Ten Classroom Sessions in Ecology[1]

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Oceanography, forestry, management of ranges, fisheries, wildlife, streams, pollution, limnology, biogeochemistry, hydrology, sanitary engineering, and many other subjects[2] are on the long list of areas of science and technology concerned with man's survival and management of the planet. These are branches of environmental science. In today's fierce competition any societal system which survives will be one with a sustained system for utilizing the environmental resources. Education of a generation of leaders who can use the environments effectively is a major need.

Just as basic English must serve the educational needs of students who later enter hundreds of different occupations with varied, heavy responsibilities of literacy, so the science in the schools must be of a basic nature to permit students to understand the essentials of the multiplicity of advanced and applied subjects in an ever more complex age of science.

The basic science concerned with the environment is ecology, the study of environments (forests, fields, lakes, seas, reefs, aquarium systems, living capsules for space, etc.). In this article are set out some fundamentals of ecology along with ten practical class exercises for the school. These exercises in basic ecology are introduced as a replacement for the miscellaneous comments on environment in many school texts.

The practical exercises are also selected to show through actual student participation some essentials of the scientific process such as comparison of hypotheses and results, relating two functions on a graph, statistical use of replications, the controlled experiment, the use of analogue thinking, the making of generalizations, the combined use of methods of several sciences, the use of instrumental measurements, and the combined use of detailed experiments and maps to understand big phenomena.

In this article some key diagrams and supplementary notes are presented for use on the blackboard with each exercise. The background readings are to be found elsewhere (Odum and Odum, 1959). The ten figures were taken from ten lantern slides used to present a lecture on the teaching of ecology at an AIBS meeting. The ten figures may again be used for this same purpose in textbooks or in education classes in the college. By addition or subtraction of supplementary details of varying difficulty, these exercises may serve to start environmental science wherever it is first given whether in the grammar school or the graduate school.

Class 1—Basic Concepts, The Ecosystem, The World Balance (Figure 1)

On the first day the principles of the balanced earth and the balanced aquarium are presented. It is shown that products of respiration exactly complement photosynthesis and vice versa. The two great energy laws are illustrated, (1) conservation of energy, and (2) degradation of concentrated energy types into unusable, dispersed, heat. It is especially important to show that all the reac-

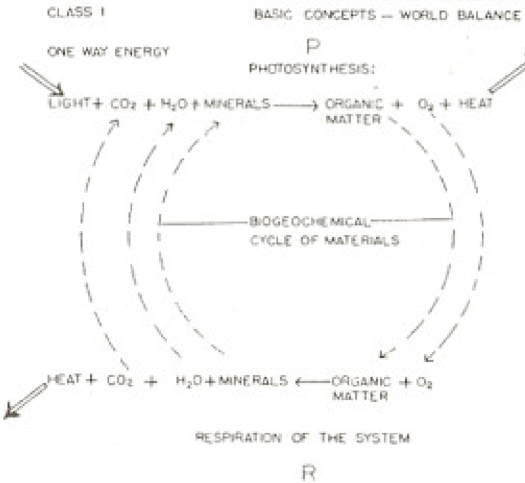

Figure 1

[1]This paper was presented at the NABT sessions meeting with the AIBS at Pennsylvania State University, August, 1959.

[2]The word conservation sometimes implies a disuse.

Reprinted from THE AMERICAN BIOLOGY TEACHER, Vol. 22, No. 2, February, 1960

tions involve degradation of energy. The usual school texts, that show energy on one side of a reaction only are very misleading about energy resources which are important to our survival. In the discussion the teacher can elaborate with specific examples, mention systems that do not balance, estimate quantities involved per acre per day, enumerate names of organisms involved in the different processes, list the mineral substances, and specify mechanisms of circulation. Then he may introduce the word *ecosystem* as the name for the functioning environments which usually have (a) photosynthesis, (b) respiration, and (c) biogeochemical circulation.

Class 2—An Ecosystem Example, Field Trip to a Fish Pond (Figure 2)

Next an outdoor pond ecosystem is visited. Large organisms are collected with a dip net. Plankton nets are made by the students by tieing a bottle in the toe of a stocking whose upper end is pinned or sewed on a coat hanger rim. A cloth bag like a sugar sack can also be used. When this net is pulled through the water on a string, the water goes through the cloth, but flea-sized organisms stay in the bottle. Hold the bottle to the light to see them or bring them back to the room and pour them into an open bowl to watch. Try to find some evidence of the microscopic suspended algae which go through cloth. When abundant, the water is green, although silt also makes water look green. The algae are the principal photosynthesizers although the big plants help some too. Use a minnow seine and husky boys to pull through the shallows to get small fish, snails, and water insects.

