestry. Record this concept in your lab book.

[5] I'll leave your big evolution questions for your lecture instructor to answer, but I do want to clarify what the lab is about today. We'll be addressing the mechanism of evolution, which is called Natural Selection. Today you will see exactly how the genes for species pass onto the next generation, resulting in a change in a population over time.

[6] Take a moment to clarify these two topics in your lab book before we go on. All biologists agree that evolution has happened on earth, but everyone enjoys arguing about HOW it happens. Natural selection is the winning explanation so far.

[7] The fellow who came up with this elegant mechanism is Charles Darwin. You may already know that as a 22 year old naturalist, he sailed around the world and collected specimens from South America and specifically, the Galapagos Islands. It wasn't until many years later, however that he finally arrived at the answer to how species became just a bit different on each island.

[8] Charles Darwin's idea is so important to biology that you can find the essence of his idea in every branch of biology. Epidemiologists use the idea of natural selection to trace how strains of bacteria change and can cause new outbreaks of disease, geneticists use the idea to trace diseases through populations, in addition to the fields of ecology, biochemistry, human behavior, and on and on.

[9] Given his achievement in revolutionizing biology, Charles Darwin is revered in England. When he died in 1882, he was given a state funeral and buried close to Sir Isaac Newton in Westminster Abbey. His image is even on the 10 pound note – quite an honor for someone who isn't a royal.

[10] So what is the big deal with Darwin's idea? Well the first major way he revolutionized biological research was to recognize the power of variation to change a population. Variation is a very hard thing to see, but all populations have it. We'll rig today's lab so we can easily see the variation, but remember this would be a very, very hard thing to detect in a natural situation. Darwin realized that variation is the key to changing species over time. Please record this idea in your lab book.

[11] The second major contribution Darwin made was to understand that it takes many, many generations to actually see the change in a population. In fact, populations are constantly evolving, but a casual observer could never detect the process. That's why biologists must do studies over generations and spend so much time measuring every little detail of a species. This is another part of Darwin's genius – he certainly was thinking in the long term when he developed his theory. Record this innovative thinking in your lab book.

[12] I'm sure you remember back in Lab 1 when I had you write down the three types of adaptations – yes? They were physical, which you could see on the organism, physiological which involved the body chemistry, and behavioral which was a response the animal had to a stimulus. Take a moment and record these in your book, just in case you need a refresher.

[13] The easiest adaptations to examine are the physical adaptations, and today we'll look at the mechanism of how species become camouflaged. Camouflage means that the organism blends in perfectly with their environment. To be a true adaptation, you have to be BORN with the genes that produce a certain trait, so let's look at real example from nature.

[14] Take a look at this little seahorse. You see him, don't you? Keep looking while I explain… Over many***, many*** generations, this species of sea horse has been adapting to live on this particular species of coral. It's incredible when we see the final product, but I'm sure you're wondering how this can happen.

[15] To see this mechanism, we'll use your knowledge of genes, an idea that Charles Darwin didn't know anything about when he developed his theory. Today we will trace genes through a population and see the mechanism quite clearly change the population. This change in gene frequency is, in essence, the definition of evolution. Record this alternate definition in your lab book.

[16] Before we go too far, let's take a minute and do a quick review of the terms we'll need for today's lab. Record the correct term for each of these definitions in your lab book before we go on to Section 2. These are all review terms, so you shouldn't have any trouble putting them in the right place.

Section 2 – Sample Squares and Frequencies

[17] Okay, if you really have a good grasp of all these terms, it's time to get started. To simulate what happens in a natural population, let's say some mice, we have to realize that the population has variation, in this case we'll look at color. Some mice are dark colored, some mice are medium, and some are light. This variation doesn't have to be this dramatic, but let's keep the variation easy to see because this variation is the key to Natural Selection. Since we can't use live mice in the lab, we're going to use colored beads to represent each color of mouse.

