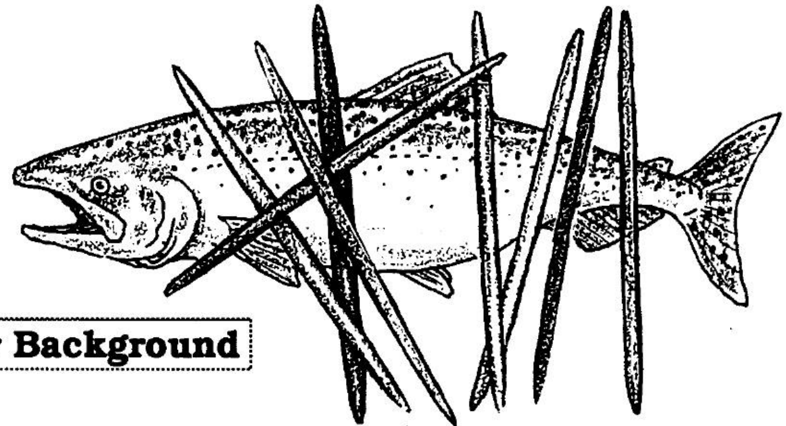


Teacher Background

Toothpick Fish

Early in this century, naturally spawning populations of salmon were severely threatened by a combination of over-fishing, damaging forestry practices, and the construction of hydroelectric dams over many northwest rivers. Salmon is plentiful today only because of successes in the technology of salmon hatcheries. Hatcheries are now widely used as a substitute for maintaining the natural environment which salmon need for spawning. Although hatcheries have probably rescued Pacific salmon as an economically viable resource, this trade-off of naturally spawning salmon for hatchery reared salmon may have had a price in the very nature of the fish themselves.

Among experienced sports fishermen, the differences between wild salmon and hatchery-reared salmon are legendary. They will tell you that wild salmon are the most spirited fighters at the end of a hook and line. Wild salmon are also touted by many for superior eating quality. Whether these stories are true or not, hatchery salmon have by the very nature of domestic rearing practices undergone genetic changes from their wild relatives.

The series of lessons which follow will help you explore with your students how this has come about. They have been adapted from an excellent activity on genetics developed by Melinda Mueller and Barbara Williams for the Pacific Science Center.

First you will need to give your students an introduction to some basic genetics concepts. Although you may want to look into this topic more deeply, here are some key ideas to start you off:

1. Most of our physical characteristics, such as the color of our eyes, are determined by the genetic material which make up our chromosomes. Chromosomes are long molecules of DNA carried in the nucleus of each of our body cells. These long molecules act as recipes for building all the chemicals in our bodies. Small sections of a chromosome contain information which determine individual characteristics. These sites along a chromosome which correspond to traits (such as eye color) are called genes.

2. Humans have 23 pairs of chromosomes in each cell. (Other animals have a different number, but the number is constant for each species.) Of each pair of chromosomes, one came from our mother and one from our father, and because they code for the same characteristics, they contain duplicate information. In other words we have two copies of each gene. But very often those genes are not identical. There may be many different versions (or alleles) of a gene, and we are very likely to have received different alleles from our different parents.

3. When the two alleles for a characteristic differ (if we carry one allele for blue eyes, say, and the other for brown eyes) one of those alleles will often be dominant over the other. The allele for brown eyes is dominant over the allele for blue, meaning that when a person has both the blue-eye allele and the brown-eye allele, only the brown-eye allele will be expressed. The person carrying those alleles will actually have brown eyes, yet he is still capable of passing either allele to his child. This is why some brown-eyed parents have blue-eyed offspring.

Vocabulary:

chromosome -strands of genetic material found in the nucleus of all cells, always found in pairs (except in germ cells or when cells are dividing).

gene -a section along a chromosome which controls one biological trait of an organism.

allele -the individual members of a pair of genes.

dominant -an allele is dominant when it is expressed in an organism's appearance and prevents the expression of the other allele in the pair.

recessive -an allele is recessive when it is not expressed in the organism's appearance because of the presence of a dominant allele.

germ cells -the reproductive cells (the egg and sperm in humans) from the parents which fuse to produce an offspring. Germ cells normally have just one set of chromosomes.

gene pool -all the genes in an interbreeding population

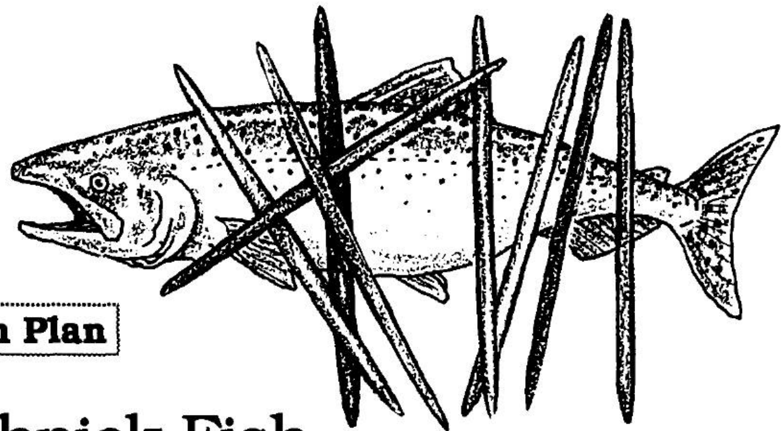
genotype -the actual genetic characteristics of an individual

phenotype -the visible or apparent characteristics of an individual

The lesson plans which follow are designed to introduce these concepts to your students in a stepwise fashion. Your students will work in pairs in a series of activities which use colored toothpicks to represent the genes for color in fish.

