Experimental evolution

- *Experimental evolution is evolution carried out in the laboratory:* Evolutionary biologists often carry out evolution in the laboratory, to test ideas about how evolution occurs. The usual mechanism is to select for some trait, or change the environment in some specific way.

- *Experimental evolution can be of practical importance:* Some labs evolve aptamers (short strands of DNA, RNA, or peptides) that bind to specific targets. For example, Andy Ellington's lab (UT Austin) has evolved aptamers that bind to the Rev protein of HIV-1. There has been a long-term study at the State Agricultural Laboratory in Illinois, running since 1896, in which oil content is selected for in corn.

- *Michael Rose selected for long life in flies:* All multicellular creatures age. In mammals, risks for cancer, cardiovascular disease, and various types of reproductive failure increase with age. In insects, cancer is rare, but other types of problems increase with age, such as missing body parts and reduced physiological ability. Aging also evolves. Mice live about three years, whereas humans live about 80 years. Our closest relative, the chimpanzee, only lives about 50-60 years, even when kept in benign environments. Why do animals age? The evolutionary explanation for aging is straight-forward: Organisms deteriorate because natural selection acts more effectively in young than in the old. The argument works like this. Imagine an organism that doesn't age. This does not mean that the organism is immortal. Far from it, as there is a chance that the organism will die each year from, say, predation. If, for example, the probability of surviving each year is 95%, this means that the probability of surviving five years is 77% but the probability of living 50 years is only 7%. A mutation that acts in early life will have many opportunities to act to promote survival or reproductive success among the many individuals that are still alive. By contrast, a late-acting mutation will find few survivors around on which to act. Natural selection, in this instance, will favor mutations that have a beneficial effect early in life, even if the same mutation has a deleterious effect late in life.

  Rose performed an interesting experiment on *Drosophila melanogaster*. Normally, this fly species lives about a month. Rose propagated the flies in circumstances such that only females that reproduce late in life contributed to the next generation. After many passages (about a dozen), he found that the flies were living longer (about 40 days, instead of 30). He has continued these fly stocks, and now has flies that live even longer (about half a year). He has termed these long-lived flies "Methuselah" flies.

- *Wichman & Bull evolved bacteriophage in the lab:* Bacteriophage are viruses that infect bacteria. ϕX174 is a DNA bacteriophage that infects *E. coli*. It has a small genome of only 5383 nucleotides. In fact, it was the first 'organism' to have its genome sequenced. One way to grow up ϕX174 is to take a growing

stock of *E. coli* and throw in some ɸX174 viruses. The viruses start to infect the *E. coli* cells, reproduce, and then emerge (burst) the cell with several hundred new viruses. These new viruses can then go on to infect other bacterial cells in the growing culture. Normally, the cultures are grown at body temperature (37°C). Wichman and Bull evolved the viruses to grow well at high temperature (43°C). They were able to completely sequence a sample of the evolved ɸX174 to see which mutations were responsible for the adaptation to high temperature.

One nice thing about this experiment is that one can see individual mutations appear, and spread through the population. These are the mutations that are beneficial. That is, they are beneficial when the temperature is high (43°C). They also were able to repeat the experiment, once in Texas and once in Idaho. They were able to show that, at least for ɸX174, that they could get repeatable results; the same mutations appeared in both experiments, though the order in which they appeared was different.

Natural selection in the wild

- *Many evolutionary biologists have demonstrated natural selection acting in the wild:* One of my favorite examples of natural selection is the work of Peter and Rosemary Grant, who both work at Princeton. They have visited the same island in the Galapagos since the 1970's, where they study the bird populations on the island. The island is small enough that they can follow all of the birds on the island, and even keep track of who parented whom. They have been able to demonstrate changes in beak size and shape as a response to seed availability over time. I am not going to discuss this example in detail, but if you are interested in their work, I recommend you read *The Beak of the Finch* by Jonathan Weiner. This book is very readable. That said, the material in that book will not be on a test. (The book is so good that I recommended it to my mom.)

