TwoOldGuys™ Study Guides
BI114 Biological Concepts for Teachers
Chapter 3. Inheritance and Evolution
3.3. Selection, artificial & natural

Based on Indiana's Academic Standards, Science, as adopted by the Indiana State Board of Education, Nov 2000.
Numbers refer to the age-appropriate grade-level for the content.

Review

We covered the Theory of Inheritance, as proposed by Mendel as the principles of inheritance, to explain why offspring tend to look similar to the parents. We also saw how the offspring can be somewhat different than either parent, and why some traits can skip generations. We, then, suggested that, since inheritance occurs as a transmission of information from one generation to the next, if the information were changed it would still transmit by the same rules. Any such change in genetic information is called a mutation, and the organism with the modified trait can be called a mutant.

Selection, Artificial & Natural

Artificial Selection (Breeding)

grades 5: to 6: (especially in rural areas)

Livestock breeding can produce prize-winning animals.

If you know what the Judges will be looking for, "all" you have to do is breed your livestock to duplicate what the Judges want to see. A major risk in the preceding sentence is that many city kids will believe it,

although almost no country kids will. We have already learned that animals differ from each other, and that some characteristics are inheritable. By choosing those animals among the herd with the closest similarity to the desired traits, the hope is that the resulting offspring will come closer to the desired traits. Anyone who has actually tried to do this knows that a major obstacle to the success of the experiment is "luck." By now most of the readers should have run enough experiments to understand the very large influence luck can have on the outcome of any highly sophisticated scientific experiment, having attempted such sophisticated experiments.

Careful breeding can increase the likelihood that the offspring will exhibit the desired expressions of the selected traits. However, there is still the Nature versus Nurture argument. The care given to the prize livestock must emphasize the desired expression of the selected trait to maximize the likelihood that your animal will be awarded the Best of Breed award.

grades 7: to 8:

Judging Criteria at the county 4-H fair predict food quality of animals

Some traits are obvious in the living animal. For example, if you are interested in egg production, the number of eggs laid by a hen can be determined without killing the hen. The feel of rabbit fur can also be determined on the living rabbit. Other agricultural traits cannot be determined until after the animal is killed or even cooked, such a food flavor, food value (nutrition), distribution of fat relative to cooking procedure [baking requires fat that will self-baste, or melt into the meat; frying requires fat to melt out of the meat to prevent sticking, and so forth]. After having determined the value of the animal as a food item, it

is difficult to mate this particular animal since it has already been eaten. If on the other hand we can determine some easily observed traits that predict the food value, then we can select animals for breeding. It is exactly such traits that are used as judging criteria at 4-H livestock judging events. Therefore the candidates for Best of Breed can be produced by selection of breeding stock based on judging criteria, with some assurance that the animal has high market value.

grades secondary: to college:

oldest known document - a "How-To Manual"

The oldest known document concerning livestock breeding principles is a “how-to manual” from an archeological dig in Mesopotamia (Turkey). The stratum in which the document was located is dated from about 5,000 BP. Before a how-to manual can be written, the procedures have to have been worked out, so we know that agricultural breeding pre-dates this document by several human generations, or many decades.

basic premise

A common misconception, urban myth, is that farmers must eat well, because they produce the food. This overlooks that farming is a business, and as such is expected to produce profits for the owners of the company [usually the farmers]. From a profit point of view, livestock come in only three classes:

- Select "best" animals as breeding stock
- Select "worst" animals as food for family
- rest of herd sent to market for sale.

The best animals are too good to sell, because you need to produce good animals for sale in the future. The worst animals aren’t worth

selling, because they will not bring a good price at market [often not enough to cover the costs of feeding them up to market weight]. Everything in between these two extremes will be sold to pay the bills.

For example, [example 1] my Grandparents egg production

My grandparents were, at one time in my life, engaged in production of chicken eggs for sale. Since birds are known to be territorial and chickens are birds, it seems reasonable to expect the same hen to lay eggs on the same nestbox every day. Recording the number of eggs for each nestbox during the week should indicate the egg-laying capacity of each hen. On Sunday morning, the hen that laid the fewest eggs (actually the hen sitting on the nestbox with the fewest eggs last week) was taken to the chopping block and became Sunday dinner. The hen sitting on the nestbox with the largest number of eggs last week was moved to the pen with the rooster. She would lay fertilized eggs, which grow up to be chickens to replace those hens which became Sunday dinner.