The students will generally be recording data on the visible characteristics (phenotype) of their fish. They will also be able to observe something that in nature we can't observe, which is the actual genetic composition (genotype) of an individual. It will be very valuable to the students to discuss both kinds of information.

The students must understand gene dominance before continuing on to more sophisticated concepts, so you will need to adjust the pace of the lessons according to your students' comprehension. Do not be afraid to spend several days on these activities.



Lesson Plan

Toothpick Fish

Student Objectives:

Students will discover some principles of basic genetics in order to learn how the rearing of salmon in fish hatcheries can change the genetic characteristics of a population of salmon. More specifically, students will:

- Record observations on the behavior of recessive and dominant genes.
- Predict and then test the impact of environmental changes on the genetic characteristics of a population.
- Explain the advantages of a large and diverse gene pool for any population.
- Apply these concepts to understanding possible consequences of rearing of salmon in hatcheries.

Materials:

- 15 boxes of colored toothpicks, each box containing 25 of each of the following colors: red, blue, green, white, and black. (Red, blue, and green toothpicks can be prepared by soaking plain toothpicks in food coloring and drying them in a warm oven. The black toothpicks can be make by "coloring" them in advance with a permanent marking pen. White toothpicks are simply the natural toothpick color.)
- 15 small paper cups
- One copy per student, TOOTHPICK FISH
- Graphics:
  - GENES AND CHROMOSOMES
  - FISH LIFE CYCLE
  - SAMPLE STUDENT DATA SHEETS

Procedure:

Because this activity is rather long, it is broken into a number of smaller lesson units.

PART I. Looking at Genes

1. Ask the students to tell you what a domesticated animal is. Have them give you some examples: cow, horse, dog, cat, etc. Ask them to try to picture if they can the non-domesticated ancestors of these animals. Explain that most domesticated animals have been changed considerably from their wild ancestors by thousands of years of controlled breeding, or artificial selection. Tell them that the activity they

are about to begin will help them decide whether hatchery rearing of salmon could be causing this species to change.

2. Tell your students that they must begin by taking a look inside their own cells to understand how genes influence our characteristics. Place the transparency, GENES AND CHROMOSOMES on the overhead. Explain that inside the nucleus of our cells are chromosomes, arranged in pairs. Along each chromosome are bands of genetic material called genes, which contain the blueprint for individual characteristics, such as eye color, curly or straight hair, left or right handedness, etc.

Call attention to the fact that the chromosomes are in pairs. We, as offspring, inherit one of the chromosomes from each of our parents. Each member of a chromosome pair has the same sequence of genes. Therefore, we have two copies of every gene, one from our mother and one from our father.

What happens when we receive very different genetic information from each of our parents? What if the gene from one parent codes for blue eyes and the gene from the other parent for brown eyes? When this happens, very often one is dominant over the other. Explain that an individual with genes for both brown and blue eyes will look brown-eyed, but he or she can still pass either the blue-eye or brown-eye gene to an offspring.

3. Now consider fish once more. Use the FISH LIFE CYCLE DIAGRAM as a transparency to illustrate how the baby fish is formed by the union of one egg and one sperm cell, each containing just one copy of every gene. After the germ cells unite, the young fish will have two copies, one from each parent.

PART II. Dominant Genes and Recessive Genes

1. Tell the students that they are now going to be using colored toothpicks to represent genes for skin color in fish. Show them a green and a blue toothpicks, while explaining that a green toothpick will stand for a gene for green color, and a blue toothpick is the gene for blue color.

When salmon spawn they release both eggs and sperm into the stream, and when an egg unites with a sperm a baby fish will begin developing. We will use a paper cup to represent the stream, and all the toothpicks in the cup will represent the gene pool, or all the available genes present in the eggs and sperm of the spawning fish.

(Put 4-5 green toothpicks and 4-5 blue toothpicks into a paper cup and shake them gently.)

2. After the eggs are fertilized, how many genes for color will each fish have?

(They'll have two.)

Show the students how to draw pairs of toothpicks out of the cup to represent the pairs of genes inherited by each offspring.

(You or a student can close your eyes and draw out a pair of toothpicks.)

The toothpicks will either both be green, both be blue, or one of each. Explain that green color is dominant over blue color for our population of fish, so a green/blue combination will result in a green fish.

2. After the last activity your students will need to establish a new gene pool from their toothpick boxes. Have each team begin again with four genes of each color, green, blue, black, red, and white. They will use Data Sheet #4 for this investigation.

3. Your students will now consider the impacts of seven additional scenarios on their fish populations. SCENARIOS C through I are included in their student texts. You can ask for their ideas to generate other scenarios if they show the interest. As before, make sure your students are making predictions before they actually perform the action on their population, and have them keep careful records on their data sheets.

