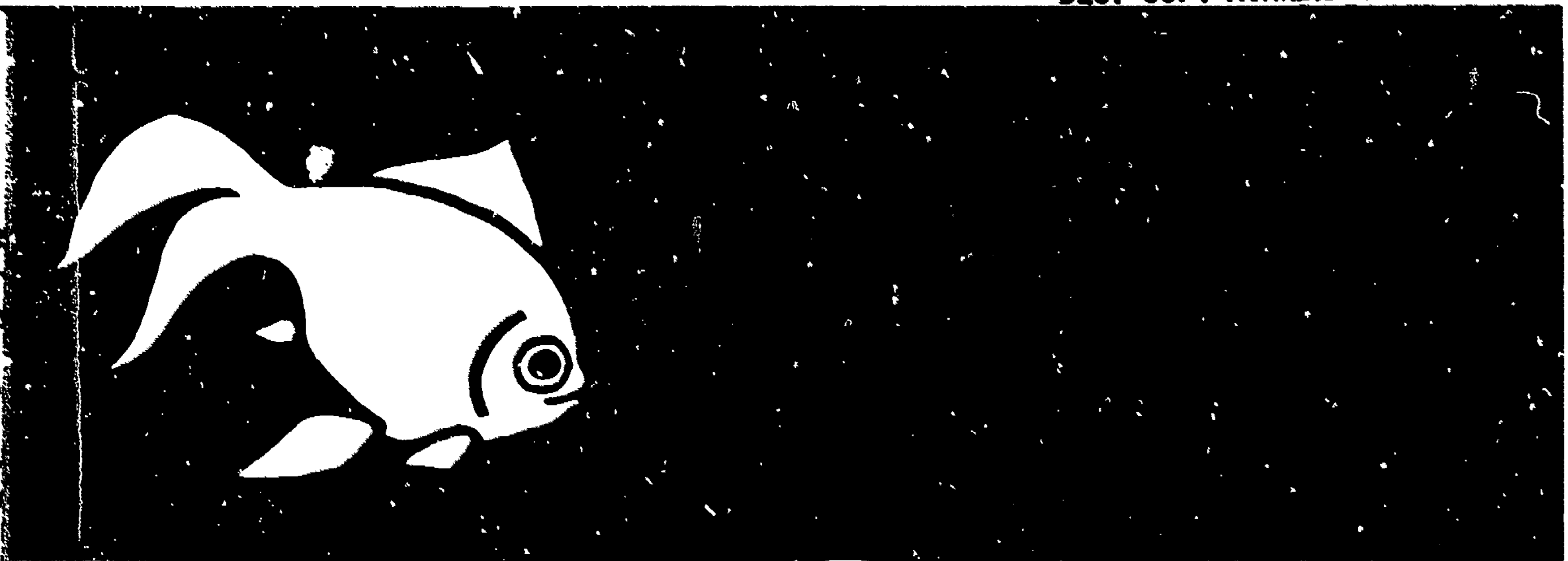
DOCUMENT RESUME

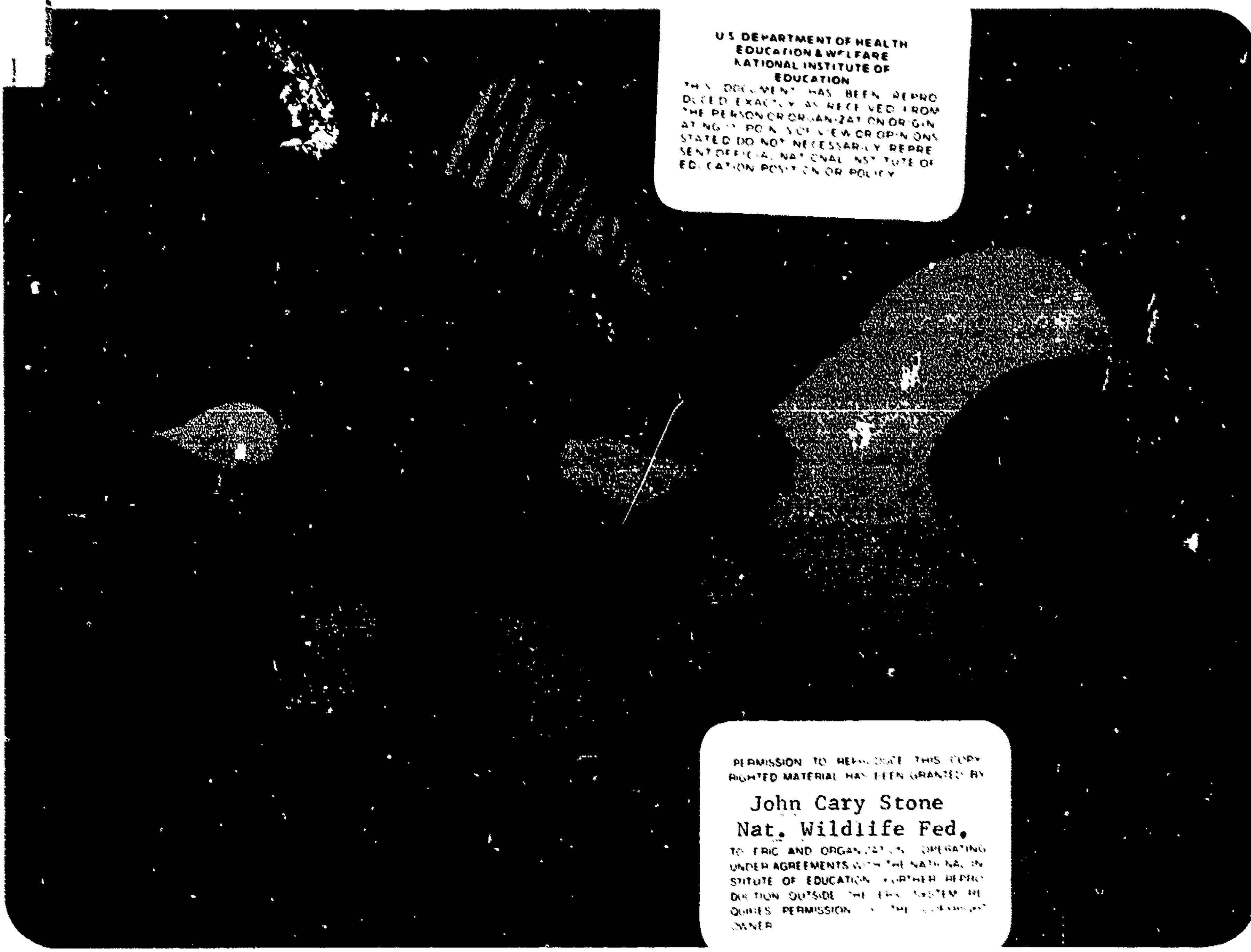
ED 103 238 SE 018 519

TITLE	Fish and Water Temperature, An Environmental Investigation.
INSTITUTION	Minnesota Environmental Sciences Foundation, Inc., Minneapolis.; National Wildlife Federation, Washington, D. C.
PUB DATE	71
NOTE	24p.; Related documents are SE 018 514-534
AVAILABLE FROM	National Wildlife Federation, 1412 16th Street, N.W., Washington, D.C. 20036 (Order No. 79070, $1.50)
EDRS PRICE	MF-$0.76 HC-$1.58 PLUS POSTAGE
DESCRIPTORS	Elementary Grades; *Environmental Education; Instructional Materials; Intermediate Grades; Investigations; Junior High Schools; *Learning Activities; Natural Resources; *Physiology; *Science Education; Secondary Grades; *Teaching Guides; Temperature
IDENTIFIERS	Fish

ABSTRACT

This environmental unit is one of a series designed for integration within an existing curriculum. The unit is self-contained and requires minimal teacher preparation. The philosophy of this series is based on an experience-oriented process that encourages self-paced independent student work. This particular unit illustrates the interrelationship between living things and their environment. The activities are concerned with the effects of water temperature on fish. Students learn to make observations, collect data, and use graphs to interpret information. The unit is designed for students in grades 4-9. Additional, more sophisticated investigations are included at the end of the materials. Materials, directions, and background information are included for the teacher's convenience. A short bibliography for students and teachers is provided. (MA)





edited and published by

NATIONAL WILDLIFE FEDERATION

written by

MINNESOTA ENVIRONMENTAL SCIENCES FOUNDATION, INC.

THE ENVIRONMENTAL UNITS

This is one of a group of Environmental Units written by the Environmental Science Center and published by the National Wildlife Federation.

In both theory and practice education is the essential base for long-range local, regional and national programs to improve and maintain the quality of environment necessary for man's welfare and survival. Citizens must be aware of ecological relationships in order to recognize, appreciate and fulfill constructive roles in society. This awareness should be launched through the existing educational process—in classroom and related school activities. No special courses on ecology can replace the need to integrate ecological learning throughout the existing curricula of our school systems. Furthermore, the life-styles and value-systems necessary for rational environmental decisions can best be acquired through repeated exposure to ecological learning which pervades the total educational experience.

It was with these thoughts that we developed these curriculum materials. They were designed for the classroom teacher to use with a minimal amount of preparation. They are meant to be part of the existing curriculum—to complement and enhance what students are already experiencing. Each unit is complete in itself, containing easy-to-follow descriptions of objectives and methods, as well as lists of simple materials.

The underlying philosophy throughout these units is that learning about the environment is not a memorization process, but rather an experience-oriented, experiment-observation-conclusion sort of learning. We are confident that students at all levels will arrive at intelligent ecological conclusions if given the proper opportunities to do so, and if not forced into "right" answers and precisely "accurate" names for their observations. If followed in principle by the teacher, these units will result in meaningful environmental education.

In the process of development, these units have been used and tested by classroom teachers, after which they have undergone evaluations, revisions and adaptations. Further constructive comments from classroom teachers are encouraged in the hope that we may make even more improvements.

A list of units in this group appears on the inside back cover.

About the National Wildlife Federation—1412 Sixteenth Street, N.W., Washington, D.C. 20036

Founded in 1936, the National Wildlife Federation has the largest membership of any conservation organization in the world and has affiliated groups in each of the 50 states, Guam, and the Virgin Islands. It is a non-profit, non-governmental organization devoted to the improvement of the environment and proper use of all natural resources. NWF distributes almost one million copies of free and inexpensive educational materials each year to youngsters, educators and concerned citizens. Educational activities are financed through contributions for Wildlife Conservation Stamps.

