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ABSTRACT

The major ideas of the unit are: normal curves, gradients, extrapolation and interpolation, directional change, cyclic change, and dynamic equilibrium. Some 28 different inquiry-oriented laboratory experiences are designed to develop understanding of these major ideas. The laboratory experience format is as follows: Introduction, Materials and Equipment, Collecting Data, and Follow-up. These experiences cut across subject matter areas, ranging from biology to chemistry and geology and include such topics as evolution, chemical indicators, and topographical maps. (BR)

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IDEA-CENTERED LABORATORY SCIENCE

(I-CLS)

The Kind of World a Scientist Thinks He Has Found

Unit D. A Scientist Assumes the Existence of Variation and Change

We talked about change and variation in an earlier unit, and saw how natural laws are really descriptions of patterns of change and variation that occur regularly and can be depended upon. Change and variation are really different aspects of the same basic characteristic of the natural world. Change is something that is happening. Variation is the result of something that has happened.

The kind of world that the scientist believes he has found is a world in which change and variation are expected. Usually the changes and variations form patterns, but not always. Usually it is possible to describe these patterns in terms of natural laws. The scientist has learned to look for certain kinds of patterns. Among these are curves, gradients, directional changes and cyclic changes.

SE 008 855

I-CLS

The Kind of World a Scientist Thinks He Has Found

Unit D. A Scientist Assumes the Existence of Variation and Change

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Idea of Normal Curves: A Way of Picturing Variation D.1.

Idea Bridge: Norms and Averages

We are accustomed to using the word "normal." It really has two meanings. One of them has the notion of "right" or "good" about it. The other means about the same as "average." An average man or woman, or an average eighth grade student, does not really exist. Instead, in an eighth grade class we find all kinds of variations around a sort of picture of "averageness." We get this picture as a result of knowing about as many as possible of the variations, and mentally averaging them. We obtain the average of a group of measurements by adding them all together, and then dividing by the number in the group. We do not do that here, but we get a similar result just by thinking about the group. This "average" of a group of variants is called the mean or norm.

In the natural world, things tend to vary in pattern fashion around a norm. A representative sample of any kind of data: the weights, or heights, or grades of students of a particular age group, the sizes of beans of a particular kind, the temperatures at 3:00 in the afternoon each day in the month of January of a particular year----all will show this patterning around a norm.

You can record such data in the form of a graph. When you do this the point on the base line of the graph where the data "pile up" is called the mode. If this point is the same as the norm or average the pattern which is formed is called a normal curve or bell curve. In this type of curve most of the data pile up at or near the norm, and the rest fall with decreasing frequency on each side of it.

LABORATORY EXPERIENCE D.1.a.

Normal Distribution Curves Show Variation in Nature

Introduction:

No two things are exactly alike. When things of the same kind differ from one another, we say that they show variation. Sometimes we can tell why things differ. More often we cannot say why. Variation is simply a fact of nature.

Peas and beans grow in long structures called pods, and generally peas or beans that grow in the same pod are very nearly alike. It is not often possible to say that that two things are as alike as "peas in a pod." Even peas or beans from the same pod, if they are carefully examined and measured, will be found to be very slightly different.

One way to see how variation occurs, and how things which vary are related to one another, is to measure a collection of lima bean seeds.

Materials and Equipment:

1 pound of dry lima bean seeds of the same kind. These may be either the small or the large limas.

12 large test tubes and a test tube rack. Four ounce fruit juice glasses or wine glasses may be used instead of test tubes, if they are made of clear, uncolored glass.

Magnifying glass

Millimeter rule

Glass marking pencil

Graph paper

Simple balance for measuring weight in grams and fractions of grams

Collecting Data:

This laboratory experience can best be done by students working in pairs. The final results of different pairs may be put together at the end of the experience to make a larger sample.

Measure the beans in groups of ten. Each "ten" should be chosen at random. For example, you might simply reach into the bag and pick up the first ten you touch, one at a time.

Measure the greatest length of each bean with the millimeter rule. Use the magnifying glass to decide the closest millimeter mark. Do not try to count fractions of millimeters. You will soon be able to do this easily, so that the measuring job will go fast.

When you have measured the first bean, put it in a test tube or glass, and mark the length of the bean on the glass with a marking pencil. Do the same thing with the second bean you measure, if it is a different length from the first one. If it is the same length, put it in the container with the first one. Keep doing this until you have finished measuring the first group of ten. Start a new container each time you find a bean of a different length.

Do your containers form a continuous series (for example, 12 mm, 13 mm, 14 mm, 15 mm, 16 mm, and so forth). Or is the series incomplete, with one or more of the measurements missing? Have the beans begun to "pile up" in one or more of the containers? When they pile up, the length which occurs most often is called the mode. Where does it appear in your series? Is there more than one mode in your series? Write down your answers to these questions. Compare your answers with those of other students.

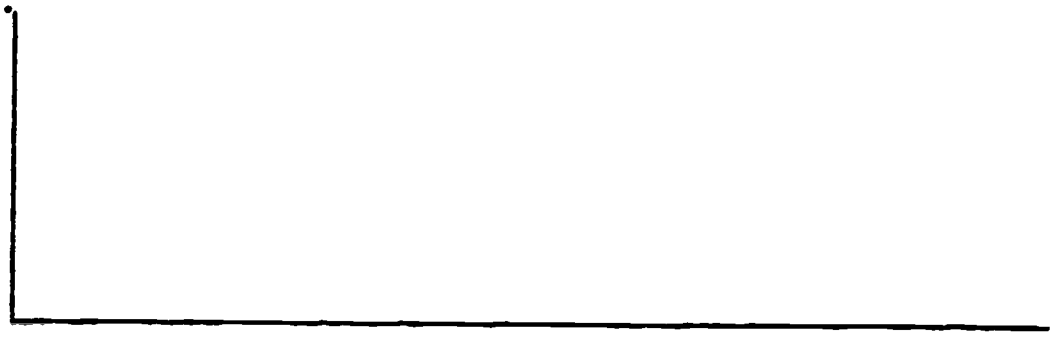
Measure a second group of ten. Do this in the same way you measured the first group. Put the beans in the same series of containers, adding them to the beans of the first group. When you have completed the second group, answer the same questions that you did before, and write down your answers. Are your answers the same at this point? If they are different, how are they different? Keep on with a third group of ten, and again write down the answers. Keep on with more "tens," as long as you have time to continue, or want to do so. Keep a record of the number of "tens" that you have measured.

How many "tens" did you have to measure before new size classes stopped appearing? How many "tens" did you have to measure before a definite mode became apparent? When you finished the experience did your size classes form a continuous series, or were there gaps in it? How many "tens" did you have to measure before you found your longest bean? Your shortest bean? Does this tell you anything about the likelihood of picking a single bean at random which would belong to one of these extremes? In the light of this, when a single specimen of an extenct race of man is discovered, what do you think of the argument that it is a freak? Do you think it is right to generalize on the basis of a single case of any kind?

How many "tens" do you think it took to make an adequate sample of the bean population? Would your conclusions concerning the nature of the population have changed if you had kept on beyond this point? Can you make a definition of an "adequate sample" on the basis of this experience that could be used with any kind of population?

Count the total number of beans in each size class, and make a graph that shows the relationship of sizes of beans to the numbers of beans in each size class.

Numbers of beans



Size classes (length of beans in millimeters)

Did the series of size classes in your containers make something close to a normal curve? Is the graph which you have made on the basis of your results something close to a normal curve? Would the measurement of a larger sample of beans have given you a better curve, either with the size classes or on the graph. After having made the graph do you wish to change your conclusions about the size of an adequate sample? Do you wish to change your definition of an adequate sample?

Combine your results with those of other members of the class. Make the same kind of graph based on the results of the entire class. Do you get a curve which is nearer to a normal curve? If so, why do you think it is so? Is there a change in either the extremes of the population or the mode when the results of the entire class are combined? At this time do you wish to make any further modifications of your conclusions concerning either the size or the definition of an adequate sample?

Follow-Up:

Have you ever seen a newspaper article based on an opinion poll? Sometimes these have to do with an election, or with a national issue of some kind. How do you suppose those who conduct opinion polls determine what makes an adequate sample? What things in addition to the size of the sample do they have to consider? How accurate are their results?

As you measured the lima beans, did you notice any kinds of variation other than the length of the beans? How about the width of the beans? The thickness of the beans? If you were to weigh all of the seeds in each of your size classes, do you think there might be a normal curve of differend weights within the same size class? Try this and see, using a simple balance that measures weight in grams and fractions of grams.

What about other kinds of seeds? Fruits? Leaves? What about various kinds of common animals? What about humans? Is the kind of variation that you have found in lima beans, found also in all forms of life? Could you make normal distribution curves for variation in other living things? Try it in cases where you can get a large enough population to make an adequate sample.

What about variation in non-living things in nature? Grains of sand? Snow flakes? Crystals? What about variations in the things that man has made? Cars of the same make? Television sets of the same brand? Washing machines? Pencils? Pens? How does variation in the things that man has made differ from variation in living nature? In non-living nature? Why?

How is variation among living things related to survival in nature? What would be the equivalent of "survival" in the case of man-made things? Can "survival" in man-made things be related in any way to "variation" in man-made things? How?

LABORATORY EXPERIENCE D.1.b.

Measuring Leaves

Introduction:

There is no part or organ of any species of animal or plant that does not show variation when it is carefully examined. For example, in our minds we have a kind of generalized picture or concept, of a human nose. If one of us were asked to draw a picture of a nose, he could possibly draw something that would pass for a nose. If we were to examine human noses carefully, however, we would find almost a limitless variety of sizes and shapes. It would probably be possible to classify noses into certain types, but there would be many that would show characteristics of more than one type, or would not fit into any type. How many different kinds of noses can you see among the members of your class?

It is the same with leaves. Of course every kind of tree has a special kind of leaves characteristic of it. But if you examine a large sample of leaves from the same kind of tree, even from the same individual tree, you will find a wide range of variation. You can pick out a great many variations in appearance by simply looking at the leaves carefully. Your study can be quantified, however, by deciding on certain measurements, making them in the same way on all the leaves, and recording the data.

Materials and Equipment:

100 leaves from any particular kind of tree or shrub

Millimeter rule

Graph paper

Collecting Data:

Measure the greatest length and the greatest width of each of the 100 leaves. Record the data on two graphs, one for length and one for width. What is the mode of the length curve? What is the mode of the width curve?

Calculate the average length of the leaves by adding all the lengths, and then dividing by the total number of leaves measured. Do the same for the average width. The average is called the mean. How does the mean length compare with the modal length? How does the mean width compare with the modal width? Which do you think would give the better generalized description of the leaf, the modes for length and width, or the means for length and width?

Which shows the greater range of variation, leaf length or leaf width?

If you collected your leaves yourself, do you think that the 100 leaves were an adequate sample of all of the leaves on the plant? If all members of the class, either working alone or as teams, used leaves from the same kind of tree, you can arrive at an answer to the above question. Combine all of the measurements for the entire class into a single "population." Make graphs for length and width from the measurements of this total group. How do your original length and width graphs compare with the graphs for this larger

"population?" How do the modes compare? The averages? The extremes (the longest and shortest measurements for both length and width)? On the basis of this comparison, do you think your 100 leaves were an adequate sample? Why or why not?

Follow-Up:

Write down all of the variations (not quantified) which you are able to discover by just looking carefully at the leaves. Be as detailed and explicit as you can be. Combine your results with those of other members of the class, so that you have as large a list of characteristics as possible.

Now write a generalized description of the leaves of the particular species of tree or shrub with which you have been working. Include characteristics which you discovered by just looking at the leaves, and the range of variation in these characteristics. Include also the measurements that you made (length and width), range of variation, and mean or mode, whichever you think gives the better description. Try to describe the leaves in such a way that a person who had never seen the leaves, but had read your description, could recognize the leaves on the tree.

LABORATORY EXPERIENCE D.1.c.

The Success of a Species Depends on Its Variability

Introduction:

Among humans two children born at the same time, twins, may appear to be almost exactly alike. Such children are called identical twins. They are always the same sex, both boys or both girls. They have identical heredity, because they develop from the same fertilized cell. They seem to be "as alike as two peas in apod." Even with them, however, the environment in which they develop may cause slight differences.

Other twins have differing heredity because they develop from two separate fertilized cells. They are not any more alike than any other two children in the same family. They may even be of different sexes, a boy and a girl, rather than both boys or both girls. Whether they are the same sex, or different sexes, the environment may make them very different. Such twins are called fraternal twins.

Children who belong to the same family are generally more alike than children from different families. It is easy to tell them apart, however, because of their differences. The children in a particular class at school, a seventh or eighth grade class, for example, are all nearly the same age. They show many differences, however. There are more differences among them than among children of the same family. This is true, even though brothers and sisters in a family are different ages.

You can study variations among people by observing the differences between the members of your own class at school.

Materials and Equipment:

Class of students, all approximately the same age

Yardstick or meter stick for measuring height

Bathroom scale for measuring weight

Graph paper

Collecting Data:

List as many kinds of differences as you can (other than sex) which you can observe among members of your class. Some examples of the kinds of differences that you may think of are height, weight, color of hair, color of eyes, color of skin, curly or straight hair----List others in addition to these. You can do this best as a group. Your teacher can write the kinds of differences on the chalk board as you think of them. The differences which you list are those that appear in every group of people.

Which of the differences that you have listed can be measured? Note: A scientist would say, "which of the kinds of differences can be quantified?" He would mean, which ones can be expressed as quantities. Can you express curliness of hair in terms of quantity?

The two kinds of differences that can be most easily quantified are height and weight. Use a yardstick or a meter stick and a bathroom scale, and measure and record the height and weight of each student in the class. In doing this you may still work as a class size group, or you may break up into teams, and combine your results when you are finished.

Construct two graphs, one showing the heights of all the students in the class, and the other showing the weights. Do the heights and weights each form a normal curve. If they do not form normal curves, what kind of curves do they form? Are any warping factors at work? If so, what do you think they are?

Do the heights and weights of the boys in the class fall in different parts of the curves from the girls, or do they overlap, or are they all mixed together? Using other sheets of graph paper, construct separate graphs for the boys' heights and the girls' heights, and for the boys' weights and the girls' weights. Compare the curves. Does each form a normal curve? Are any warping factors at work for the boys only, or for the girls only? If so, what do you think they are? Is sex a warping factor?

Do you think that your class-size sample was large enough to give a good normal curve? Answer this question on the basis of your findings with the lima beans in your earlier laboratory experience. If you think your sample was not large enough, how many classes like yours do you think you should have measured in order to get an adequate sample?

Follow-Up:

A difference which has nothing to do with appearance, but which can readily be quantified, is the rate of the heart beat. For this you will need a watch with a second hand. Count the heart rates of all members of the class. Is there a normal curve? Separate the data for boys and girls. Do you get two normal curves? Do they overlap, or are the data all mixed together? How are the curves for boys and girls related to one another?

See if you can think of ways of measuring (quantifying) some of the other differences that you observed, which could not be measured with a bathroom scale or a yardstick. Maybe you cannot think of any way to measure these, but possibly you can. In any case it is interesting to try to do so.

Try measuring some of these differences if you can think of ways to do so. Will the expression of these differences tend to follow a normal curve type of distribution if they can be measured? Think of various kinds of differences that have nothing to do with peoples' appearance. Can these be measured? If they can, do they follow a normal curve type of distribution?

Try to answer these questions, whether or not you are actually able to do the quantification. What is the basis for your answer in each case?

LABORATORY EXPERIENCE D.1.d.

Which Way Does The Wind Blow?

Introduction:

People who live on farms and others who work outdoors are conscious of the direction and force of the wind. People who live in cities and work in schools, offices, and factories are less likely to notice the wind. They seldom pay attention to it except when it reaches gale proportions, or drives rain, or drifts snow. They think of it blowing in other places when they see television news reports of the effects of a hurricane in Florida or Texas.

Actually, the wind blows nearly all the time. There are periods of time completely without wind, but they usually do not last very long. Even on a calm day, there is usually a breeze which you can feel if you are out in the open.

It is possible, by carefully observing and keeping records, to learn some of the things that affect the behavior of the wind. It also helps to study weather patterns which are shown in television weather reports and weather maps in daily newspapers. These show continental weather. Weather may be related also to local geographic features, such as rivers and lakes, or nearness to the ocean.

Materials and Equipment:

Weather vane mounted in a location where the wind can reach it freely from all directions.

Note: This may be either purchased or constructed. The material from which it is made should be light enough, and it should be mounted in such a way that the slightest breeze will cause it to turn, and to point in the direction from which the wind is blowing.

Compass for checking wind directions

Daily newspaper that publishes weather maps

Collecting Data:

Observe the direction of the wind, as shown by the weather vane, at 10:00, 11:00, 12:00, 1:00, 2:00 and 3:00 on Monday, Tuesday, Wednesday, Thursday, and Friday, for a month. Check the direction with the compass each time.

Summarize the results of your observations in the form of a series of six graphs, one for each of the hours of the day when you have made observations.

Let the horizontal axis of each graph represent the points of the compass. Start on the left side of the graph and list the points of the compass from left to right: east, southeast, south, southwest, west, northwest, north, northeast.

Let the vertical axis of each graph represent the number of days the wind was blowing from each direction at each hour of observation. Your series of six graphs will then constitute a summary of the behavior of the wind through the days for a period of a month.

Number of days

(at 10:00 A.M., for example)

Points of the compass (listed clockwise)

E ____________

From what direction did the wind blow most frequently? Least frequently? Were there any warping factors at work which influenced wind direction? If there weren't any warping factors, would you expect, on the basis of pure chance, that the wind at any particular time of day, would be as likely to blow from one direction as another? Would this result in a normal curve? Or would it result in an equal number of readings from each point of the compass?

If there were any warping factors, the result would be some kind of a pattern. This might be a normal curve. Would it have to be a normal curve? What other kind(s) of pattern might it be? Why? What kind of pattern was it? What kind(s) of warping factor(s) do you think may have produced it. See if you can find out or figure out.

See if you can relate your graphs showing the behavior of the wind during the month to weather reports on radio and television. To daily weather forecasts and weather maps in newspapers.

Keep a record of weather each day during the month, so that you can study it later in connection with the graphs. Do you think there may be a relationship to local geography (nearness to large lakes, rivers, the oceans, or mountains)? Do you think there may be a relationship to season of the year?

How much shifting in wind direction generally takes place in a single day? To what extent do days differ in this regard? Why? How slowly or how rapidly do shifts in wind direction take place?

Follow-Up:

What about velocity of the wind? This is measured by means of an instrument called an anemometer. If one of these instruments is available, use it to study wind velocity. If not, possibly you can watch for reports of wind velocity on local television. How does wind velocity rise and diminish? Slowly or suddenly? What causes wind?

Continue your study of weather. Learn about <u>cold fronts</u>, <u>warm fronts</u>, and <u>stationary fronts</u>. How are they related to local weather? Learn about <u>continental air masses</u>. How do they behave in different seasons? How are they related to local weather? How are winds related to rain, snow, and fog? What are tornadoes and hurricanes? What is the basis for monthly long-range weather forecasts? How do weather observation satellites help in studying the weather?

Idea of Gradients: Directional Variation D.2.

Idea Bridge: Variation Can Be Continuous

On a particular day in April, a television news report showed the cherry trees in bloom in Washington, D.C., and at the same time a group of visiting senators wading through snow drifts in Nome, Alaska. Strawberries from Mexico and southern Texas begin appearing in the markets in March. They are ripe in Arkansas in April, in Missouri in May, in Southern Michigan in June, and in Minnesota in July. Thus strawberries ripen later as go northward.

Temperatures in the northern hemisphere generally decrease as you go north, or as you go up a mountainside or as you go up in the air. The rate of decrease, generally, is related directly to how far north you go, or how far up you go. It is generally hot in the tropics, but there is always snow and ice in the arctic, and on the tops of high mountains. In these cases we say that temperature decreases in terms of a gradient. Gradient is a term that means a gradual but steady variation in a particular direction.

If you take the temperature on a clear day in summer, every thirty minutes from sunrise until noon, and record the temperatures on a graph, you have a picture of a temperature gradient. A gradient expressed in the form of a graph is a two-dimensional model of this kind of variation.

LABORATORY EXPERIENCE D.2.a.

Gradients in Color

Introduction:

If you compare an elephant and a whale, which one is big? Which is small? What about an elephant and a St. Bernard dog? What happened to your "small" elephant when you made the second comparison? What about a St. Bernard dog and a terrier dog? What about a terrier and a cat? A cat and a mouse? A mouse and a fly? Do the words "small" and "big" describe the sizes of objects very well? Why or why not?

Scientists use a special word for comparing things that go from small to big along with all the "in between" sizes. They use the word gradient. From flies to whales there is a gradient of size. There is also a gradient of size in the height of the students in your class. There is another gradient in their weights, and still another in their foot sizes. When you walk out into a lake you experience a gradient of depth. When you climb a hill you go through a gradient of height. There are many other kinds of gradients.

In this laboratory experience you will make a gradient of color.

Materials and Equipment:

Yellow paint

Red paint

Small jars or other containers for paint

Drawing paper

Small paint brushes

Collecting Data:

Paint a band of yellow at one end of a piece of drawing paper. Add three drops of red paint to the jar of yellow. Stir thoroughly. Paint another band on the paper that just touches the edge of the first band. Add three more drops of red paint; stir again, and paint a third band just touching the edge of the second. Continue adding red paint, three drops at a time and painting bands of color. When your paper is full, you have a gradient of color.

How is this like the gradient of size in animals? Can you make other gradients of color? What colors would you use? Are there any gradients of color in nature? What are some examples?

Follow-Up:

Make a gradient of hair color, using specimens of hair from students in the class. Are there any "red heads" in the class? How do they fit into the picture? Are they a part of the gradient? Why or why not?

Make a gradient of skin color by lining up students. This will be more interesting if there are Negroes in the class. Are Negroes really black? Are Caucasians really white? Where do Indians, Spanish-Americans and Orientals (Chinese and Japanese) fit into the skin color gradient? Would there be any difference in the gradient if you arranged the students in the summer or the winter? Why?

What accounts for differences in skin color? What are pigments? What pigments are present in humans? Read about carotene, melanin, and rhodopsin. Where is carotene found besides in human skin? What is an albino? Why do albinos occur? Are they limited to any particular race? Where would an albino fit into your skin color gradient?

LABORATORY EXPERIENCE D.2.b.

Gradients of Taste

Introduction:

Gradients of size and color are observed by using your sense of sight. Sometimes it is interesting and important to use other senses for observation. This laboratory experience will enable you to use your sense of taste. We will also use a simple laboratory device to help you see a gradient that you can also taste. Scientists use instruments as aids to their senses and also as extensions of their senses.

