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Catalog No. FB2203
Publication No. 11408

Natural Selection: Flinn Modeling, Inquiry and Analysis

Student Laboratory Kit

Introduction

Evolution by natural selection is the primary mechanism for adaptive evolution of organisms ranging from single-celled prokaryotes to multicellular organisms. Organisms that have traits that allow them to survive in their environment live longer and reproduce more often, passing those traits to their offspring.

Concepts

- Natural selection
- Artificial selection
- Fitness
- Antibiotic resistance

Overview

The purpose of this learning module is to facilitate understanding of natural selection, fitness and antibiotic resistance. First, use the Evolution and Selection POGIL™ activity to discover how natural selection works by examining models from the real world. Then participate in a game that models antibiotic resistance and the importance of taking antibiotics. This model demonstrates how changing the environment of the organism changes which individuals survive. Finally, use the engineering design cycle to engineer a fish for optimum speed.

Part 1. Establishing Background Knowledge

In groups, complete the Evolution and Selection POGIL™ activity.

Part 2. Antibiotic Resistance Demonstration

This simulation demonstrates how antibiotics impact the survival of various strands of bacteria when taken as directed or taken less frequently than directed. The antibiotic changes the environment of the bacteria and a classic struggle for existence ensues.

Materials

Bingo chips, red, 20
Bingo chips, blue, 15
Bingo chips, yellow, 15
Colored pencils
Die

Procedure

1. Obtain 20 red bingo chips, 15 blue bingo chips, 15 yellow bingo chips, and one die. Place 13 red, 6 blue, and 1 yellow bingo chip on the work surface in front of you and your partner. These chips represent harmful bacteria found in a patient's body before beginning antibiotic treatment. Set aside the remaining bingo chips.

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2. It is time to take the first dose of antibiotics. Roll the die and follow the key in the table below.

Number tossed	Event	Results
2, 3, 4 or 5	Antibiotic was taken at appropriate time—bacteria killed	Remove 5 disks in the following order: remove red bingo chips first, followed by blue and then yellow as needed.
1 or 6	Antibiotic was not taken at appropriate time.	Do not remove any bingo chips.

3. Record the number of each remaining type of bacteria in the data table on the *Natural Selection Worksheet.*
4. Bacteria are constantly reproducing in the host; in this case, the host is the patient's body. If one or more bacteria of a particular type (color) are still present in the patient's body after the first dose (step 2), add one chip of that color to the population. *Example:* If the patient still has blue and red bacteria present, add one blue and one red chip to the population.
5. Repeat steps 2–4 at least eight times (or until all bacteria have been eliminated) to complete the table on the worksheet.
6. Using the data from the table, construct a graph displaying the number of each type of bacteria versus the number of doses. Use different color pencils to plot the following data: total number of bacteria, least resistant bacteria, medium resistant bacteria, and most resistant bacteria. Connect each set of data points by drawing a colored line.
7. Complete the questions on the *Natural Selection Worksheet.*

Part 3. Engineering Design for Fitness

Fitness is the contribution an individual makes to the gene pool—all the alleles available in a population—compared to the contributions of others. In other words, an individual with high fitness is capable of surviving to reproductive maturity and producing many healthy, fertile offspring that in turn can survive to reproductive maturity. Most falsely assume that fittest means the largest, strongest or fiercest individual; however this is only the case when those traits help in survival and reproduction. A wild rose with an alluring, sweet fragrance attracts more pollinators than a wild rose with a less aromatic scent, thus the former has a higher level of fitness.

Fitness is achieved through adaptations. Adaptations are inherited characteristics that improve fitness. Through natural selection these adaptations improve an organism's ability to survive and reproduce in a particular environment.