About the Environmental Science Center—5400 Glenwood Avenue, Minneapolis, Minnesota 55422

The Environmental Science Center, established in 1967 under Title III of the Elementary and Secondary Education Act is now the environmental education unit of the Minnesota Environmental Sciences Foundation, Inc. The Center works toward the establishment of environmental equilibrium through education—education in a fashion that will develop a conscience which guides man in making rational judgments regarding the environmental consequences of his actions. To this end the Environmental Science Center is continuing to develop and test a wide variety of instructional materials and programs for adults who work with youngsters.

Fish and Water Temperature

An Environmental Investigation

BY

NATIONAL WILDLIFE FEDERATION

MINNESOTA ENVIRONMENTAL SCIENCES FOUNDATION, INC.

Design and Illustrations by
JAN BLYLER

Like the other units in this series of Environmental Investigations, **Fish and Water Temperature** is designed to give the student a better feeling for the contents and workings of his own environment. In this unit specifically, temperature and breathing rate of goldfish are shown to be linked. This interrelationship is only a minute portion of the elements of the environment. But, if the student can grasp the existence of a small segment of these elements and understand how one can affect another, then a larger implication should follow—namely, that he, too, is **sharing** space and **dependent upon** the well-being of his environmental "neighbors." Younger students might not be able to say this, but hopefully the concept will be an outgrowth of partaking in the activities.

Parts of this unit may provide material for your mathematics program; written reports of the students' investigations could be part of a language arts writing assignment; or, the implications of the model which is developed might be discussed in conjunction with certain social studies problems.

We hope you will be adventurous in using this unit. Everything relates to everything else.

Table of Contents

INTRODUCTION

All living things are affected by their environment. Some of the changes caused by environmental factors are not readily noticeable, while others can be observed easily. It all depends on which factor and which organism you consider. In this unit, your class will examine fish. Hopefully, each student will discover for himself how the rate of respiration of a fish is affected by changing the temperature of the fish's environment.

In fish, the mouth movement other than that associated with feeding, is actually a "swallowing" of water. This water is expelled through the gills. In observing a fish, it is apparent that the gill covers move as the mouth closes. When this happens, the water is like the air humans use in breathing. The fish opens its mouth, takes in water, closes its mouth, and forces the water back across the gills. Dissolved oxygen is extracted and carbon dioxide is released. The rate of movement of the gill covers and mouth is directly related to the temperature of the water which surrounds the fish. This is the case because the oxygen demand of a fish is dependent upon body temperature, and body temperature is determined largely by water temperature.

In general, as temperatures are lowered, the rate of chemical reactions is also reduced. For fish, effects of environmental temperature changes can be visibly noted by checking the changes in the rate of movement of the mouth or the gill covers. Fish, and organisms like them which cannot maintain a constant body temperature, have metabolisms which react very sensitively to heat changes. When the "body" temperature of a fish is lowered, the rate of chemical reactions inside its body slows down. In turn, the fish's oxygen demands are lowered, the volume of water passed over the gills is reduced, and thus, the rate of movement of gill covers and mouth is reduced. An observer watching the gill covers and mouth should be able to detect these changes in rate of movement.

The activities in this unit are designed to give students the opportunity to construct a model of a system whose components are initially unknown. These components will be determined through investigation. At first, the idea of what constitutes a model may be difficult for some students to grasp. A model could be a graph showing interrelationships of variables, such as breathing rates and temperature changes. In one sense a model is like a story. You are given a collection of information. The information, in turn, gives a clear picture of some event or phenomenon. Just like a story, a model may tell you not only **what** happens, **when,** and under **what conditions,** but it also may give clues for **why** certain things have occurred.

Essentially, the model the students will construct in this unit will contain information which indicates that the breathing rate of a fish will change as the temperature of the water changes. Using the model, the students should also be able to discover possible reasons for why this happens. The extent to which you pursue the idea of a model with your students or discuss with them the concept of respiration will depend both upon their sophistication and your ideas for developing this unit.

MATERIALS

- goldfish—2 for each group of 2 or 3 students
- dip nets
- small containers with lids—2 for each group of 2 or 3 students
- centigrade-Fahrenheit thermometers
- 2 large aquariums, each with pump and aerator
- guppy food
- assorted pails or large jars
- "aged" water*
- refrigerator
- measuring cups
- graph paper
- gravel

*Aging the water will allow any chlorine to escape, and the temperature to adjust.

Fish and Water Temperature

INVESTIGATING GOLDFISH BEHAVIOR

MATERIALS

goldfish
small transparent containers—approximately 16-20 ounces in size—(1 for each group of two or three students)
dip nets
aged water
2 aquariums
2 pumps and 2 aerators
refrigerator
thermometer

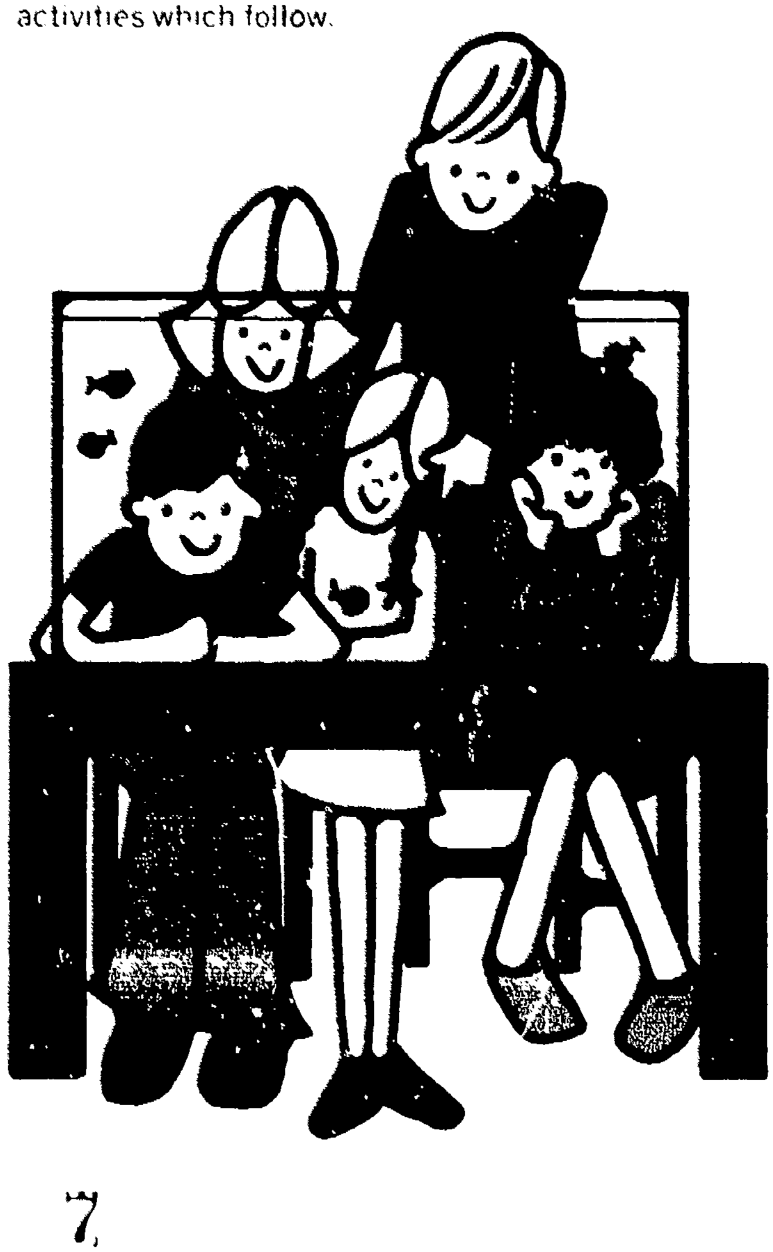
On the day before you plan to begin the activities, obtain the goldfish from a variety store. Divide the fish evenly between the two aquariums, which have been filled with "aged" water– that is, water that has been allowed to stand exposed to the air of the classroom overnight. Each aquarium must have a pump and aerator. (There should be a thermometer in the water of each tank.) Leave one aquarium in the classroom so that it can adjust to room temperature. Place the second aquarium in the refrigerator. The refrigerator should be one that can be adjusted to temperatures of about 34-35 F. (approximately 1.5 C.) and about 44-45 F. (approximately 7.1 C.). For the first part of this experiment, set the refrigerator at the lower reading. The pump and aerator should be kept running while the aquarium is in the refrigerator.

Be sure the room temperature aquarium contains enough fish so that there is one fish for every two or three students. The refrigerator aquarium should contain the same number of fish.

It is important that all temperature changes in the water be gradual; otherwise, the fish might be harmed. However, if temperatures are raised and lowered over a period of time, the fish should adjust adequately. When you put the aquarium in the refrigerator, do not add cold water to lower the temperature quickly. Let the refrigerator do the cooling gradually. Also place enough empty jars in the refrigerator so that each group will have one later.

The presence of the fish in the classroom may have already generated a number of questions. The students might wish to pursue these preliminary questions for a short period of time. The questions might even provide the direction for this first section. Obviously, not all questions can be explored or answered. There may not be time to do so. However, time spent in searching for some answers should not be considered wasted. Investigation is of value in and of itself. Younger students should have a chance to "get acquainted" with their fish. Later on when attention is directed to more specific problems, they will be less apt to want to play with the fish. It is also possible that during this period of unstructured observation the students may raise questions pertaining to other activities in the unit. These questions may provide a convenient bridge between this first activity and the remaining ones.

The direction and duration of these preliminary observations should be guided primarily by the interest and sophistication of the students. Observation and discovery should be enjoyable; when it is not, the students may be ready for the more specific activities which follow.



Start these next activities using the water and the fish from the **room temperature** aquarium.

Divide the class into small groups. One student from each group could be responsible for filling that group's container with aged water and putting one fish in each container. The groups should then observe the behavior of the fish, possibly seeking answers to some questions already raised.

Question:

Do the fish always stay together in a group?