[18] The colors of dark, medium and light are, of course, their phenotypes. The combinations of genes that result in these colors are the genotypes. To have a nice variety, we'll use a pattern of incomplete dominance between the A and A' alleles. Answer the questions below the table at the beginning of Section 2 before you go on.

[19] Our population will live and grow in a field of grass. As time goes by, different mice will mate with each other and we can use our trusty punnett squares to predict the offspring. A dark mouse is represented by the dark green bead and has a genotype of AA. All of its offspring will receive one A allele from him or her since this is the only allele it can pass on in its haploid gametes.

[20] The medium mouse will be represented by the yellow bead, and can pass on either the A or A' allele, since it is heterozygous. The light mouse will be represented by the colorless bead, and have two A' alleles.

[21] Take a moment and fill in the punnett squares and offspring ratios in Section 2 of your lab. This will be a big help when we get the population going, because we're going to assume that each mating pair of mice have four offspring, just like the punnett square shows. Come back to the program when your squares are complete.

[22] Our goal today is watch the change in gene frequencies as the population grows. The trick on calculating a gene frequency is to remember that every diploid individual has TWO alleles. Look at this little sample population, which is also shown in your lab book. First, figure out what color all those little mice are. Now count up the number of dark, medium and light mice in the field, then calculate how many alleles are represented.

[23] If you count up the total number of alleles in the population, you should get 36, double the number of mice. It has to be double the number of individuals – every mouse has two alleles.

[24] Now count up each kind of allele. How many A alleles are in this bunch of mice? How many A' alleles? Record the total of A alleles and A' alleles in the table in your lab book, then divide by the total number of alleles. Congratulations, you've just calculated an allelic frequency.

[25] If you have any questions about calculating the frequency, stop now and ask the instructor for help, because we're going to jump right into watching our population grow and there are going to be lots and lots of calculations and punnett squares coming up. Ready?

Section 3 – Selection Pressure – The Predator

[26] We're now going to gather up our population. Go up to the demo table and collect the following beads to represent our little mouse population – 10 green, 10 yellow and 10 colorless beads. Place the beads in the plastic container at your booth, so they don't roll away. This group of beads will be our "parental" or "P" generation.

[27] Fill in the table showing your population and complete the allelic frequency calculation at the beginning of Section 3 before we go on.

[28] I hope you found the allelic frequency to be .50 and .50, in other words, 50% of the alleles are A, the other 50% are A'. A quick way to check this calculation is to add up the two frequencies and make sure they add up to 1.00, or 100% of the alleles.

[29] Our population of 30 little mice are having a wonderful time, living in a field of grass that we will represent with this crummy old yellow carpet. Now I'm afraid I have some very bad news for our 30 little mice. An owl has just moved into the neighborhood and he just loves mice. Swallows 'em whole. Now let's see some Natural Selection.

[30] Take your plastic container with the 30 little mice beads to the demo table and follow the instructions in your lab manual for the "Darwin Box" exercise. A couple of hints on the box – make sure you are **looking** in the box when you hunt down your little beads, just like an owl would. Remember that if you picked up a bead, it died. The survivors are the ones still in the box. Continue when you have Section 3 completed and the instructor has signed your book.

Section 4 – The Next Generation

[31] Well that wasn't very pleasant for our little mouse families, was it? Oh well, circle of life and all that. But I think they've calmed down enough to get to the next important step of population change – reproduction. You'll be glad you completed all those punnett squares a while ago, because we're going to need them next.

[32] So after predation, we have our 20 terrified mice left. Place your 20 survivors in the plastic container and pull them out two at a time, forming mating pairs. Record the numbers of each type of pair in the table at the beginning of Section 4. You may have several pairs of the same type, or you may not have any of a particular pairing. Everyone gets different answers. Come back to the program when you have recorded the mating pairs.