4. Discuss the effect of each situation on the students' fish populations.

5. Brainstorm with the students other situations which might befall their fish populations, help them decide on the effect each will have on particular groups of fish, and have the students continue to test out the effect of these events on their populations.

PART VI. Hatchery Salmon

1. Now give your students a final scenario:

Scenario J.

A dam is being erected on the river where their salmon spawn, and they will need to start fish hatcheries to compensate for the loss of their wild populations.

Rule: Each team will draw just two salmon (four toothpicks) to be their brood stock. Regardless which four toothpicks are drawn, these will be copied 4 times to give a total of 20 toothpicks in the next generation. All remaining salmon in the previous population will be discarded, since the dam will prevent the rest of the fish from spawning.

2. Again, have the students predict what impact this will have on their fish. Then continue with the steps described above. From the hatchery population, draw the next generation, and record the results.
Have the students describe what has happened to their fish populations. They are probably now much more uniform. Each hatchery will only have a few colors of fish present, and there should be fewer types of genes in their gene pools.

Ask the students which genes are no longer present in their fish populations.

What special abilities have their populations lost?

What situations that they explored earlier could their fish no longer survive? You could have them repeat some of these situations to make the point clear.

Ask the students to consider the possible consequences of eliminating all wild salmon stocks and relying strictly on hatchery rearing. Many responses are possible: The loss of a great many genes, greater susceptibility to disease, and populations which are less able to respond to a variety of environmental pressures.

3. You may want to share with your students that each Northwest river is a unique environment with very different obstacles and opportunities for salmon. The salmon which used them were once delicately adapted to the very specific conditions of the stream. But many of the original salmon runs have now been eliminated or threatened by dams and environmental damage, so when salmon is reintroduced, it usually not with the native strain. This further reduces the variety of our Northwest wild salmon stocks.

You and your students should know that in spite of past mistakes, fisheries managers now work hard to avoid unnecessary loss of genetic variability in salmon stocks.

Part VII. Wild Salmon/Hatchery Salmon

1. Explain the following real situation to your students.

On many of our rivers, environmental problems have prevented many salmon from spawning naturally. Hatcheries have been built throughout Puget Sound to keep large numbers of salmon returning to the area. But once they are released from the hatchery, these fish compete for food with wild fish. In rivers, and even in places like Hood Canal, there is not always enough food for young wild salmon and hatchery salmon both.

On top of that, fishermen catch both hatchery and wild salmon in the same net. But to spawn in the wild, more salmon must be allowed to escape than are needed when they are reared in a hatchery. It takes only a few returning salmon to provide all the eggs a hatchery needs. But in the wild, fewer young will survive their natural enemies, so many more to adults must be allowed to spawn.

Here is the very real problem fisheries biologists face: If fishermen catch all the hatchery fish which they may safely take, they may be taking too many of the returning wild salmon. This is not an easy problem to solve.

2. Give your students the following questions to consider either as a discussion topic or a writing assignment.

- If you were a fisheries biologist and had to make a choice between protecting the wild salmon or releasing large numbers of hatchery salmon, which would you choose?

- Can you think of any possible ways to prevent hatchery salmon from competing with wild salmon?

- Are there any possible ways to have people that are fishing catch fewer wild salmon than hatchery salmon?

3. After students have been given an opportunity to consider these questions, you can discuss the practices currently in use to try to manage hatchery and wild stocks somewhat independently.

In each region of Puget Sound, the salmon species are evaluated to determine which is producing more fish, the wild or hatchery runs. The fishery for that species is then managed for the stronger of the two runs. In Hood Canal, hatchery runs of chinook and chum are favored over wild runs, but coho and pink are managed for wild salmon. (Sockeye have negligible runs in Hood Canal.) Ask your students to consider whether this is a good system or not.

Hatcheries can also control the time of their salmons' return to some extent, and the fishing openings (times and places where fishing is allowed) can also be controlled. If a hatchery run can be made to fall at a different time than the wild run, fishing openings can be timed with the hatchery salmons' return, but closed when the wild salmon are running.

Your students may be interested to know that chinook and coho in Puget Sound as a whole are now 60% hatchery reared, but chum and pink are still predominately wild.

Answer Key:

Part I. Looking at Genes (answer key)

1. chromosomes
2. the mother and the father
3. One gene is usually "dominant," that is, it is expressed in the physical characteristics of the individual. The unexpressed gene is called "recessive."

Part II. Dominant Genes and Recessive Genes (answer key)

1. A population is a group of related individuals. You may want to add that a population implies a group of organisms that interbreed and share a common "gene pool."
2. Two toothpicks are needed to represent both the gene from the father and the gene from the mother.
3. Green
4. Green. Green is dominant over blue, so every time a green toothpick is present, the fish will be green, even if a blue toothpick is also present.

Part III. Fish of Many Colors (answer key)

1. Green will probably be most common.
2. Theoretically white should be least common, although there may be some variation in this answer among students.
3. Again, green expresses itself whenever it is present, so fish are more likely to be green than any other color. White is least likely to be expressed because the gene for white is recessive to all other color genes.