Suggestion #1 for the students:

Try placing a single fish in each of two small containers set next to each other. Observe whether or not the fish orient themselves toward one another. Do they seem to notice other fish? How do they behave? Separate the containers with a book or piece of paper. Does the behavior change? (Do not suggest what they probably will do. Encourage the students to describe the actions of their fish.)

Question:

Do the fish prefer light or dark places?

Suggestion #2 for the students:

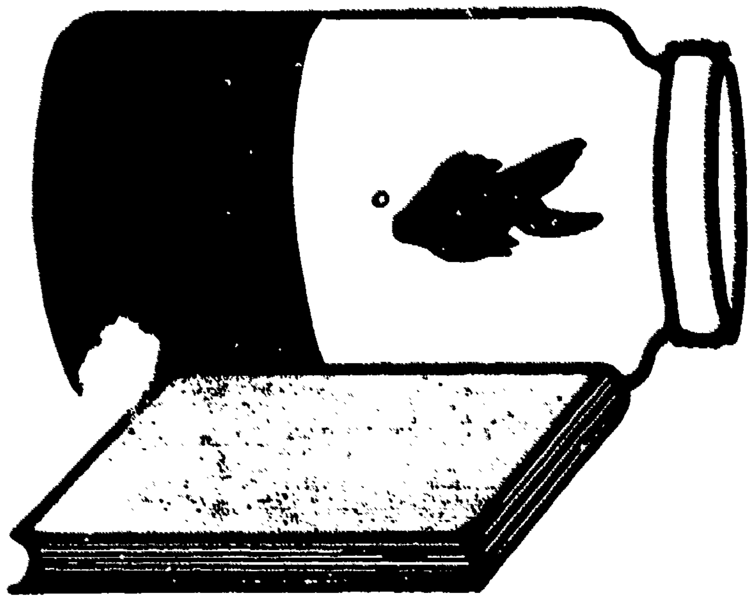
Cover one half of a container with black paper or some other material so that part of it is darker. Put the lid on for a few moments and turn the jar on its side. Support the jar with books to prevent it from rolling off a desk (see diagram). Observe the position the fish takes in the container.

Question:

Do the fish always swim near the bottom of the aquarium?

Suggestion #3 for the students:

Observe a fish to see if it moves up and down more freely in a jar than it does in the aquarium.



Question:

What might happen if several fish are placed in the small aquarium?

Suggestion #4 for the students:

Place several fish in one container and compare their behavior with that of a single fish. Is the group of fish more or less active than the single fish? (This investigation can be done by one group of students. They can then share their observations with the class.)

Question:

What is happening when the fish opens and closes its mouth?

Suggestion #5 for the students:

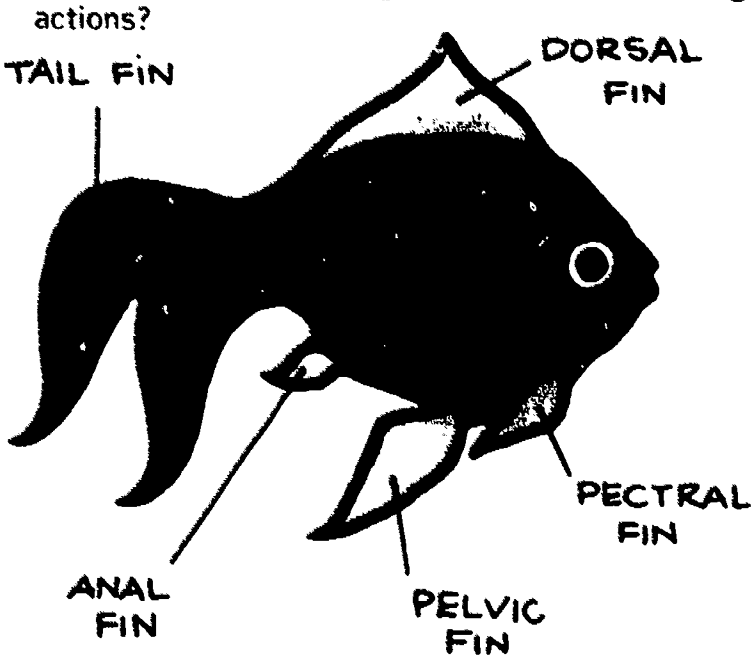
Observe the mouth opening and closing and then observe whether or not anything else—fins, gills—may also be moving at about the same rate as does the mouth. Count the number of times the mouth and gill covers open and close in a convenient time period. (Fifteen seconds is a convenient time period, but others can be used as well. To get a good **average** "counts per 15 seconds," have the children take several 15-second counts, add all the counts together and divide by the number of timings made. Two students are required to do this—one to time and one to count. If eight 15 second timings were made and found to be the following counts—11, 9, 8, 12, 11, 10, 9, 10—that would be 80 counts in 2 minutes or an average of 10 counts per 15 seconds. Note that in some of the experiments you may also want to adapt the counting procedures and determine, for example, the counts per minute. Again, it would be best to average several timings.) Does there seem to be any relationship between the opening of the mouth and the opening of the gill covers?

Question:

How do the fins work?

Suggestion #6 for the students:

Observe the action of the fins as the fish moves. Some fins are paired, others are not. Notice if one fin in each pair always moves in the same way as the other. Do the movements of certain fins seem to have anything to do with swimming actions?



The children may ask many other questions which cannot be answered readily through simple experimentation, for example:

- How old are females when they start laying eggs?
- What kind of fish are they?
- Why do they have scales?
- Is this the largest they get?
- Do male fish lay eggs?
- How often should you clean the aquarium?

Some discussion may be necessary in order to have the students understand what constitutes a **testable** question.

DEVELOPING A MODEL FOR CHANGING BEHAVIOR

In the previous section, "Investigating Goldfish Behavior," the students raised some questions about fish, investigated some aspects of fish behavior, and may have even proposed tentative explanations for what they observed. In this present activity, their attention will be directed to one specific investigation: Will the fish behave differently if the temperature of their water environment changes?

In order to answer this question, the students must become involved in several scientific operations—experimentation, measurement, and recording of data. The end result of these activities will be the construction of a graph depicting the interrelationship between the breathing rate of the fish and the changing water temperature. The graph will serve as a foundation upon which to base future predictions.

Parts of this section include measurement and recording activities. The success of the unit will be dependent upon **obtaining accurate measurements** and **recording them systematically** in some standard fashion. You will want to discuss these topics with the students before they begin the experiments.

Part 1. Determination of Breathing Rates at Room Temperature

[illegible]

goldfish—one for [illegible]
fish should have [illegible]
temperature at [illegible]
dip nets
thermometers ([illegible]
12-inch size [illegible])
small water containers
sufficient supply of [illegible]
of room temperature [illegible]
16 ounces per group [illegible]

A method for determining the breathing rate of the fish was suggested in the first section of this unit, "Investigating Goldfish Behavior". If none of the students tried that activity at that time, it is suggested that they do so before continuing with this section. (See suggestion #5 on page 5.)

The students will work in small groups. Each group will need a thermometer, a small container, a goldfish from the room temperature aquarium, and a standard amount of aged water at room temperature. (Thermometers break easily; caution the students about their use.) Before the students obtain their water and goldfish, they should determine the quantity of water to be used.

Once the class has decided on some standard quantity of water (there must be an amount sufficient for the fish to swim in), the groups may obtain it from the aquarium or another supply which has been provided. Now the fish may be placed in the water. Some of the fish will become quite active as a result of the transfer. The gill cover and mouth movement count will not be accurate under these circumstances. It is necessary to delay counting until the fish have adjusted to their new environment. The temperature of the water should be taken and recorded. Since all students are using the same water source, temperatures will probably be about the same for all students.

As was noted in "Investigating Goldfish Behavior," counts will probably be most accurate if they are done for fifteen-second time intervals. Thus, eight counts of fifteen-second duration each can be taken (this can be varied) and recorded by each group of students. The fifteen-second counts may be added together and divided by the number of counts to give counts per 15 seconds. Another temperature reading should be taken and recorded. Set aside fish and containers for use in **Part 2.**

When the class has finished, ask if there were any similarities among the eight counts each group obtained. Ask what factors are apt to influence the degree of similarity. Ask if the water temperature was the same before and after the eight counts. If not, ask how they would account for and deal with the difference.

In **Part 2** the students will obtain additional data on the goldfish at lowered water temperatures. You might want to start off by discussing with the students some ideas for what might be done to cause a change in the counts per 15 seconds.

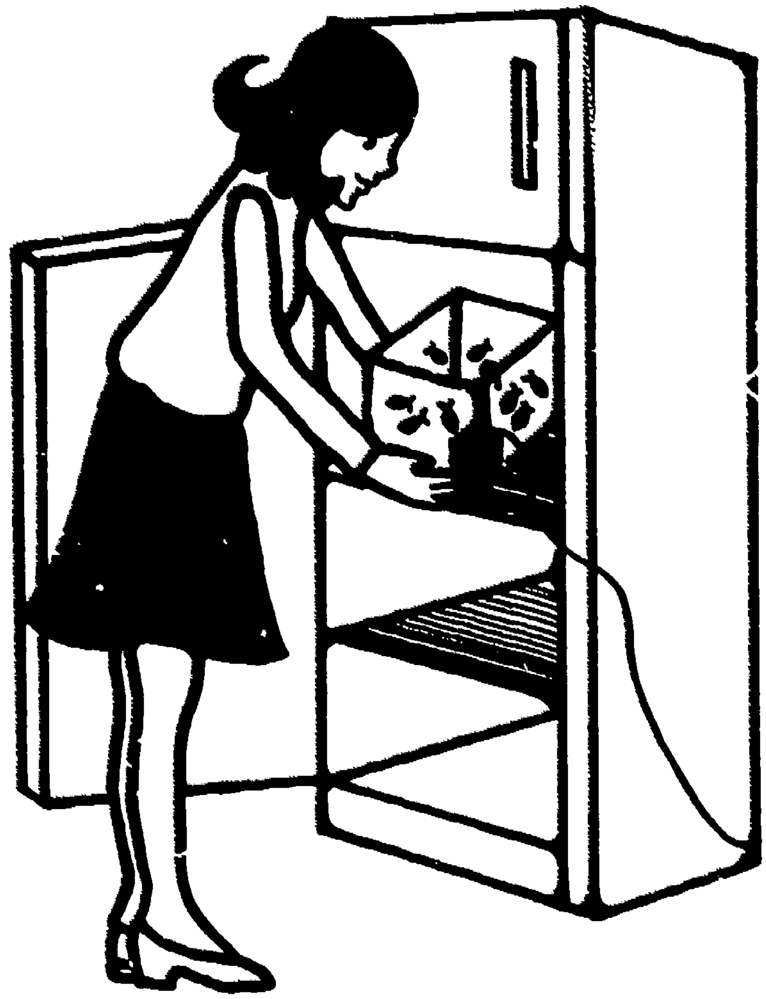
Part 2. Determination of Breathing Rates at Lowered Temperatures

MATERIALS

goldfish
containers and water, all from the aquarium that has been in the refrigerator overnight. (The goldfish should be about the same size as those used in Part 1.)