After some collecting is done in this way, the teacher draws the class together and tells a story about the inflow of light energy—taking note of the depth that photosynthesis can occur by noting the depth that a stick can be observed. Explain how the hidden algae make the food; the flea-size animals eat it; and the rest of the larger creatures eat the little animals. Then pull up some black, bottom mud on a stick and explain that the bacteria are decomposing the left-overs and releasing the minerals and carbon-dioxide for another round. Show how the wind waves supply the circulation. Show how photosynthesis is in the top of the pond and much of the respiration is in the lower levels of water and bottom mud. Indicate that the pond is a typical ecosystem; refer back to the ideas introduced in Class 1. Try to keep the boys from becoming overconcerned with the fish. Make them see the ecosystem more than creatures. Explain that the great oceans are built and work almost in the same way.

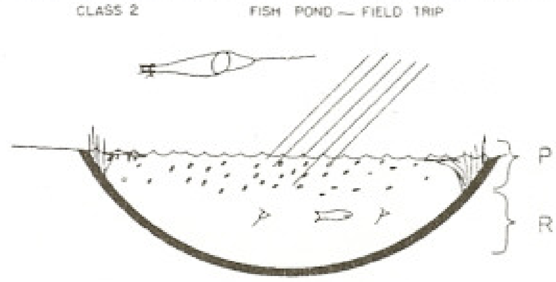

Figure 2

Class 3—Preparation of Microcosms, Little Laboratory Ecosystems (Figure 3)

In the third session some of the water and live materials collected from the pond ecosystem are used for the construction of several types of little systems in the classroom. One kind has more animals than can be supported by plants as in the usual aquarium full of fish. Respiration exceeds photosynthesis ($R > P$); oxygen comes in from the air continuously. Another type without big animals is fertilized with some plant nutrients, such as Vigoro or other fertilizer from the dime store, and placed in bright light. After one to two weeks of growth such a system has more photosynthesis than respiration ($P > R$). To start these systems, seed them with the collections from outdoors and wait to see what the microcosms will produce. Each will be different. Apply the same ideas as in the previous sessions in order to understand the functions. Systems with circulation supplied with a stream of bubbles will be different from the ecosystems with less circulation. Systems that are closed up tight with plastic sheets except for necessary light will approach a balance ($P = R$). Making such aquarium systems has been a custom in schoolrooms for years, but these systems need to be studied further as suggested in the following paragraphs.

The teacher should explain that nearly a half-million dollars a year in defense money is now going into research on balanced systems for space capsules. Surprisingly, until several years ago no one outside of the schools worked with balanced systems which are now suddenly of national defense importance. It is too bad we do not have the combined experience of the schools recorded in the scientific publications. The teacher may use this situation to show how pure intellectual pursuits may unexpectedly lead to things of great practical importance later. Also at this point the teacher can readily emphasize the need for writing down results, keeping records, and publishing in the type of journals that libraries keep on permanent record.

There will be a tendency for students to set up fish tanks neglecting the system. Many aquarium magazines are filled with recommendations for eliminating algae and bacteria thus eliminating the most interesting aspect of the self-regulating microcosm. A fish tank is to the microcosm what the fish hatchery is to the pond. A pond runs itself; a hatchery does not.

Avoid chlorinated tapwater which often has toxic metal substances and unfavorable basic conditions.

Class 4—Dissolved Oxygen Measurements

In Class 4 a simple, inexpensive, and reliable chemical procedure for measuring dissolved oxygen is taught for use in subsequent classes. If the class is an elementary one, the procedure is done in cookbook style omitting the details of the chemistry, but if the class is at a more advanced level, some first principles of chemistry can be taught at the same time. The oxygen procedure may be carried into the field for study of outside waters too. This is a major tool of the fishery biologist and sanitary engineer.

The procedure for measuring oxygen is shown in the upper two pictures of Figure 4. The solutions are made up and added with the procedure below. Careful weighing is required only in making up the solution of the hypo although one does not need an analytical balance. In the reaction, first dissolved oxygen reacts with manganous ions to form manganic ions. When the solution is made acid, the manganic ions react with the iodide ions to form iodine. In the titration the thiosulfate