Part IV. Natural Selection (answer key)

1. Answers will vary.
2. Answers will vary.
3. There should be few, if any white fish by the third generation.
4. There will probably be fewer white toothpicks, but they are probably still present in most of the students' populations.
5. Answers may vary, but most students will probably predict a major loss of green fish.

6. Students will probably report a drastic reduction in numbers of fish. No green fish should remain.
7. Answers will vary.
8. Yes. Green.
9. Yes. It should be very much smaller.
10. When a harmful trait is dominant, all genes for the trait are eliminated immediately. When a harmful trait is recessive, genes for the trait are lost very gradually. Therefore, the second scenario should have much more drastic consequences than the first.)

Part V. Genetic Diversity (answer key)

1. Red toothpicks should increase dramatically. Red fish may also show an increase.
2. White toothpicks may increase and black toothpicks may decrease for most student teams. Not all teams will draw toothpick configurations which allow this scenario to have an effect.
3. Green fish should increase as long as green toothpicks are still present in the parent generation.
4. Population size may drop sharply if few black toothpicks are present in the parent generation.
5. Answers may vary.
6. Genetic diversity gives a population of organisms the ability to adapt to environmental changes. When a variety of genes are present in a gene pool, there are more chances that some individuals will have the combination of traits needed to survive an environmental crisis like the ones explored in this lesson.

3. Ask students to read Part I, "Looking at Genes" and Part II, "Dominant Genes and Recessive Genes" in their student text, while you distribute to each pair of students:
   - 1 paper cup
   - 1 box of colored toothpicks

4. The students are to place 4 green toothpicks and 4 blue toothpicks in their cup. They are to leave the rest in the box and put it aside for now. They should shake the toothpicks gently in the cup, and without looking, draw out four pairs of toothpicks (representing four fish), and lay the pairs on the table in front of them. Have the students decide what color each fish will be. Most of the fish should be green, since the both the green/green combination and the green/blue combination produce a green fish. Have the students record the observed color or phenotype of their fish on DATA SHEET #1.

5. Check carefully that all groups are identifying the colors of their fish correctly. You can do this by circulating around the room, or by calling for each group's results at the board. You may find it useful to use portions of the graphic, SAMPLE STUDENT DATA SHEETS as a transparency to aid in compiling student data and discussing class results. When you are satisfied that your students are able to work comfortably with two genes, go on to the next section.

PART III. Fish of Many Colors

1. Have your students turn to Part III, "Fish of Many Colors." They should now add the following toothpicks to their cup from their toothpick box:
   - 4 black toothpicks
   - 4 red toothpicks
   - 4 white toothpicks

   Like the blue and green toothpicks, these genes will also express themselves as dominant or recessive to one another. In the following sequence, each color is dominant to all colors on the right, and recessive to colors on the left:

   Green Blue Black Red White

   That is, green is dominant over all other colors. Blue is dominant over black, red, and white. Black is dominant over red and white, but recessive to green and blue, etc.

   Now have them mix up the genes and randomly draw out 10 pairs of toothpicks, laying them on the table in front of them. They can now record this information on their data sheets entering it as the first generation. (See example below.)

Sample Student Data Sheet:

Generation	Green	Blue	Black	Red	White
1	6	2	1	1	0

2. Write the results of 5-7 pairs of students' results on the overhead data sheet.

Ask why they think there are more fish of some colors than others. (Accept all reasonable observations, but lead the students to understand that there are more green fish because green is dominant and therefore is expressed more often.)

PART IV. Natural Selection

1. Ask the students what happens when a fish dies before it has a chance to reproduce. What becomes of its genes? What effect does this event have on the gene pool of future generations?

(The genes are lost. Unless other fish with those genes survive, they cannot be passed to future generations.)

Explain that one of the main factors determining which fish live or die is the fish's environment itself.

2. To see how environment can affect survival, the students will consider how their fish populations might be affected under two very different scenarios.

Scenario A

The fish are living in a dark river with lots of green plants. The white fish will be very visible. Predators will probably be able to spot them and eat them before they have a chance to reproduce.

All white fish (the white/white combination) will be discarded in the new generations. These toothpicks are put back in the box and not used again.

Before allowing the students to actually draw out any new generations, have them first predict how this scenario will affect their fish populations. They will record predictions on Data Sheet #2, in the student section.

Now have the students draw out two generations in succession, each time discarding any white fish which appear. They will record the results on Data Sheet #3.

Again select 5-7 groups of students and write their totals in the overhead data sheet. Discuss what has happened to the white fish.

- Have they all disappeared? *(Yes)*
- Are there any white genes left? *(There should be.)*

Scenario B

Factory waste has been dumped into the stream. It does not kill the fish, but it does kill the green plants. The remaining background is of multicolored rocks, against which the blue, red, black, and white fish are well camouflaged, but the green are conspicuous. With this change of environment, the green fish are now eaten before they can reproduce.

Have the students return their genes to the gene pool (cup). In this next generation they are going to discard all green fish. Again have the students first predict the outcome, then draw out the new generation and dispose of all green fish.