Each group of students should be given a jar full of water from the aquarium which has been cooled overnight, and one goldfish from that same aquarium. Again, it will be necessary to allow the fish to adjust before taking the counts. Then, repeat the counting procedure as in **Part 1,** recording temperatures and counts per 15 seconds. As soon as this counting is finished, the aquarium should be placed back in the refrigerator at the **warmest** setting and left until the next day. (Later in this section the students will be asked to record breathing rates at this intermediate temperature. Again the aquarium should contain pump, aerator and thermometer.)

As an alternative, you may want to use the same fish that were used in **Part 1.** After recording the data for the breathing rate at room temperature, you should place these fish in the aquarium which contains water at room temperature, and then place the aquarium in the refrigerator overnight. The only major disadvantage here is that the students will not be able to do both parts on the same day. There is an advantage, however, in that you would be able to record changes for the same fish.



Part 3. Graphing the Data

MATERIALS

graph paper marked with ¼-inch or larger squares

In this part of the unit, the students will begin to organize the data collected in **Parts 1** and **2.** Your approach to this problem will depend upon the experiences your students have had with data organization and graph construction.

The immediate problem will be to organize the data in some fashion so that the entire class may view one another's results. Permit the students to suggest how this can be accomplished by asking them to consider some ways of collecting the data so that it can be discussed by everyone. If a student suggests a chart, have him put his ideas on the blackboard. Maybe one student will produce a chart somewhat similar to the following sample. (Note: The data on this and following graphs are only for illustration and are not intended to indicate, necessarily, the information the children will find.)

GROUP #	1	2	3	4	5	6
No. of counts for each of eight 15-second timings at cooled temp. 35°F (1.7°c)	8.7. 7.6. 7.8. 7.6.	7.8. 8.7. 9.9. 8.8.				
Average	7	8	7	8	8	7
No. of counts for each of eight 15-second timings at room temp. 68°F (20°c)	36.35. 35.35. 37.34. 34.34.	35.35. 35.36. 35.34. 34.36.				
Average	35	35	35	36	34	34

(Fig. A)

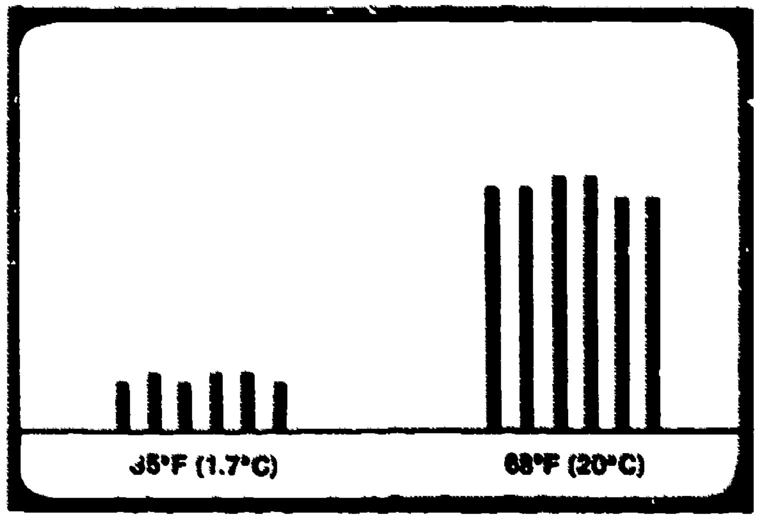
The important thing is to make certain that all data appearing on the charts are related to the proper temperature. If no one suggests a chart, have one person from each group go to the board and record his data and temperatures in any fashion he wants. Then, through questioning, the class can be helped to see that more organization is needed to discuss the results intelligently.

While a chart represents the first step in the organization of the data by depicting some interrelationships between variables, there are still better ways to do this. Can the students think of any of these ways? If someone suggests the construction of a graph from the charted data, maybe others will suggest how the graph can be made. Will the data have to be averaged? If so, should all the data be averaged for one temperature or are there ways to show each group average on a graph?

In the event that no one suggests a graph or has any notions of how to construct one, you may wish to use some of the following techniques in guiding them through its construction. It may be best to begin by asking them why certain observations are often put into graph form. You will want them to see that a graph communicates a great deal of information efficiently. Most students have seen graphs and have had to read them. They probably know that there are many different types of graphs—pie graphs, bar graphs, line graphs—but they may not know that under certain circumstances one type is preferable to another. A line graph can be constructed from a bar graph and it is often easier for students to begin graphing this way.

A bar graph can be easily constructed from a data chart. Make each gill beat or mouth movement equal to ½ inch on a strip of paper. Let's say, for example, there is an average of 7 beats per 15 seconds for a given temperature. Then a strip of paper 3½ inches long would represent that datum. The students could then cut strips of paper to represent their respective group's data for each temperature. These could be mounted on the board in order of increasing temperature, as follows:

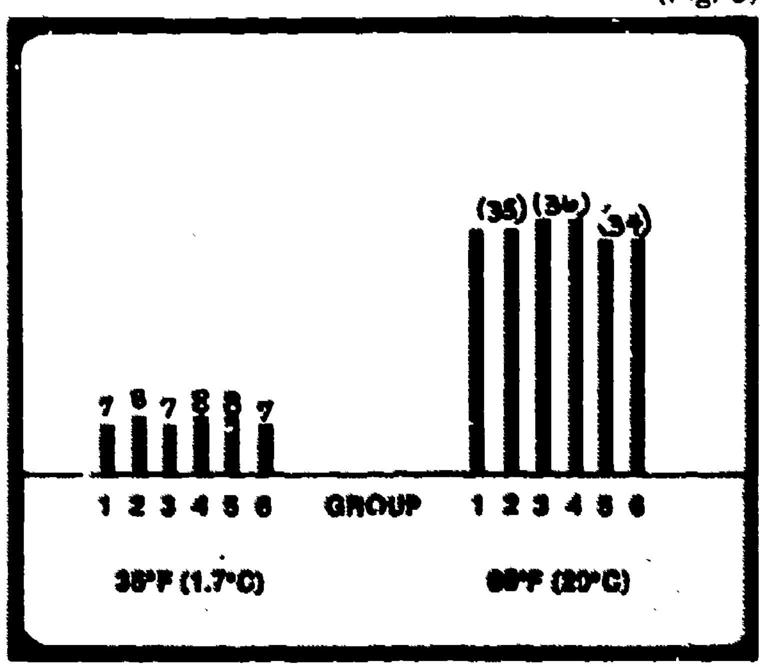
(Fig. B)



All bars touch a common base line. This is a "rule" the students should understand. Younger students may need a more elaborate explanation of graphs.

The students know what the strips mean, but without some labels, no one else would understand what they signify. Ask them where labels could be placed to make the meaning clearer to an "outsider." Each strip could be labeled but that might be confusing; however, if labels were placed along the left side and across the bottom, the meaning would be greatly clarified. Since the **length** of the strip is determined by the average gill or mouth beat for fifteen seconds, ask the class what kind of label would be used to express that idea and where it should be placed. Each strip also represents a temperature. Ask the class where it would be appropriate to place a label indicating temperature. The following is an example of an improved graph.

(Fig. C)



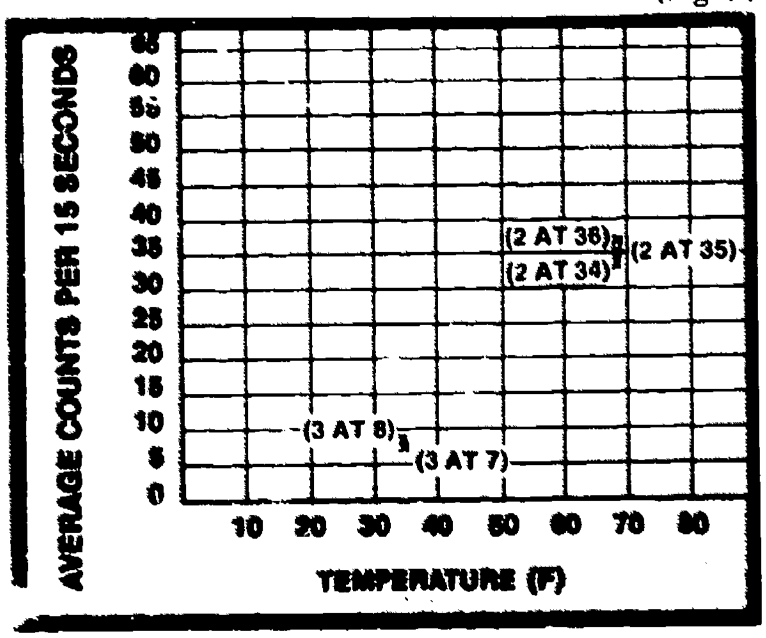
The preceding graph is not *completely* satisfactory for class purposes. Counts made at temperatures between the two existing sets, for example, would necessitate moving some of the bars. Some means of simplifying the graph should be explored with the students.

Substituting numbers and points for the strips would be one way to simplify the graph. It is possible to replace the strips with two sets of numbers and still retain all of the data. In order to do this, data collected by the students could first be transferred to graph paper as a **bar** graph. Each square on the grid could represent one beat. The result would be a reproduction of the paper strip graph, but on a much smaller scale. Also, each student could have his own graph.

