Selection

Darwin thought that evolution by natural selection was a very slow process, however it can also be very fast, only taking a few generations. Scientists can generate **experimental evidence** using organisms that have a short life cycle, such as bacteria, yeast, and flies (Drosophila).

For example, consider guppies. Females are more attracted to male guppies with many large brightly colored spots, than to male guppies with fewer, smaller, or duller spots. However, bright colors attract predators. So, the brightly colored guppies survive less but reproduce more, while duller fish survive more but reproduce less.

Endler and Reznick transplanted fish from a predator-filled pool at the bottom of a waterfall into the predator and guppy-free waters at the top of the waterfall. Therefore, a population of fish with drab colors was moved into an environment with no predators. There, within generations the male fish quickly came to have more spots that were larger and more brightly colored. This field experiment demonstrates the response of heritable phenotypes to a change in selection for a trait.

Sexual Selection: Why are females attracted to males with brighter colored spots? There are two primary hypotheses.

1. **Good Genes Hypotheis:** The bright coloration of males is a trait linked to other traits that allow for increased selection and survival. Therefore, females can use it as a proxy to determine their approximate fitness.
   a. Don't anthromorphize this, however: this doesn't mean the fish are consciously considering mate choice – it is simply an adapted preference, much as humans enjoy the taste of sugar and fat.
2. **Sensory Bias:** The food that guppies consume is brightly colored, so the female is biased to be attracted to bright objects, since they may be food. Therefore, the female preference for brightly colored males is simply that same existing color preference being exploited by the males to increase their mating potential.
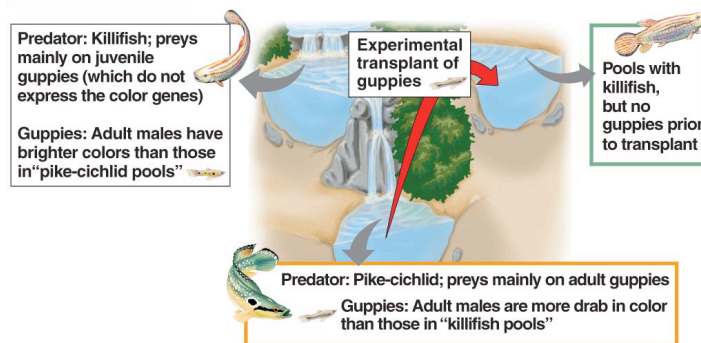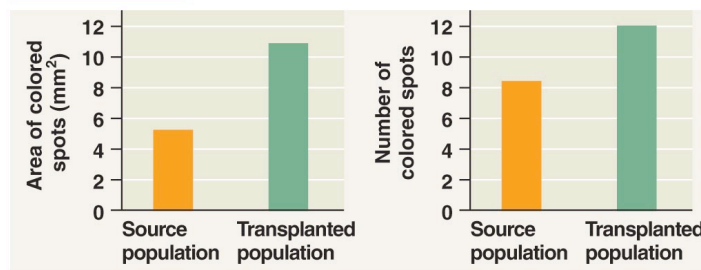
Figure 1: Guppy Experiment.
Campbell 8th Edition. *Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings* (pg 460)

Genomic Signatures are another way to see whether natural selection is operating in a population. It has become increasingly popular as the technology to do so has become more advanced and the cost of such tests has decreased markedly. A **candidate gene approach** targets genes (consider the pocket mice example: MC1r, agouti) known to cause such effects. Contrarily, a **genome scan** sequences an entire genome and searches for regions of very low variation.

      Why would we look for regions of low variation? A gene that is not under selection will accumulate variations through both mutation and the opposing effect of genetic drift. However, if a gene is under strong and recent directional selection, then there will be much less variety, as one variant of the gene will be more conducive to survival (for the lava flow mice, the darker phenotype).
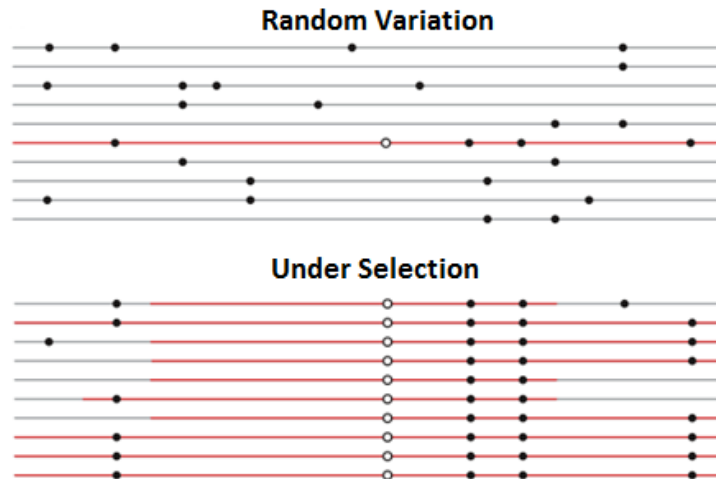
Random Variation

Under Selection

Figure 2: genetic variation for traits under selection and under no selection
Copyright J. Stovz, 2005

      For example, consider small and large breeds of dogs. All of these dogs are descended from a common ancestor that has been subject to intense artificial selection. A genome scan of small dogs revealed that all small dogs that were sequenced shared a single genetic location that exhibited very low variation. This location contained a known gene for a growth factor: when sequenced, larger dogs did not have the same variant as small dogs. This implies that recent selection on this growth factor is what makes small dogs small. (As for what makes small dogs so yappy, that's presumably still being researched.)