[33] Each pair will have four offspring, in the ratios that the Punnett square predicts. These offspring will represent the F1, the next generation after the "P" generation. Because you might get multiples, let me show you an example of how to calculate the right number of offspring. If you have 3 mating pairs of yellow crossed with yellow, it's like having three families. You could do the punnett square three times, but wouldn't it be easier to multiply the results of the square by the number of pairs? The square shows a 1:2:1 ratio, but we will actually have a ratio of 3 green beads to 6 yellow beads to 3 colorless beads when we account for all the offspring of the three families.

[34] Fill in the rest of the table with the correct number of offspring from each pair, then total the alleles as we did before. This table reflects our next generation of mice, the F1. When the table is complete, have the instructor sign off your table. Continue when you are ready to begin Section 5.

Section 5 – And the Next Generation

[35] When we last saw our mice, they all had nice little families. The parents (our original 20 mice that survived the owl attack) have died of old age and the kids have grown up. Copy the F1 totals from Section 4 into the table at the beginning of Section 5.

[36] You should have 40 little mice that represent the F_1 generation. In fact, there are so many tasty little mice running around, it has attracted the attention of the owl. Our predator is acting as a constant selective pressure, and he'll do his part in our drama coming up.

[37] The F1 generation contains the same varieties of dark, medium and light mice, and the owl has no trouble seeing the dark mice against the light grass field. We will assume the owl will swoop down once again and take the same percentage of dark mice he was able to catch before. Calculate the number of dark mice surviving and complete the F_1 generation survivor table, then return to the program.

[38] Make sure your survivor table uses only whole numbers. If you calculated a fraction of an organism, we won't bother counting it because this little fellow might be missing a leg, or even his head, so it's very unlikely to survive. Calculate the new allelic frequencies and come back to the program.

[39] Now that the owl has left, we can see that we still have plenty of survivors to continue the population. Refer to your F_1 generation survivor table to see how many mice survived the attack. This is your new population, so place the correct number of each color of bead in your plastic container. Make sure you have the right number of beads before you continue!

[40] You can probably guess what the mice will do next – that's right, reproduce. Pair the survivors up as you pull them out of the plastic container and record the mating pairs in the table. Calculate the number of offspring each pair will have, then complete the rest of Section 5. Ya know, those mice better watch out, cuz I think I saw that owl again and he looks hungry…

Section 6 – Summarizing Selection over Three Generations

[41] We're ready to calculate the final effect of predation over three generations. Complete the Frequency Change table at the beginning of Section 6 by going back through your lab and recording the data from the three generations – the Parental generation before predation, Parental generation after predation, the F1 after predation and the F2 generation after predation.

[42] The gene frequency has changed, and you've just watched evolution happen. Most importantly, you measured it. Now if you had just walked up to the field of grass every once in a while, it is very unlikely that you would have noticed the change, but because we now have the numbers in front of us, it's pretty obvious what has happened.

[43] Here's a graphic that might put the whole lab into perspective for you – all the generations at once. Notice how you wouldn't ever be able to see the genetic change happening because the change does not happen in the individual – it happens in the population. It's impossible to see evolution happening unless you're measuring the entire population over several generations.

[44] Take a moment and answer the summary questions in Section 6. There's a pretty big question towards the end, so take your time and review the lab so far if you need to. Come back to the program when you're ready for the last question about frogs.

[45] Before we get to the frogs, take a look at this stick insect. Now can you see how this trait developed over time? We start with a population that has variation. Think about what would happen to stick insects that looked a bit more like leaves than others. Wouldn't they be the ones left to reproduce? And what would their kids look like? What would have happened to those stick insects that didn't have quite the right color or shape? You can see that the population changed based on who is still around to reproduce.

[46] So here are some tropical frogs – see 'em? There are actually three individuals in this photo. Based on the dynamics you've seen in today's lab, you shouldn't have any problem answering the question at the end of Section 6. Good luck!