Now ask the students if there would be a way to improve the graph so that they could tell more easily what each bar signifies. The idea of placing a vertical number line at the left side of the graph should emerge from the discussion. Once the vertical number line is established, ask if the bars are necessary. Ask what could be done to replace the bars and retain the information. Maybe the use of points will be suggested. If each count can be represented by a point, ask if the class can also think of a way to represent the temperature more easily. Might another number line be created across the base of the graph to show temperature?

The results of this discussion could be a graph similar to the one which follows.

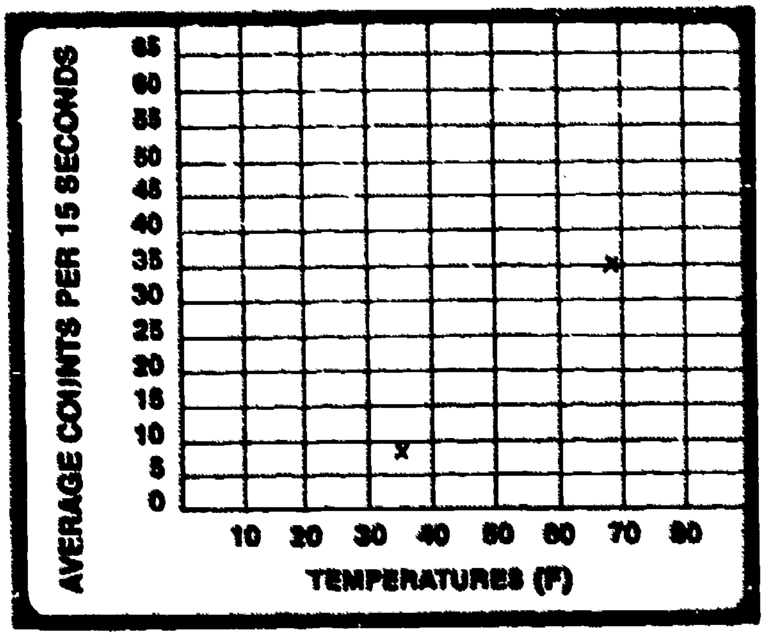
(Fig. D)



If two or more pairs of students obtain exactly the same data from a given temperature, those points will fall on top of one another. Further simplification can be accomplished by **averaging the averages for each temperature;** however, it might be instructive to start off by discussing some reasons for the differences in each set of data.

The final product might appear similar to the following graph, where average counts and temperatures have been computed and plotted.

(Fig. E)



Ask the students what kind of line should be drawn to connect these points—straight or curved? (This cannot be properly answered until data for at least one more temperature is obtained.) Ask what that line means in very general terms. Can numbers be associated with its meaning even though they do not appear on the graph?

Now the graph is a model of sorts—a **representation** of the interrelationship between breathing rate and temperature for the particular fish used. It can therefore be said that **as the temperature of the water changes, so does the breathing rate of the fish.** Ask what the direction of this change is. Does the rate increase or decrease as the temperature is lowered? These observations can be elicited from the students after the graph has been constructed. As a model, the graph reveals more than the fact that a change has occurred in the fish-water system. But in order to be certain of the direction of change, more data must be gathered.

Part 4. Determination of Breathing Rates at Intermediate Temperatures

Again, each group of students should be given a jar full of water from the aquarium that has been cooled overnight but this time at the **warmest** setting and one fish from that aquarium. Once again it will be necessary to allow the fish to adjust to being moved around. Have the students begin this part by taking the temperature of the water. Next, have them record predictions for the number of counts per 15 seconds that a goldfish would have at that temperature. Then, they should check their predictions by testing the counts per 15 seconds. Each student should compare his prediction with the experimental result and record the latter on his graph.

Ask how their predictions compare with the data obtained. What are some of the reasons for error in their predictions? Can the accuracy of predictions be improved with the addition of more data?

The students are now at the point where you will want them to be able to read and interpret the graph with some competency. The success of the next section will be dependent upon the degree to which they have developed those skills.

REFINING THE MODEL

Review with the class the events of the preceding section, and discuss in more detail the idea that the graph is a **model** of the fish-water system. Explain that you now wish to **verify** the usefulness of this model by doing some activities related to the system. When a model is **verified** it is tested for its applicability. You want to know if the model can be used in such a way that it represents reality. Most students have seen models of the solar system or globes of the world. Neither are the real thing, but both are attempts at representation of reality and, as such, can be useful devices.

Our model will prove useful if the students are able to **predict** with increasing accuracy the results of additional trials.

MATERIALS

goldfish
dip nets
thermometers
warm water, approximately 77° F. (25° C.)
cooled water, approximately 55° F. (13° C.)
containers

On the day before you want to conduct the activities in the following section, take the aquarium that has been in the refrigerator (with its fish) and place it in a spot where the temperature will level off at about 55 F. In the winter you might be able to accomplish this by placing the aquarium in a cool spot in the hallway. Place the other aquarium (with its fish) near a radiator or some other place where its temperature will level off at about 77 F.

At the beginning of class on the day you plan to do these activities, prepare two sets of containers— 7 or 8 containers in each set. (1) Each jar in the first set will contain about 16 ounces of the warm water (77 F) and one fish each from the warm aquarium. (2) Each jar in the second set will contain only the cooled water (55 F) and one fish each from the cool aquarium.

Divide the class into two groups with half the class in each group. Members of each group should form into pairs. You will probably have seven or eight pairs of students in each group. Each pair in the first group will receive a container of the warm water and a fish from that aquarium. Each pair in the second group will receive a container of the cool aquarium water and a fish from that aquarium.

Ask the first group to take a gill or mouth rate count as done before and to predict the water temperature after obtaining the rate. At the same time, the other group can take the water temperature of its samples and predict a respiration rate. The fish will already be in the water, but the students should not take their count until they have made their estimates. What are the results of their predictions? On what were they based? How can their predictions be verified?

The students can verify this by filling in the missing components of their systems, i.e., taking a thermometer reading or a fish respiration count. After verification you may want them to plot the new data on their graphs and then discuss the entire curve. Some questions for discussion might include:

1. What is the shape of the line? Is it straight or curved?

Using only the graph, have the students consider two or three breathing rates which have not been determined experimentally but which are within the range of the ones already plotted.

2. Can the students estimate at what temperature each count would be found?
3. How certain can they be of the predictions which fall outside the counts-per-15-second range that they've recorded?

The operation needed when predictions go beyond the range of known data is **extrapolation.** "Extrapolation" literally means "outside the poles". The "poles" in this case are the first two sets of data collected by the students in **Parts 1** and **2** of the previous section. "Developing a Model for Changing Behavior." Those data were obtained for two temperature extremes. Additional data were obtained for temperatures **within** those established limits in **Part 3** of "Developing a Model for Changing Behavior." When predicting beyond the known limits of the data students must make inferences based upon what is known.

The accuracy of the inferences is often considerably less than the accuracy one obtains through the operation of **interpolation**—predicting additional data **within** the range of known data. Accuracy is also dependent upon the interrelationship between the variables. If the graph is a straight line, both operations will produce accurate data. If the mathematical interrelationship is represented by a curved line rather than a straight line, extrapolation is not advisable. The students may extrapolate to some extent with their data, but only with decreasing accuracy. It is not necessary for the terms "extrapolation" and "interpolation" to be used with the younger students. For these students, it is preferable to perform and discuss the nature of the operations without the terminology.

The next section will consider some of the broader implications of the model as it applies to several fundamental problems of environmental science.

APPLYING THE MODEL TO ADDITIONAL PROBLEMS

In the preceding sections students have devoted some time to an interpretation of the graph. They should understand that the graph is a model of a relationship between the breathing rate of the goldfish and temperature of their environment. This relationship can be expressed by the following generalization: **As environmental temperature varies, a corresponding variation in breathing rate occurs.** This generalization applies to goldfish. Ask the students whether they think it will apply to **all** fish? Can this generalization apply to animals other than fish? Is variation in breathing rate the only response an animal makes to temperature variation? What are the implications of the model relative to wildlife management?

These and other questions will provide the focus for a discussion with the students which will lead them to some applications of their model, and possibly to further study.

If the students are able to apply their model to the "solution" of some rather basic problems in biology, they will broaden the model's significance and begin to develop the power which comes from understanding it. The ability to explain new phenomena in terms of this new model will also indicate the degree to which they have understood the model.

MATERIALS

graphs completed in Part 3

Work completed up to this point in the investigation of relations between temperature and behavior of goldfish showed that there was a correlation between temperature and goldfish breathing rate. Students have already formulated models of this relationship and graphs to predict the results of experimentation. Now the student is ready to generalize and expand his model. Through induction he will increase his understanding of **heat** as an **environmental factor.**

Included in the following pages are graphs presenting data which relate temperature variation to the behavioral patterns of organisms which have been exposed to those variations. This information may be given to the student for examination. Expansion of the concept may be brought about through class discussion. Perhaps a student will wish to take the materials home and try to formulate his own model prior to the class activities.

Data shown in Figure 1 indicate that a relationship exists between the depth of a body of water and the temperature at varying levels. There may well be some students who are already aware of this fact. Their experiences can be used to draw the class into a discussion of the possible reasons for this phenomenon. Figure 2 shows that this relationship is continuous throughout the year but subject to modification by the air temperature. One can therefore use these graphs to illustrate the influence of **climate** on aquatic habitats. Do the students think that there is a significant mixing of the lake water occurring in Figure 1? Ask if they think that the depth of a lake could be a factor which influences the amount of mixing that occurs.

Figures 3 and 4 indicate that the response of some living things will correspond to variations in temperature. The depth at which fish are found will vary with temperature gradients and also with the seasons. Ask the students if this is because the temperature of the water in winter may not be the same as the summer temperatures indicated in Figure 1. Ask if the tendencies shown in Figure 2 are in agreement with their hypothesis. Ask if some fish represented on the graph are affected to a greater degree than others.