      Directional Selection is when the ideal phenotype shifts from that of the original population to a phenotype more adapted to the environment. For example, light-colored mice living on a lava floe would shift to a darker coat color.
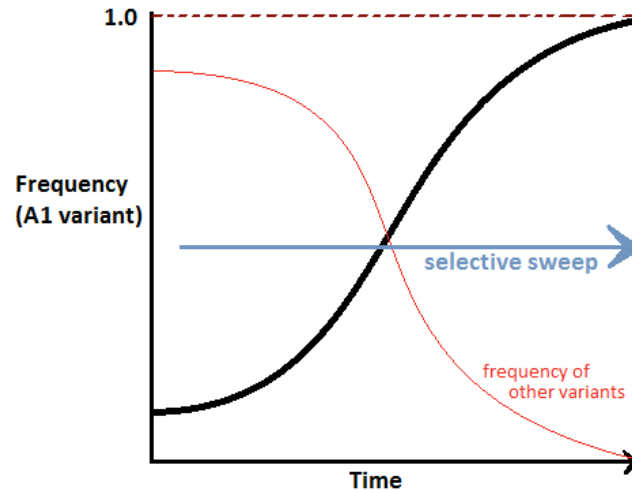
Figure3: change in phenotypes with strong directional selection
2010 Pavia.

Coevolution

Coevolution, or reciprocal selection, is when each species affects the fitnesses of phenotypes in the other species.

Mutualistic coevolution is when both species receive a benefit from the coevolutionary relationship. This can become an obligate (required) trait. For example, attine ants (also known as leaf-cutter ants) harvest leaves and bring them back to the ant nest, where they are digested by fungi. The fungi receives its nourishment from digesting the leaves, but the ants receive their nourishment from consuming the product produced by the fungi digesting the leaves.

Antagonistic coevolution is when species interact negatively. Consider a host and a pathogen coevolving: the pathogen would develop surface proteins that the host cannot detect. The host's immune system would then develop sensors that could detect that pathogen. This sequence of evolutionary events has often been called an **evolutionary arms race** or a **Red Queen** situation: to remain in one place (survive without being vulnerable to pathogens), you have to keep evolving new defenses.

In this case there is **frequency-dependent selection**, where the common phenotype has a reduced fitness (pathogens will easily infect individuals who all have the same genes) and the rarer phenotype has an increased fitness. This works to maintain genetic variation. (Neat note: The MHC, or major histocompatibility complex, is one of the most variable genomic regions in mammals, and is responsible for our immune systems. It's very complex, and has a lot of different interacting genes.)

Another example would be a predator and its prey: predators which are more able to catch the prey will be favored, while prey that can escape from predators more often will be favored.

Alternatively, a prey species such as the Pacific newt might be very poisonous. However, its coevolved predator, the gartner snake, has the ability to detoxify the poison and prevent itself from being harmed by the poison. This coevolutionary process might continue with the newt evolving more toxic poisons, while the gartner snake would become more poison-resistant.

Why have sex?

Evolutionarily, there are several strong disadvantages to sex:
1. Requires having two separate genders and expending resources on creating an entire gender (males) that waste energy by not directly producing offspring.
2. Requires that, once fully mature, individuals find a mate. This can consume a lot of time and energy that could be directly spent on offspring or survival.
3. Uses energy and entails risk.
4. By shuffling genes, sex breaks down good gene combinations.

The are alternatives to sexual reproduction. Some animals (1% of lizard species) practice **parthenogenesis**, or cloning to give birth to offspring genetically identical to the parent. Some plants have the same practice, called **apomixis.** Daphnia have a sexual-asexual system, where they reproduce asexually when the environment is favorable, and then switch to sexual reproduction when the environmental conditions are harsher.

Sexual reproduction has several advantages over asexual reproduction.
1. Produces variation through random mating, independent assortment of alleles, and recombination.
2. Recombination slows the accumulation of mutations (Mueller's ratchet)
3. Brings together good combinations of genes.
4. Produces genetically variable offspring, which:
    a. Can use more resources, and have an advantage in variable environments, in that they can adapt to changing environments more readily.
    b. Increase ability to evade pathogens and parasites. (Imagine if you have a species of clones where the only variation is due to mutations: they are going to be very vulnerable to a pathogen that is genetically adapted to that genome.)

Australian Gecko Populations
Consider *Heteronotia binoei*. These lizards reproduce parthenogenically (clonally). These clones are triploid (3N) and are all female, and arose from hybridization between different sexual morphs. The clones are genetically identical. This species of lizards has spread across a large swath of Australia. However, there will be up to 200 times as many parasites on these lizards as related sexual lizards, since these lizards are all genetically identical to each other (excepting mutation inherent in creating offspring). These parasites increase water loss and reduce survival rates.