Charles Darwin (1809–1882) first presented his idea of natural selection in 1859 when he published *On the Origins of Species*. Finches that Darwin observed on the Galapagos Islands were similar to a finch from the mainland in many ways, but ultimately belonged to different species. He noticed that the island finches differed from each other as well. He explained that an ancestral finch population migrated to the islands from the mainland and each new population accumulated adaptations suited to the different environments on each island. In the case of the finches, beak shapes adapted to accommodate the most available food source.

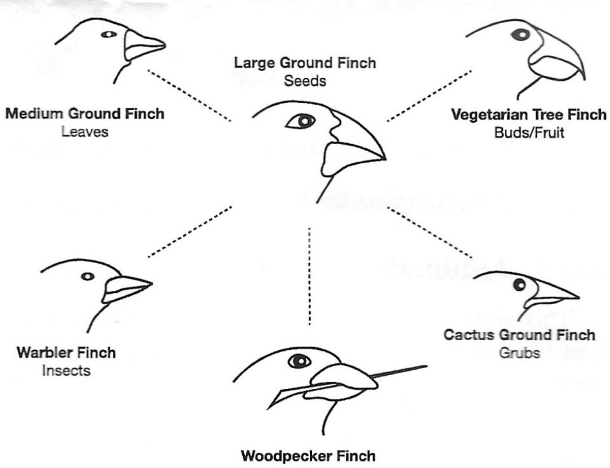

Figure 1.

Natural selection acts upon individual finches. Those with inherited characteristics well-suited to the environment had more offspring on average than other individuals. For example, the finches with thick, stout beaks survived at higher rates in environments with seeds as a food source. They produced offspring and passed those characteristics to their offspring. The offspring, in turn did the same, leading to survival of the fittest finch—the finch with the thickest, stoutest, seed-cracking beak. If this finch had migrated to an environment where insects were the primary food source, it would have had low fitness because its beak was not adapted to the new food source.

Just as the finches adapted—and continue to adapt—to food and diverse island life on the Galapagos Islands, fish also adapt to the environmental pressures of aquatic life. The body shape of a fish is related to the niche it fills. For example, fish with a streamlined body shape, like tuna, have adapted to life in the open ocean. They swim long distances in search of food and mates while avoiding predators. They move seamlessly through the water in opposition to friction and drag due to their narrow, forked tails and sleek body shape. Fish that rest on the ocean floor, like the sting ray, typically have flat bodies with eyes on top of their heads allowing them to hunt prey above them. They move by making wave-like motions with their bodies, and are usually camouflaged to blend in with the sandy ocean floor. There are as many fish as there are niches, and therefore many adaptations to exploit those niches.

The purpose of this investigation is to design and mold a clay model of the fish body shape you believe is capable of the fastest speed across an aquarium. Speed is calculated by dividing distance by time. The fish model must have all the given design criteria and deflect no more than 5 degrees from its vertical support as it moves across the aquarium.

Pre-Lab Questions

1. Explain how natural selection leads to changes within a species.
2. Calculate the average speed of a cheetah that chased an impala a total of 260 meters in 9 seconds before it made the kill.
3. Predict the body shape that would allow for the fastest fish, which, in this investigation, indicates the highest level of fitness. Explain your prediction.

Materials

- Aquarium/Clear tote
- Clay, 15 g
- Fishing line
- Meter stick
- Paper clip
- Protractor
- Stopwatch or timer

Procedure

Part A. Fish Model

1. Using one piece of clay, shape and mold a fish body that will move efficiently through the water.
2. Fish requirements:
   a. All 15 grams of clay must be used in the design.
   b. Fish must have a minimum of one dorsal fin (see table below and Figure 2).
   c. Fish must have two pectoral fins.
   d. Anal fins and pelvic fins are optional.
   e. Caudal fin must be vertical, not horizontal.