Sample Overhead Data Sheet:

Generation	Green	Blue	Black	Red	White
1	146	91	58	26	13

Again use the results of 5-6 groups of students on the overhead data sheet. Compare what has happened to this generation with the previous ones. Discuss these questions:

- What change did you see in your fish population after this event? *(Since most fish were green before, a great many fish have been eliminated. Now there are no green fish -- or even green genes.)*
- Have any genes disappeared entirely? *(Yes -- green)*
- Has the population size changed? *(Yes -- drastically)*
- How does this result compare with the generations in which white fish were discarded? *(Accept all reasonable observations.)*
- Which disappeared faster when the environment was hostile to them, the dominant green genes or the recessive white genes? *(The green. This demonstrates that harmful dominant genes are rapidly eliminated from a population, but harmful recessive genes are retained at low levels.)*

PART V. Genetic Diversity

1. Now a new rule will be added. Occasionally a gene may affect more than one characteristic. (The gene for sickle cell anemia is such a situation. When the gene for sickle cell is inherited from one parent, a person has resistance to malaria. When a person inherits the gene from both parents, his or her body will produce mis-shapen and poorly functioning red blood cells, causing sickle cell anemia.)

   Let's assume that some of the genes for color will confer secial characteristics to our fish population. In each case, only one gene needs to be present in a fish for it to have a special attribute, and the fish does not need to have the color of that gene expressed.

   a. Black gene -- can wait to spawn. (A fish with at least one black gene is flexible about when it spawns. If conditions aren't good, it will wait until they are.)

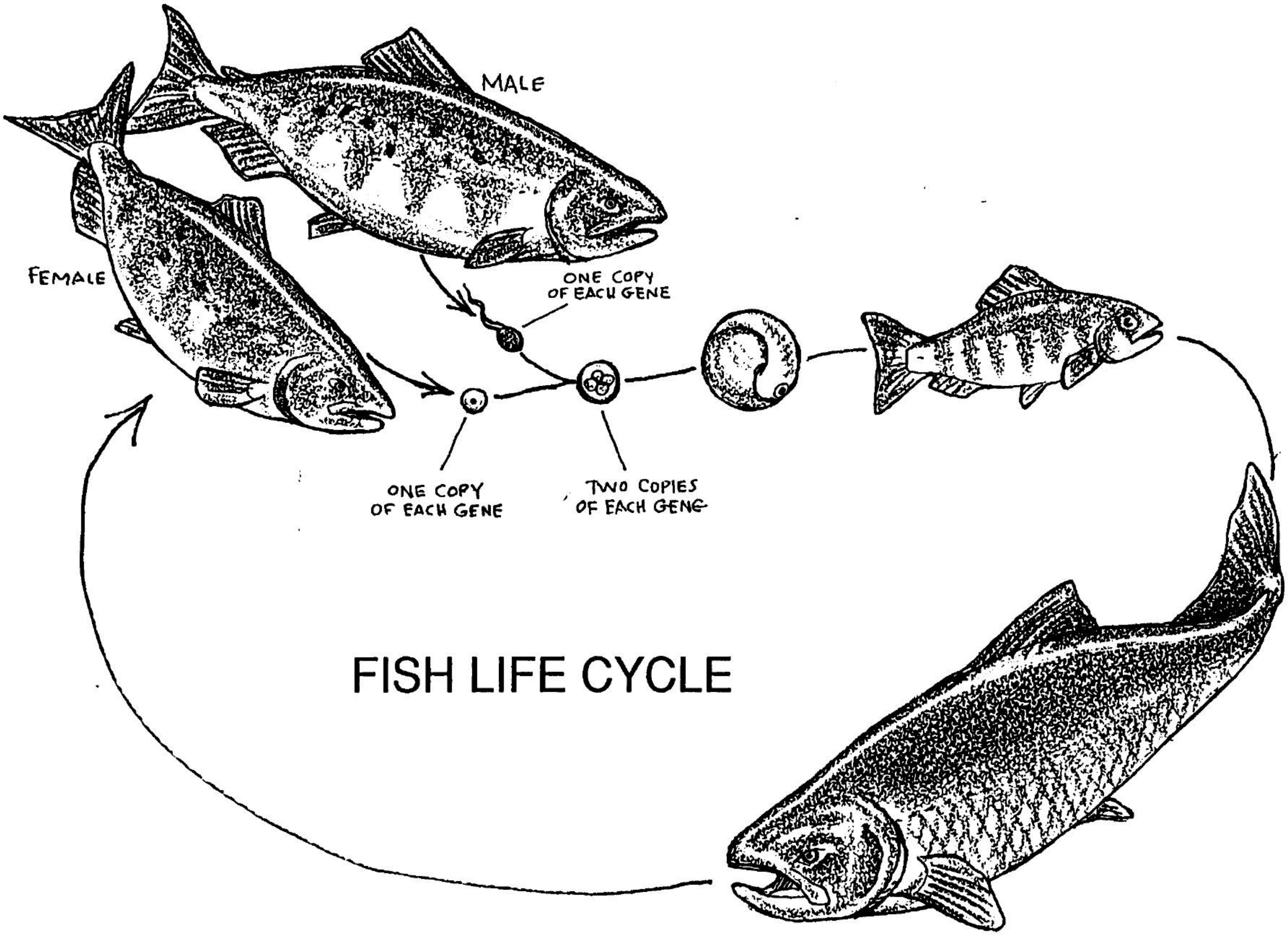
   b. Red gene -- strong swimmer, powerful jumper. (A fish with even one gene for red color will be an extremely strong swimmer and powerful jumper.)

   c. White gene -- resistant to disease. (A gene for white color gives the fish resistance to certainly deadly fish diseases.)