Materials and Equipment:

Test tubes or baby food jars

Sugar

Medicine dropper

Salt

Lemon juice

pH paper

Set of measuring spoons, $\frac{1}{4}$, $\frac{1}{2}$, 1 teaspoonful

Wax pencil

Collecting Data:

Put nine test tubes or small jars (all the same size) in a continuous row. Label them #1 through #9. Put the same amount of water in each. Then prepare them as follows:

Add nothing to #1

Add $\frac{1}{4}$ teaspoonful of sugar to #2

Add $\frac{1}{2}$ teaspoonful to #3

Add 3/4 teaspoonful (1/2 + 1/4) to #4

Add 1 teaspoonful to #5

Add $1\frac{1}{4}$ teaspoonful to #6

Add $1\frac{1}{2}$ teaspoonful to #7

Add 1 3/4 teaspoonful to #8

Add 2 teaspoonfuls to #9

Stir to make sure that the sugar is dissolved.

Now put a few drops of the solution from the different containers on your tongue. Compare #1 and #9, #2 and #9, #5 and #9, #8 and #9. Why is it easier to compare #1 and #9, or #2 and #9, than #8 and #9, or even #5 and #9?

Empty the test tubes or jars. Wash them well. Repeat the above experience using salt instead of sugar. Is your tongue better at detecting saltiness than sweetness? Have your partner give you the drops to taste without keeping them in the proper order. How well can you tell where on the gradient a particular drop belongs? Can you do so?

For another gradient use drops of lemon juice in water. Follow the same procedure as you did with the sugar and the salt. After you have completed the tasting part of this experience, put a piece of pH paper in each container. Compare its color with the scale on the box. Mark the pH number on each container. This is a gradient of sourness. Does the pH make it easier to recognize the degree of sourness than by using your tongue? Why or why not? What does pH mean?

Follow-Up:

There are many other gradients that you could make, using kitchen materials and water. How could you make a gradient of bitterness? (the basic tastes that we are able to recognize are sweet, salt, sour, and bitter.) Could you make a recognizable gradient of thickness by using a mixture of flour and water? A gradient of color by using food coloring? Think of others and try them.

LABORATORY EXPERIENCE D.2.c.

A Gradient in Heating Water

Introduction:

We work with gradients all the time. If you fill a vessel with water you are creating a gradient of increasing volume. If you walk upstairs you are doing work against a gradient of increasing height. It would be easy to think of many others.

In this laboratory experience you will be creating a gradient of increasing temperature by carrying on a very simple activity: heating water and causing it to boil.

Materials and Equipment:

Vessel for boiling water (beaker or pan)

Source of heat (hot plate or bunsen burner)

Thermometer that will register temperature of 100°C or 212°F

Graph paper

Watch or clock for timing

Collecting Data:

Start with water at room temperature or lower. Record the starting temperature. Make a graph. Let the horizontal axis of the graph represent time, and the vertical axis represent temperature.

Heat the water over a bunsen burner or on a hot plate. Record the temperatures taken at one minute intervals. Represent each temperature with a dot on the graph. Continue until the water is actively boiling.

Connect the dots on the graph with a line. Describe the line. What does it look like? If you did this with containers of water of different volume, would the line look the same? Try it with containers of several different volumes and see. Try to account for any differences you may find.

Follow-Up:

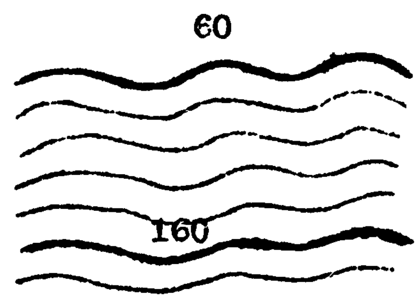
What happens if you continue to heat the water after it reaches the boiling point? Why? What really happens when a liquid boils? What happens when a liquid freezes? Do liquids other than water behave differently? What about mercury? What about alcohol? What are boiling points and freezing points? What about gases like oxygen? What about solids like iron? Could gradients be set up in all cases? Why, or why not?

LABORATORY EXPERIENCE D.2.d.

Gradients from a Topographical Map

Introduction:

A topographical map is a map showing changes in elevation. When you first look at a map of this kind you observe a lot of "squiggly" brown lines that make it different from the maps you usually use. These lines connect points of the same elevation above sea level. They are called contour lines. You will notice that every fifth contour line is darker than the others, and is numbered (like this):



These lines are one way of drawing a gradient on a flat surface. You will find a scale at the bottom of the map with this information:

Contour interval ----feet

It may say 10, 20, 30, 50 feet, depending on the map you are using. The contour interval is the difference in elevation between any two brown lines. In the illustration above the darkened lines show a difference in elevation of 100 feet, and the contour interval is 20 feet.

In this laboratory experience you will find the gradient of a stream, and the gradient of a hill or mountain.

Equipment and Materials:

Topographic maps (Each contour map covers an area called a quadrangle)

String

Magnifying glass (for counting contour lines)

Ordinary physical maps

Raised physical maps (relief maps)

Collecting Data:

Find a stream of water on the map. This will be marked with a blue line or band. Use the string to follow the curves of the stream. Follow it as closely as you can. Find its length in this way. Use the scale of miles at the bottom of the map to determine the actual length of the stream in miles. If the scale says:

Scale 1:62500*

you may use one inch of your string to equal one mile. Measure the length

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*There are approximately 62,500 inches in a mile. How many feet are there in a mile? Check the exact number of inches in a mile for yourself.

of the stream on the map with your string three times and then average your measurements. It is easy to make a mistake with the string in attempting to follow the curves.

Now find the difference in elevation of the stream from the beginning of the portion you measured to its end. Remember that only a portion of the entire length of the stream will appear on any one contour map. Use the magnifier, if necessary, to count the contour lines and read the numbers on each fifth line. Subtract to get the difference in elevation.

Use the following formula (mathematical model) for finding the gradient of the stream:

$$\frac{\text{difference in elevation in feet}}{\text{distance in miles}} = \text{gradient in feet per mile}$$

Why do some streams flow more rapidly than others? Why do mountain streams flow rapidly? Why are cultivated fields on hillsides more likely to be damaged by erosion than those in valleys?

Find a place on the map where the brown lines are close together. Use a topographical map of a mountainous area if one is available. Again use the scale of miles to find the distance, and the contour interval to find the difference in elevation. Use the formula given above to compute the gradient of the hill or mountain. What conclusion can you reach about the relation of the closeness of the contour lines and the steepness of the gradient on the side of the hill or mountain?

Compare a contour map of a quadrangle in a level area, and one in a mountainous area. Observe particularly the differences in closeness and regularity of the contour lines. Why is there a difference in regularity of the lines?

Follow-Up:

Compare topographic maps with ordinary physical maps. What are the advantages of each? The disadvantages? When would you use each? What kinds of information do highway maps show that ordinary maps do not show?

Find out how to draw a profile of a region by using a topographic map. What is a profile? When you use feet of elevation per mile of distance on a topographic map, the elevation is greatly exaggerated. Is this true on a raised physical map (relief map)? Why or why not?

Idea Of Extrapolation And Interpolation:

Predicting From a Gradient D.3.

Idea Bridge: Judging the Future by the Past

If the temperature during a particular summer day has risen five degrees each hour from 6:00 a.m. till 11:00 a.m., it is reasonable to expect that it will rise five more degrees between 11:00 and 12:00. If you have used the temperature data between 6:00 and 11:00 to construct a graph, you have a gradient. When you predict another two degree rise between 11:00 and 12:00, you are really extending the graph. You are using it for prediction. This is called extrapolation.

Interpolation is related to extrapolation. It consists of "filling in the gaps" between data that we have, rather than projecting forward from data that we have. For example, if we knew that the temperature at 6:00 was 70 degrees, and 75 degrees at 7:00, 85 degrees at 9:00, and 90 degrees at 10:00, but we did not know what the temperature was at 8:00, we could reasonably assume that the temperature at 8:00 was 80 degrees. We interpolated the missing temperature, by assuming that the degree of temperature rise was constant.

When we extrapolate or interpolate we are making judgments on the basis of the data that we have. We are projecting, predicting, and filling in. We are assuming that the world is consistent, that it will continue to behave as it has been behaving, or as it has behaved before.

"The only way to judge the future is by the past." " A leopard cannot change his spots." "As the twig is bent ---." "History repeats itself." How many other proverbs and old sayings can you think of that say the same thing? Long before there was any modern science people were trying to look into the future to try to see what it was likely to bring. The only way they could do this was to study the past, project any trends that they found there into the future, and assume that these trends would continue.

If a scientist wishes to estimate what the population of the world will be in 2000, he studies the census figures for the present century, and projects the present rate of population growth forward till the end of the century. If a writer wishes to write a believable science fiction story, he studies the results of scientific research up to the present time, projects present trends forward into the future, and then writes the story as if we were now in the future and the projected discoveries had already taken place.

Scientists themselves do the same thing. Thus, there is serious consideration of artificial hearts and kidneys, replacement of whole organs from organ banks, changing heredity in man and other organisms, weather control, chemical control of human behavior, synthetic food, and simple forms of life produced in the laboratory. All of these are only extrapolations of research that is already well advanced. On the other hand, there is no serious talk of travel backward in time, because there is no basis for the probability of this in any present-day research. And there is no possibility of it by the application of any principles that we know. Here, there is no basis for extrapolation.

A scientist's use of extrapolation is nothing more than the common-sense practice of making reasonable predictions. Everyone does this on the basis of what has happened and what is happening now. A scientist interpolates by filling in the gaps in what he knows with reasonable approximations.

LABORATORY EXPERIENCE D.3.a.

Stacking Coins

Introduction:

A graph is really a picture of a relationship. Sometimes we have to take part of such a picture "on faith." This is really saying that we have to take it on someone else's authority. We all have to take some things on faith in this way, simply because we do not have the time or the means (or both) to check on all of the data ourselves. It is better, however, when we are able to do this job for ourselves. We can be more certain that way.

In this laboratory experience we are able to build a simple gradient, which we can verify by counting and measuring. We can practice extrapolation and interpolation with this gradient. We can draw a graph to make a picture of the gradient. We will do this on the basis of data that we can see and show a relationship that we can see.

Materials and Equipment:

150 pennies

Foot ruler

Graph paper

Collecting Data:

See how many pennies you can pile up one on top of another without the stack toppling over. Record the number. Try it again. Are the results the same? (This is for practice in stacking pennies)

Now stack 10 pennies one on top of another. Mark a fixed point on a piece of paper. Draw a line running to the right of this fixed point. Move the stack of 10 pennies to a point on this line where the left edge of the bottom coin is exactly two inches from the fixed point. Measure the distance on a slope from the fixed point to the left edge of the top coin in the penny stack. Be sure that the pennies are as evenly stacked as possible. What is the distance? Measure as carefully as you can. Record the distance.

If you were to stack 20 pennies, and place the stack so that the left edge of the bottom coin was exactly four inches to the right of the fixed point, what would be the distance from the fixed point to the left edge of the top coin of the 20-penny stack? See if you can figure this out. Then try it and see if you were right on your calculation. Again, be sure that the coins in the stack are evenly piled and make the measurement as carefully as you can.

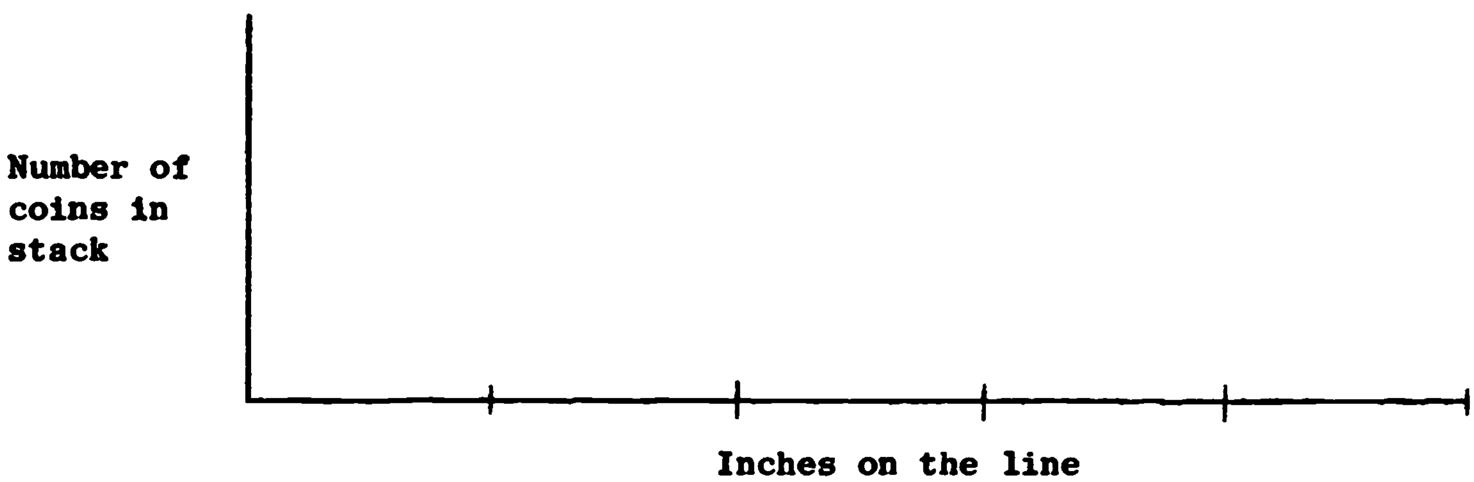
Stack 30 pennies, and do the same thing at a distance of six inches to the right of the fixed point. Is the relationship a constant one? Try it with 40 pennies at eight inches, if you can stack that many. What would be the measurement on the ruler if you were to place a stack of 50 pennies at ten inches? Sixty pennies at twelve inches? One hundred pennies at twenty inches?

Now see if you can figure out how many pennies would be needed to make a stack whose left edge at the top would touch the ruler if the stack were placed at <u>three inches</u> to the right of your fixed point? What would be the measurement where the top coin in the stack touched the ruler? Try it and see if your method of figuring was correct. Try it again at <u>five inches</u>; at <u>seven inches</u>.

In your work with the stacks of pennies, when were you <u>extrapolating</u>? When were you <u>interpolating</u>? How do the stacks of pennies, arranged as you placed them, constitute a <u>gradient</u>?

<u>Follow-Up</u>:

Construct a graph showing the results of your laboratory experience with stacking pennies. Let the <u>horizontal axis</u> of your graph represent the line on the paper beginning at the left with your fixed point. Let the vertical axis of the graph represent the numbers of pennies in the stacks.



Is your graph a true picture of the results of your penny-stacking experience? Could you <u>extrapolate</u> and <u>interpolate</u> from the graph as readily as you did by using the line, the pennies and the ruler?

Would it be possible to predict the number of pennies that it would take to make a stack that would touch the ruler at 49 inches? At 33 and a half inches? At any other desired point?

How is the method used to predict what a particular human population will be in the year 2000 or 2100 related to your penny-stacking operation? How accurate do you think predictions of human population are? On what do they depend?

LABORATORY EXPERIENCE D.3.b.

Extrapolating and Interpolating on a Clock Face

Introduction:

In order to construct a graph you must have data which are stated in terms of quantities. These are obtained by weighing, measuring, counting or some related process. The simplest way of collecting quantified data is by counting.

In the following laboratory experience, you will study a simple relationship through counting. This is a relationship you look at everyday, but probably have not thought of in the sense that it is used here. Ordinarily you use a clock to tell time. Here you will be using a clock to study the relationship of two constant rates of movement.

Materials and Equipment:

Clock having a round face, with an hour hand and a minute hand, and with spaces to represent minutes

Graph paper

Ruler

Collecting Data:

This laboratory experience has no relationship to "time of day." You are not concerned with "what time it is," but rather with the action and relative position of the two hands on the clock face.

Note that the clock face consists of a circle, marked off into 60 spaces of equal length. For purposes of this laboratory experience we will call these spaces "minute spaces." Note also that there are two "hands." The longer one is called the "minute hand," and the shorter one is called the "hour hand." They are both fastened at the center with the outer ends left free. Each hand moves around the circle at a constant rate of speed, the minute hand moving faster than the hour hand.

At regular intervals the minute hand passes directly over the hour hand. How often do they do this? Are the time periods between such "conjunctions" of the hour and minute hands always the same? Why or why not?

Start the experience at any point on the clockface at which the minute hand is exactly above the hour hand. Record this starting position in your notes.

Notice that as the minute hand moves beyond the hour hand, the number of minute spaces between them, starting with zero, increases progressively.

Count the number of minute spaces that lie between them at the following time intervals. Figure fractional spaces to the nearest full minute.

a. After 7 minutes

b. After 13 minutes

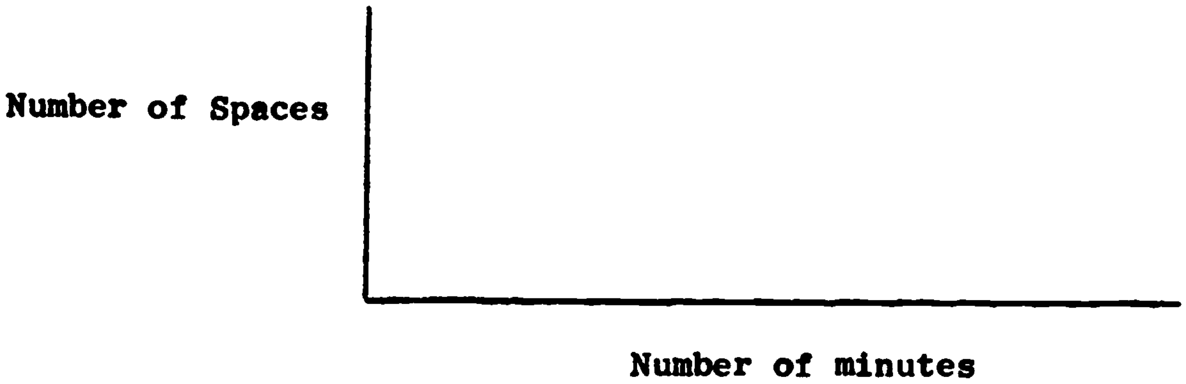
c. After 18 minutes

d. After 32 minutes

e. After 36 minutes

f. After 45 minutes

Record these data on a piece of graph paer. Let the horizontal axis represent the number of minutes that have passed since the beginning of observation. Let the vertical axis represent the number of minute spaces between the hands at each observation.



Draw a line connecting the positions on the graph. Describe the line. What are its characteristics? Why?

By interpolating place a dot at a point indicating the number of spaces by which the hands were separated after 27 minutes. After 41 minutes.

Can you, by extrapolation, indicate the number of spaces by which the hands would be separated after 75 minutes, 89 minutes, 97 minutes, if it were not for the physical limitations of the clock face? Could a clock be made where this continued relationship would be possible? If so, how?

What is the relationship which your graph shows? Is there any reason why this relationship should necessarily be limited to the possibilities of any clock face, or any other physical device?

Follow-Up:

Fasten a yard stick or meter stick in a horizontal position. Suspend a small weight from a string above the middle of the stick. This weight and string are a pendulum. If the pendulum is suspended above the middle of the stick, it is possible to measure the length of each swing of the pendulum.

Start the pendulum swinging. Note and record on a graph the length of the swing at regular intervals (one minute intervals, or longer intervals, but the same length intervals in each case). Do this as the pendulum "runs down." Let the vertical axis of your graph represent length of swing, and

the horizontal axis represent time. After several recordings, extrapolate the line on your graph to the point in time when the pendulum will cease to swing. After doing this, continue your observations, and test the hypothesis based on your extrapolation. Do this several times. How do your different trials compare with one another? Why? Why was it possible to use pendulums in making some old-fashioned clocks?

Would it be possible to make a clock that would mark the passage of days, weeks, months, years, centuries? What difficulties would be encountered if one should attempt to make such a clock? Has such a clock ever been made? How are the difficulties related to those that have been encountered in making calenders? To what are the difficulties due in both cases?

LABORATORY EXPERIENCE D.3.c.

The Growth of Corn Plants

Introduction:

Living things are not always as dependable as non-living things. They do not lend themselves as well to a prediction of their future behavior on the basis of quantified data which have been collected in the past. In studying them we have to make allowance for this, and leave room for exceptions. Sometimes we can figure out the reason for such irregular behavior. Sometimes we cannot do so.

In this laboratory experience we will follow the growth of three corn seedlings. We will collect data on the rate of growth of all three of them. We will compare them and see if there are any differences between them. We will try to see if it is possible to extrapolate future growth. It may or may not be possible to do this.

Materials and Equipment:

3 flower pots, 6" in diameter

Garden soil

Grains of corn

Ruler

Graph paper

Collecting Data:

Fill three flower pots with good garden soil to within an inch of the top. Plant two grains of corn in each pot, about an inch below the surface. Place the pots in good light, preferably in a window having direct sunlight. Keep them warm, and keep the soil moist.

If both grains of corn germinate, destroy the last one to do so. Planting two grains in each pot will insure that you have one corn plant growing in each case.

Keep a record of the growth of each corn plant on a separate sheet of graph paper. Start measuring and recording growth in each case as soon as it is possible to make a measurement of the length of the spike above the ground. The plants in the three pots may not reach this point of measurable growth on the same day. Therefore, you should record the growth of each plant as "Day 1," "Day 2," "Day 3," and so on. In this way the days of growth will be comparable in the three cases, even though the plants may not have all attained measurable growth on the same day. Once measurable growth is reached, you should measure the plants in all three pots at approximately the same time each day.

The corn plant starts growth as a spike which pushes up through the ground. As it grows it unfolds and the leaves spread out. The leaves increase in number and grow in length. When this happens you should gently pull the leaves together and point them upward. Hold them in this position while you measure. Measure from the ground to the tip of the longest leaf or leaves held vertically.

Continue making your measurements as long as you can or wish to do so. After you have measured the plants for a full week (leaving out the days on the weekend) you are in a position to do three things:

1. Interpolate the height of each plant for the days over the weekend or any other days that you have been unable to make measurements.

2. Extrapolate the height of each plant at the end of the week ahead.

3. Compare the growth of the three plants both as to the amount of growth that has taken place, and as to the predicted growth a week ahead. Try to account for any differences that you may find.

At the end of the second week of growth you are in a position to do again the three things listed above,and also to do a fourth thing:

4. Compare the actual growth of each plant during the second week with the prediction which you made by extrapolation at the end of the first week.

Continue, following the same procedure for a third week and a fourth week, if possible. You may continue longer if you wish to do so and can. In the case of each week predict by extrapolation what you think the next weeks' growth will be, and then compare the expected growth with the actual growth at the end of the week.