If number of eggs laid is a trait, and therefore inheritable, this procedure should improve egg production. The worst layers experience an increased death rate, reducing the number of poor egg layers; and the best layers experience an increased reproduction rate, increasing the number of good egg layers.

example 2: dogs

There are no less than 150 separate breeds of dogs recognized by the American Kennel Club (AKC)

www.akc.org/breeds/index.cfm

Some examples include:

- German Shepherd, Retrievers, Collie, Bloodhound,

- Beagle, Bulldog,
- Poodle, Terriers, Chihuahua...

all of which are believed to have been bred from a single wolf-like ancestor, the Norwegian Elkhound, which originated in Norway as early as 5,000 B.C. [or 7,000 BP].

To illustrate how artificial breeding might be able to produce the variety of dogs represented in the AKC registration database, I shall provide some speculative breeding histories. I do not know these to be true. Consider starting with the Norwegian Elkhound, and breeding the largest individuals from the litters to produce a strong working sled dog. This could lead to the Siberian Husky. Continuing to select the largest of the litter, we could perhaps create the Alaskan Malamute. Returning to the Siberian Husky, consider breeding for herding instinct, producing the German Shepherd. Part way along the breeding of the German Shepherd, a failed attempt to produce a herding dog may have shown good hunting skills for smaller game (than does the Norwegian Elkhound). Breeding for this trait, we might have produced the Black and Tan Coonhound. Choosing the smaller animals in the litter, we could produce the following sequence; Black & Tan Coonhound (25-27" tall), English Foxhound (24" tall), Harrier (19-21" tall), Beagle (13-15" tall), Bassett Hound (14" tall). It is important to remember that these speculative breeding programs are based solely on superficial similarities among the dogs discussed, and are not intended to represent the actual process of producing these breeds.

If wolves can be bred to produce everything from a Saint Bernard to a Mexican Hairless, it seems reasonable to conclude that "simple" genetics is capable of producing an astonishingly large diversity of living creatures.

example 3: pigeons

The diversity of pigeon breeds is similar to the diversity of dog breeds. There are a wide range of different looking creatures under the name of pigeon breed, and all of them appear to have been bred from a single, city-hall pigeon. If you have any interest in seeing this diversity, I recommend any county 4-H fair. Pigeons are usually displayed in the poultry barn.

One famous pigeon breeder was named Charles Darwin. Darwin later joined the merchant marine, and shipped out as a cabin-boy on a voyage from England, around South America to the west coast of tropical South America. There off the coast are the Galapagos Islands, where Darwin was able to observe the diversity of finches on the islands. Darwin was surprised by the similarity of these wild bird species to the pigeon breeds with which he was familiar.

Darwin reasoned that the diversity of finches could have resulted from natural breeding from a single immigrant bird [pair obviously], in much the same way as the diversity of pigeons breeds resulted from artificial breeding from a single pair of birds. Since animals breeders refer to the process of choosing which animals to breed as "selection," Darwin suggested the terms artificial selection to describe the agricultural version, and natural selection to describe the same process in Nature.

Natural Selection (according to Charles Darwin)

grades 2: to 5:

The diversity of wild plants and animals, seen in chapter 2, helps plants and animals adapt to extreme environments. Biologically, the greatest extreme is the land environment compared to water-based environments, where the challenge is to retain water. More familiar to your students will be some of the extreme environments such as the

Arctic and Antarctic environments with their extreme cold and deserts with their extreme lack of water. Animals of the extreme cold environments include Polar Bears [Arctic] and Penguins [Antarctic], although your students may have seen the cartoon in which Chilly Willy, a penguin, hangs out with Polar Bears. Plants of the extreme dry environments include cactus.

grades 5: to 8:

The traits of wild plants and animals may give them some advantage in surviving the environment in which they normally live. As suggested above, this is comparable to selecting those livestock which are 'inferior' to be eaten by the family of the farmer. The animals not selected as food are the ones which are allowed to survive because they have desirable traits.

Similarly, other traits of wild plants and animals may also give an advantage in reproducing. This is comparable to selecting those livestock (or agricultural plants) which will be used for breeding to produce offspring with desirable traits.