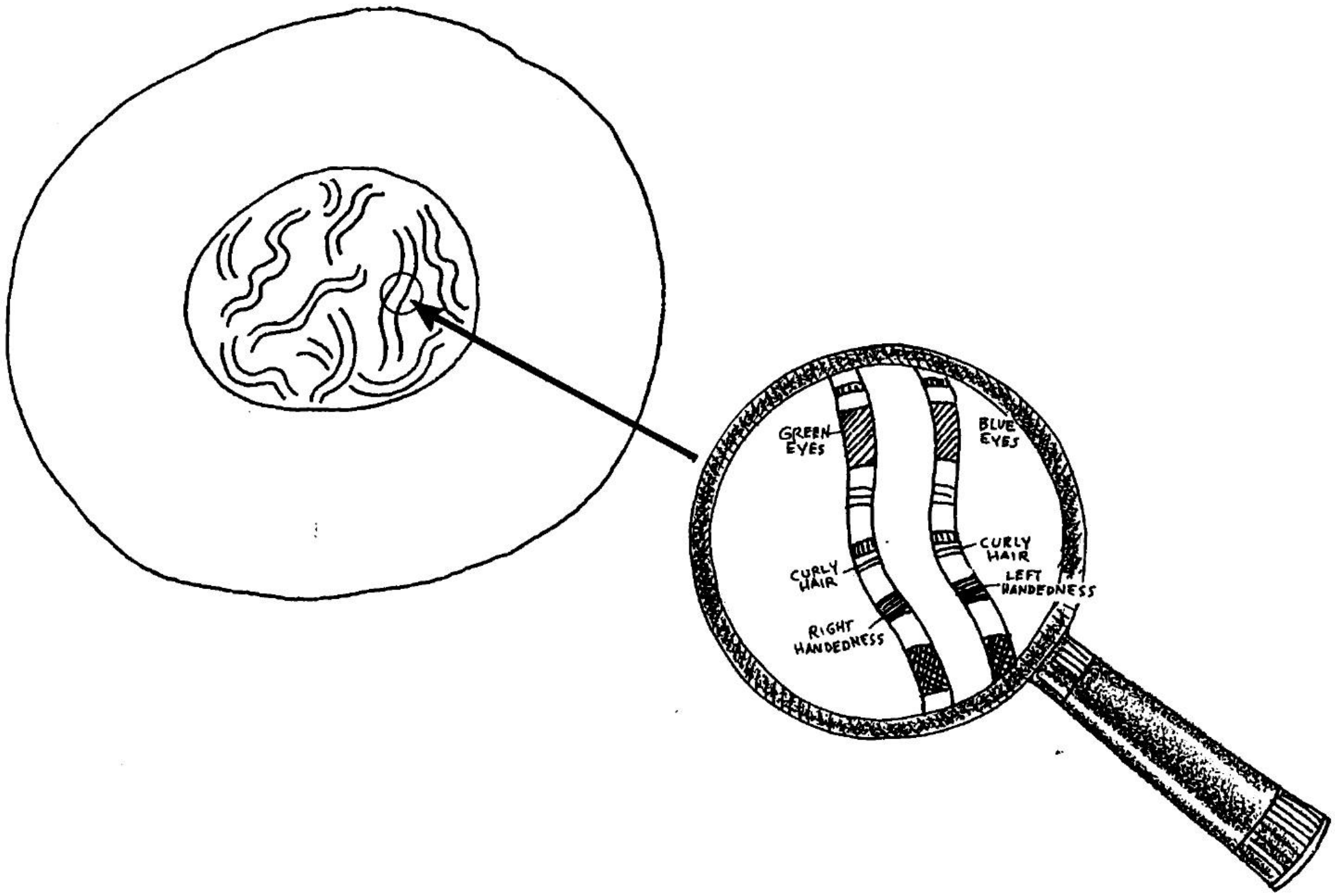
SAMPLE STUDENT DATA SHEETS

Data Sheet #1		
Generation	**Green**	**Blue**
1		
2		
3		

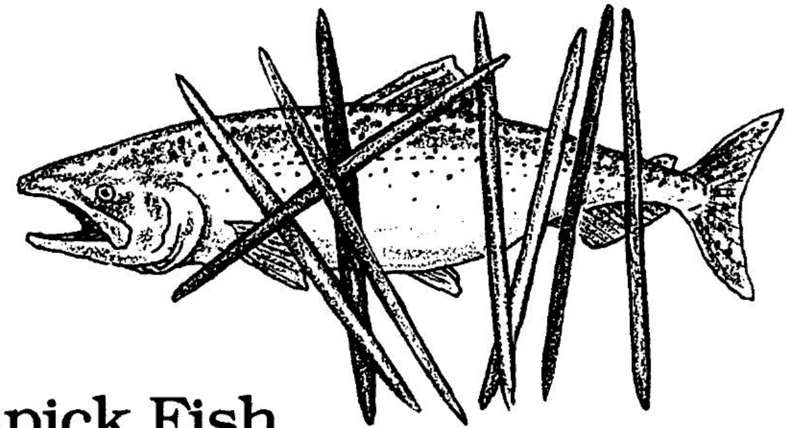
Data Sheet #2 or Scenarios					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					
3					