Fin	Function
Dorsal	Provides stability in swimming, prevents rolling and assists in sudden turns or stops
Caudal	Propulsion, move body forward
Pectoral (paired)	Locomotion and side to side movement
Pelvic/Ventral (paired)	Assist in up/down movement through water, sharp turning and quick stopping
Anal	Provides stability in swimming

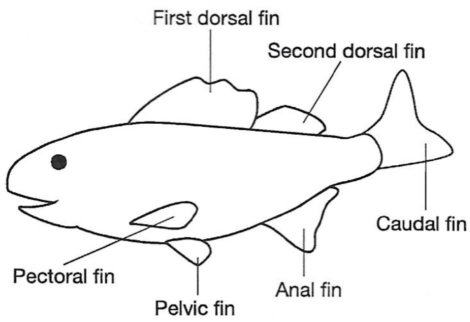

Figure 2.

3. Draw the fish design in Part 3 of the *Natural Selection Worksheet*.

Part B. Fish Attachment

1. Affix a small paper clip through the hole on the straight edge of the protractor as shown in Figure 3. This creates an easy attachment and removal system for the fishing line in order to make adjustments to the design. Tie a knot in the fishing line to create a loop and attach to the paper clip.
2. Thread the fishing line through the body of the model fish. Adjust the fishing line so that the fish hangs down 90° from the top of the protractor. Adjust the fishing line on the fish so that the fish hangs parallel (horizontal) to the ground as well.
3. Adjust the length of the fishing line to the predetermined length set by the instructor.

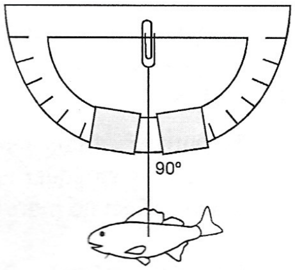

Figure 3.

Part C. Testing Fish Models

1. Position the fish in the water so the "head" is at the start mark on the meter stick (see Figure 4).
2. Hold the protractor so the straight edge is at the top. *Note:* The fishing line should be taut and hang straight down, crossing the 90° mark on the protractor.
3. Practice moving the fish through the water at a constant rate so the deflection remains steady.
4. Use the meter stick as a guide to keep the protractor level as the fish is pulled through the water. The fishing line will not hang straight down due to the resistance of the water, causing the fish to lag behind. The faster the fish is pulled, the more the fishing line will deflect. To keep competition fair, adjust the movement to keep the fishing line deflected by 5° or less as marked on the protractor. As the fish is pulled through the water, the deflection mark cannot be passed by the fishing line. If it is, discard that run.
5. After a practice run, return the fish to the start mark of the meter stick.
6. One partner sets the stopwatch.
7. Determine a "go" signal and move the fish from the start mark to the finish mark.
8. Time from the "go" signal until the head of the fish, not the fishing line, reaches the finish mark.
9. Repeat steps 6–8 for three trials.
10. Record the time for each trial on the *Natural Selection Worksheet*.

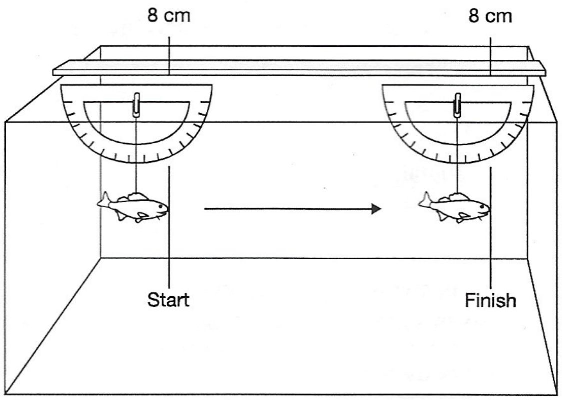

Figure 4.

Part D. Improved Fish Design

1. After completing the trials with the original fish, calculating the speed and recording observations, make improvements to the original fish design to increase speed/fitness.
2. Follow the same requirements for clay usage, required fins and fishing line length.
3. Practice moving the improved fish design through the water at a constant rate of deflection.
4. Record data on the *Natural Selection Worksheet* for three trials with the improved fish design.