Scientists have also demonstrated that there is a correlation between the environmental temperature and the song of crickets. (A more detailed discussion of this topic is given in the back of the book.) Data presented in Figure 4 shows that the number of chirps (stridulations) per minute is dependent upon temperature. Now the generalization might be expanded to include other organisms in the animal kingdom. This data could be used as the impetus for outside reading in search of the reason for this variation in chirp rate. This information might help the student expand his model into a more meaningful generalization about his own environment. Other topics, such as hibernation, could be discussed in relation to this unit.

Figure 1. Relation between depth and water temperature in a deep water lake in summer.

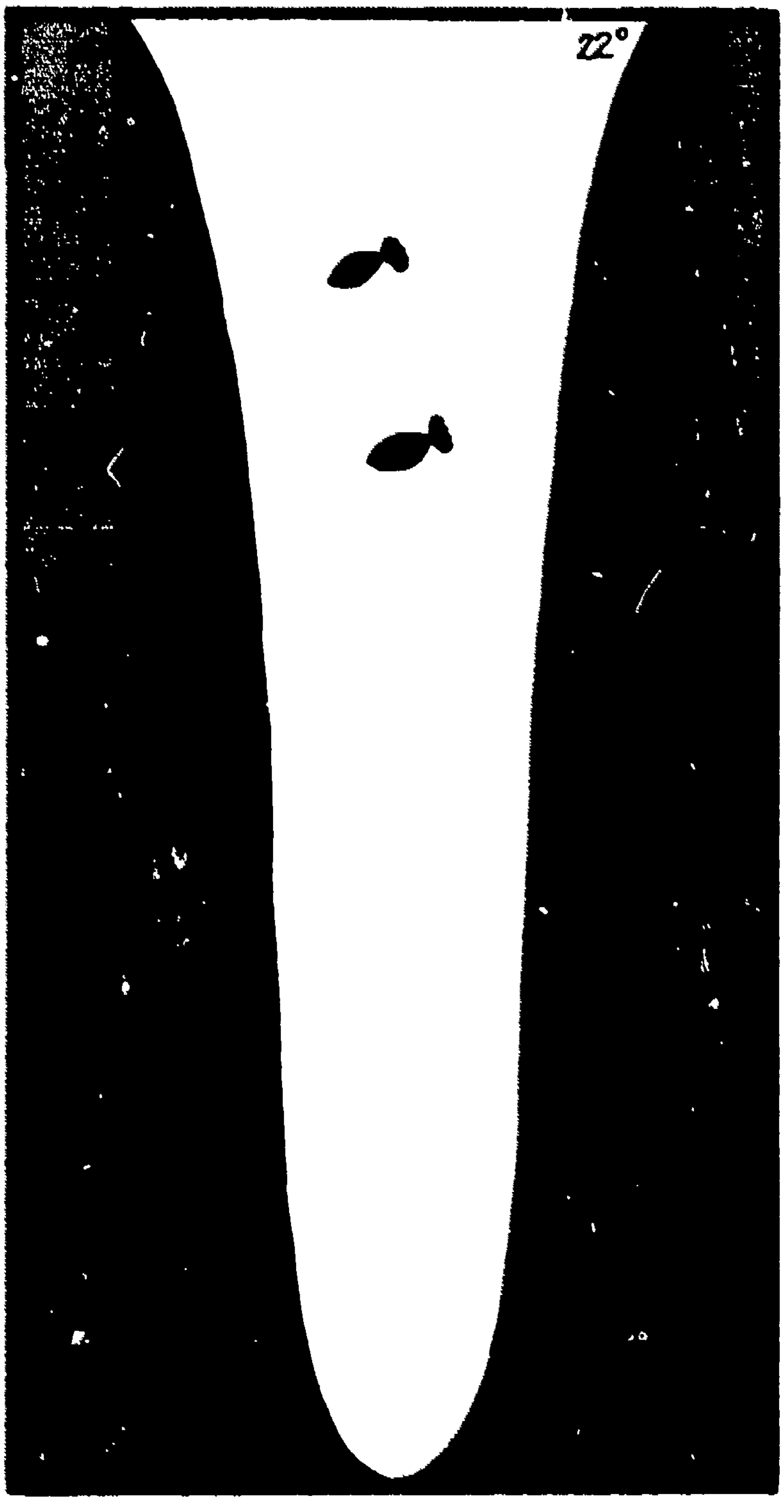
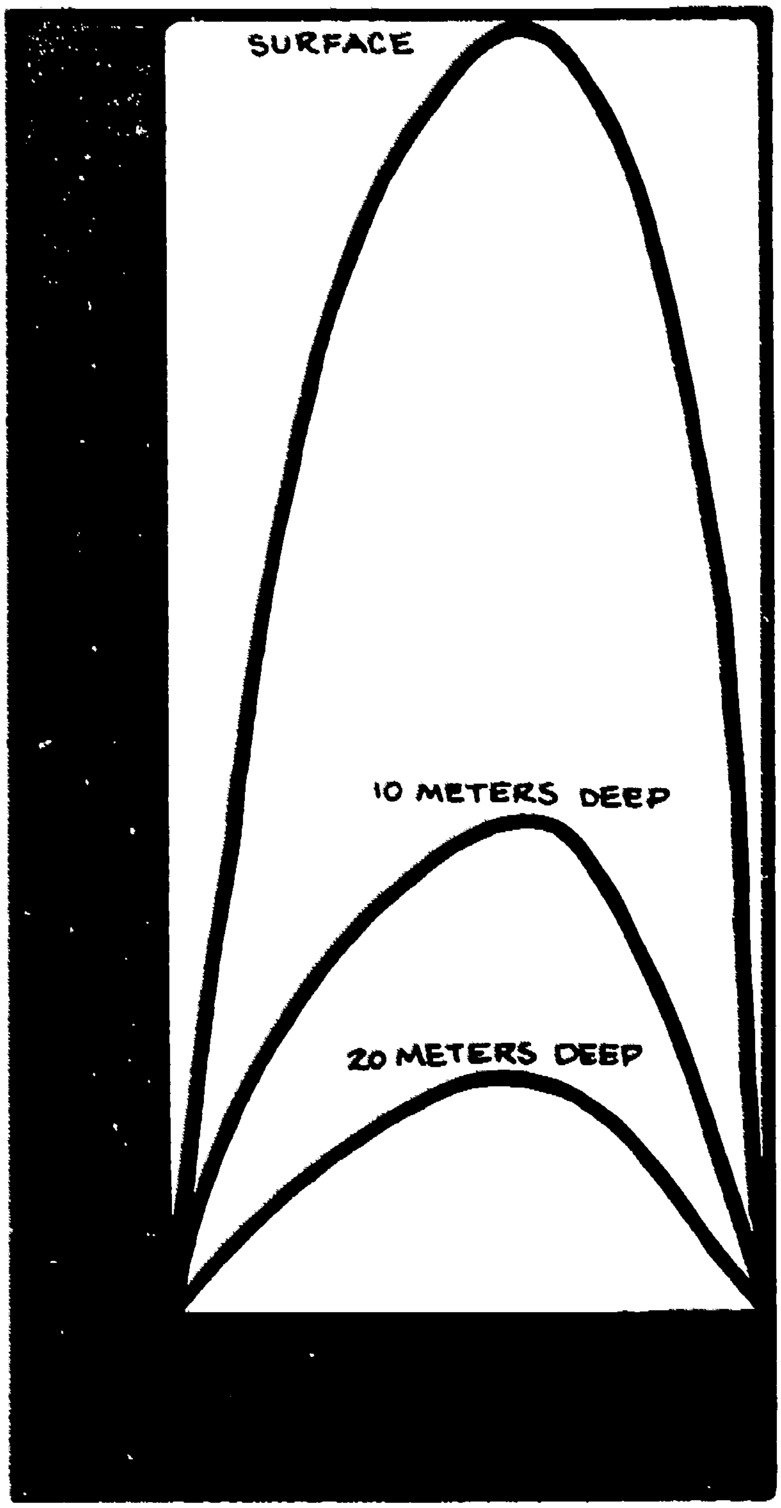


Figure 2. Seasonal change in water temperature at different depths as recorded in a midwestern lake.