FISH LIFE CYCLE



GENES AND CHROMOSOMES



Toothpick Fish

Part I. Looking at Genes

By now you probably know that whether you're a fish or a human, you inherit many of your characteristics from your parents. The information your parents passed to you is contained in your DNA. DNA are long, complex molecules inside each of your cells. Like a roadmap, DNA guides your cells in making every part of you.

Small sections of DNA give directions for making certain details of your body. We commonly call a section a "gene." The entire DNA molecule is called a "chromosome."

We have two copies of each chromosome roadmap, one from Mom and one from Dad. For each of your characteristics, your body usually chooses to read only one of the roadmaps. The one your body chooses to read is called "dominant." The one your body is not using is called "recessive."

Now let's check your understanding of heredity.

1. What is the name of the long, paired molecules of DNA found in each of your body cells, which give your body all the information it needs to make you?

2. Fish (and humans) have two copies of each gene, one from _______________ and the other from _______________.

3. When the two copies of a gene are different, what usually happens? (What happens, for example, if you have one gene for blue eyes and one for brown eyes?)

Part II. Dominant Genes and Recessive Genes

Now that you understand how an individual inherits characteristics, we will begin exploring how genetics works in group of related individuals, or a population. We will use a population of fish in a stream for our experiments. But instead of using live fish, we will use toothpicks to represent the genes for just one characteristic of fish, color. Since each fish has two genes for color, two toothpicks will represent one fish.

1. What is a "population"?

You will begin with a small population of fish that can have genes for green color, or genes for blue color, or both. In our experiment, green color will be dominant over blue color. This means that a fish with one gene for green color and one for blue color will always be green.

Place four green and four blue toothpicks in the cup. (Leave all other toothpicks in the box for now.) These green toothpicks represent the eggs and the milt of your fish population in the stream.

Without looking, draw two toothpicks at a time out of the cup and lay them in pairs on the table. Each pair of toothpicks represents the genes for color in one fish.

2. Why do we need two toothpicks to represent one fish?

3. If green is dominant over blue, what color is a fish represented by a green and blue toothpick combination?

Record the numbers of green and blue fish in your new generation on the Data Sheet #1, next to "Generation 1."

When you have recorded Generation 1, return the toothpicks to the cup and draw out Generation 2. Record your results for generation 2. Repeat the procedure for Generation 3.

Data Sheet #1		
Generation	**Green**	**Blue**
1		
2		
3		

4. What color fish occurred most often? Why?

Part III. Many Colors

Now you will expand your population to include individuals with genes for three more colors. From your box, add four black, four red, and four white toothpicks to the "gene pool" in your cup.

Each of the colors is dominant over colors to the right, and recessive to colors to the left:

Green Blue Black Red White

Mix the toothpicks well and then draw out the 10 pairs of toothpicks which represent the first generation in this population. On the data sheet below, record the actual color of each individual. Repeat this process twice more.

Data Sheet #2					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					
3					

1. Which color is most common in your population?

2. What color or colors are least common?

3. Explain why this is happening.

Part IV. Natural Selection

If a fish dies before it can spawn, its genes are lost. They are not passed on to the next generation. On the other hand, a fish which produces more offspring than other fish will leave more copies of its genes in later generations.

The environment of the fish may help decide which fish will die before spawning and which will survive. Here is an example:

Scenario A: A Green River

The fish are living in a dark river with lots of green plants. The white fish will be very visible. They are very likely to be eaten before they have a chance to reproduce.

Use your toothpicks to recreate this situation in the following way:

In the next generations, if any white fish are produced, you will take them out of the population and return these toothpicks to the box.

Before creating a new generation, first make some predictions.

1. What effect will removing white fish have on fish colors within your population?

2. What effect do you predict this will have on the total number of white genes (white toothpicks) in your population?

Now draw a new generation. Record the color of each offspring on the Data Sheet below. Then eliminate any white fish produced, and draw out a second generation. Again record the color of offspring. If any white fish are produced in this generation, again destroy them. Finally draw a third generation and record results.

Scenario A: A Green River					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					
3					

3. What change if any did you observe in fish color?

4. How was the number of white toothpicks in your population affected?

Scenario B: A Grey River

Factory waste has been dumped into the stream. It does not kill the fish, but it does kill the green plants. The rocky background is good camouflage for the blue, red, black and white fish. But now the green fish are conspicuous. They will be eaten before they can reproduce.

To simulate this situation, each green fish appearing in new generations will be removed. Toothpicks representing green fish are returned to the box.

5. Predict the change you expect to see in your fish after a few generations in this new environment.

Return your toothpicks to the cup and draw a new generation.