Is the growth of each corn plant consistent from week to week? Does it grow at the same rate each week? What kind of a line on the graph does its growth follow? Are all three plants the same? Are they comparable? What questions are in your mind at the conclusion of the experience? Can you suggest answers for your questions? Why, or why not?

Follow-Up:

Carry out the same experiment with bean plants. These can easily be grown in the laboratory, following the same methods as corn plants. How do they differ in their manner of growth from corn plants? Does this make them easier or more difficult to study?

How about the growth of a child? Does it take place at the same rate each year? Does it take place at the same rate throughout any particular year? Do all children grow at the same rate? Why, or why not?

LABORATORY EXPERIENCE D.3.d.*

Alternative Hypotheses: An Experience in Extrapolation

Introduction:

All prediction is extrapolation: saying what we think will happen on the basis of what we know. Any hypothesis is a prediction. It is based on extrapolation. What we are saying is "All of the data that we know about can be explained in this way. If or when other data are discovered, they should also fit this explanation." We are extrapolating on the basis of the few data that we have. We are predicting the nature of the additional data that we expect to find.

It is sometimes possible to set forth several alternative hypotheses. (We say, "Any one of these hypotheses might possibly be true.") This is especially likely to happen when the data that we have are extremely limited. In such a case, we continue to look for additional data, and when we find them we see which of the possible hypotheses they fit. If we find that they do fit one of the hypotheses, we not only confirm it, we also eliminate the others.

We have something of this kind in the puzzle-problem that is the basis for this laboratory experience.

Materials and Equipment:

Pencil and paper

Chalkboard and chalk

Ruler

Collecting Data:

Place four dots on a piece of blank paper. Arrange these so that each one is equidistant from the two others that are nearest to it. Arrange the dots in any way (or ways) that you can. Is more than one arrangement possible? All members of the class should participate in arriving at a decision. Put the arrangement(s) on the chalkboard.

Now for the arrangement that you have (or for each arrangement if you have more than one), see how many figures you can draw for which the four dots, arranged as you have them, constitute points on its perimeter or outer boundary. Consider as possibilities square, rectangle, circle, triangle, figure X, figure 8, and any others. Put all figures on the chalkboard, showing the four dots in the outer boundary of each one. How many figures are you able to make? Again, all members of the class should participate in the decision.

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*This laboratory experience is based in part on " A Demonstration of the Use of Alternative Hypotheses," by Charles H. Coleman in School Science and Mathematics 66:81-85, January 1966.

Your four dots are four bits of data in the solution of a problem, or a series of related problems. Each figure constitutes a hypothesis. Each one sets forth a possible solution to the problem. If future data in the form of additional dots fit the hypothesis, then it is correct. In the case of each of these figures we assume that all future dots will fit into the perimeter of the figure. They will add to the four that you already have, and serve to further outline the figure.

When you predict the existence of additional dots beyond your original four, you are extrapolating on the basis of the data that you have. In the case of each figure, a limited number of additional dots will serve to define the figure. They will outline it to a sufficient extent that you can be certain of its shape.

In the case of each figure that you have drawn with the four original dots in its perimeter, extrapolate a sufficient number of additional dots to define the figure. Do not put in any more dots than are necessary to define it. How many additional dots are necessary in each case? Is the number the same in all cases? Remember that there must be enough dots so that some of them cannot lie in the perimeter of any of the other figures, other than the one in which you have included them.

Are there any of the new dots that can be in the perimeters of more than one of the figures? If so, you may use them, but you must use others in addition to these to define each of the figures.

Follow-Up:

If, through research, you were to discover that only those additional data which serve to define one of the figures actually existed, what would that do to the hypothesis represented by that particular figure? What would it do to the hypotheses represented by the other figures? In this case, how would the procedure which you followed in your hypothesis making, and your later research in discovering the additional dots, be comparable to the procedure a scientist uses in solving a problem?

How was your procedure in postulating additional dots in the case of each figure an example of interpolation as well as extrapolation. To what extent do extrapolation and interpolation constitute specialized aspects of the same process?

Idea of Directional Change:

A Gradient in Relation to Time D.4.

Idea Bridge: Response to the Challenge of the Environment

All gradients are the result of variation or change in a particular direction. However, there are two special kinds of directional change. One of these is the change that we call evolution. This is the kind of change that things go through with he passage of time. The other is cyclic change. This is change that repeats itself over and over again. We will examine the Idea of Cyclic Change in the next unit. We will examine evolutionary change in this unit.

Evolution is most easily seen in the case of the things that man makes and uses(automobiles, airplanes, weapons, household devices, clothing, language). It is easy to use automobiles as an example of this kind of evolution because we all know about them. If the inventions and innovations that are shown on the new models each year are really improvements, if they "work" better than what was used before, then they survive and are put on models in the years that follow. If they do not "work", or if they "work" less well, they do not appear on the models that are shown the following year. Television sets, washing machines, and other things that people use follow the same pattern.

Evolution of language and clothing take place similarly. New words are invented, and new ways of saying things. If they meet a need and people accept them, they become a permanent part of the language. If they do not meet a need, people soon quit using them. Most "slang" is used only for a little whilte, and then disappears. It does not survive and does not become a permanent part of the language.

New kinds of material, new colors, new styles, and variations in the form of garments for men, women, and children are constantly being thought up. If these "work", if they meet a need, if they last longer, or are prettier, or for any other reason are thought desirable, they continue to be used. They become a permanent part of the available range of clothing that people buy and wear. If they do not "work," or "work" less well, or are thought less desirable compared to what people have been accustomed to, they soon disappear from the market.

Evolutionary change takes place in species of plants and animals over long periods of time. It results from the interaction of two things which scientists have found to be general properties or behaviors of nature. Scientists have leanred (1) that nature shows variation and change, and (2) that in nature that which "works" survives, while that which does not "work," or "works" less well is eliminated. If you put these two characteristics together you have "survival of the fittest", or at least "elimination of the least fit."

We know that living things, plants and animals, including humans, show a wide range of variation. Sometimes these variations are advantageous. Sometimes they are less advantageous. Sometimes they are even harmful. Sometimes they are not even survivable.

The matter of whether or not living things survive is dependent on their environment. And the environment does not stay the same. When we say that living things do or do not survive we are thinking of tnem in relation to their environment.

The environment not only changes; it usually changes in a particular direction, toward hotter, colder, wetter, drier, or in terms of some other physical factor. Sometimes these changes are sudden---too sudden for living things to adjust to them. Usually, however, the changes take place slowly, and living things are able to adjust---throuch directional change or evolution.

We can summarize the whole picture of the evolution of living things as follows:

1. Living things show variation.

2. Environment affects the survival of living things.

3. Living things that are adjusted to the environment survive. Those that are not adjusted to the environment do not survive.

4. The living things that survive are likely to reproduce other living things that possess the same characteristics that they have.

5. Environment changes in a certain direction.

6. Living things continue to show variation as the environment changes.

7. The variants that can live in each new environment survive and reproduce. The variants that cannot live in the new environment are eliminated.

8. If the environment continues to change in the same direction, the species changes slowly in the direction of adaptation to the changing environment.

In the following laboratory experiences, we will examine various examples and models of variation and survival.

LABORATORY EXPERIENCE D.4.a.

Natural Selection in the Animal Kingdom

Introduction:

Living things record their own history in fossil remains. Louis Agassiz, a famous naturalist of the nineteenth century, said, "the earth is a vast cemetery. The rocks are tombstones on which the buried dead have written their own epitaphs." Scientists who study the record of the rocks are called paleontologists. They learn about life of long ago by studying the fossil remains of animals and plants that have lived during the millions of years since life began. Paleontologists depend on a law of science called the Law of Superposition.

This states that in a sequence of undisturbed sedimentary rocks (rocks that are formed by the lithification* of sediments deposited in water---See Laboratory Experience D.5.e., The Rock Cycle) the younger rocks must always lie on top of the older rocks. How might it be possible for rock layers to be disturbed so that older rocks were on top of younger ones? How could the younger layers get on top? If the top layer consists of lava, would you expect to find fossils in it? Why, or why not?

Since fossils are usually found in sedimentary rocks, paleontologists study the fossils in each stratum (layer) in order to better understand directional change (evolution) of animal life.

Materials and Equipment:

Earth science textbooks written for the junior high school level

Popular books on fossils, such as Golden Book of Fossils, Fossils (by Fenton and Fenton), All About Dinosaurs, All About Animals of Long Ago

A fossil collection in a museum, if available

Collecting Data:

Paleontologists have studied strata of sedimentary rocks in the cores that are brought up when oil wells are drilled. They have studied rock strata in the Grand Canyon and other places where rivers have cut down through different layers of rock. They have studied excavations made for roads, dams, and mine shafts where these have penetrated rock strata.

Each time when they have examined undisturbed strata of sedimentary rock, they have found that the lowest layers (oldest) contain fossils of simple animals. As they examined layers nearer to the surface they have found that these contain fossils of more complex animals. On the basis of this evidence paleontologists have developed geologic time scales. These vary slightly, but all of them are essentially like the one included here:

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*Lithification means "turning to stone"

ERA	PERIOD	EPOCH	LIFE FORMS
Cenozoic	Quarternary	Recent	Modern man
		Pleistocene	First primitive man
	Tertiary	Pliocene	Ancestors of man
		Miocene	Ancestors of man
		Oligocene	
		Eocene	Eohippus (first horse)
		Paleocene	
Mesozoic	Cretaceous		Dinosaurs extinct
	Jurassic		First birds, dinosaurs
	Triassic		First mammals, dinosaurs
Paleozoic	Permian		Trilobites extinct
	Pennsylvanian		First reptiles
	Mississippian		
	Devonian		First amphibians, first insects
	Silurian		First land animals (spiders, scorpions)
	Ordovician		First fishes, (vertebrates)
	Cambrian		Many marine invertebrates, first molluscs, graptolites
Proterozóic			First trilobites, brachiopods, marine worms, corals, sponges, jellyfish, first echinoderms
Archeozoic			Primitive trilobites, marine worms, sponges, jellyfishe

Read a geologic time scale from the bottom up, rather than from the top down in the way you usually read a page. Why?

Study this and other geologic time charts that you can find. Notice the gradual change in animals from simple forms at the bottom, to more complex forms at the top. What does this tell you? Why? What animals would be more simple than jellyfish? Why is it difficult to find fossil evidence of their existence? What about hard body parts like shells or bones? What about size?

Some scientists think that every presently known phylum (major group) of animals was in existence in Pre-Cambrian (Proterozoic) time. They believe that it is only species that have become extinct as new species developed. Can you find any evidence for or against this belief in the geologic time scale?

Can you find any evidence that a new phylum appeared? When did vertebrates develop? Read about the emergence and extinction of trilobites. What were they? To what phylum did they belong? Do we have any trilobites now? Do we have any near relatives of them? Is this evidence that a major group of animals (phylum or class) ever became extinct?

Read about the emergence and extinction of dinosaurs. To what phylum and class did they belong? Find out when certain kinds such as brontosaurus, stegosaurus, pterosaurus, pleiosaurus, and tyrannosaurus emerged, was dominant, and then became extinct. What are some hypotheses that have been proposed to explain their extinction?

Read about the development of Equus (the modern horse) from Eohippus (the dawn horse). What stages were there in between? What changes occurred in the body structure of the horse? Why?

Read about the little brachiopod called lingula. Why is it an interesting member of this phylum of animals?

Graptolites are other interesting fossil remains. These puzzled scientists for many years. Why were they called graptolites? What hypotheses have been proposed to explain their extinction?

The phylum of echinoderms includes crinoids, asteroids, echinoids and holothurians which still live in the sea today. What are the common names of these? Cystoids and blastoids are kinds of echinoderms that are now extinct. Scientists have found fossils of all of these except holothurians in rocks from 500,000,000 years ago to the present. Why have they had such a long period of existence? Why have holothurians left no fossils in the rocks?

Another interesting story is the development of insects. There were very large insects during Pennsylvanian time. At present insects are better known for their number of species (600,000) than for their size. Why? Read about insects preserved in amber. What is amber, and how did insects get into it?

Follow-Up:

Collect some fossils and identify them as to phylum and class. If possible find out the age of the rock in which they are found.

Look up the stories of the development of different kinds of mammals (elephants, camels, marsupials and others) and share them with your classmates.

Discuss the factors that scientists believe lead to the development of new species: isolation, mutation, and interbreeding of sub-species. Are these operating now?

Find out what animals have become extinct in the last century. Why has this happened? Which ones are threatened with extinction now? Why?

Learn the relationship of the different levels of classification: phylum, class, order, family, genus, and species. Find familiar groups that are examples of each of these classification levels. What does a scientific name consist of?

LABORATORY EXPERIENCE D.4.b.

Variation in Feet and Hands

Introduction:

Everyone is aware of differences in shoe sizes. They are a standardized way of expressing variations in the size and shape of peoples' feet. Even so, they do not take into account many individual variations. Do you have any difficulty getting fitted in shoes? Do you have difficulty wearing certain styles of shoes? Are both of your feet alike? Do you know anyone who has "foot trouble" because of not being able to get shoes to fit? Do you know of anyone who has to have shoes made special to fit them?

Many of the characteristics of people's feet can be expressed in terms of the ratios of certain measurements to one another. In terms of variation within a population, these characteristics can be expressed in the form of graphs and scattergrams. You have made and used graphs many times before. Scattergrams are related to graphs. We will see how they are made and how they are used to express relationships in this laboratory experience.

All you need to do to study foot characteristics is make and record a series of measurements on a group of people of approximately the same age. Would it be a good thing to consider the measurements of boys' and girls' feet separately? Try to find an answer to this question as you go along.

With slight changes in the way you carry on the problem you can study variations in hands as well as those in feet, or instead of them. You will find both feet and hands about equally variable.

Materials and Equipment:

18 inch rule cut from a yardstick

The remainder of the yardstick, cut into two 9 inch lengths

Steel carpenter's tape

Graph paper

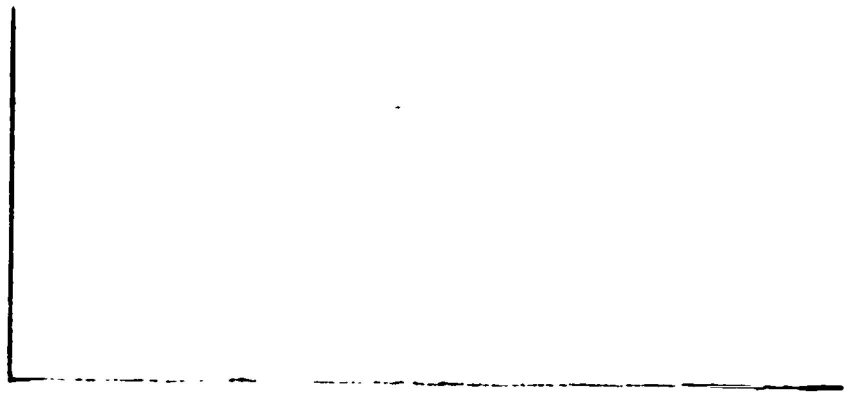
A group of people of comparable age (such as a class of about 30 individuals)

Collecting Data:

You should work in pairs, each making measurements on the other, and checking each other in recording data.

Measure the length of the right foot, to the nearest half-inch, from the heel to the tip of the big toe. Do this by placing the foot on the 18-inch rule, and setting one of the 9-inch rules at right angles to the 18-inch rule snugly behind the heel, and the other snugly in front of the big toe. Collect the foot lengths of all members of the group and construct a graph showing the range of variation in foot length in the group:

Number of
Individuals



Foot length (half inches)

Do the boys tend to be in one part of the range, and the girls in another? You may represent this by making three distributions on your graph, one to include boys only, one girls only, and one the entire group. You may use red and black lines to represent boys and girls, and a third color for the line representing the entire group.

Measure the left foot and see if it is the same as the right. What is the relationship between foot length to size of shoe worn? Is the relationship the same for men's sizes and women's sizes? For children's sizes and adult sizes?

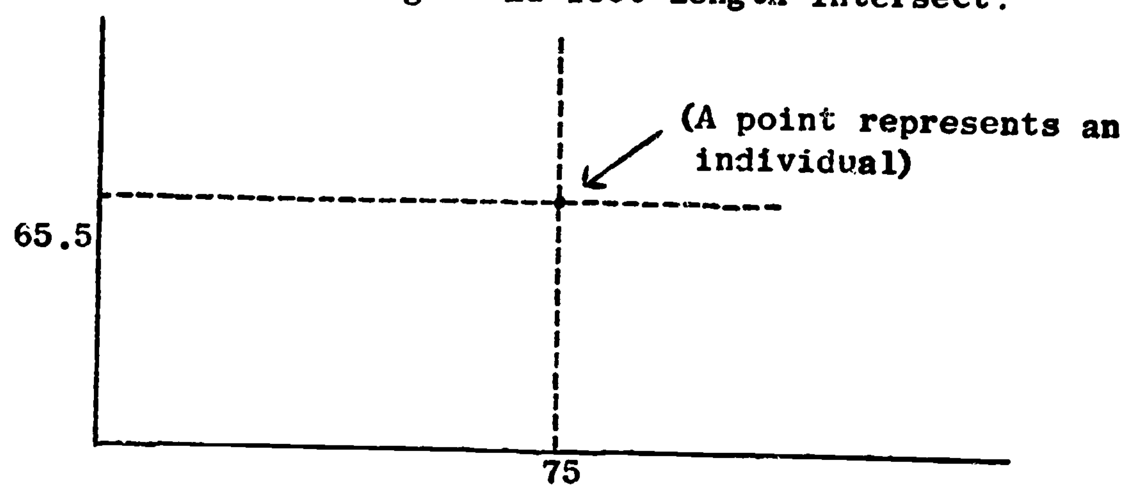
Now measure the height of each individual to the nearest half-inch. Use the carpenter's tape. Set up a ratio for each individual.

Length of foot in half-inches: Height in half-inches
(for example: 7.5:65.5)

Compare the ratios for all members of the group. Is there a consistent relationship between height and length of feet? Do tall people always have bigger feet? Do short people always have smaller feet?

You can study the relationship of foot length to height for the entire group by constructing a scattergram. Do this in the same way that you constructed the graph showing distribution of foot length, except that in this case the horizontal axis of the graph shows foot length, and the vertical axis shows height. Each individual in the group is represented by a dot at the point where the lines for his height and foot length intersect:

Height (in
half inches)



Foot length (in half-inches)

In plotting the entire group in this way, if two individuals have identical foot length and height, and thus have to be represented by the same point, this can be shown by placing a small (2) near the point. In a group of people the size that you are studying, however, such duplication is unlikely. You may use black dots and red dots to distinguish boys and girls. Is there a difference in the distribution of the dots representing boys and girls?

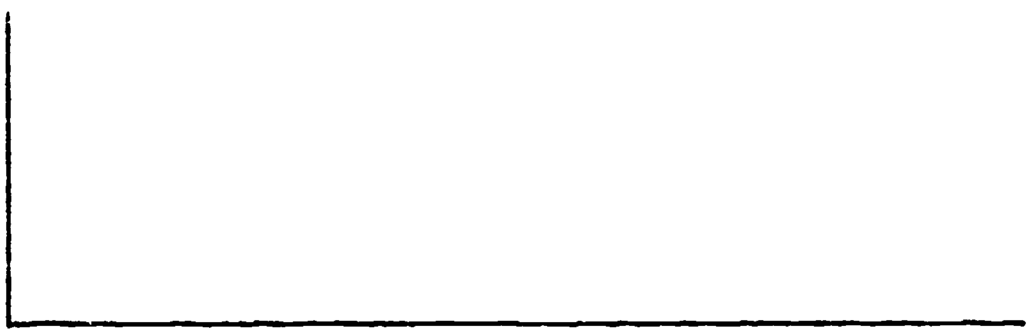
In this scattergram, if the heights and foot lengths were to show a direct correlation in all cases, all of the dots representing individuals would be in a diagonal straight line rising from the lower left to the upper right. Why?

Does the actual distribution of the dots show any indication of an approach to such a correlation? Does the scattergram give you a picture of the relationship of foot length to height?

Now measure the greatest width of the right foot to the nearest quarter-inch. The greatest width is found across the ball of the foot, in front of the arch, at about the point where the toe bones attach to the body of the foot. Proceed as you did in measuring the length by using three rules, one with the foot resting on it, and two set up at right angles at the side of the foot.

Construct a scattergram for foot width in relation to height. Here again you may use black and red dots to distinguish boys and girls:

Height (half-inches)

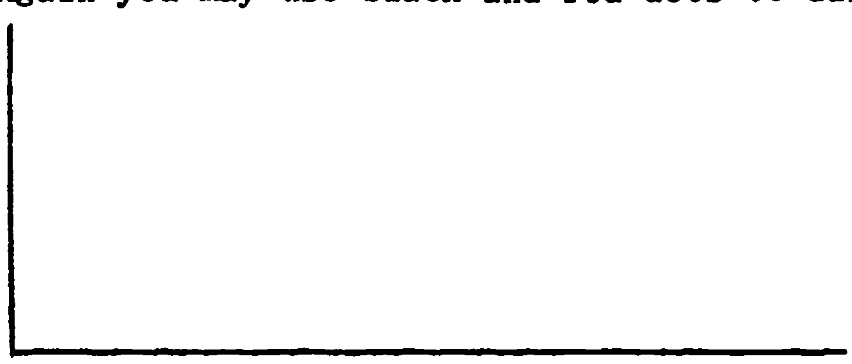


Foot width (quarter-inches)

Is there any correlation between foot width and height? Do tall people tend to have narrow feet? Do short people tend to have broad feet? Is the opposite true? Is there a difference in the distribution of dots representing boys and girls? Compare the picture shown in this scattergram with that for foot length and height? Are they similar? Are there any apparent differences? Can you make any generalizations about the relationship of either foot length or width to height? Measure the left foot in the same way that you measured the right. Is it the same? What is the relationship between foot width and shoe size? How is width of foot expressed in terms of shoe size.

Now set up a scattergram to show the relationship between width of foot and length of foot. Again you may use black and red dots to distinguish boys and girls:

Foot width (quarter-inches)



Foot length (half inches)

Is there any correlation? What kind of picture do you get? Note the dots representing individuals with long, narrow feet. With short, broad feet. Are there any with long, broad feet? Any with short, narrow feet? Find out by inquiry among the group if there are any individuals who have difficulty in getting fitted with shoes. Note what type of feet they have. Why do you think they might have difficulty? Do you think the relative numbers of such individuals might be in any way related to their difficulty in finding suitable shoes? Why?