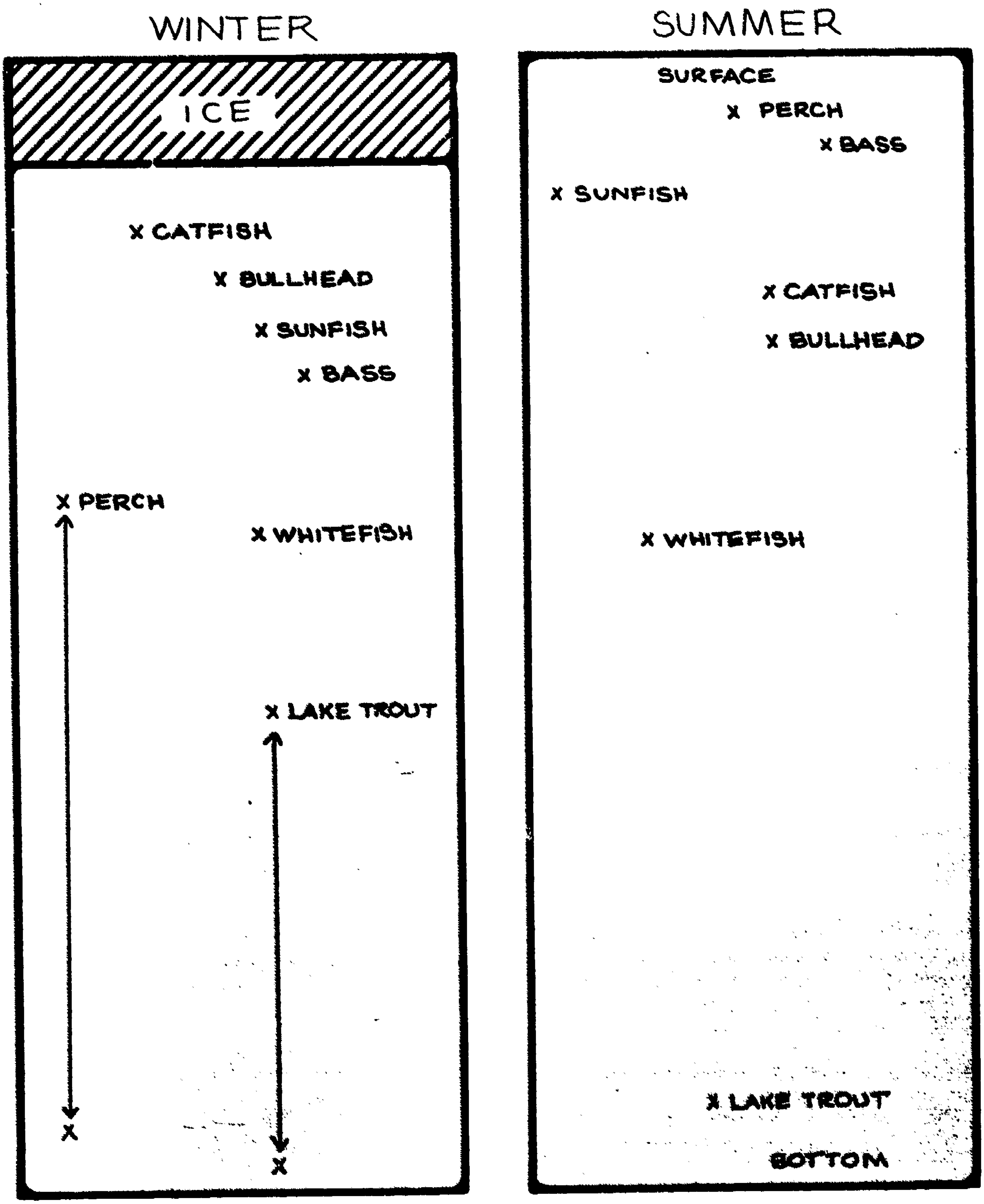
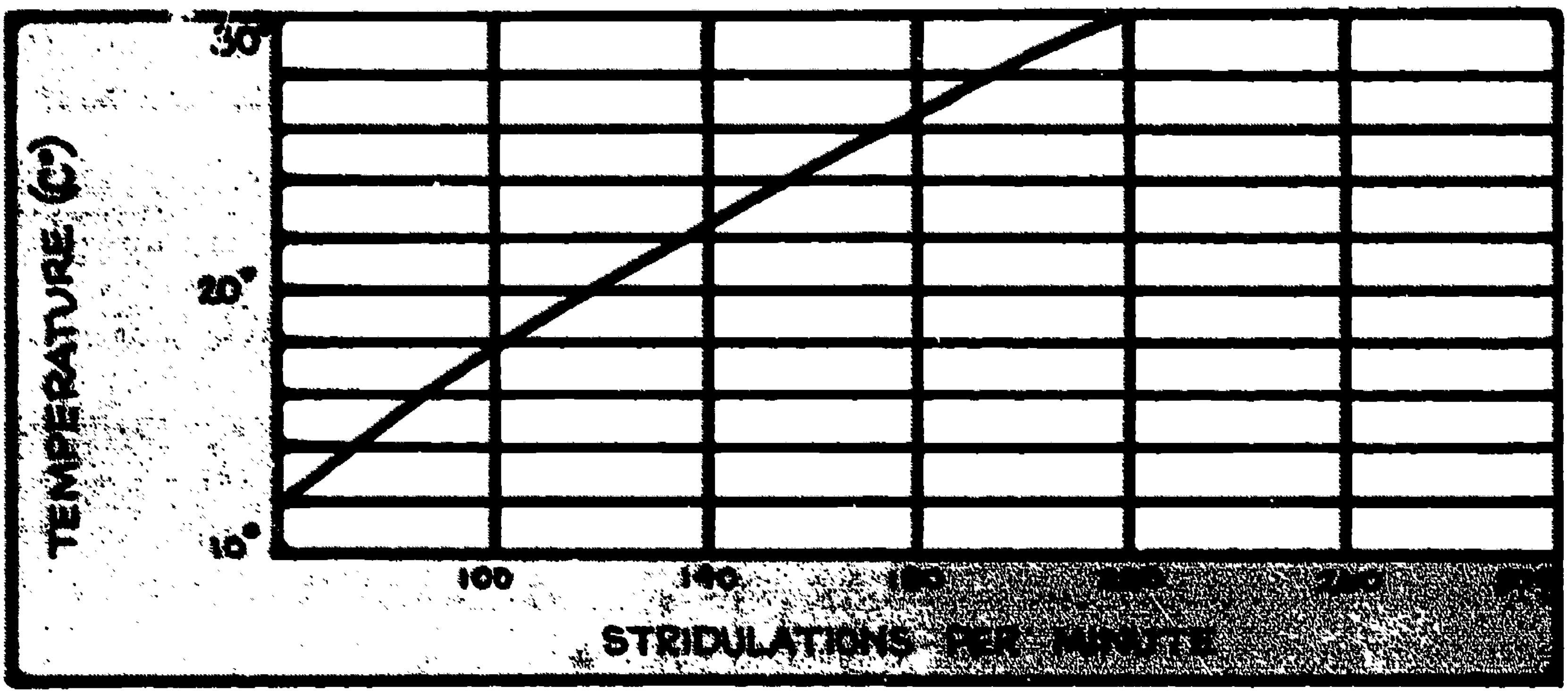


Figure 3. Comparison of the ranges of some fish as related to seasonal temperature changes.

Figure 4. Relation of chirp rate of the tree cricket to temperature.



ADDITIONAL INVESTIGATIONS

Fish and Water Temperature is one unit in a possible sequence of units investigating animal behavior in response to stimuli. A major concern in these units is the development of materials which will relate a behavioral sequence to other areas of investigation in environmental science. Some of the following suggestions could function as "idea-bridges" between the behavior factor and the other factors.

These suggestions are offered as ways of increasing the flexibility of this unit. They may provide students with ideas for independent investigations or provide more appropriate activities for higher grade levels. Some may serve as transitional activities which could come between this unit and what you have planned to follow it.

I. Investigating other organisms whose respiratory responses vary with temperature change.

The respiratory behavior of frogs can be easily investigated by the students. The floor of a frog's mouth moves up and down as it gulps either air or water. These movements may be counted as were gill and mouth movements in goldfish. Frogs cannot be expected to behave as fish do. Some very real problems in experimental design will pose a challenge to the students who might undertake such an investigation.

II. Investigating respiratory responses among animals whose temperature does not vary with the environmental temperature.

One of the easiest organisms to work with would be the student. There is almost always a changing temperature in the classroom over the day. As that temperature increases (it usually will), have the class determine if there is a corresponding change in student respiratory rate, given approximately the same level of activity over a period of time. A confusion factor may be the relative invariance of body temperature. Respiration rates increase with activity, but body temperature does not. Ask the students how these factors can be accounted for in the design of such an experiment.

III. Investigating respiratory behavior in response to stimuli other than temperature variance.

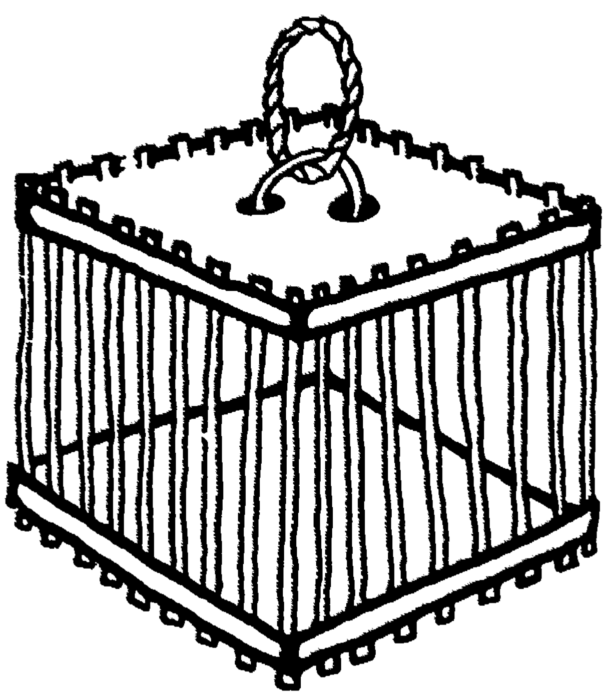
Ask the students what might happen to the respiratory rate under crowded aquarium conditions. Do the students think the rate will vary as light intensity varies?

THE BACK OF THE BOOK

Crickets

Crickets all chirp. We know them best for the sounds they make in fields or trees during the summer (day or night) and perhaps in or around the house in autumn.

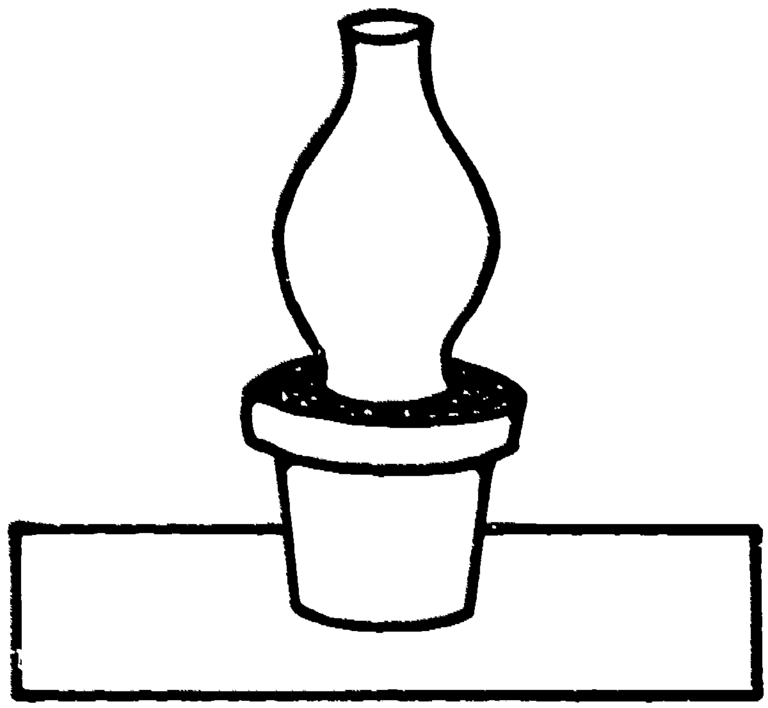
The crickets' coarse chirping should not be confused with the more piping song of tree frogs in a pond in early spring, or the long, sustained "breeeee" of the cicada in late summer. Crickets chirp by rubbing a saw-like comb of one wing against a sharp ridge on the other wing.