Record the color of first generation offspring on the data sheet below.

Scenario B: A Grey River					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					

Discard all green fish produced and draw a second generation.

Again record data.

6. What change did you see in your fish population after this event?

7. How did your results compare with your prediction?

8. Have any genes disappeared entirely? Which ones?

9. Has the population size changed? How?

10. How do these results compare with the earlier situation in which white fish were discarded?

Part V. Genetic Diversity

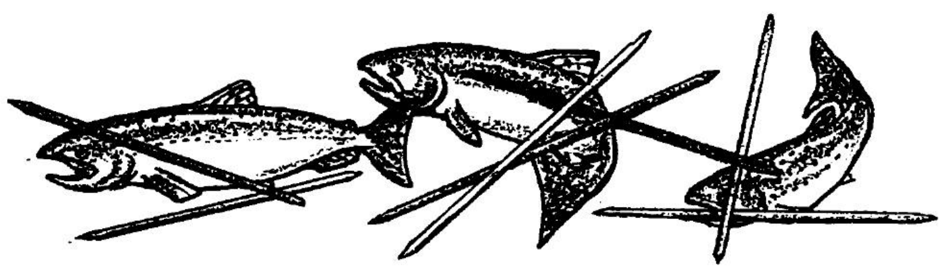
Your fish population was dealt a major blow by that last event! Fortunately a new, well balanced school of fish is soon to move into your stream, and you will be able to begin the next activity with a fresh population. Replace any toothpicks left in your cup with twenty new toothpicks, four of each color.

This population has a new feature. Some of the genes for color, even when the fish carrying them are not actually that color, give the fish some very special abilities. For example:

a. Black gene -- can wait to spawn. (A fish with at least one black gene is flexible about when it spawns. If conditions aren't good, it will wait until they are.)

b. Red gene -- strong swimmer, powerful jumper. (A fish with even one gene for red color will be an extremely strong swimmer and powerful jumper.)

c. White gene -- resistant to disease. (A gene for white color gives the fish resistance to certainly deadly fish diseases.)



Now let's test your population against some unusual and possibly dangerous situations. Can the fish survive? Let's find out!

For each of the following senerios, record the following information on the DATA SHEET below it:

1. What you think will happen before you draw any generations.
2. The colors of each offspring for three generations.
3. A description of what actually happened to your population in this scenario.
4. In addition, answer any questions that you see.

Scenario C: Windfalls on the River

A storm has knocked down many trees, some of which lie across the river. Fish with a red gene are the only fish able to jump over the trees and spawn upstream of the windfalls. Fish with a red gene now have an advantage over fish without a red gene.

My Prediction:

Scenario C: Windfalls on the River					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					
3					

What is happening to population?

Rule: Discard all fish which don't carry a red gene. Double both genes of each fish which does carry a red gene.

1. What has happened to the number of red toothpicks?

Scenario D: Volcano

Mount St. Helens has just erupted, filling the streams with white ash. Any white fish will have a strong advantage, and black fish will be very conspicuous.

My Prediction:

Scenario D: Volcano					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					
3					

What is happening to population?

Rule: For each white fish in the new generation, add two new white toothpicks. Discard any black fish created in that generation.

2. What has happened to white and black genes in your population?

Scenario E: A Green River Again

Fortunately, your fish are now having a normal year. Green fish have the advantage once again in the well-shaded streams.

My prediction:

Scenario E: A Green River Again					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					
3					

What is happening to population?

Rule: Discard any white fish and replace with green toothpicks.

3. How has this affected the number of green fish?

Scenario F: Low Water

A drought has reduced the flow in all the rivers and the fall rains are especially late. The fish can't reach the tributaries where they usually spawn because of low water. This year only fish with a black gene will be successful in spawning because none of the others can delay spawning until the rains finally come.

My prediction:

Scenario F: Low Water					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					
3					

What is happening to population?

Rule: Discard all fish without a black gene and double the toothpicks of each fish which carries the black gene.

4. What has happened to the number of fish in your population?

5. Have any colors been eliminated? If so, which ones?

Scenario G: Deadly Illness

This season an outbreak of a deadly bacterial infection threatens the population. Only fish with the white gene are safe.

My Prediction:

Scenario G: Deadly Illness					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					
3					

What is happening to population?

Rule: Discard all fish which don't carry a white gene. Double the toothpicks of all fish which do carry the white gene.

Scenario H: A Green River Again

Once again, a normal year, with green fish favored and white fish easily caught.

My Prediction:

Scenario H: A Green River Again					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					
3					

What is happening to population?

Rule: Remove any white fish, replacing their toothpicks with green.

Scenario I:________________________

Create a circumstance of your own. Decide how it will affect portions of your fish population. Predict the effect this will have on your fish population as a whole, then test out your predictions.

Describe your scenario:

My Prediction:

Scenario I: ____________________					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					
3					

What is happening to population?

When your population has many different genes present (all five colors of toothpicks, for example) your population has "genetic diversity.

6. How does genetic diversity help a population of animals or plants survive in a changing environment?

Scenario J: Hatchery					
Generation	**Green**	**Blue**	**Black**	**Red**	**White**
1					
2					
3