Now determine the distance from the tip of the big toe backward to the line which you previously measured across the greatest width of the foot. Measure this distance to the nearest half-inch. Set up a scattergram showing the relationship of this measurement to total length of foot for the group:

Tip of big toe to line of greatest width (half-inches)

Total foot length (half-inches)

Is there any correlation? What kind of picture do you get? Compare it with the picture obtained for the relationship of foot width to foot length? What effect do you think that differences in this relationship might have on the degree of comfort one would find in wearing different styles of shoes? To what extent do shoe manufacturers take it into account? To what extent do purchasers of shoes take it into account? To what extent should they do so?

Now, with the foot flat on the floor, establish an arbitrary line at right angles to the length of the foot, three inches in front of the tip of the big toe. Then measure the distance to the nearest quarter-inch from this line backward to the tip of the second toe. Set up a ratio of these two distances to one another for each individual:

Distance to tip of big toe (3 in.): Distance to tip of second toe

(for example: 3:3.25)

Compare with all other members of the group. How much variation do you find? In terms of the relative distances from the arbitrary line to (1) the big toe, (2) the second toe, and (3) the little toe, describe in broad terms the profile of the end of each person's foot.

Now draw the profile of the end of the foot for each member of the group. First, draw a horizontal reference line, corresponding to the line from which you made your measurements. Make this line equal in length to the previously determined greatest width of the foot. Then place points in relation to this line for the tips of the big toe, second toe and fifth toe that you have measured. Measure the distances to the tips of the third and fourth toes

in the same way and place points for these also. Connect the points for all of the toes. Do the measurements for the third and fourth toes change the general character of the profile of the end of the foot?

Summarize what you have learned in this laboratory experience with regard to variation in foot shapes and sizes. To what extent do the measurements you have made and their relationship to one another give you a quantitative picture of foot shape in a sample population (quantitative means expression in terms of measurement). Is there any advantage in the study of evolution in the expression of variation quantitatively?

Follow-Up:

If you wish to study variations in the sizes and shapes of hands you will need to vary slightly the procedures which you have followed for feet. Use the right hand for your measurements, but compare the left hand with it.

Measure the length of the hand with the palm upward. Measure from the line where the hand joins the wrist to the tip of the middle finger (third finger). Measure the width of the hand just back of the points where the index finger and the little finger join the hand, and also at the point where the thumb joins the hand. Compare these two width measurements for members of the group. Is the relationship between them consistent for members of the group? This relationship is important in any description of hand shape.

The length and width of the hand may be compared with one another, and also with total body height, as in the case of feet. In making these comparisons use the width of the hand at the point where the index and little fingers join it. This is comparable to the foot width which you used.

In comparing relative length of fingers use a technique for measurement similar to that used in the case of toes. With the hand lying flat, palm downward, draw an imaginary line three inches beyond the end of the index finger. Measure backward from this line to the tips of the other fingers and thumb. In the case of the thumb, draw it as close as possible to the side of the hand while making the measurement. You can draw a profile of the ends of the fingers as you did of the ends of the toes.

Use ratios, graphs, and scattergrams in making comparisons of hand measurements as you did in the case of foot measurements. You can compare hand measurements with corresponding foot measurements. Is there a correlation between the shape of hands and feet in the same individual? Which shows the greater degree of variation, hands or feet?

What other relationships can you think of that would add to your understanding of variability in the sizes and shapes of human feet and hands? Think in terms of how you would express them quantitatively. What additional individual differences or peculiarities did you observe in your group study of hands and feet? Do you know of any others that were not observed in the group? Do you know of any in your own family? In the families of others?

Foot and hand characteristics are strongly hereditary in families. Can you trace any in your own family? How far back? Are your feet and hands like those of your parents and grand parents? Do they more strongly resemble the feet and hands of one parent than the other?

Can you think of any activities or professions in which variations in the size and shape of people's hands might be a factor in their success or failure? What about music? What about mechanics? Any others?

LABORATORY EXPERIENCE D.4.c.

Natural Selection at Work: A Field of Competition

Introduction:

Selection among plants and animals in nature occurs as a result of elimination of the least fit. These are the members of a species that are unable to survive under the conditions of the environment. They are not "good enough to get by." It is like a game in which those that are not able to compete are eliminated from further competition. Athletics---all kinds of games---are like this. We compete for grades, for social acceptance, to "keep up with the Joneses."

This laboratory experience is a tournament (like a basketball tournament or a bridge tournament) to determine which student in the class is able to put a simple puzzle together in the shortest time. Since we will run a series of contests using the same puzzle, the ability to improve the skill involved in putting the puzzle together will play an important part in determining who will be the winner.

In each series of contests it is the least skilled that are eliminated, but the process continues through several series of contests, so in the end, it is the most skilled, or those who are capable of becoming the most skilled, that survive. It is much the same among organisms in nature.

Materials and Equipment:

Filing cards 3" x 5", cut into simple puzzles

Numbered tags

Scissors

Envelopes

Ruler

Collecting Data:

Each student in the class is given the pieces of a simple puzzle in an envelope, and draws a numbered tag from a box or bag. All puzzles are alike. The number on the tag determines the student's order of participation in the first series of contests.

Students will contest in pairs. As many pairs may contest at a time as there are umpires to watch them. Students who are not contesting at a particular time may serve as umpires. In each contest, the student who gets the puzzle together first is the winner.

Each student will contest three times in each series of trials. For the first trial, the pairs numbered (1) and (2), (3) and (4), (5) and (6), (7) and (8) and following, will contest. For the second trial, numbers (1) and (3), (2) and (4), (5) and (7), (6) and (8), and following, will contest.

For the third trial, numbers (1) and (4), (2) and (3), (5) and (8), (6) and (7) and following, will contest. Students who lose all three contests will retire from the game.

The numbers are collected at this point. The students who are still in the game will draw new numbers in a series beginning with (1). They will repeat the process, each contesting three times in the same numerical order as before, using a puzzle of the same kind. Again the three-time losers will retire from the game.

Additional contests following the same pattern will continue until all students except one have been eliminated. This remaining student will be declared winner of the tournament. If more than one class group has been engaged in the same laboratory experience at the same time, and if the same puzzle has been used, the champions of the various class groups may contest for a grand championship.

How is this laboratory experience like selection in nature? How is it different? How is it like competition in the field of business or politics? How is it different?

Follow-Up:

Can you think of ways that this experience might be modified in order to give everybody a better chance to compete? Should everyone get a chance to compete with everyone else in the first series of contests? Should each of those remaining in the second and later series of contests get a chance to compete with each other person remaining in the same series? Would this give more reliable results. Try it again with a new puzzle, and a new order of contesting, and see if the same people win, or different people. Why might the results be the same? Why might they be different?

Try other skills in competition. What about an old-fashioned spelling match? This would be a contest involving correctness rather than speed. What about an old-fashioned "ciphering" match (working simple arithmetic problems in the skills of adding, subtracting, multiplying, and dividing). This would be a skill involving both correctness and speed. Can you think of other possibilities? What about manual skills? If you try some of these other kinds of competition, do you find that the same persons tend to win different ones? Or do different people appear to have different kinds of abilities? What kind of conclusion can you reach in regard to patterns of ability?

If you wish to find out which student can put the puzzle together most quickly, why not simply time each student with a stop watch? What factor or factors would you have missed if you had done this instead of carrying on the series of contests?

LABORATORY EXPERIENCE D.4.d.

A Quantitative Study of Competition Between Species

Introduction:

Competition is a factor in natural selection. Within a species, some individuals contain heredity factors which enable them to survive and reproduce to a greater extent than others. These individuals tend to replace the others. Thus the whole species becomes modified in the direction represented by the surviving individuals. Ultimately the whole species becomes like them. This is the kind of competition that we ordinarily think of as resulting in evolution. It is difficult, however, to demonstrate or measure this kind of competition in a short term laboratory experience.

Competition also takes place between species that live in the same environment. This kind of competition is less important on a short-term basis as a factor in evolution. It plays an important part, however, on a long-term basis in determining whether or not various entire species survive or become extinct. Competition between species can be made the basis for a laboratory experience very easily. The results of this experience can be expressed quantitatively.

Materials and Equipment:

3 wooden greenhouse flats (20" x 12" x 2½")

Good garden soil of uniform quality sufficient to fill these flats. Be sure that it is moist but not wet.

Plastic kitchen wrap sufficient to cover the three flats

Garden trowel

Wooden dowel

Paper towels

Laboratory balance, preferably sensitive to 0.1 gram

Tomato seeds

Radish seeds

Collecting Data:

Fill the three flats with soil to within ½" of the top. Firm the soil gently with your hands or with the back of the trowel. Draw longitudinal furrows with the wooden dowel on the surface of each flat, 1/8" deep and 2" apart.

Plant tomato seeds in one flat ½" apart in each row.

Plant radish seeds in the second flat ½" apart in each row.

In the third flat, plant tomato and radish seeds alternately $\frac{1}{2}$" apart in each row.

Cover the seeds lightly with soil by partially filling the furrows in all three flats. Firm the soil over the seeds gently with your hands. Sprinkle the surface lightly with water. Be careful not to over-water or wash out the seeds. Cover the flats with plastic and put them in a warm place. As soon as the seeds have germinated, the flats should be placed in good light, and the plastic should be removed.

Water the seedlings lightly each day until the seedlings are large enough that heavier sprinkling will not injure them. Do not allow them to become dry. Be sure that all three flats are watered equally. Why?

If the flats are in a location such as a window sill, where all of the light comes from one side, they should be turned daily. Why?

At the end of 6-8 weeks, when the plants are fairly large, but before they begin to weaken and lose their uprightness, remove all of the plants, including their roots. Wash the soil off the roots carefully. Blot up all of the moisture from the roots that you can with paper towels. Then weigh the plants in the following categories:

a. All of the tomato plants grown in pure cultures

b. All of the tomato plants grown in mixed culture, and multiply the result by two.

c. All of the radish plants grown in pure culture

d. All of the radish plants grown in mixed culture, and multiply the result by two.

Why did you need to multiply the results by two in the case of the plants grown in mixed culture?

Compare the total weight of the tomato plants from the pure culture with the total weight (X2) of the tomato plants from the mixed culture. Do the same with the radishes.

Was there an advantage or a disadvantage, from the standpoint of total weight attained, in growing the tomato plants in pure culture? Was there an advantage from the same standpoint in growing the radish plants in pure culture? Did either the tomatoes or the radishes show an advantage at the expense of the other in the mixed culture? Which one? How can you give a quantitative answer to this question?

Follow-Up:

Try to think of situations where competition occurs between species in nature? Why do we try to eliminate weeds from our cultivated crops, gardens, and lawns? What is a "weed?"

Some types of plants, such as carrots and walnut trees, are believed to produce and release into the soil substances which prevent certain plants from growing near their roots. Do you think that anything of this kind might be taking place in the case of the radishes and tomatoes?

Certain molds and bacteria produce substances called antibiotics. What is an antibiotic? What function do antibiotics serve in nature for the organisms that produce them? How is this function related to their function when they are used as medicines? How is all this related to competition? To survival?

When antibiotics are used as medicines, disease organisms sometimes respond by developing strains that are resistant to the antibiotics. Insects develop strains that are resistant to DDT and other insecticides in the same way. Weeds develop strains that are resistant to herbicides (weed-destroying chemicals). Do you think that something like this may occur in nature? What do you think would happen if it did? How is this related to evolution?

Agriculture, as developed by the American Indians before the coming of the Europeans, was a "mixed-up" agriculture. Maize (corn), beans of various types, and squashes or pumpkins were all planted together in the same field. We learned to grow these crops from the Indians, but we usually plant them in "pure stands," since the system of agriculture developed by our European ancestors planted crops in this way. Which system do you think is the more efficient? Why?

In a free society we have many people in the same business or profession who are competing with one another (grocerymen, salesmen of office equipment, building contractors, physicians, lawyers). This sytem seems to work very well. Why? In other professions (teachers, priests or ministers, scientific researchers) competition is regulared, reduced, or absent. This also seems to work very well. Why? Which system do you think works better? Would a society in which competition was eliminated as far as possible work better or less well? Why or why not?

Would it be possible to eliminate <u>all</u> competition? Would any evolution occur, either in the world of nature or in human society, if all competition were eliminated?

To what extent does competition enter into the things that people do for fun? Is this good or bad? Why? Do you know of anyone who doesn't enjoy competition? Do you? Is this good or bad? Why?

LABORATORY EXPERIENCE D.4.e.

Protective Coloration: A Mechanism for Survival

Introduction:

One of the ways in which living organisms, especially animals, are able to survive in nature is to look like something else. A snake that is not poisonous has a color pattern like that of a poisonous snake. An insect has a color and shape that make it look like a leaf or twig. A small mammal has the same color as the soil. A small bird is almost invisible among the vegetation of the forest edge. A young deer is spotted in a way that matches the pattern of sunlight in the undergrowth. Some birds and mammals are different colors in summer and in winter. It is possible to survive by not being noticed. Protective coloration is a way of doing this.

All of these things are facts that are widely known, easily told, and taken for granted. It is possible to set up a laboratory experience which will make it possible for students to see for themselves and measure the effectiveness of protective coloration.

Materials and Equipment:

Poster paint (water soluble) in the following colors

- Green
- Blue
- Brown
- White
- Yellow (a double quantity)

White poster paper

Paper punch

Watch or stop watch

Baby food jars, or other small containers of uniform size

Quart jars, or other larger containers of uniform size

Pegs and string

Yardstick or carpenter's tape

Graph paper

Accessibility to a freshly mowed lawn and/or a sandy beach

Collecting Data:

Mix yellow, green, and blue paints to produce a series of shades by dilution: (a) green toward blue and (b) green toward yellow. You may thin the paints with water if necessary. Place the paint of each color or shade in a separate baby food jar or other container. Keep a record of the dilutions used. Your jars show a gradient of colors.

Mix brown, yellow, and white paints to produce a series of shades by dilution: (a) yellow toward brown, and (b) yellow toward white. Thin with water if necessary. Place the paint of each shade in a small, separate container. Keep a record of the dilutions used. Your jars show a gradient of color.

Color both sides of one piece of poster paper uniformly with each of the shades you have produced.

With the paper punch, punch out as many small circles as possible from each piece of colored poster paper. Place all of the circles of the same shade in a separate large container.

Measure off on a freshly mowed lawn and/or on a sandy beach, areas three feet square. Mark the areas by pegging the corners and running strings attached to the pegs along the borders.

Scatter a large quantity of the circles colored with the various yellow-green-blue shades over one of the three feet square areas on the lawn for each student carrying on the experience. Similarly scatter a large quantity of the circles colored with the various white-yellow-brown shades over one of the three feet square areas on the beach for each student carrying on the experience. Be sure to mix the circles colored with the different shades of each series thoroughly before they are scattered, and then be sure to scatter the circles as uniformly as possible over each of the squares. Why?

With a team of three, one student can hold the watch, another can keep records, and the third can look for and pick up circles. Later the jobs can be exchanged, and the first two students can have an opportunity to hunt for circles.

Give each student an opportunity to pick up as many circles as possible of whatever shades he can find on one of the squares during a five minute period. He should put these in a large open container, such as a quart jar, making no effort to separate the different shades as he finds them.

After the five minute period is finished sort the circles which each student has found into small containers, according to shade.

Lay off a sheet of graph paper in equal sections along the horizontal axis, one section for each shade in the yellow-green-blue series; then on another sheet of graph paper one section for each shade in the white-yellow-brown series.

Record on the vertical axis the number of circles of each shade that the student was able to collect during the five minute period.

Combine the results for each series of shades for the entire class.

Is there a relationship between the number of circles of the different shades collected and the color of the background environment? Check this by laying a complete series of each set of circles in a straight line on the appropriate background (grass or sand) and inspecting them. Which shades are easy to see? Which are hard to see? Do the quantitative results of the collection and the visual results of the inspection show a relationship to one another? Are they what you expected them to be?

To what extent were there individual differences among students in the total number of circles collected? In the relative numbers of different shades within a series? Can you account for any differences that appear?

Follow-Up:

What relationship is there between this laboratory experience and the survival in nature of a species preyed upon by enemies? To what extent do you think shape was a factor in your seeing and picking up the circles? To what extent do you think size was a factor? Can you think of a shape and/or size that might have worked better on the grass background? On the sand background?

Can you find through reading, any examples of cases where protective coloration has worked to change a species of animal in nature over a recent period of time? Can you think of any examples of protective coloration in man, or in the things that he has made and used?

Can you explain how protective coloration furnishes an example of the interaction of variation and survival in nature to produce evolutionary change? How important do you think protective coloration is in evolution?

Repeat the experience. Is there any improvement through practice? Why?

LABORATORY EXPERIENCE D.4.f.

Selection and the Gene Pool: A Working Model

Introduction:

Inherited characteristics in man, other animals, and in plants are brought about by genes. These are passed from parents to their children through the germ cells (sperm and egg or ovum). Two germ cells, one from each parent, come together at the beginning of each individual's life. They unite to form the single cell from which the new individual develops. This single cell is called the fertilized egg or zygote.

The two germ cells which unite are actually only "half-cells" in terms of the number of genes that they contain. The union of the two half-cells makes a whole cell. In this way, the amount of heredity-bearing material in the form of genes remains the same from the parents' generation to the children's generation.

All of the genes that are found in all of the individuals of a species (such as man) may be thought of as making up a single huge pool. Each individual consists of a temporary sampling of genes drawn from this pool. If he or she leaves descendants, their genes are poured back into the pool. If no descendants are left, their genes are lost.

Think of the gene pool of a species as being like a swimming pool filled with water. Each individual of the specids is a cup of water drawn from the pool. If he or she produces children, the cup of water is poured back into the pool. If he or she leaves no children, the cup of water is poured out on the ground and is eliminated from the pool.

A human pair must produce at least two children to replace themselves in the population. If they produce only one child, then another pair who produce three may be thought of as replacing themselves and also one of the possible children of the first pair. In this case a part of the two cups of water representing the first couple is poured out onto the ground, and only a part back into the pool. In the case of the second couple, three cups of water are poured back into the pool for the two taken out. Thus the gene combinations found in the second couple are favored in the next generation, while those found in the first couple are partially eliminated.

The gene pool of the species, therefore, slowly changes, with an increase of the genes which are found in those individuals that reproduce to a greater extent, and a decrease of the genes found in individuals that reproduce to a lesser extent.

If there is any factor that cuts down on the rate of reproduction in the case of a particular gene or combination of genes, and if this factor operates constantly and consistently over a number of generations, then this gene or combination will ultimately be eliminated from the gene pool. It will be replaced by a more successful gene or combination.

There are many kinds of factors or influences that may operate to cut down reproduction of certain genes and gene combinations. These factors bring about the process called natural selection. A factor or influence

which brings about natural selection is said to exercise selection pressure on the gene pool. So long as the factor continues to operate, selection pressure continues to modify the gene pool in that particular direction. This results in directional change (evolution) in the species.

Genes exist in pairs. (See Laboratory Experience B.3.f., "Models for Probability: Heredity") One member of each pair is contributed by each parent. When the members of a pair of genes are identical then a trait, such as black coat color is produced in the individual having the pair of genes in its cells. However, a gene may mutate, (change its nature and the way in which it expresses itself.) When this has happened, the gene pair may exist in an individual in any one of three different combinations:

RR (both members of the pair have the original form)

rr (both members of the pair have the new or mutated form)

Rf (one member of the pair has the original form and the other the mutated forn

If an individual carrying the RR combination is black an individual having the rr combination might be white. An individual having the Rr combination might be gray if the two genes interacted with one another equally, or might still be black if the "R" gene were strong enough in its expression to overcome its partner.

Sometimes a gene may produce death by intraction with the environment. Such a gene is called a lethal. If the gene "A" is normal, and the gene "a" is lethal, then either AA ("pure normal") or Aa ("mixed normal") would survive and leave an adequate number of descendants. However an aa ("pure lethal") combination would be eliminated. We would expect, therefore, that natural selection would ultimately eliminate the lethal "a" genes from the gene pool, and thus change the species.

How rapidly and to what extent would this take place?

Materials and Equipment:

200 objects (beans, corn grains, or buttons) of one color (Color A)

100 objects of the same kind, size, shape, and texture, of a second color (Color a)

Paper or cloth bag, or other container of appropriate size, and of such nature that the investigator can put his hand inside it and withdraw objects from it without observing its contents.

Graph paper

Collecting Data:

Students should work in pairs, one member of the pair doing the manual operations, and the other serving as recorder. They may trade jobs as often as they wish. Be sure to keep a record of all operations.

Place 100 objects of Color A, and 100 of Color a in the container described above. Place the remaining 100 objects of Color A in a second container ("the kitty").

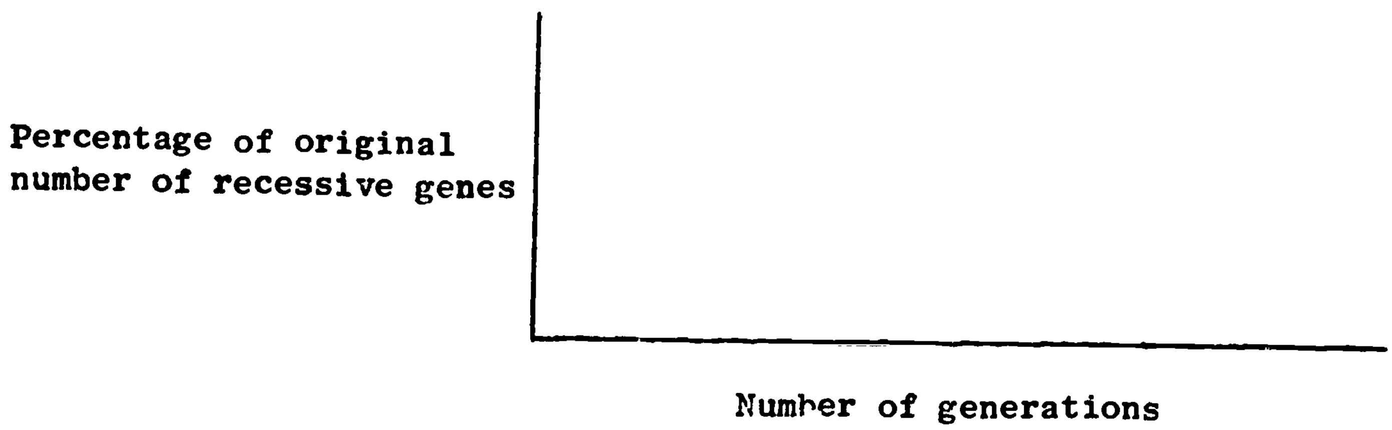
Shake the 200 objects (100 of each color) in the first container to make sure that they are well mixed. Repeat this at least one time after each ten withdrawals during the progress of the experience.