The Chinese built small cages to keep house or field crickets (*Gryllus sp.*) for they thought it lucky to have a cricket chirping in the house. Only males chirp and they sing best when a female is around. The females can be identified by a long ovipositor or egg-laying tube at the end of the body which is used to place eggs in the soil.

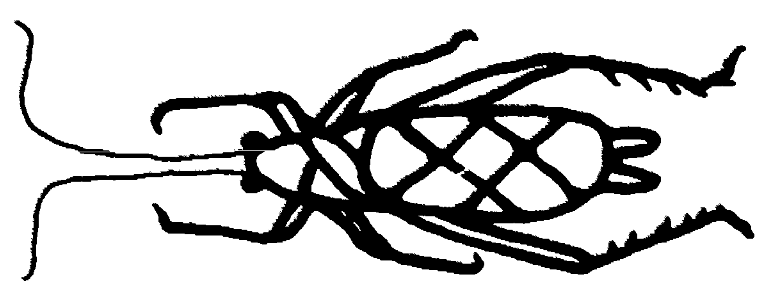
field cricket (*Gryllus sp.*)

The true crickets *(Gryllus)* are easy to keep as pets although you won't be able to teach them any tricks. They will eat just about anything including each other, and they do not mind a confined space. Feed them vegetables, fruit, moist bread, meat, dog food and some bone meal to prevent cannibalism. An old-fashioned cage that works well is a large flower pot of soil with a lamp chimney confining the crickets.



Gryllus females will lay eggs in moist soil. The eggs hatch a few weeks later into miniature adults.

Crickets slow down in cool weather, and speed up in warm weather, like other cold-blooded animals. This means that chirping will be faster on a warm day. Much has been made of telling temperature from cricket chirps. The best indicator is *Oecanthus niveus*, a pale green tree cricket which is called the temperature cricket. If you count the number of chirps per minute, divide this by four, and add 40, you get the approximate temperature Fahrenheit.



temperature cricket (*Oecanthus niveus*)

If you want more accuracy, use the following formulas which were worked out by someone who patiently sat and counted the chirps of crickets at varying temperatures.

For field crickets (*Gryllus sp.*), count the number of chirps in 14 seconds and add 40.

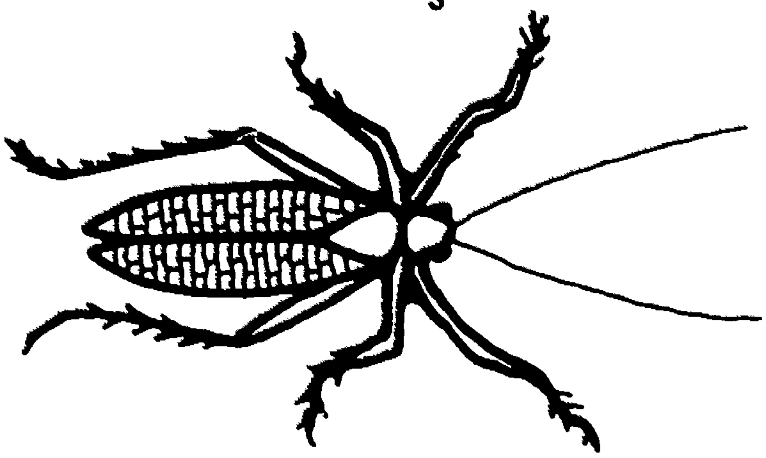
For the house cricket (*Acheta domestica*), use the formula:

T Temperature
N - Number of chirps per minute

$$T = 50 + \frac{N-40}{4}$$

The katydid (*Pterophylla camellifolia*) which sings at night, usually high in trees, is related to the crickets. Its formula is:

$$T = 60 + \frac{N-19}{3}$$

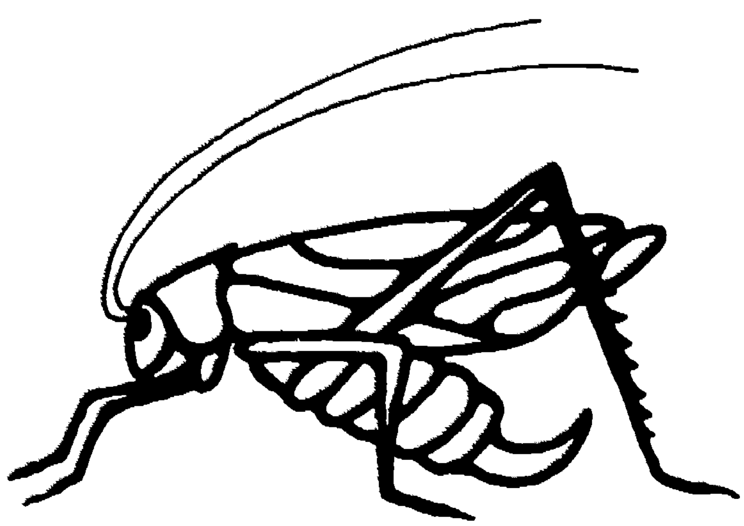


katydid (*Pterophylla camellifolia*)

The false katydid (*Amblycorypha oblongifolia*) sings in low bushes. We have no formula for it. Perhaps you can work one out.

Unfortunately, the crickets never read these formulas. Some days they won't tell you the temperature at all. And when a female comes near, the formula doesn't work, because the male very obviously chirps faster.

Remind the students that they won't know what temperature it is unless they apply the formula to the right cricket.



false katydid (*Amblycorypha oblongifolia*)

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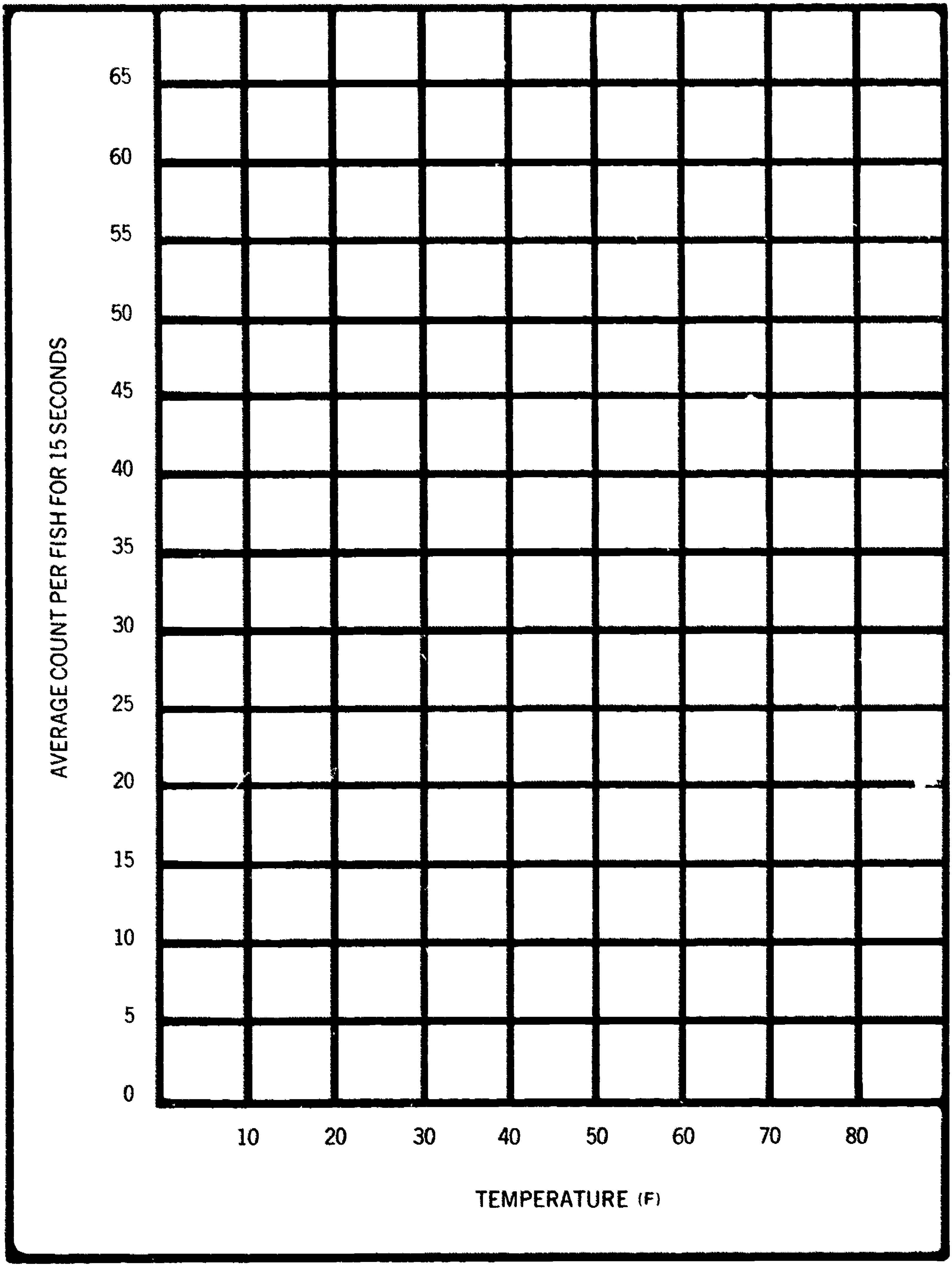
DATA SHEET FOR RECORDING AVERAGE COUNTS PER 15 SECONDS



DATA SHEET FOR RECORDING RESPIRATION RATES AT VARYING TEMPERATURES

	water from refrigerator at coolest temp: ____° (A)	intermediate temp. #1 ____° (B)		water from refrig. at warmest temp: ____° (C)		intermediate temp. #2 ____° (D)		water at room temp. ____ (E)
	actual count	prediction (counts or temp.)	actual count	prediction (counts)	actual count	prediction (counts or temp.)	actual count	actual count
count #1								
count #2								
count #3								
count #4								
count #5								
count #6								
count #7								
count #8								
average count								
temp. at end	____°	____°		____°		____°		____°

Take readings in this order: A, E, C, B, D

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