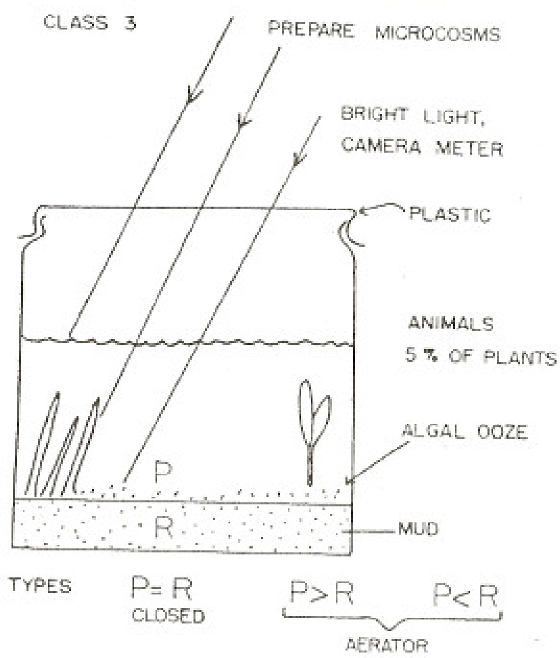

Figure 3

decomposes and changes iodine to iodide.

The Winkler Method for Measuring Oxygen in Parts Per Million Dissolved in the Water

1. Fill your oxygen sample bottle (100 to 150 cc. capacity) with water to be studied. Do it without bubbling. Siphon with a tube from a bucket dipped into the pond.
2. Add 10 drops (about 0.5 cc.) manganous sulfate solution. To make solution put 480 grams of manganous sulfate ($MnSO_4$-$4H_2O$) in 1 liter of water. This keeps indefinitely.
3. Add 10 drops (about 0.5 cc.) potassium hydroxide-potassium iodide solution. To make up solution add 500 grams sodium hydroxide or 700 grams potassium hydroxide to a liter of water. It gets hot. Then add 135 grams sodium iodide for 150 grams potassium iodide. Keep in rubber-stoppered bottle.
4. Put top on bottle and mix with three wrist motions. Keep bubbles out if possible.
5. Wait one minute in fresh water. (15 minutes in salt water).
6. Take out top and add 15 drops sulfuric acid (about 0.5 cc.). Put top in and mix with wrist motion. This is concentrated sulfuric acid obtainable from any service

station where it is used for batteries. This burns holes in clothes, metal, skin if not washed off.

7. The sample bottle should be yellow due to the formation of iodine. There is an equivalent amount of yellow iodine present for dissolved oxygen originally present. If there is no oxygen the bottle will be clear; if there is much oxygen, the bottle will be bright orange. Thus you can tell something roughly without the next step. At this point the sample or samples may be kept for a day or two. One can do this part outdoors and bring back to school for the rest.
8. With a measuring device of some sort (graduate cylinder, pipette, glass with a mark on it) measure out 100 cc. of the yellow solution.
9. Add several drops of fresh starch solution, enough to give a black or blue-black color. Starch solution can be made by boiling a tablespoon of mashed fresh potatoes in a cup of boiling water for 5 minutes and filtering through a fine cloth. It filters slowly, but one only needs a few drops. One can also use corn starch, crackers, or scraps of notebook paper in a pinch.
10. Then titrate with hypo solution. One does this by adding drop by drop hypo solution from a burette or graduated pipette until the solution changes from black through blue until clear. The number of cc. of hypo solution added is the number of parts per million dissolved in the original solution. The hypo solution is made by adding 3.102 grams sodium thiosulfate (hypo from photo shop) to a liter of water. In refrigerator this keeps for several weeks. The hypo and the starch have to be made up fresh when one starts work after a period of time.

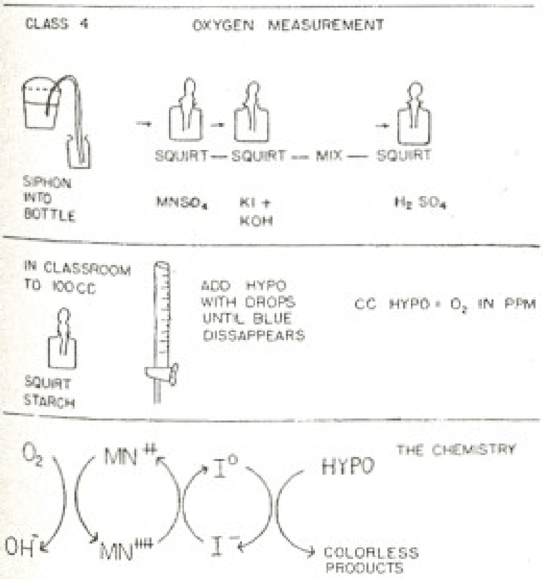

Figure 4

The reactions which take place are shown in the lower part of Figure 4. The overall result is that some yellow iodine is made in the bottle in an amount equivalent to the dissolved oxygen in the water. Then one causes the iodine color to disappear by adding a solution of hypo. If the solutions are made up as indicated above, the amount of hypo solution added indicates the amount of dissolved oxygen that was present.