Withdraw two objects at a time. If both are Color A, return them to the container. If one is Color A and one Color a, return them to the container. If both are Color a (representing a lethal combination) put them on a third container and replace them in the first container with two objects of Color A taken from the kitty. In this way the population of genes in the gene pool is maintained at a constant level. Why is this necessary from the standpoint of getting valid results from the working model?

Continue to withdraw objects until 100 pairs have been withdrawn. In each case proceed as you did with the first pair. Consider that a group of 100 withdrawals constitutes a"generation." How many of the recessive genes (Color a) were eliminated in the first generation? What percentage of the total number of recessive genes originally present in the population did these constitute?

Continue to withdraw pairs in generations of 100, until three successive generations have been withdrawn which result in no further elimination of recessive pairs. At this point you can assume that for practical purposes the recessive genes have been eliminated from the population. Why? Are the recessive genes all eliminated? What percentage of the original total of Color a genes still remains in the pool? Will the recessive genes ever all be eliminated? Why, or why not?

Construct a graph showing the progressive elimination of the recessive genes in each generation in terms of percentage of the total:



Does the line on the graph constitute a gradient? Why? What do you think would be the result of carrying the experience through additional generations? Why?

Compare your results with those obtained by other pairs of students. Are there similarities? Are there differences? Why do you think these occurred?

Follow-Up:

Think of the results of this experience in terms of what you know or can find out concerning the human gene pool. Do you know of any hereditary human traits that are present in the human gene pool in very low percentages, and therefore show up in individuals only occasionally? Are any of these lethal, or partially so? What happens to them in terms of natural selection? Does modern medical science interfere with the operation of natural selection? How? Why? What do you think of this? Why?

Lethal genes may operate at different periods of life. They tend, however, to operate at the same period of life for different members of the same family: for example, heart attacks in the 60's; cancer of a particular type in the 40's. Of course, things like this depend on environment interacting with heredity.

What do you think about the probability of survival of a gene in the gene pool that interacts with the environment to produce death among members of a particular family in the 50's or 60's? Compare this with the probability of survival of a gene which interacts with the environment to produce a fatal disease among members of a family during childhood? What does time of expression of a lethal gene in the life cycle have to do with the probability of its remaining in the gene pool? Why?

Can you think of any human traits that are present in the gene pool in very high percentages? Are these determiners of normal or abnormal traits? Can you think of any traits that are present in percentages somewhere between high and low? Are these normal or abnormal? Would it be possible to construct a gradient of the percentages of genes in the gene pool for various human traits? If so, where on the gradient do you think abnormal traits would tend to be located? Why?

If a recessive mutation advantageous to a species were to occur in a single individual, do you think it would be possible for it to increase in the gene pool to a point where it would take over in the species and replace the dominant form, which was less advantageous?

Has natural selection operated in the human gene pool in the past? Is it operating now? If so, how is it operating? In terms of what specific traits or kinds of traits?

Idea of Cyclic Change: Sequences that Repeat Themselves D.5.

Idea Bridge: Cycles in Nature

Many events in nature occur in sequences similar to gradients, except that they repeat themselves. The same things happen in the same order, over and over again, with the same starting point and the same end. We call this a cycle. It is possible that there is a closer relationship between cyclic change and directional change than there appears to be. If you were to see only part of a cycle, the sequence of changes or events would appear to be directional, and it may be that most or possibly all of directional change would be seen as cyclic if you could look at it on a large enough scale or over a long enough period of time. Do you think the evolution of life on earth type planets could be cyclic?

Cyclic changes are found in both living and non-living nature. There are life cycles of plants and animals. There is a long term cycle of diastrophism (uplift erosion, and deposition) on the earth's surface. This includes the formation of mountains by uplifting, and the wearing down of these mountains by erosion. The material that is washed away is deposited in shallow seas near the land, and eventually is uplifted into mountains again. There is a cycle of rock formation, including rocks that form from melted material, rocks that are formed from erosion deposits, and rocks that are changed by heat and pressure. There is a water cycle. In this, liquid water is changed into water vapor. This becomes part of the air. Condensation changes vapor to water which forms clouds and falls to the earth as rain or snow (or in some other form). It is absorbed into the soil, becomes part of the bodies of plants and animals, or runs away in rivers to lakes and the ocean to start the cycle all over again.

Besides these there are cycles of movement of heavenly bodies: the earth itself, the moon and planets, and the apparent movement of the sun and stars as the earth turns. There are cycles of use of chemical elements, such as carbon and nitrogen, in all living things. There are cycles within living bodies, such as the cyclic action of the heart when it beats, the cycle of body temperature change during the 24 hours, cycles of sleep and waking, and many others.

We can examine a few of these cycles in the laboratory.

LABORATORY EXPERIENCE D.5.a.

An Animal Life Cycle: The Fruit Fly (Drosophila)

Introduction:

All living things, animals and plants, go through life cycles beginning with minute reproductive bodies and finally reaching maturity, at which time they give rise to new reproductive bodies that start the cycle over again. The stages of the human life cycle are well known: the unborn child, birth, infancy, childhood, youth, maturity, reproduction. Strictly speaking, although old age is a part of the life of each person who lives out a normal life span, it is not really a part of the cycle. Why? What is the relation of death to the life cycle?

In other animals there is a comparable cycle. The life cycles of some insects are well known and easy to study. It is easy to read about the life cycles of common insects in books, and it is not difficult to observe some of them in the laboratory. Studying them in the laboratory is interesting, not only from the standpoint of learning about them first hand, but also because of the questions that the observations raise in our minds.

One of the easiest insects to grow in the laboratory is the fruit fly, Drosophila. It has a relatively short life cycle. It can be grown in small containers on easily obtainable food. It can be studied quite readily under low magnification. Because of these characteristics it has been used extensively in the study of heredity (genetics). Since we are not concerned with the study of heredity at this point, we will use it simply to study the stages of its life cycle.

Materials and Equipment:

Compound microscope

Hand lens

Slides

Cover slips

Medicine dropper

Stapler

Pint milk bottles, or other wide mouth bottles of similar size (these can be obtained from biological supply houses)

Paper towels

Cotton

Laboratory forceps (4 to 6 inches long)

Ether

Ripe banana

Yeast cake (Red Star or Fleishman's)

Fruit flies (cultured or wild)

Collecting Data:

A. Learning About The Fruit Fly Life Cycle

In general there are two types of insect life cycles. In one of these the young insect proceeds through a series of progressive changes, roughly comparable to those of a human, with growth in size, but without radical alterations in body form after hatching from the egg. This is called incomplete metamorphosis. The life cycle of the grasshopper is an example of this. Metamorphosis means change, and incomplete refers to the fact that no complete or total change of body form occurs at any stage.

The other kind of insect life cycle is called complete metamorphosis. In this there are four distinctly different stages: egg, larva, pupa and adult. Each has a radically different body form. This type of life cycle is characteristic of beetles, moths and butterflies, and flies. The fruit fly is an example.

The eggs of the fruit fly are small. They are generally deposited on the surface of the food material. They are hardly visible with the unaided eye. At room temperature they hatch into larvae in about 24 hours. The larvae are minute "worms" or maggots. They can be observed eating in the food material. They increase rapidly in size.

They change into pupae, which look like little seeds. These are attached to something and are inactive. When the larvae are ready to pupate, they usually climb up the sides of the culture bottle, or on a piece of paper towel which has been placed in it.

The adult flies emerge from the pupal cases. At first they are very weak, and they will die if they become stuck in the food material. As they become stronger, their wings expand and they are able to fly.

Male Drosophila can be distinguished from females by the presence in the male of a broad block tip on the abdomen. Both sexes have black bands across the abdomen, but the female lacks the broad, black tip. These markings can readily be seen by examining the flies with a hand lens. With a little practice, males and females can be distinguished from one another with the unaided eye.

B. Learning How Fruit Flies Grow

Drosophila live in nature around decaying fruit. They eat the yeast cells that grow on the fruit, not the fruit itself. You observed yeast cells in connection with an earlier laboratory experience (Looking for Examples of Patternless Change, A.3.b.), but it might be a good thing to look at them again now, in connection with your fruit fly experience. Place a very small piece of yeast cake on a glass slide. Put a drop of water on it. Mix it thoroughly with the water. Cover it with a cover slip, and observe it under

both low and high power of the microscope. What do yeast cells look like? How do they reproduce? What do they live on? What well-known substance is a byproduct of their life processes?

There are several species of Drosophila that occur wild in nature. The species which is commonly used for laboratory experimentation is Drosophila melanogester (literally the "black-bellied Drosophila, so named from the black-tipped abdomen of the male). They can be raised in the laboratory in any kind of bottle or glass container that has an opening small enough to be closed with a plug of cotton. Why a cotton plug rather than a rubber stopper or other solid top?

Their food in the laboratory consist of any kind of medium on which yeasts will grow. The standard culture medium is made up in agar. This is a gelatin-like material which can be prepared ahead of time with standard amounts of the necessary ingredients, and sterilized to get rid of molds and other organisms that might get in the way of the yeasts or the fruit flies. Also, it has a firm surface, which lessens the danger that freshly emerged flies, or those that have not waked up from anaesthesia, will get stuck in it.

Fruit flies can be grown quite easily, however, on mashed banana, seeded with yeast. The banana does not need to be cooked or sterilized. Some cultures grown in this way may be lost because they become infested with molds, but in such case the molds themselves have a life cycle which is interesting to observe (See the following laboratory experience: Simple Plant Cycles D.5.b.).

When growing flies on mashed banana, there is greater danger that the original pair of flies, before they wake up from anaesthesia, and the adults freshly emerged from the pupal stage, will become entangled in the surface of the culture medium. Most of this risk can be eliminated, however, by placing a small inverted cone made of paper towel in the bottle, and being careful to deposit the original pair in this cone while they are still under anaesthesia.

In a way, growing the flies in a natural medium such as banana, is more interesting because it is less standardized and therefore presents a greater challenge.

C. Preparing Culture Bottles

1. Thoroughly wash a pint milk bottle with soap and water, and dry it, or allow it to dry.

2. Put mashed banana in the bottle to a depth of about one inch.

3. Break up a piece of yeast cake about the size of a pea in a small amount of water, to make a milk-like suspension. Fill a medicine dropper about one-fourth full of the suspension, and spread it thinly over the surface of the mashed banana.

4. Fold a piece of paper toweling two or three inches square into the form of a cone.

5. Staple the side of the cone where it has been folded so that it will retain its shape.

6. Place the cone in the bottle point downward, with a pair of forceps.

7. Press the point of the cone into the mashed banana as much as is necessary to hold it erect.

8. Prepare a cotton plug which you have to squeeze in order to get it into the opening of the bottle, and close the bottle with it.

D. Handling the Fruit Flies

If you wish to catch wild fruit flies, you may be able to do so during the warm season by placing a milk bottle containing ripe banana near any decaying fruit outdoors. When your milk bottle trap has a number of fruit flies in it, close it quickly with a cotton plug. Remove the freshly caught flies as directed in (1 and ff) below. Anaesthetize them, and distinguish between males and females. Place one or more males and the same number of females in a fresh culture bottle prepared as directed above. Plug the bottle and observe the life history stages as they appear.

You may obtain laboratory cultures of fruit flies from a biological supply company. Since these are mainly used for genetical experimentation, most of them are strains carrying special hereditary characteristics. The ones best suited for simple observation of the life cycle are what are called "wild type." These are similar to the ones which you would catch around decaying fruit. When the culture is first received, remove the flies as directed in (1 and ff) below anaesthetize them, distinguish between males and females, and place one or more males and the same number of females in a fresh culture bottle, prepared directed above. Plug the bottle and observe the life history stages as they appear.

To remove the flies either from the bottle in which you trapped them, or the bottle in which you received them, proceed as follows:

1. Take a clean, empty bottle with an opening, the same size as that of the bottle containing the flies. Prepare two cotton plugs for it but do not insert either of them.

2. Tap the bottom of the bottle containing the flies gently against the palm of your hand, to shake them down from the top.

3. Quickly remove the cotton plug from the bottle containing the flies, and hold the mouth of the clean, empty bottle tightly against the mouth of the bottle containing the flies.

4. Hold the two bottles so that the bottom of the clean, empty bottle is pointed upward, and toward the light.

5. The flies crawl or fly toward the light. When all of them have gone into the clean bottle; close it with one of the cotton plugs, while it is still held mouth downward.

6. If you are using laboratory-cultured flies, replace the cotton plug in the culture bottle. You may wish to put part of your flies back into it.

To anaesthetize the flies:

1. Open a bottle of ether. Hold the bottom end of the extra cotton plug against the mouth of the bottle of ether. Tip the ether bottle so that some of the ether is soaked up by the cotton plug. Avoid letting too much ether soak into the cotton plug. Keep away from fire! Ether is highly flammable.

2. Turn the bottle containing the flies bottom upward toward the light. Allow all of the flies to crawl or fly upward toward the bottom of the bottle.

3. Quickly remove the cotton plug from the bottle containing the flies, and replace it with the etherized plug.

4. Turn the bottle top end upward. Watch the flies closely. It is easy to give them too much ether and kill them. You only wish to make them inactive. How do they respond to the ether? Do they all "go to sleep" at the same time? Why, or why not? As soon as the last fly has become inactive, remove the etherized plug. Pour the etherized flies out onto a sheet of white paper.

5. Examine the flies with a hand lens. Use the forceps gently to move them around on the paper as you examine them. Do not touch them with your fingers. They are easily injured. Separate males from females.

To set up a breeding culture:

1. As quickly as you can select one or more pairs of flies.

2. Pick up each fly with the forceps, holding the fly by one wing.

3. Place each fly carefully in the cone of paper towel in the culture bottle that you prepared earlier. Do not drop the flies onto the surface of the mashed banana.

4. When you have dropped all of the selected flies into the cone, close the culture bottle with a cotton plug.

5. If you wish to put the remaining flies back into the original culture bottle you may do so. In this way, if your new bottle is not a success, your original stock will still be available. Handle each fly as directed in (2) above, and place it carefully in the bottle.

6. Watch the flies in the new culture bottle emerge from anaesthesia. Do they all do so at the same time? Compare their emergence with the way in which they went into anaesthesia. Did all of your flies "come out of it?" If they did not, then you know that you gave them too much ether. You will know better next time! Sometimes practice is necessary. Is there anything else that you would do differently if you were to repeat the experience?

Record the date when you set up the culture. Observe the development of the culture over a period of two to three weeks. Are you able to see the eggs on the surface of the food material? How long before the larvae appear? Where do you see them? What kind of activity do they show? Are you able to see them eating? Observe their growth in size. How large do they get? How long do they remain in the larval stage?

How long before the first pupae appear? Where are they formed? Observe as much as you can of the process of pupation. How does it appear to take place? If the larvae or the pupae are observed on the sides of the bottle, look at them with a hand lens. As the pupae become older, how much structure can you see inside them? Relate what you see to structures on adult flies.

How long before the first adults emerge? Observe the freshly emerged adult flies. Why are they weak? Watch them gain strength. How long does it take them to do so? How do their wings strengthen? How long before they can fly?

Your new generation of flies are now adult, and they are ready to repeat the cycle. If you have time, set up a new culture, and watch them go through the cycle again. Do the life history stages occupy the same length of time that they did before? If they are not the same, why do you think this might be?

What have you been able to observe concerning the effect of various environmental factors on the flies? Your attention has been called to their relation to light. What about temperature? Do you think temperature has anything to do with how long it takes them to go through their life history stages? Your flies developed at room temperature. If you go through the cycle a second time, try experimental cultures at warmer and cooler temperatures.

Follow-Up:

Fruit flies live on yeasts which will grow on anything containing sugar. Try growing them on other kinds of fruit, without mashing it. What do you find to be the best kind of fruit, and the best method? Get a box of sweetened gelatin dessert at the grocery store (Jello or similar product). Follow the directions on the box in preparing it. Pour some of it while hot into a clean culture bottle. Seed it with yeast. Try growing flies on this material. Does it work? Try enriching the gelatin dessert with sugar when you are preparing it. Try different amounts of sugar. What is the most effective amount?

What do you think is the best readily available material for growing fruit flies? Other interesting insect life cycles you can observe are the ant, the housefly, the Monarch butterfly, the tent caterpillar and the meal worm. These can be observed in the laboratory.

What other kinds of phenomena in living organisms are cyclic? Think of as many examples as you can. What about the process of cell division (mitosis)? Read about this process. Study diagrams of the stages of it. See a motion picture devoted to it, if you can. Think of it as a continuous cyclic process. To what extent does mitosis take place in all living organisms?

LABORATORY EXPERIENCE D.5.b.

Simple Plant Cycles: Common Molds and Bacteria

Introduction:

Simple plants, like complex plants and animals, go through cycles of development from minute reproductive bodies, through a period of vegetative growth, to the formation again of reproductive bodies like the ones that gave rise to them. Many of the molds show excellent examples of such simple life cycles.

Molds may be obtained in pure cultures from biological supply houses, grown in the laboratory, and kept pure under controlled conditions. They may also be captured "in the wild," and grown on common, easily obtainable materials. It is interesting to catch them, and to observe the cyclic changes through which they pass.

Bacteria do not generally pass through true life cycles, at least not involving easily observable changes in physical form. They are usually captured in nature along with molds, however, and their growth and propagation in the laboratory is interesting, and can be seen along with that of molds.

Materials and Equipment:

Compound microscope

Slides

Cover slips

Medicine dropper

Hand lens

Dissecting needle

Forceps (four to six inches long)

Bunsen burner or other open flame

Source of heat for boiling water

Small cooking vessel

Petri dishes, or other shallow dishes that can be covered

Potatoes

Collecting Data:

Prepare your cultures by following these steps:

1. Cut a raw potato into slices approximately three-eighths of an inch thick. Leave the skin on.

2. Place the slices in water in a cooking vessel over a source of heat. Bring the water to a boil, but do not continue to boil the slices, and do not allow them to stand in the water. They will become soft, and will break when lifted, if they are overcooked.

3. Remove the slices and place each of them in a petri dish, or other small, shallow dish which can be covered. These dishes need not have been sterilized, but they should have been washed clean with soap and water, and kept covered after being washed.

4. Cover the dishes containing the potato slices, and allow them to cool to room temperature.

5. Uncover the dishes long enough to inoculate them. Do this in as many different ways as you can devise. (For example, cough on one, put dust from the table top on one, put dust from the floor on one, touch one with your finger in several places, et cetera.)

6. Cover them again, as quickly as possible. Put them in a warm place. Look at them once a day. When you do so, uncover them only long enough to observe them carefully. Then cover them again.

7. Leave one dish uninoculated, but simply remove the cover while you are inoculating the other dishes. This will show you the extent to which reproductive forms of molds and bacteria may be picked up merely by exposure to the air. Leave another dish covered all the time with the potato slice in it. Do any changes occur in this dish? Why?

Each slice of potato that you have inoculated will almost certainly develop colonies of micro-organisms: molds and bacteria.

Colonies of bacteria will appear as white or yellow spots. A bacterial colony will develop wherever a single bacterium has "touched down" on the surface of the potato. Sometimes bacterial colonies will differ in appearance in ways other than color. How many different kinds of bacterial colonies can you distinguish? Mold colonies are generally black, blue, green, yellow or brown. A mold colony will develop wherever a mold spore (reproductive body) has "touched down." How many different kinds of mold colonies can you distinguish?

Tease out a small fragment of each different type of bacterial colony with a dissecting needle. Put it in a drop of water. Spread it out in the water as much as possible. Cover it with a cover slip, and observe it with the high power of the microscope. Can you distinguish the individual bacterial cells? Are they motile or non-motile? Are they single or attached to one another (pairs, bunches like grapes, long, hair-like chains, none of these)? Do the different kinds of bacterial colonies show different kinds of cells?

There are three different body types of bacteria: cocci, which are round, bacilli, which are rods, and spirilla, which are spirals. Cocci are generally non-motile. They may form pairs (diplococci), chains (streptococci) or bunches like grapes (staphylococci). Bacilli may be motile or non-motile. They may be single cells or colonies. They are generally motile as single cells.

Prepare fresh slices of cooked potato in clean, covered dishes. Inoculate some of them with material from the bacterial colonies which you think would be interesting to propagate. Proceed as follows:

1. Sterilize the end of a dissecting needle by holding it in the flame of a bunsen burner or other open flame.

2. Allow it to cool.

3. Insert it into the surface of the bacterial colony, and then into the fresh potato slice. Replace the cover of the newly inoculated dish immediately.

4. Put the dish in a warm place, and examine it each day as before. Does the same kind of bacterial colony develop at the point where you inoculated it? Are there other kinds of colonies? Bacteria? Molds? If so, how do you account for them being there?

Examine fragments of each kind of mold colony in a drop of water under the microscope. Low power is generally satisfactory for looking at molds. They consist of vegetative strands, which give rise to spore-bearing, knob-like ends that are called sporangia when mature. Mash a sporangium by pressing on the cover glass to release the spores. See if you can observe vegetative strands, sporangia, and spores.

Inoculate other freshly cooked potato slices with material from the ripe sporangia of mold colonies which you think would be interesting to propagate. Proceed as you did with the bacterial inoculation, but use forceps instead of a dissecting needle. Sterlize the ends of the forceps before using them to transfer the mold material. Does the same kind of mold colony develop at the point where you inoculated it? Are there other colonies? Other kinds of colonies? If so, how do you think they got there?

You have now followed through the process of growth and propagation for two kinds of simple plants. Of these, the molds have a true life cycle involving (a) vegetative growth and (b) sporangia containing spores which are reproductive bodies. To what extent are the growth and reproductive phenomena that you have observed in these simple plants comparable to the life cycle of a higher plant or animal?

Follow-Up:

Study molds growing on cheese, bread, rotten wood, and anywhere else you can find them. What similarities and differences do they have? Much modern commercially baked bread contains mold inhibitor. Therefore it keeps better, and is less likely to become mold infected. Nevertheless, you might try growing molds on bread by using the following technique:

1. Place a drinking glass in a saucer. Fill the glass about half full with water, and fill the saucer with water around the glass.

2. Inoculate a slice of bread with mold spores from an active colony which has been growing on a potato slice.

3. Place the slice of bread on top of the drinking glass.

4. Cover the whole assemblage with a battery jar to form a moist chamber. Put it in a warm place and observe it daily.

Does a mold colony develop? Is there any difference in the growth of molds on different kinds of bread. How about whole wheat bread? How about rye bread? How about home made bread?

Try growing molds under different environmental conditions. Is there a relationship to light? To temperature? To relative humidity? To the moisture content of the medium on which the mold is growing?

LABORATORY EXPERIENCE D.5.c.

Growth Cycles of Higher Plants

Introduction:

Growth cycles of higher plants, including the common seed plants that are grown in our fields and gardens and contribute to our food supply, are more complex than those of simple plants like bacteria and molds. It will not be possible to observe the growth of any of these plants over a long enough period or in enough detail to see all of the stages of their development. A portion of their life cycle, however, can be watched in the laboratory.