Section 7 – Measuring Evolution – The Grant Study

[47] Occasionally you hear people say that evolution is happening so slowly, that you can't see it happen. Well there are many studies measuring species changes, but remember that it takes time to track generations. We were able to show this change in lab today because we had beads reproducing in plastic containers, but it takes much longer to study the real thing.

[48] Peter and Rosemary Grant from Princeton University have been studying Darwin's favorite animals, the Galapagos Finches. A single species of finch reached the Galapagos from the mainland 600 miles away and developed into a variety of species, each adapted to the unique microclimate on the different islands.

[49] One species of finch became several, all varying in the type of food they prefer. This is obvious when you look at all the different bill shapes. So you might think, well, that's it, evolution is done. But remember that populations are constantly under pressure, and in any population, only some members pass on their genes.

[50] To study evolution, the Grants have been capturing, marking and measuring EVERY bird on the island of Daphne Major. That's thousands of birds. After marking, each bird was watched to see what it ate and how many offspring it produced during its lifetime. And it may interest

you to know that they've been going back to the island every year since 1973. That's what it takes to study evolution.

[51] The Grants were on hand to watch what happened to the bird population in 1977 when a terrible drought occurred. 1200 of the 1400 marked birds died. But the important question is who survived to reproduce the next year? Look at this data and find the answer.

[52] That's right – birds that had slightly larger bills were able to eat the tough old seeds that were available with such limited rainfall. These numbers may not look like a big difference to you, but remember these are small birds, and just a millimeter difference allowed a bird to crack open a seed when others could not. It is the small variations that shape species many generations later.

[53] The size of a bird's beak is set for life – it can't change. But natural selection doesn't happen by changing the individual. Just like our beads don't change color, we don't need any change to happen to the individual. We just need the natural variation in bill size that the population already had before the drought happened. Answer the questions about the Grant's study before we go on.

[54] Each island may have had different amounts of rain, or different types of plant seeds which means each bird population had its own set of circumstances to deal with. That's why the Galapagos Islands are often called a living laboratory for evolution and the species of each island may look just a bit different.

[55] Darwin visited these islands for only five weeks on his way back to England. There is no way he could have seen shifts in gene frequencies in only one visit to a population, and yet he was able to surmise how these different species developed. Now scientists have even found the gene responsible for different beak sizes in these birds. Darwin would be so proud of us!

Section 8 – Adaptations to High Altitudes

[56] Okay that's all very good for frogs, insects, mice and finches, but have you ever wondered if humans are evolving? Well certainly they are! But you have to remember from today's lab, that we would have to follow many generations to detect how very subtle variations can set this in motion.

[57] Camouflage was fairly easy to track through a population, but what about adaptations we can't see – the physiological ones? Here are two highly adapted populations – the people that can live at extreme high altitudes. It turns out that the people of the Andes and the people of the Himalayas have solved high altitude problems in two different ways.

[58] Studies of the Andean population show that they have a greater concentration of hemoglobin in their blood, while the Himalayan population deals with low oxygen by having higher rates of respiration. These are just two different solutions to getting oxygen to the tissues, but separate populations came up with different, yet effective solutions. Record these physiological adaptations in your lab book.

Section 9 – Extinction

[59] But evolution can't always keep up with environmental change. There have been many, many loser species in the millions of years life has been on this planet. One type of organism that had been very successful were the trilobites, little sea creatures that looked like pillbugs that you may have seen in your garden.

[60] Trilobites were once worldwide in distribution and there were many successful species. But sometime at the end of the Permian, about 250 million years ago, they just weren't able to adapt to either the change in climate or to more efficient predators, and the entire group died out.

[61] To finish the lab, make a sketch of one of the fossils on display, just to appreciate some cool creatures that aren't around anymore.

[62] So I'll leave you with a quote from Darwin's journal to ponder as you pack up your stuff for the last time. And come back to the program when you're ready for one last question.

[63] That's it! You've completed the Bio 3 laboratory! Good luck on your finals!