"Struggle for Existence"

grades 4: to 8:

Plants produce far more seeds than grow to be new plants. Seeds tend to be produced by the tens or hundreds, yet only a few actually survive to become new plants. Large numbers of seeds are eaten by animals, and many fail to germinate in suitable habitats. Assuming, as Darwin did, that those that do survive have some traits which help them

survive, the population of plants will gradually become better adapted to the local environment.

Wild animals also produce more offspring than survive to adults. Although this may seem less obvious than the situation for plants, consider robin nests. A typical robin pair will lay about five eggs. Frequently one of these eggs will be eaten by snakes or other animals. Of the remaining four nestlings, it is somewhat unusual for more than two to be fledged. The other two will likely be eaten by cats or other animals. Still if robins were to successfully fledge two babies per year, and reproduce approximately three successive years before dying, a single pair of robins would produce three pairs of new robins. If this occurred, the number of robins would increase dramatically. Yet the number of robins in a local area tend to remain relatively constant over time. Clearly, many of the fledged robins do not survive winter.

grade secondary: to college:

Malthus Essay on Population Growth (A.D. 1859)

Malthus noted the following principles:

- reproductive potential is very large
- actual population sizes rend to remain constant

Consider a pair of mice, which produce a litter of six babies. Assume that all six survive as three pairs, and that the parents do not survive to reproduce again. Over a few generations, the number of mice will increase to ridiculously large populations.

generation	pairs of mice	offspring
0	1	1 * 6 = 6
1	3	3 * 6 = 18
2	9	9 * 6 = 54
3	27	27 * 6 =162
4	81	81 * 6 = 486
5	243	243 * 6 = 1458

Real mice do survive to reproduce more than once, so the number of mice should be even higher. However, if a pair of mice comes into your house in the fall, there will not be over a thousand mice in the house five generations later [at three generations per year means less than two years to accumulate 1,458 mice]. You should learn that Malthus wrote his essay before Darwin and before Charles Dickens. Malthus suggested that the growth of the human population, by 1859, was increasing at its potential rate, and that, if nothing was done to slow the growth, the human population would soon exceed the capacity of agriculture to feed them. Dickens, in his C*hristmas Carol*, refers to Malthus when he has Ebenezer Scrooge respond to the gentlemen collecting for the poor that if the poor would rather die than live in the poorhouses, then they should die and decrease the surplus population.

Darwin concluded that if natural populations do not increase although the population growth potential is so high, that there must be a "struggle for existence" among the offspring. If there is “natural selection,” comparable to “artificial selection,” then the

- the "best" animals will exhibit an increased birth rate, and
- the "worst" animals will exhibit an increased death rate,
- resulting in an adaptation to the local environment.

Darwin also was familiar with an obscure publication by Lyell, which later revised the entire field of Geology.

Lyell Principles of Geology (A.D. 1872)

Lyell's thesis was that geological processes are extremely slow, and therefore Earth must be very old. At the time, the religious community had determined the age of the Earth to be about 3,000 years, based on the Judeo-Christian biblical account of creation. Lyell argued that the Earth must be millions (or even billions) of years old.

The basis of the slow nature of geological processes has to due with the rate at which dust accumulates in an abandoned house. If you were to avoid dusting for twelve months, you could determine the rate of dust accumulation. By measuring the dust depth in an abandoned house, you could then calculate how long the house has been abandoned. By extension you could determine the age of archaeological deposits from their depth [hence our estimate of the date of the oldest known document describing agricultural breeding practices]. However, just as snow piled up by successive snow storms compresses the underlying snow (eventually to ice), dust accumulating over geological time compresses the underlying dust, eventually to rock. Again based on depth to a fossil, we can estimate the age of the fossil.

Darwin concluded from Lyell's argument that the time available for selection to occur could have produced the observed diversity of species. Therefore, it is completely reasonable (Darwin reasoned) that the evolution of species by natural selection is possible, and therefore likely.

Combining the reasoning of Malthus with that of Lyell, then, we have the "Theory" of Evolution. You need to know that this theory does not meet our earlier criteria to be a theory, because it makes no predictions of observable events to confirm the theory.

Works Cited

American Kennel Club. 2004. www.akc.org

Darwin, Charles. *The Origin of Species*. New York: New Library of World Literature, 1958.