We have dealt with the early development of some of these plants (corn, beans and tomatoes) in previous laboratory experiences. We have not watched any of them, however, very far beyond the seedling stage. We will start them again, and this time we will observe them as long as we can.

Materials and Equipment:

Seeds of corn and beans

Flower pots at least 8" tall

Shallow dishes for holding the flower pots

Garden soil

A large shallow pan or tray

Paper towels

Collecting Data:

Place several layers of paper towels in the bottom of a broad, flat pan. Sprinkle them with water to a point where they are wet, but not water soaked. Lay a dozen seeds of corn and the same number of beans on the wet towels. Cover them with additional layers of paper towels, also wet but not water soaked. Place the pan containing the seeds in a warm place. Keep the towels wet.

Examine the seeds daily. Watch the process of germination. How does it occur? Is the process the same in the corn and in the beans? If it is different, in what ways does it differ? Throw away the seedlings when you are sure that you have observed them to the point where they would have pushed through the soil if they had been planted.

At the same time you put the corn and bean seeds in the germination tray, plant both corn and bean seeds in soil. Fill six large flower pots with garden soil to within one inch of the top. Be sure the soil is moist but not wet. Plant three corn grains in each of three pots and three bean seeds in each of the other three. Plant the seeds about two inches apart in a triangle in the center of the pot. Plant them ½" to 1" deep. Firm the soil gently with your hands. Sprinkle with water. Place each of six pots in a shallow dish to allow for drainage. Place the six pots in a well-lighted location, such as on a window sill. Water regularly, but do not over-water.

When the seedlings have pushed through the soil, and you are sure that they are going to grow, thin both corn and beans, leaving only the single best plant in each pot. Watch the growth of corn and beans. You do not need to measure the plants in this experience, but observe them regularly and keep a record of any changes. Continue your observations as long as you can. Do any flowers develop before you have to quit watching them? Is there any evidence of the development of seeds? What development or necessity finally causes you to end your observations?

Summarize the experience by naming the life cycle stages through which your plants passed during your period of observation. Compare the two different kinds of plants as you were able to observe them. How were they alike? How were they different? How about the way the seedlings pushed through the ground? How about the manner of growth? What about the general characteristics of the leaves and stems? In what ways do both of them differ from molds?

Follow-Up:

Read about seed plants generally, and about corn and beans in particular. Examine pictures, charts, models and any other sources of information that are available. Look at motion pictures showing the life cycles of these and other seed-bearing plants.

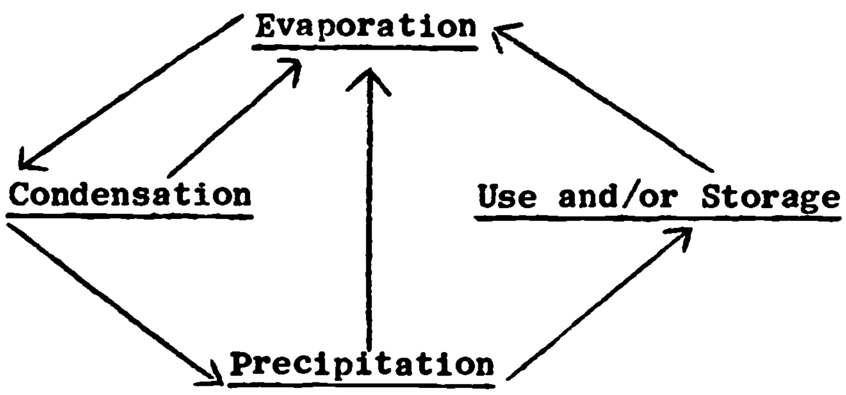
What life cycle stages take place beyond the ones that you were able to observe? What is the relationship between flowers and seeds? How do seeds develop? What are the differences between the two major groups of seed plants, as represented by corn on the one hand and beans on the other? What about the way the seedlings push through the soil? What is the major difference between the flowers of the corn plant and those of the bean plant? How is this difference important in the life history of the two plants?

LABORATORY EXPERIENCE D.5.d.

The Water Cycle

Introduction:

Water goes through a series of changes that are part of an endless cycle. It may go through a complete large cycle or it may go through smaller cycles within the large cycle.



In this laboratory experience we will work with some examples of changes within this cycle. We will read about and discuss other changes within the cycle.

Materials and Equipment:

100 ml. graduate cylinder

Beakers

Metal pie plates

Large test tubes

Bunsen burner or other source of heat

Potted cactus or other plant without leaves

Potted geranium or other leafy plant approximately the same size

Razor blade

Microscope

Slides and cover slips

Plastic bags

Tea kettle

Fruit juice cans

Watch with second hand or stop watch

Collecting Data:

Evaporation changes liquid water into an invisible gas called water vapor. What factors affect the rate of evaporation?

Pour the same measured amount of water into each of the following numbered containers:

Container	Conditions	Amt. of water	Amt. left	Amt. evaporated	Time to evaporate all	Area	Ratio of area to time
Beaker #1	Rm. temp 24 hrs.						
Beaker #2	Boiling 10 min.						
Beaker #3	Fan 45 min						
Pie plate #1	Rm. temp 24 hrs.						
Pie plate #2	Boiling 10 min.						
Pie plate #3	Fan 45 min.						
Test tube #1	Rm. temp 24 hrs.						
Test tube #2	Boiling 10 min.						
Test tube #3	Fan 45 min.						

Follow the conditions indicated on the chart in the case of each container for the time given. At the end of the time, pour the remaining water in each case back into the graduate cylinder. How much is left? How much has evaporated? Calculate how long it would have taken for all the water to have evaporated from each container.

Measure the diameter of each container and find the area of the surface of the water. Use the following formula:

$$A = \pi r^2$$

What is the mathematical relationship between the area of the surface in each case and the time required for total evaporation to take place? How could you determine the mathematical relationship between the temperature and the rate of evaporation? Could you find a mathematical relationship between air velocity and rate of evaporation? This would require several fans running at different speeds. Since these would be difficult to obtain, this determination would probably be impossible to carry on in your laboratory.

Place a tea kettle containing water on a source of heat. Let it come to a full boil. Notice the clear space between the opening of the spout and the "cloud." Although this "cloud" is frequently called steam, this is really incorrect. How is this like a cloud in nature? What is in the clear space? Is it visible? What happens to it when it cools slightly? This "cloud" consists of tiny droplets of liquid water. What change in the water cycle is occurring?

Hold a very cold plate in the "cloud." What forms on the place? Do some droplets of water fall? What change in the water cycle is this?

In nature evaporation, condensation and precipitation are frequently much more complicated than they are in the laboratory. This is because water is often temporarily diverted from the cycle. It may be stored for longer or shorter periods as ground water, or as surface water in ponds, lakes, streams, et cetera. Some ground water is "fossil water" that has been stored for millions of years. Depletion of ground water and pollution of surface water are two of the biggest problems facing our country and many other countries. Find out about these problems as they relate to your area.

Water is also diverted from the cycle temporarily by passing through the bodies of plants. It is absorbed by minute structures on the roots called root hairs. Some of it is used in photosynthesis. and becomes a part of food substanches. Any surplus of water passes into the air by evaporation from the plant surface (transpiration).

Fasten plastic bags as closely as possible around:

- a potted cactus or other leafless plant
- a potted geranium or other leafy plant approximately the same size

The pots should be the same size, and both plants should receive the same amount of water at the time the bags are fastened around them. The bags should be fastened around the bases of the plants rather than around the pots, and should allow approximately the same amount of space inside the bag around each plant.

Place the plants side by side in the sunlight, and allow them to stand for a few hours. Remove them to a cool place, and allow them to stand until moisture droplets form on the inner surface of the plastic bags. Where did the moisture come from? What are the relationships involved? Is there any difference in the amount of moisture on the inside of the two bags? Can you suggest reasons for any differences that you observe? Why did the moisture not appear when the bags were in the sunlight? What is transpiration?

With a razor blade remove a small, thin portion of the surface layer of the cactus, and of the surface layer of a leaf of the other plant. See if you can tear off only the outer layer of cells in each case. This may require several attempts and a little practice. Put a specimen from each plant in a drop of water on a microscope slide. Examine with the lowest power of the microscope. Describe any differences in structure that you are able to observe. Look for minute openings called stomata. They are located among the cells of the surface layer of the leaf. They have two small bean-shaped guard cells at the sides of the opening. What is the function of these openings? How are they related to the appearance of moisture on the inside of the plastic bag? Is there any difference in the number or appearance of the stomata on the surfaces of the two plants? Is the total amount of surface different in the two plants? How does this affect the total number of stomata?

What about the natural habitats of the two plants? Try to interrelate (a) the amount of moisture formed on the inside of the plastic bags, (b) the surface structure of the two plants (c) the total amount of surface of each plant, and (d) the natural habitat of each plant. What is the relationship? Why? How does the amount of water evaporated from an acre of green vegetation compare with that from an acre of open water? Why?

Water may also be diverted temporarily from the cycle by passing through the bodies of animals (including man). Some of it is used in building new cells. Some will be returned ultimately to the water cycle by the lungs, skin and kidneys. The kidneys and skin excrete liquid water directly. The lungs excrete it in the form of water vapor. Blow your breath on a cold glass surface. Why do droplets of water form on the surface? Where does it come from?

Water burdened with human waste material in the form of sewage is responsible for much of the pollution of surface water. How does water polluted with sewage become purified? How long does it take? How do sewage disposal plants work?

Water is used in many industrial processes. Frequently it is polluted with industrial waste products when it comes out of the factory. How and when does it become purified? How and when is it returned to the water cycle?

Water cannot be created or destroyed except by physical or chemical means, but it can be rendered temporarily unusable. Water conservation consists of assuring a supply of pure or usable water in sufficient quantity for human use wherever and whenever it is needed. Specifically, water conservation involves prevention or removal of pollution, control of runoff, prevention of floods, impoundment in reservoirs, and other specific measures looking toward an ample supply of pure water.

Follow-Up:

Condensation of water vapor to form clouds, and the precipitation of water as rain, hail, sleet and snow are important parts of the natural water cycle. Study clouds and learn the different kinds of clouds. Observe cumulus clouds closely. How long do they retain the same detailed structure? How are they related to water vapor? How are rain drops formed? Snowflakes? Hailstones?

What kinds of clouds are indicators of rain? What is the relationship of certain kinds of clouds and wind direction to areas of low and high pressure? Study the daily weather map. Look up information necessary to interpret it. Correlate your observations of clouds with what you find on the weather map. What does a farmer or other outdoorsman mean when he says, "It looks like rain?" What does he see that leads him to say this?

Recently, there has been great interest and research in the desalination of sea water. Deriving usable water from the sea is going to be necessary because of greatly increased human needs. Rapidly growing human population and expanding industry in some areas are outrunning natural supplies of fresh water. Of course water derived from the sea through evaporation has always played a major role in the water cycle, but the time is approaching when this must be supplemented by artificial means in areas of concentrated human use. Unless a practical method of getting fresh water from the ocean can be devised, water may well become a limiting factor for man's population before food does.

On your school ground select a number of different kinds of locations:

a. Grassy plot

b. Packed area where the grass has been killed by trampling

c. Ground that has been cultivated and the surface soil loosened

d. Others

Using a metal cylinder made by cutting both ends from a small juice can, push the cylinder tightly against or slightly into the soil surface in each location. Do this in such fashion that no water can leak out around the lower edge. Fill the can to the same level with water in each case. Using a watch with a second hand or stop watch, determine how long it takes the water to soak into the soil in each case. Is the time different for the different locations? What can you say about soil permeability? What does surface vegetation have to do with it? How is soil permeability related to the run-off of surface water? How is it related to the water cycle?

How is the water cycle related to soil erosion? How is it related to flood control? How is it related to wildlife? How is it related to the location of human industry? To the distribution of human population and the location of cities? To the production of human food?

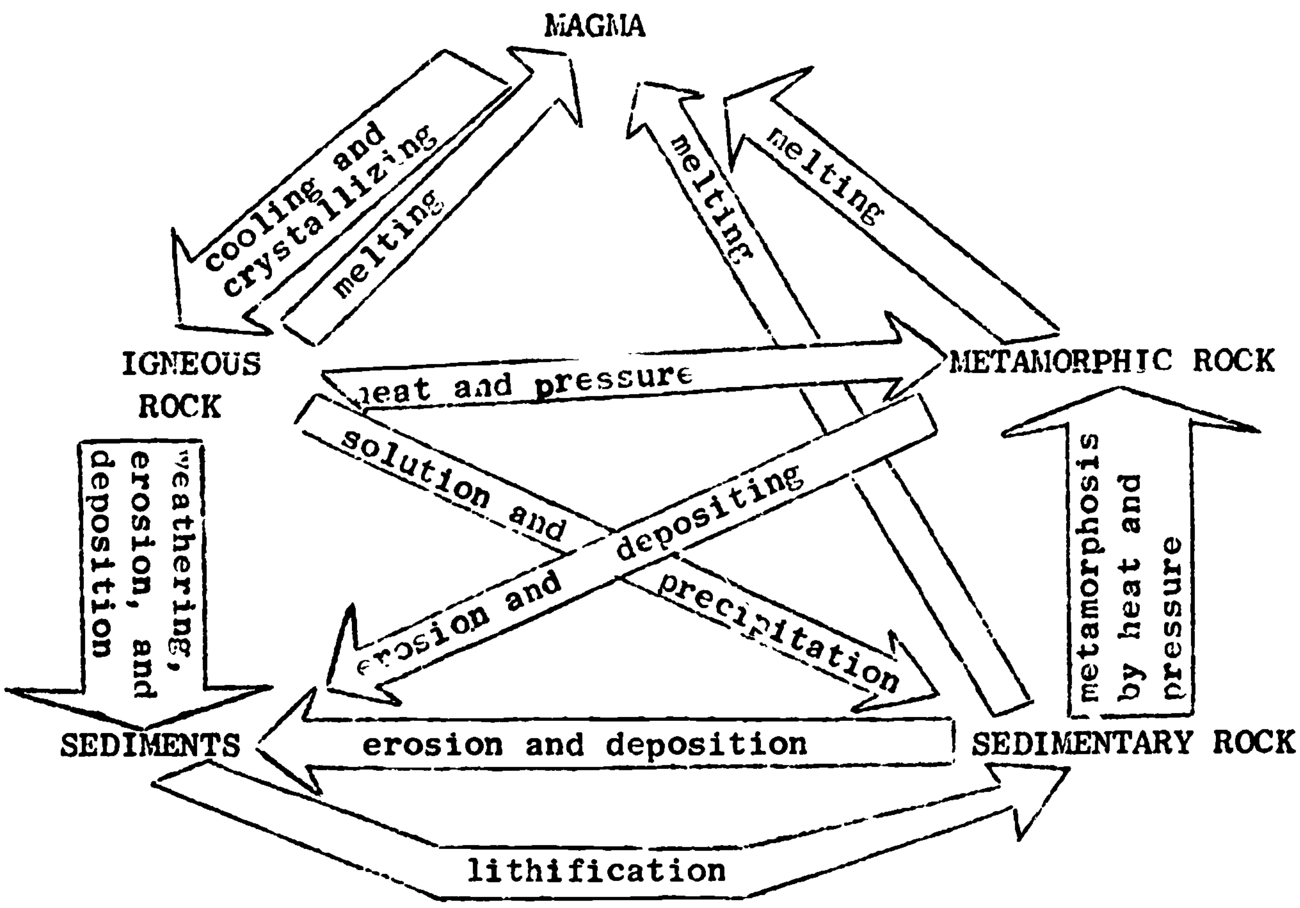
Outline the water cycle as a cycle, and show all of the side relationships that you can think of.

LABORATORY EXPERIENCE D.5.e.

The Rock Cycle

Introduction:

The rock cycle is even more complicated than the water cycle because there are so many smaller cycles possible within it. Study this chart carefully as you collect data.



Materials and Equipment:

Rock specimens

Gravel

Sand

Clay

Portland cement (ordimary cement used in construction work)

Quart fruit jars

Pipette (larger than a medicine dropper, if possible)

Hand lens (10X)

Salt

Collecting Data:

Examine your rock specimens. Make groups of those that have common characteristics. Try to make at least three groups. Use a 10X magnifier to look for characteristics that might help you decide on your groups. What characteristics did you use for each group? Compare your classification with that made by other students. What characteristics did others use? Is it possible for everybody to agree on three groups? Why or why not? Secure a few more specimens. Do these fit into the groups that you have already made?

Petrologists (scientists who study rocks) have agreed to classify them by origin. Of course this was not the basis of the classification that you made for your specimens. You had no way of knowing the origin of your specimens.

Melted materials in the earth's crust are called magma. All rocks formed by the cooling and hardening of magma are called igneous rocks. If the magma reaches the surface in a volcanic eruption, it is called lava. When lava cools and solidifies it forms extrusive igneous rocks. If the magma never reaches the surface, but cools and solidifies under a cover of rock, intrusive igneous rocks are formed.

Igneous rocks may be glassy and smooth like obsidian, or coarsely grained like pegmatite. The texture depends on the sizes of the mineral crystals in the rocks. Igneous rocks may be light colored like granite, or dark colored like gabbro. The color depends on the minerals in them. In all cases, however, igneous rocks are formed by the cooling of magma. Find the place in the rock cycle chart where the formation of igneous rocks is shown. It is possible to melt rock in the laboratory, and watch the formation of crystals as the molten materials solidify, but temperatures of 1100°F to 2200°F are necessary. We can't do this in a school laboratory.

Weathering and erosion break up rocks into smaller and smaller pieces. When these become small enough they may be carried by wind and water. They may be deposited far from the bedrock from which they came. These rock particles are sorted by water, and are deposited as sediments.

Place a handful of stones one inch in diameter, a handful of smaller stones, a handful of sand, and about the same amount of clay in a quart jar. Fill the jar with water. Cover the jar and shake vigorously, but not hard enough to break the jar. Set the jar down and watch the sediments settle out. Can you distinguish layers or strata? If sediments are deposited where a stream enters a body of still water, which size pieces would settle closest to shore? Which size pieces would settle farthest from shore? Why?

Lithification is the process by which sediments are changed to sedimentary rock. Geologists believe that pressure alone will hold fine particles together. Larger particles must be held together by natural cements such as silica, lime and limonite.

To change your jar of sediments to sedimentary rock add some portland cement. Shake again. Allow to settle. Pour off as much of the clear water as you can without disturbing the sediments. Let stand until the cement sets. You'll have to break the jar to get your sedimentary rock out. Study the chart and see where on the rock cycle your activity fits.

Some sedimentary rocks such as halite (rock salt), gypsum, and some limestones are precipitates rather than sediments. Put salt into a jar of water. After all is dissolved that will do so, add still more salt. Shake vigorously. Allow to settle. Does the salt settle to the bottom. How could it be removed from the water? How are precipitated sedimentary rocks formed? Find this in the rock cycle chart. Ask your teacher how to make a "crystal garden" (See Teacher Notes under Laboratory Experience C.3.b.) How are crystals formed in this case? How is their formation related to the formation of sedimentary rocks by precipitation?

A third kind of sedimentary rock is formed from organic materials. Shells of animals form chalk and limestone. Remains of plants form coal. Why are they not in the rock cycle chart?

Metamorphosis of either igneous rock or sedimentary rock forms metamorphic rock. Heat that is below the melting point, with pressure, causes a recrystallization of the minerals and/or development of a foliated (layered) structure. Sandstone becomes quartzite. Limestone becomes marble. Bituminous (soft) coal becomes anthracite (hard) coal. Shale becomes slate or phyllite or schist. Several different kinds of rock become gneiss. Follow the arrows on the rock cycle chart that show the formation of metamorphic rock. What can happen to metamorphic rock? Study the rock cycle chart to find out.

With your teacher's help and by the use of pictures, reclassify your rock specimens by the method used by petrologists. Review the chart of the rock cycle to find out all of the smaller cycles within it that you can. How many can you find?

A study of rocks is interesting, and making a rock collection can be fun. Try one or the other or both.

There are several good films about the classification of rocks according to origin. If possible, see one of them.

D.6. Idea of Dynamic Equilibrium: Interacting Changes That Result in Balance

Idea Bridge: An "Almost" Balance That Constantly Approaches Balance

We talk about the "balance of nature" without thinking about the often cruel forces that produce this state of apparent balance. Actually nature never comes to a true balance. All you ever really have is a condition in which a great many changes are constantly taking place. Many of these changes oppose each other, and either counteract each other or cancel each other out. The result is that once a fairly stable or constant relationship is reached, things tend to stay pretty much the same. What you really have is a dynamic balance. This can best be described as "an 'almost' balance that is constantly approaching a balance, but never quite reaches it."

There are many common examples of dynamic balance: (1) a laboratory balance where the indicator almost comes to rest at the zero point, but cannot because it is constantly being disturbed by people walking past, trucks going along the street, or currents of air from people opening and shutting doors; (2) a forest in which the natural community of living organisms is constantly being disturbed by conditions of rain and drought, disease and changes of the seasons; (3) a plant or animal which keeps a state of approximate internal balance as a result of the interaction of forces of build-up and break-down that are going on inside it. A good example of this is a person maintaining a more or less constant body weight.

On either a short term or a long term basis, all of the natural world exhibits states of dynamic balance or dynamic equilibrium.

LABORATORY EXPERIENCE D.6.a.

Internal Equilibrium: Maintenance of Weight in Humans

Introduction:

Modern people are very conscious of their weight. This is especially true of adults. Children also may be over weight or under weight. Weight is not only important from the standpoint of personal appearance, but also of health.

Growing children, of course, are slowly increasing in weight throughout their period of development, although the rate of increase is not constant. Throughout mature adulthood, while there are normally slow changes with increasing age, a balance is normally maintained. With the onset of old age, these changes may become somewhat more extensive. In periods of ill health, rapid changes in weight, either loss or gain, may indicate serious internal maladjustment or illness.

We may think of the period of growth in early life as being the time during which the "building-up" processes operate in excess of the "tearing-down" processes. During healthy adulthood, the building-up and tearing-down processes are essentially in balance, and a state of equilibrium, or homeostasis, is maintained. In old age, the tearing-down processes generally outweigh the building-up processes. This may or may not be reflected in body weight.

When people diet to lose weight, they reduce their total food intake, and particularly their intake of energy producing foods (carbohydrates and fats), to a point below the amount necessary to maintain the body in its normal activities. Some of the body's stored fat (representing weight that has been accumulated) is then broken down to make up the difference. Thus some weight is lost. The body continues to lose weight until finally it is allowed to stabilize at the desired level. This weight is then maintained through carefully controlling food intake at the point necessary to keep it that way. Not too much; not too little.