- *Hopi Hoekstra and Michael Nachman studied coat coloration in pocket mice:* Rock pocket mice (*Chaetodipus intermedius*) live in the southwest of the United States, and have striking coat color variation. These coat coloration variations were first described by mammalogists in the early part of the 1900's. Several of these people had connections with UC Berkeley (such as Sumner and Benson). The pattern these mammalogists noted was that the coat color appears to match the substrate on which the mice live. The dorsal pelage is a light sandy color for those pocket mice that live on the granites and sands, whereas the coat coloration is dark for those mice that are found in the relatively recent basalt lava flows. (If you drive along US 8 you will see these lava flows, and they are quite striking. One of them, the Pinacates lava flow, is in Arizona.)

  Hopi Hoekstra and Michael Nachman were interested in these mice. Specifically, they were interested in two things: (1) what is the genetic cause of the dark coat color?; and (2) is the coat color adaptive?

First, though some cleverness and hard work, Hoekstra found that, at least in the Pinacates mice, the dark coat coloration was caused by a mutation in a single gene, melanocortin-1 receptor (*Mc1r*). The hair pigmentation is a bit complicated, but works like this: Mc1r is a transmembrane G-coupled receptor that is highly expressed in melanocytes (the cells responsible for hair pigmentation). Melanocyte-stimulating-hormone (a-MSH) activates Mc1r, resulting in elevated levels of camp and increased production of eumelanin. The pocket mice then have dark hair. Agouti is an antagonist of Mc1r. Expression of Agouti results in suppression of synthesis of eumelanin, and increased production of phaemelanin. The pocket mice then have yellow (light) hair. I imagine that you are probably wondering whether you have to know the chain of events that leads to light or dark hair in mice. Answer: You don't. This part you should know, however. Hoekstra was clever because she noticed the hairs of the dark pocket mice resembled a known mutation in the house mouse, which is a laboratory work horse. She knew some of the genes that were responsible for the mutations in the house mouse, so she figured that the same genes might be responsible in the pocket mice (they are related, after all). Hence, she was able to use a candidate gene approach. She found a perfect association between dark hair color and four mutations in Mc1r.

Second, Hoekstra and Nachman asked whether the coat coloration was adaptive. There was some previous research to go on. Dice performed an experiment in 1947 in which deermice were released on to two differently colored substrates (dark and light). He did this in a barn. Owls were then let loose in the barn, and Dice counted up how many dark and light colored deermice were eaten by the owls on dark and light colored substrates. As you might expect, the mice that were a mismatch for their substrate (e.g., light colored mice on a dark substrate) were eaten more frequently. Although Hopi was working with pocket mice, she had good evidence that coat coloration was adaptive in other mice. She was also able to demonstrate a very good correspondence in the wild between coat coloration and the substrate on which the mice were found. Dark mice are typically found on the dark basalt lava flows. The light mice were found in the lightly colored sands.

Hoekstra and Nachman were also interested in the dark mice found on the other lava flows. (The discussion, above, was about the pocket mice found on the Pincates Lava flow.) They found that different genes were responsible for the dark mice on the other lava flows. This means that dark coat coloration evolved independently several times in these mice. This is really cool.

Example test questions

Q1. Mutations at the Mc1r gene cause _____ coats in Pinacates rock pocket mice, and is maintained by _____.

    A. agouti/migration
    B. dark/mutation
    C. dark/natural selection

D. melanic/gene flow
E. mutant/mutation

Q2. The experiment by Dice, in which Barn Owls were released into a barn with deermice on different colored substrates demonstrates what?

A. That natural selection acts to maintain dark coat coloration in Pinacates mice.
B. That the mice are selectively bred to avoid owl predation.
C. That mice can easily outrun owls.
D. That owls can more easily see and prey on mice whose coats mismatch their substrate.

Answers: C, D, C