Materials and Equipment:

Bathroom scales

Graph paper

Collecting Data:

Record the weight of one or more adults, and one or more children, taken at the same time each day, over a period of at least three weeks. Plot the daily weight on sheets of graph paper which can be fastened together to make a continuous story.

Try to find an adult who is trying to lose weight by dieting, and record this person's daily weight for the same period, and in the same way.

If a number of individuals or teams in the class are carrying on this laboratory experience at the same time, try, by looking at all of the data together, to get a "picture" of (1) the relative stability of adult weight in a representative sample of the population, and (2) the results of attempting to control overweight through dieting. Get as many weight records of adults and children, dieters and non-dieters, as possible.

To what extent is homeostasis maintained? In adults? In children? In men? In women? In boys? In girls? In dieters? In non-dieters? To what extent does fluctuation occur? Are the dieters able to lose weight consistently? Are they able to hold a stable weight? Is there any evidence of progressive slow increase in weight in children?

To what extent in your study is there evidence of equilibrium between the building-up and tearing-down processes? What are the processes that are involved? Does heavier eating on holidays and weekends make a difference? Does this difference appear in the records of all individuals, or only in some? Are these any rhythms or cycles apparent? Are those similar or comparable in different individuals?

Follow-Up:

Continue the study for a period longer than three weeks, if possible.

Find out all you can about current trends in the consumer demand for diet foods, non-caloric sweeteners, calorie-free soft drinks, animal and vegetable fats (butter and margarine, lard and cooking oils). How are these related to current popular fears of the relationship of overweight to heart disease and other health dangers?

What are some examples of diet foods?

Weight is only one indicator of homeostasis or equilibrium of body functions. What are some others?

LABORATORY EXPERIENCE D.6.b.

A Chemical Indicator

Introduction:

Chemists recognize two large classes of compounds called acids and bases. These are soluble in water, and a particular solution may be acidic or alkaline (basic). When an acid and a base react chemically, the results are a compound belonging to a third class called a salt and water. Common table salt is one kind of salt. It is called sodium chloride (NaCl) and it is formed by allowing sodium hydroxide (NaOH), a base, to react with hydrochloric acid (HCl).

$$NaOH + HCl \longrightarrow NaCl + HOH \text{ (or } H_2O)$$
$$\text{sodium hydroxide + hydrochloric acid} \longrightarrow \text{sodium chloride + water}$$

There are many kinds of acids, bases, and salts. A common household acid is vinegar. It contains acetic acid. A common household base is ammonia (ammonium hydroxide NH_4OH).

Some pigments, when in water solution, are very sensitive to acids and bases. They react to them by changes of color. One pigment of this kind is the purplish or bluish pigment found in "red" cabbage. Such pigments are called indicators.

Since the materials and equipment necessary for working with this indicator are easily obtainable, you can learn about chemical equilibrium by working with it in the laboratory. You will also be learning something about acids and bases at the same time.

Materials and Equipment:

"Red" cabbage

Household ammonia

Vinegar

Small, smooth board

Razor blade

Four small fruit juice glasses

Shot glass, or other small, clear glass container

Small tea strainer

Small pan, and a source of heat for heating water

Teaspoon measure

Two medicine droppers

1. Remove two or three leaves from the outside of a head of red cabbage. Select the thinnest portions of the leaves, and cut them up as finely as possible by placing them on a smooth board and cutting them into little bits with a razor blade.

2. Place the cut-up material in one of the fruit juice glasses. Heat a small quantity of water to boiling, and carefully pour enough water over the cabbage material to cover it. The less water you use the better. Let the mixture stand for a few minutes, stirring it frequently. What happens? Allow all of the purple (or blue) pigment to go into solution that will do so.

3. Pour the colored solution into a second fruit juice glass. Pour it through a small tea strainer to hold back the solid cabbage material.

4. Pour a small quantity of ammonia into a third fruit juice glass, and a small quantity of vinegar into a fourth glass.

5. Put two teaspoonfuls of the colored solution into a shot glass or other small glass container. Add vinegar with a medicine dropper, drop at a time, to the solution. What happens? What color does the solution become? Stir the solution as you add the acid. When there is no further change, add ammonia, drop at a time, using the second medicine dropper. What happens? Why use the second medicine dropper? Again, stir as you add, until there is no further color change.

Is it possible, now, to reverse the color change by adding acid? Try it and see. If you succeed in reversing it, add ammonia and try to change it back the other way. Does it change again? How many times can you change the color back and forth? If you come finally to a point where a reversal is no longer possible, why do you think this has occurred?

Now replicate the experience, beginning with a new sample of the indicator. Are your results the same as before? Explain what you have observed in terms of equilibrium. What do you think was the original condition of the colored pigment solution? Neutral? Acid? Alkaline? Why?

Follow-Up:

For this, you will need some additional equipment and materials:

Test tube rack

Nine small test tubes

Tablespoon measure

pH paper

A third medicine dropper

Put a tablespoonful of water in each of nine test tubes in a test tube rack. Beginning at the left, add vinegar to the first four tubes as follows: (Use the same dropper that you used with the vinegar before.)

No. 1	20 drops	No. 3	10 drops
No. 2	15 drops	No. 4	5 drops

Do not add anything to the water in test tube No. 5. Continuing, then, from left to right, add ammonia to the remaining four tubes as follows: (Use the same dropper that you used with the ammonia before)

No. 6	5 drops	No. 8	15 drops
No. 7	10 drops	No. 9	20 drops

Now you have a gradient of dilutions from left to right, ranging from very acid, through neutral, to very alkaline.

pH paper contains a pigment which, like that in red cabbage, changes color, becoming red with acid, blue with alkaline. Test your gradient of acidity and alkalinity with pH paper. Note color changes. Do you obtain a gradient of color? Are they reversible in the case of the paper?

Add a few drops of the cabbage pigment solution to each of the test tube dilutions. Use a third medicine dropper. Note all color changes, both kind and degree. Do you obtain a gradient of color? Why? What would you say as to the relative sensitivity of pH paper as compared to your cabbage pigment solution? Are both equally sensitive?

What practical use do indicators have? What is meant by pH? How is it related to what you have been doing?

LABORATORY EXPERIENCE D.6.c.

Equilibrium in the Landscape: Opposing Forces at Work

Introduction:

Conflicting forces are constantly changing the surface of the earth.

Movements of the earth's crust are caused by tectonic forces which get their energy from inside the earth. Tectonic forces cause diastrophism and vulcanism. Diastrophism is folding or faulting (breaking) of the earth's crust. Vulcanism is movement of magma (melted rock). Geologic evidence indicates that these tectonic forces have kept part of the rocks that make up the surfaces of continents above sea level since the beginning of time.

The gradational forces of erosion and deposition receive their energy from the sun by way of the water cycle (See Laboratory Experience D.5.d.) These forces constantly "counter attack" the earth's surface to make it level.

The opposing tectonic and gradational forces work at unbelievably slow rates. They work so slowly that we must study speeded-up models of their action in the laboratory in order to see them in operation.

Materials and Equipment:

Modeling clay (different colors)

Two small flat boards

One 2" x 4" x 8" block of wood

Saw

Sand paper

Rock specimens

Pictures that show folds, faults, and intrusions

Earth science textbooks

Dictionary

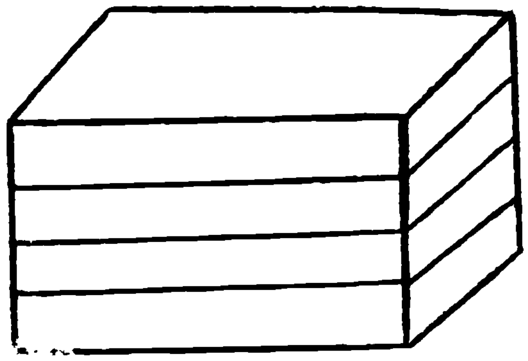
Dirt piles

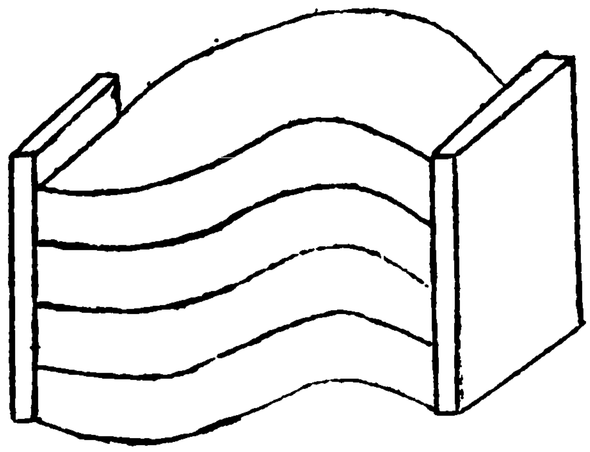
Collecting Data:

Examine a piece of folded sedimentary rock or a picture showing folding. Since sediments are always deposited in horizontal layers, there must be an explanation for folded layers.

Use several different colors of modeling clay. Place layers of different colors on top of one another horizontally. Firm them together but do not crush them. Slowly, very slowly, compress them by pushing from the sides or ends

with two flat boards. Can you make the clay layers fold? The anticlines are upfolds, and the synclines are downfolds. These make a wavy or uneven surface. Do we find these in nature?

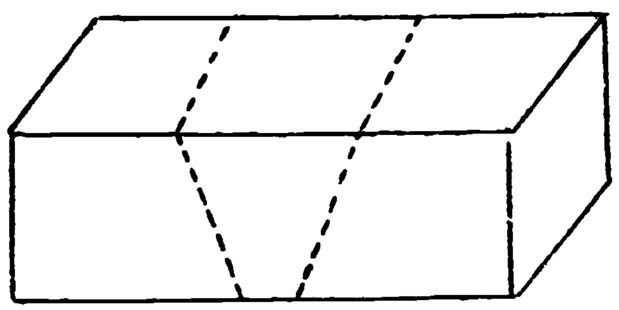




Compare folding clay layers and folding rock layers as to the amounts of pressure and time required. What conditions must exist for rock layers to fold?

The Himalayas of Asia, the Andes of South America, the Alps of Europe, and the Rockies and Appalachians of North America are mountains that consist of long, parallel folds that roughly correspond to the margins of the continents. Although both diastrophism;and vulcanism have had a part in their formation, folding seems to have been the most important formative cause.

Folding is one of the forms of diastrophism the other is faulting. Saw a block of wood as illustrated in the accompanying diagram. Smooth the sawed surfaces with sandpaper.



Hold the three pieces with just enough pressure to keep them together. Gradually increase the pressure. What happens to the center block? Gradually decrease the pressure. What happens to the center block?

Tension (stretching) and compression may cause rock layers to move or fault. Rock layers may also fault horizontally (slide past each other). Can you show this with the blocks of wood? Faulting may be sudden and cause earthquakes, or it may be extremely slow. Fault block mountains such as the Sierra Nevadas are formed by faulting of great areas of the earth's surface.

Tectonic forces also cause vulcanism. You are familiar with the eruption of volcanoes. You can read about famous volcanoes such as Mauna Loa and Kilauea in Hawaii, Mt. Katmai in Alaska, Mt. Etna in Sicily, and Mt. Vesuvius in Italy. A less well known form is intrusive vulcanism. Masses of molten rock (magma) that cannot find an opening to the surface intrude between rock layers or fill in cracks. These intrusions form dikes, sills, laccoliths, stocks and batholiths. (Look up these words in a dictionary.) All of these tend to push up the surface rock.

The geological processes of diastrophism proceed so slowly that only their long-term effects can be observed at any one period of the earth's history. The geological processes of gradation, however, can be observed going on around us all the time. Everyone has observed eroded fields and roadsides. Small, temporary streams behave exactly like larger creeks and rivers, and the valleys that are cut by such small, temporary streams go through the same developmental stages as larger valleys.

Observe a freshly-made pile of dirt at a construction project immediately after a heavy rain. Note the stream channels down its sides. What is the shape of the channels in cross-section? Why? Note the sediment that has been deposited on the surface of the ground at the mouth of each stream channel. What is the shape of the deposit? Why is it called an alluvial fan? What is the character of the particles of dirt that make up the deposit? Compare them with the original pile from which they came. Are there any differences? What are these differences? Why? Does the kind of soil make any difference? What and why?

Observe the same or a similar pile of dirt after it has been eroded by many rains. Compare the extent, shape, and general appearance of the stream channels in this pile with those made by a heavy rain in freshly-piled dirt. What differences do you see? Why? Make a similar comparison of the deposits at the mouths of the stream channels on its sides. What differences are there? Why?

If possible, observe the effects of erosion on a very old pile of dirt. Make the same comparisons as before.

Observe the results of erosion along the right-of-way of a freshly-constructed highway, and/or on a hillside in a field. Compare what you see there with what you observed on the piles of dirt. Make comparisons similar to those which you have made before. Can you determine the age of the erosion in a field or a road cut by a study of the stream channels and alluvial fans? Is there any evidence in the case of the field that some of the erosion is more recent, and some older? What is the evidence?

Study a relief model or a relief map of North America. What do you see that can be related to what you observed on the dirt piles, along the highway, or in the field? What would you say about the age of the ranges of mountains on the map? Why?

What is the history of a stream valley as it grows older? How can you tell the relative age of a valley? Have you ever observed young valleys as you traveled through the country? Where? Old valleys? Where? What is a peneplane? Are there any peneplanes in North America? If so, where? How do we know that they are peneplanes? How old are they, geologically? What is the relationship of a peneplane to the attainment of equilibrium on the earth's surface?

What can you say about the attainment of equilibrium in the case of a dirt pile? Or a road cut, or an abandoned field? What would correspond to a peneplane in the case of a dirt pile? Try to find a dirt pile that is approaching this point. Is equilibrium ever really reached in the case of a dirt pile? A road cut? A field? A mountain range? Why or why not? Is there such a thing as a landscape in a state of equilibrium.

Follow-Up:

Read about the San Andreas Rift in California, and the earthquakes that have resulted from sudden faulting along it. Where are other great earthquake areas of the world? Are they all of the same type? Read about the New Madrid earthquake that took place in 1811 in the Mississippi Valley. Was it like the earthquakes that have taken place in California and Alaska?

Contrast man-made erosion with geological erosion. How are they the same or similar? How are they different? Man can destroy a field or area through the erosion which results from his activities. How long does this take, relative to the time required for geological erosion to occur? Such an eroded field or area is restored to something approximating its original condition through the natural process of ecological succession. What is this process? How long does this take? Can man also take measures to restore the field or area? How? How long does this take relative to the time required for the natural process?

How is soil formed under natural conditions? Study the soil layers in a road cut or on the side of a freshly dug ditch. Identify the A-layer, B-layer, and C-layer. You can find these if the surface has not been distrubed previously. What are they? How are they related to one another? How are they related to the distribution of soil nutrients? How are they related to soil destruction through erosion, and to soil restoration?

What are "oxbows" and "oxbow lakes" in terms of the age and history of streams? How are they formed? In what kind of landscape would you look for them? Why? What are "canyons" in terms of the age and history of streams? How are they formed? In what kind of landscape would you look for them? Why?

LABORATORY EXPERIENCE D.6.d.

A Balanced Aquarium

Introduction:

One of the best laboratory examples of dynamic equilibrium is a balanced aquarium. It is a small, relatively perfect plant-animal community. It contains all of the basic living elements that any plant-animal community must have in order to continue to exist: green plants (food makers), animals (food users), and organisms of decay (decomposers).

The green plants make food from carbon dioxide, water, and mineral salts by the process of photosynthesis which uses the energy of sunlight. The plants use some of this food themselves for growth and seed production. Much of it, however, is used by animals that are unable to make food. It serves them for growth, activity, and reproduction. Finally the decomposers (molds, bacteria and other "colorless plants") break down waste products and dead bodies to carbon dioxide, water, and mineral salts that can again be used by green plants in the making of food.

Of course the plant-animal community to which the balanced aquarium is most closely related is a pond or stream pool. Like these, it is an aquatic (water) community. The balanced aquarium is called a microcosm of a pond or pool community. All that this means is that it is small and complete within itself.

In a larger sense, however, the balanced aquarium is comparable to all plant-animal communities. All of them, in the water, or in various habitats on land, are in dynamic equilibrium. This is true of forests, grasslands, even deserts. There are three niches (occupations) in every community: food makers, food users, and decomposers. Each of these has a job to do that is necessary for the continued existence of the community in a state of balance.

Materials and Equipment:

Wide mouth gallon jar (the mouth must be large enough to get your hand into it)

Clean sand

Water (not chlorinated)

Green aquatic plants (Many kinds are available. Elodea and eelgrass are among the best kinds)

Aquatic snails

Collecting Data:

Use a jar of at least one gallon capacity, which has an opening large enough to get your hand into it. Get some river or lakeshore sand which is free of dirt and debris. Wash it thoroughly through many changes of water. Put about two inches of sand in the bottom of the jar. Fill the jar with water to a level so that when you put your hand to the bottom, the water will not overflow. Allow the sand to settle until the water becomes clear.

You may need to do this several times, pouring the water off and using clean water each time, before you are able to get clear water above the sand.

Put several aquatic plants into the jar, "rooting" them in the sand with your hand. The best way for you to get aquatic plants is to purchase them at an aquarium or pet store, or at such department in a larger store. You may, of course, collect your aquatic plants from a pond or stream pool. Be careful, however, if you do this, to get plants that you know will live and are not too large.

Why must your plants be able to live and grow completely submerged in water? Why would it be unwise to get plants from an actively flowing stream? Why are size relations important?

Put a few aquatic animals in the aquarium. Why "a few?" Snails are plant eaters (herbivores), and are more likely to find an adequate food supply in the aquarium. Larger animals, especially fish, would require feeding. Why would this keep the aquarium from being in dynamic equilibrium? Why would it be unwise to include tadpoles? Why would it be unwise to include carnivores (animals that eat other animals)?

Cover the jar with its own lid or with a cover of glass or plastic wrap. This will cut down loss of water from evaporation. Allow your aquarium to stand in a well lighted place (but not in bright or hot sunlight) for at least two weeks. If, at the end of this time, the water is clear, if it smells "fresh," if the plants appear healthy, and if the animals are alive, your aquarium is approximating a dynamic balance. The longer it continues in this condition, the better is the balance.

If you have been successful in building your aquarium it is balanced at the "snail level." This means simply that snails are the largest animals that the community can support in a condition of dynamic balance. Study the activities and relationships of the animals and plants in the aquarium. Look at it and smell of the water every day, if possible. What does the odor of the water indicate? What are the snails doing? Are the plants growing? Are there any interrelationships between them? Is there beginning to be an accumulation of gray, decaying materials on the sand at the bottom of the aquarium? This is "humus" and is the result of the activities of the decomposers. It should begin to appear after about two or three weeks. When this appears it is probably the best indication of balance. What does it consist of? What function does it serve in the community?

Although your balanced aquarium in a gallon jar is probably too small to maintain itself as a community indefinitely, as a pond or pool would do in nature, it may last for several months to several years. Why would it probably not maintain itself as a community indefinitely?

Follow-Up:

For a balanced aquarium to support carnivores, it would have to be much larger, and contain many more plants and small herbivores. Why? How much larger do you think it would have to be?

You balanced aquarium will maintain itself successfully in any window during the winter months. An east or north window is best for a year-around location, because the environment of the aquarium is more stable in a place where it receives plenty of strong, indirect light, and not more than a small amount of direct sunlight. In summer, west and south windows are generally too hot for an aquarium. Try various locations with aquaria and see if they remain in balance.

Although daily and seasonal light and temperature changes in the classroom are not as extreme as they are outdoors, such changes do occur. Watch the changes that take place in your aquarium as the seasons change.

IDEA-CENTERED LABORATORY SCIENCE

(I-CLS)

The Kind of World a Scientist Thinks He Has Found

Unit D. A Scientist Assumes the Existence of Variation and Change

TEACHER NOTES

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1969

I-CLS

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TEACHER NOTES

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LABORATORY EXPERIENCE D.1.a.

Normal Distribution Curves Show Variation in Nature

TEACHER NOTES

There are several interesting side lights which can be developed in connection with this laboratory experience. It is, of course, pointed directly toward the Idea of Normal Distribution Curves and their function as models for describing not only morphological variation in the living world, but also other kinds of phenomena involving variation in the biological and also the social sciences. This broader relationship of normal curves should be pointed out. Students interested in public opinion polls, grade distributions in a class and other phenomena which behave in this way can follow up their interests with profit and increased understanding.

The question of variation in the physical sciences, and how and why it differs from variation in the biological sciences is another interesting side light. In the first place, where does it occur? And is there any area in the physical sciences where no variation occurs? Where and why? Students may consider rocks, grains of sand, crystals and anything else in the general area of the physical sciences that they can think of.

The question of variation in man-made things of the same kind, and of related kinds furnishes still another interesting sidelight. Are two man-made things, or all man-made things of a certain kind (all cars of a certain model; all plastic spoons of a certain kind) really as alike as they appear? If they do differ, how is it possible for them to do so?

Somewhat more directly related to the laboratory experience is the question of the relationship of variation in living things to natural selection and evolution. Although you will almost certainly want to point out this relationship, you may not wish to follow it up at this time. You can, however, if there is a real interest in it, and if questions are asked about it. A study of variation is fundamental to an understanding of evolution, and some consideration of the role of natural selection is a natural follow-up of variation.

LABORATORY EXPERIENCE D.1.b.

Measuring Leaves

TEACHER NOTES

This laboratory experience is designed to give the students further practice in recognizing that variation is found in all of the world of life, and when it can be reduced to measurement it tends to follow a normal curve type of picture. There is an opportunity to think in terms of modes and means of populations, range of variation, extremes, and adequate samples.

If you wish to introduce the students to mathematical methods of comparison of two populations, you are, of course, free to do so. Your own familiarity with and facility with these methods will help to determine whether you should do so or not. Do not fall into the trap, however, of thinking that, because you understand the mathematical relationships and find them easy and interesting, the students will also do so. The opposite may be true.

LABORATORY EXPERIENCE D.1.c.

The Success of a Species Depends on Its Variability

TEACHER NOTES

The major Idea to be brought out here, and the one toward which the laboratory experience is directed, is, of course, the wide application of normal curve distribution in describing variation in nature. An important subsidiary concept, however, is that of the widespread variation in all kinds of characteristics which occurs among humans. This wide variation is more characteristic of humans than of any other species of animal.

This broad range of variation is a major factor in the nearly universal adaptability of the human species. It has enabled man, when coupled with his problem-solving brain, to spread to all available habitats of earth, and, with the aid of artificially evolved devices, to the sea floor, into airless and weightless space, and probably onto the surface of the moon and the nearer planets.

Man is facing many challenges in the immediate future on this increasingly crowded planet, with its polluted atmosphere and waters and its diminishing resources. His ability as a species to survive into the coming centuries may well depend on his wide range of variability. A highly variable species always stands a better change of surviving serious environmental challenge than a less variable species. Rather than suppressing a recognition of differences among humans, it 's time that we acknowledged them and exploited them. If the human species is to survive, it will probably require the best use of all of the abilities that we each possess. Discuss this idea with the class.

LABORATORY EXPERIENCE D.1.d.

Which Way Does The Wind Blow?

TEACHER NOTES

With this study of wind as a start, you may take the class (or some individuals in it) as far as you wish to in studying weather. Children in an earlier generation in rural areas grew up with this kind of weather observation (in a less formal fashion, of course), but modern city children do not have an opportunity to learn this kind of thing unless we teach it to them, or at least point it out to them, and give them an opportunity to learn it on their own. It carries a great deal of inherent interest and maturation, however, and like most interesting things in the environment it is readily accessible.

Rural children in former times did not have the advantages of radio, television, nor always even daily newspapers, which the modern city child has, either at home or in the school or both. By combining observation with information available through modern means of communication, the modern city child, even in disadvantaged areas, can arrive at a real understanding of weather that the rural child in former times never had.

Furthermore, modern meterological knowledge of fronts and air masses has been available only for about the past thirty years. This knowledge makes possible for the first time, a real understanding of weather, other than as a purely local phenomenon.

Although this laboratory experience is included under the Idea of Normal Curves, it goes beyond it. It is related and contributory also to the Idea of Patterns and Natural Law in Unit A. You should refer back to this in talking with the students. The patterns which are formed on the graphs in connection with this wind study will probably not be normal curves. They may be warped curves, or they may show up as gradients, or be related to normal curves in some other way. Some of the patterns will be consistent, and will tend to repeat themselves in different days or weeks. Others probably will not. In any case the relationships shown on the graphs in connection with the weather during the month will be interesting and should be studied carefully.

LABORATORY EXPERIENCE D.2.a.

Gradients in Color

TEACHER NOTES

In discussing gradients in the Introduction the emphasis is on a gradient of size. In the Follow-Up there is an opportunity to show that there is an easily demonstrated gradient of skin color in almost any group of late twentieth century Americans. This will serve to show that there is no real separation of "blacks" and "whites." Negroes are not really black, and Caucasians are not really white. The only truly white person is an albino. The sociological implications of this experience will be of particular importance in racially integrated school populations and areas.

It is important to point out in this connection that Caucasians contain varying amounts of melanin in their hair, eyes, and skin, and that the other pigments, carotene and rhodopsin, are of importance in various human racial types and individuals. Call particular attention to any red heads in the class. Look for evidence of the presence of rhodopsin in their skin and eyes, as well as in their hair.

Bring Indians, Spanish-Americans and Orientals into consideration in discussion, whether or not there are any individuals of these back grounds in the class.

LABORATORY EXPERIENCE D.2.b.

Gradients of Taste

TEACHER NOTES

Gradients are interesting to work with in the laboratory. The Idea of Gradients is one that we use all the time, in daily living and in science, and it also is one of the basic understandings of science. It can also be called the Idea of Intergradation. This means simply that there are no sharp boundary lines in nature. Related classes of phenomena throughout all of the natural world tend to grade imperceptibly into one another in the area where they meet. In a sense, therefore, all of nature consists of gradients. It would be well, if you can, to introduce students to this broader application of the Idea of Gradients.

The concept that scientists use instruments, sometimes simple ones like pH paper, sometimes more complex ones like thermometers, and sometimes extremely complex ones like electron microscopes and computers as aids to and extensions of their senses is an important one. You can teach it in a simple form with this laboratory experience.

LABORATORY EXPERIENCE D.2.c.

A Gradient in Heating Water

TEACHER NOTES

This is a laboratory experience so simple that it requires little comment or direction. It is an excellent example of a gradient. Students will also learn a great deal about boiling points, freezing points and the three states of matter if they wish to consider the Follow-Up. You may introduce them to the Kinetic-Molecular Theory in a simple form if you wish to do so. It should tie in very well with a review of Brownian movement which was seen in an earlier unit.

LABORATORY EXPERIENCE D.2.d.

Gradients from Topographical Maps

TEACHER NOTES

You will be introducing a number of new terms and new techniques in this laboratory experience. You must be careful in pointing these out to the students. Define, discuss, and demonstrate until you are sure that all students understand before you begin the actual laboratory experience.

This experience carries the Idea of Gradients one step farther than any of the other experiences in this unit. Yet it simply applies the Idea to an area in which its use is common and well understood.

Topographic maps are available from:

Washington Distribution Section
U.S. Geological Survey
Silver Spring, Maryland

A check to cover the cost must be sent with the order.

An index to topographical maps for any particular state may be obtained from:

Map Information Office
U.S. Geological Survey
Washington 25, D.C.

LABORATORY EXPERIENCE D.3.a.

Stacking Coins

TEACHER NOTES

You may use poker chips or iron washers of a uniform size instead of coins with this laboratory experience. These would stack somewhat more easily than pennies. The reason for suggesting the use of pennies instead of these is that we have utilized pennies in earlier laboratory experiences, and using them again here carries the advantage of familiarity.

In making the graph under Follow-Up, the distances on the horizontal axis of the graph should be the same as the distances on the line of the paper (two inches, four inches, et cetera). The units representing numbers of pennies in the stacks should be set up proportionally. In this way the students will be better able to see that the graph is simply a picture of their manual operation.

The problem in any case is to give the students a simple direct experience with the Idea of Extrapolation and Interpolation, and its relationship to the Idea of a Gradient. Do not allow students to lose sight of the close relationship between these two Ideas.

LABORATORY EXPERIENCE D.3.b.

Extrapolating and Interpolating on a Clock Face

TEACHER NOTES

The thought here is to show students that they are really studying the constant relationship which exists between two rates of movement: that of the hour hand and that of the minute hand. The clock face is only a device for studying this relationship. Once this thought is established in the students' minds, they can see that the relationship can be projected off the clock face altogether. There is no limit to the extrapolation that is possible.

The study of the pendulum under Follow-Up is another way of getting at the same thought. Here the decreasing length of swing can be projected to zero, and then the extrapolation can be tested by observation. The time of each swing, however, remains the same. This is why old clocks could be built which depended on a swinging pendulum for marking the passage of time.

The difficulties which would be (and are) encountered in making clocks to mark the passage of longer periods such as weeks, months, years, and centuries lie in the irregularities in the movement of the earth and other heavenly bodies which are the ultimate basis for the marking of the passage of time. These irregularities are known, of course, and are predictable, on a cyclic basis, but are difficult to build into a clock, or a calendar. Nevertheless, such clocks can be and have been made.

LABORATORY EXPERIENCE D.3.c.

The Growth of a Corn Plant

TEACHER NOTES

This experience serves to introduce the students to the idea of the greater complexity of living organisms as compared to non-living things. The consequence of this, of course, is the greater difficulty involved in all experiments with living things, the lesser degree of predictability; and the greater frequency of exceptions to expected behavior.

You should stress the importance of quantitative data and the fact that living things can be studied quantitively, even though the results are somewhat less susceptible to exact and uniform interpretation.

The reasons for the variable and less predictable behavior of living things are not always apparent. There are more unknowns and unanswered questions at the end of a study of living things. Students should learn that this is true, and learn not to be disturbed by it. They should not fail, however, to seek for explanations and answers. They should leave the corn plant experience, for example, with the thought that if they could continue it for a longer period, and/or could repeat it many times under more carefully controlled conditions, they might eliminate some of the unknowns, and find some of the answers.

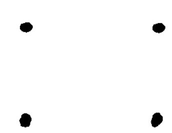
LABORATORY EXPERIENCE D.3.d.

Alternative Hypotheses: An Experience in Extrapolation

TEACHER NOTES

This is mainly a problem in visualizing. Therefore you should use the chalkboard freely at all points. Treating the problem as a collective problem for the entire class helps also.

So far as the writers are aware, there is only one possible arrangement for the original four dots:



a square. It is not beyond the bounds of possibility, however, that some student may come up with a new kind of arrangement. The question, therefore, should be left open.

The same thing is true of the number of figures which can be drawn with the four dots in the perimeter. The number is limited, though here, again, students may come up with a new one. Here, too, the question should be left open for each class group to decide. The suggestions that are made constitute a good basis for class thinking.

Actually, the postulating of additional dots that serve to define a figure constitute both extrapolation and interpolation. It is extrapolation in the sense that it is going beyond the data that we have. It is interpolation in the sense that it consists of filling in the gaps in the data that we have.

LABORATORY EXPERIENCE D.4.a.

Natural Selection in the Animal Kingdom

TEACHER NOTES

The all important theme in this laboratory experience is that evolution is directional change from simple one-celled organisms to complex forms, including man. The use of many books, especially those with pictures, and as many fossils as possible will make this an interesting laboratory experience.

Variation that survives is evolution. Evolution is a directional change. Don't get "bogged down" with a supposed conflict between science and religion, or "man from monkeys" or any other controversial topics.

LABORATORY EXPERIENCE D.4.b.

Variation in Feet and Hands

TEACHER NOTES

The major function of this laboratory experience is that it constitutes an attempt to deal quantitatively with an area of variation in humans. The students are brought to look at a whole field of variation in relation to themselves. None of the relationships are difficult to study and students are already familiar with the use of graphs. A new technique----that of making scattergrams, is introduced.

If there is any reason for deemphasizing the making of measurements on students' feet, hands may be substituted entirely. Feet do offer certain advantages, however, since measurements and relationships can readily be related to shoe sizes, which are of general interest to everyone. Of course, the use of both feet and hands, and a comparison involving corresponding measurements of both, furnishes the best laboratory experience.

LABORATORY EXPERIENCE D.4.c.

Natural Selection at Work: A Field of Competition

TEACHER NOTES

A sufficient number of puzzles should be prepared ahead of time so that each member of the class can have one, although it is a good idea to collect them and redistribute them following each contest, in order to avoid "carry-over clues" that might affect the succeeding contest. All puzzles should be made according to the same pattern. Each one consists of a 3" x 5" filing card cut into ten pieces. The pieces should be approximately the same size, and of as many shapes as possible. The cuts, however, must all be along straight lines, and must not include angles that will make identification easy. The pieces of each puzzle should be put into an envelope, but neither pieces nor envelopes should be marked in any way.

A series of numbered tags should also be prepared ahead of time, beginning with (1), equal to the number of students in the class. These should be placed in a box or bag, and shaken up each time, before the members of the class draw their numbers. When the numbers are collected at the conclusion of each set of trials, a number of tags should be withdrawn equal to the number of students that have been eliminated from the tournament. This should again leave a series of tags numbered beginning with (1), and equal to the number of contestants in the new set of trials.

You should miss no opportunity in this laboratory experience to help students to understand that all competition, in nature and in human affairs, is basically the same. In all cases it is the least fit that are eliminated. You may have an opportunity to point out, however, that competition is not necessarily a matter of "dog eat dog." Sometimes it involves cooperation, and ability to cooperate may result in survival, while failure to cooperate may lead to failure and consequent elimination.

LABORATORY EXPERIENCE D.4.d.

A Quantitative Study of Competition Between Species

TEACHER NOTES

This laboratory experience will require a period of six to eight weeks. In carrying it out, the entire class may be divided into teams, or a single team of two or more students may carry it out and demonstrate it to the entire class. When several teams do it, there is an advantage in that a comparison of results is possible.

There is an excellent opportunity here to develop thinking and discussion concerning the part which competition plays in our world, both in the natural world and in the cultural world in which we live. How important is competition? What are the relationships between competition and cooperation in the evolution of plants and animals? In our relationships with one another? Is it necessary to curb or regulate competition? To what extent <u>can</u> we do this? <u>How</u>? Could we get along without competition altogether? Is competition enjoyable? Should it be enjoyable? When is competition "right," and when is it "wrong?"

Such a discussion will probably have to be arbitrarily limited, or even terminated, because it could run on for a long time. Of course, no final conclusion can be reached, though a summary would help.

LABORATORY EXPERIENCE D.4.e.

Protective Coloration: A Mechanism for Survival

TEACHER NOTES

This experience is simple in itself, but preparation for it takes time and effort on your part. You can probably have the students do some of the preparation, but good results depend on how carefully the preparation is done.

The experience can well be carried out by teams of three students. Each member of the team, however, should be given an opportunity to hunt for circles.

Either the "mowed lawn" part or the "sandy beach" part can be done alone. Hopefully both can be done. It will probably be necessary to carry on the lawn portion of the experience, and then move some distance to the beach to carry on the rest of it.

Using poaster paper, which possesses some thickness, it should be possible to recover a fair percentage of the circles for re-use after each student completes the experience. Nevertheless, many of them will be lost, and a new supply will have to be prepared periodically. In renewing the supply, be sure to use the same paint dilutions to produce the different shades. Follow the record made when the dilutions were originally prepared.

Prepare a new plot for each student. Do not attempt to re-use the old ones.

LABORATORY EXPERIENCE D.4.f.

Selection and the Gene Pool: A Working Model

TEACHER NOTES

The concept of natural selection is a difficult one to teach unless you have something experimental and concrete to tie it to. This is particularly true when the related concept of the gene pool is introduced. In this laboratory experience both concepts are reduced to the simplest terms possible, and are then tied to an activity which helps to make them meaningful. There are "genes" (objects of two different colors) in an actual "pool" (the large withdrawal container). "Selection pressure," in the form of an arbitrarily stated lethal relationship, is exercised to eliminate "genes" of one color, as opposed to "genes" of the other color.

The important thing is to keep before the students the Idea of Directional Change in terms of natural selection. More than most of the other Ideas of I-CLS, this one needs to be discussed thoroughly before the laboratory experience is attempted, and again, by way of summary, when it is completed.

LABORATORY EXPERIENCE D.5.a.

An Animal Life Cycle: The Fruit Fly (Drosophila)

TEACHER NOTES

Catching wild fruit flies and developing a laboratory culture from them is an interesting experience, and quite easy to do, but you will probably prefer to order them from a biological supply house. There are a number of such companies,

General Biological Supply House, Inc.
8200 South Hoyne Avenue
Chicago, Illinois or

Carolina Biological Supply Company
Burlington, North Carolina 27215

are both quite reliable. Orders can be delivered quickly by air to any part of the country. You might wish, however, to find a local biological supply company nearer to your school.

You may also wish to order culture bottles, already prepared with culture medium containing agar. You can also prepare it yourself, by following the directions given below. In this case some of the ingredients will need to be ordered from a biological supply company.

Mashed banana, however, can be used quite satisfactorily, with reasonable care.

In case an agar culture medium or any other specially prepared medium is used which has a firm surface, the use of a paper cone for placing the anaesthetized flies is not necessary. They can be dropped directly onto the surface of the medium without the danger of becoming entangled in it. If the mashed banana is used, the paper cone serves the double function of receiving the flies safely, and furnishing a surface for the larvae to crawl upward on, and pupate. With the agar or other medium with a firm surface, the latter function is served by the strip of paper toweling which is placed in the culture bottle.

Be sure to caution students about the danger of fire when using ether. They have probably never had any experience with it before. Getting the flies to just the proper point of etherization without killing them may take a little practice. Perhaps you should demonstrate this to them before they attempt it themselves. Also the preparation of a cotton plug for inserting into a culture bottle may well be demonstrated. Use your own judgment about demonstrating other techniques. Individual students will differ widely in their ability to carry through these operations. A team approach will probably be helpful.

*Formulae for Making Culture Media for Growing Fruit Flies

Note: The materials for making up these media can be purchased in part at any grocery store. Those which cannot be obtained locally can be ordered from a biological supply house.

Banana Agar

575 cc. water

20 gr. agar-agar

35 gr. brewer's yeast

125 cc. white corn syrup

225 cc. crushed ripe banana

½ gr. mold inhibitor

85% alcohol

Add the agar-agar to the water, and bring it to a boil. Stir in the mashed banana and mix thoroughly. Add the syrup and mold inhibitor, and boil for ten minutes. When the material is cooled to lukewarm add the yeast. Pour into culture bottles, and add strips of paper toweling which have been dipped in a solution of 1.5 gr. mold inhibitor dissolved in 5 cc of 85% alcohol. Plug each bottle with a cotton plug.

Oatmeal

600 cc. water

45 gr. yellow corn meal

45 gr. oatmeal (Use old-fashioned Quaker Oats, not the quick-cooking kind)

25 cc. molasses

4 gr. brewer's yeast

1 gr. mold inhibitor

85% alcohol

Add the corn meal and the oatmeal to the water. Cook slowly over a low flame. Do not boil. Slowly add the molasses and the mold inhibitor. Stir constantly. Cool to lukewarm. Add the yeast. Pour into culture bottles and add strips of paper toweling which have been dipped into a solution of 1½ gr. mold inhibitor dissolved in 5 cc of 85% alcohol. Plug each bottle with a cotton plug.

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*Taken from Turtox Service Leaflet No. 15., General Biological Supply House, Inc., Chicago, Illinois.

LABORATORY EXPERIENCE D.5.b.

Simple Plant Cycles: Common Molds and Bacteria

TEACHER NOTES

This is an interesting opportunity for students to learn about bacteria and molds. Of course since sterile techniques are not used, a considerable amount of contamination inevitably occurs, but students are able to observe the growth characteristics of these simple forms of life, and learn something about them. In growing them on slices of boiled potato, we are reverting to the earliest days of microbiology in the middle ninteenth century, when beef broth, milk, potato slices, and other simple media were used. The potato slices are easy to prepare and handle, and work very well.

If it is desired to do so, agar plates, sterile techniques, and standard laboratory procedures may be introduced also by way of demonstration or may even be substituted.

LABORATORY EXPERIENCE D.5.c.

Growth Cycles of Higher Plants

TEACHER NOTES

This laboratory experience can best be carried out by a team of students and set up in the class room for the entire class to observe.

Since it is a very long term experience, other class activities can be carried on while it is in progress. The regular observations called for will not consume more than a few minutes of any day or week. The plants can even be watched casually while other activities are going on.

You may go as far as you wish to, and think best to, under Follow-Up. You may simply terminate the experience with the actual class room observation. It is a natural point, however, to bring in motion pictures and other illustrative materials, as well as readings, on the life cycles of seed plants. This would round out the experience and make it more nearly complete.

You may also go into the relationship between flowers, seeds and fruits, and the differences in structure between monocots such as corn, and dicots such as beans if you wish to do so.

LABORATORY EXPERIENCE D.5.d.

The Water Cycle

TEACHER NOTES

There may well be more suggested activities in this laboratory experience than you will have time to do, or wish to do. In such case you may wish to leave out something. Students should come to understand that the water cycle is a cycle, and is an example of a wide variety of cyclic phenomena in the natural world. If this is kept in mind and definitely taught, you may feel free to pick and choose the laboratory activities that lead to an understanding of the Idea.

There is a good opportunity to correct a common misunderstanding of what "stream is." What you see when a teakettle boils is really a miniature cloud. The invisible zone at the end of the spout of the boiling teakettle is water vapor or steam.

You will almost certainly have to help students peel off bits of leaf epidermis and mount them on slides under the microscope to observe stomata and guard cells. You may wish simply to demonstrate this for the entire class. This is all right. The main point is, they should all see these structures. An adequate understanding of transpiration and the relationship of green plants to the water cycle is not possible without their doing so.

LABORATORY EXPERIENCE D.5.e.

The Rock Cycle

TEACHER NOTES

Use samples of granite, basalt, gabbro, sandstone, limestone, shale, bituminous coal, quartzite, marble, slate, schist, gneiss, and anthracite coal. The emphasis here is not to name rocks, but to understand the rock cycle and the small cycles within it.

Any earth science textbooks, the Golden Book of Rocks and Minerals, the Field Guide to Rocks and Minerals, All About Rocks and Minerals, and any other similar books will help you with necessary identifications.

The construction of a crystal garden (See Teacher Notes under Laboratory Experience C.3.b.) can profitably be re-done in connection with this laboratory experience.

LABORATORY EXPERIENCE D.6.a.

Internal Equilibrium: Maintenance of Weight in Humans

TEACHER NOTES

It will be necessary to have cooperation of adults outside the school and of students outside the classroom in order to carry on this laboratory experience. Beyond that it is very simple to do.

It would be best if the weight records were carried on in all cases over a period beyond the three weeks minimum. This is really too short a period to do more than indicate the existence of relative stability, or of trends in adult weight. Three months would be much better than three weeks, but any period in between would be quite acceptable.

It is doubtful if even three months would be long enough to reflect any weight change resulting from a child's growth, although it might do so. The principal value of including children's weights in the study is to allow the children to take an active part in the experience, and to furnish a kind of check on the balance existing, or hopefully achieved in the adult weights.

LABORATORY EXPERIENCE D.6.b.

A Chemical Indicator

TEACHER NOTES

The red cabbage pigment can be extracted with cold water, but more of it will go into solution if the water is hot.

You may expand this laboratory experience to include other indicators, and to study the pH of various solutions in the environment: water in an aquarium, water from a marsh, water from a lake, water from a clean stream, water from a polluted stream, water in which soil samples have been allowed to stand.

Remember, however, that the laboratory experience is pointed toward the Idea of Dynamic Equilibrium. Don't allow the students to lose sight of this Idea. It is easy for them to become so interested in acids, bases, and the behavior of indicators that they forget the Idea.

LABORATORY EXPERIENCE D.G.c.

Equilibrium in the Landscape: Opposing Forces at Work

TEACHER NOTES

In this laboratory experience it is impossible to supply references in all cases, either at the student reading level or for the teacher. Any earth science textbook will be of some help, either for the students to read under your direction or for you to read and interpret orally for the students. A dictionary and/or the glossaries of earth science textbooks must be consulted in order to get satisfactory working definitions of all new terms.

Remember that the objective is to develop a better understanding of dynamic equilibrium when opposing forces are at work, as they are in the shaping of the earth's surface.

LABORATORY EXPERIENCE D.6.d.

A Balanced Aquarium

TEACHER NOTES

A balanced aquarium is easy to construct, and there is nothing that attracts more interest in a classroom or laboratory. The term "balanced aquarium is much too loosely used, however, by most people. Actually for an aquarium"to be truly balanced it must be both stable and completely self-supporting. It must not require feeding (as of fish or other animals) and it must not need to have air bubbled through it to supply oxygen for the animals in it. All of the natural chemical cycles must be complete and self-renewing in it. This is the difference between a balanced aquarium and an artificially an created "fish bowl with plants in it."

This distinction must be made clear to the students in order for them to understand the Idea of Dynamic Balance as applied to an aquatic community, whether it is in a gallon jar or in a pond or lake.