The method should be tried out in some aquarium waters. Then a pan of clean water about an inch deep should be left on a table overnight. The oxygen in the water becomes adjusted to the amount which will dissolve into it from the air at the temperature. If one measures this amount of oxygen, one can state the approximate saturation value for the temperature of the room. It will be probably about 8 ppm., depending on the temperature. Exact values may be obtained from tables such as the abbreviated one that follows:

Abbreviated Table of Saturation Values for Oxygen in Parts per Million (ppm.)

	Temperature, Degrees Fahrenheit			
	32	50	75	90
Oxygen in fresh water	14.2	10.8	8.2	7.2
Oxygen in salt water, 3.5%	11.3	8.7	6.7	4.1

Class 5—Functional Relationships of Light and Plant Activity (Figure 5)

The oxygen technique learned in Class 4 is used next to measure the metabolism of plants in quart-sized containers in bright light and in the dark. Any kind of sheet of plastic may be cut to float on the water to keep oxygen from exchanging with the air very fast. Measurements of oxygen may be taken every hour and the change measured. The aquarium should be moved to a different light intensity nearer or further from the window as indicated by the light meter. Any light meter such as commonly used in photography will work. Many students have them. Then the teacher may show the use of graphs to relate two measured quantities, light and hourly oxygen change. For successful work bright lights are needed. No artificial classroom light is likely to be over 200 foot-candles, whereas best results are obtained if values up to 1000 or more foot-candles are used. Such light comes in the window from the outdoors.

The teacher may discuss the results in terms of hypotheses predicting oxygen increase in the light and decrease in the dark. The reactions of photosynthesis may again be examined as in the first exercise.

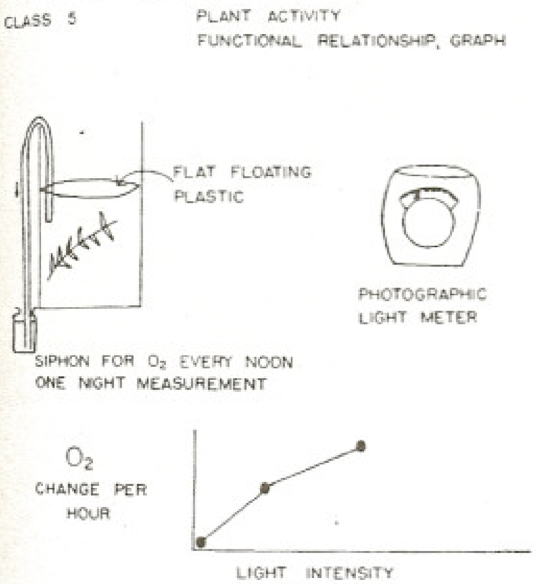

Figure 5

Class 6—Animal Metabolism and Temperature

The oxygen technique is again used, this time to study respiration of animals at different temperatures. Changes in oxygen every hour are measured with some animal such as a goldfish or crayfish in a quart of water. Graphs are plotted of the results. The role of temperature in animal respiration and the season of nature can be discussed.

Class 7—Measurement of P and R in an Ecosystem, Statistical Replication

In Class 7 the combined action of the plant photosynthesis and the respiration of animals, plants, and microorganisms in the mud is followed by making measurements in one system. The pool must be large so that many samples

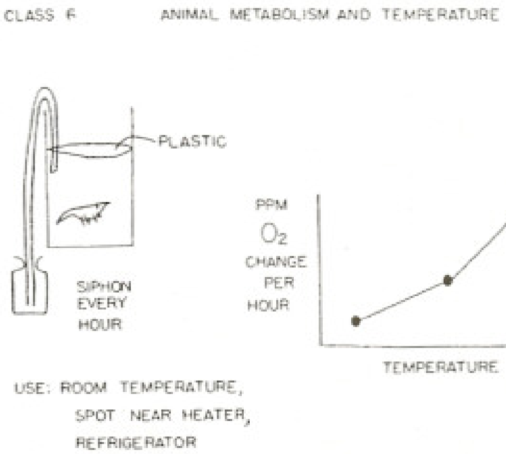

Figure 6

of water can be removed without depleting the water. One may use a fish pool, pond, tub, or big tank in the class, providing it has been fertilized, is in bright daylight, and has good green growth of algae or other plants in the water or on the walls.

In this work the idea of replication for statistical accuracy should be introduced. If the duplicate measurements taken at the same time vary less than the changes from hour to hour, then one has proof that the whole water is actually changing and that the observed values represent the water as a whole. It is desirable to mix the tub gently before sampling to improve the reproductibility.

If a curve is obtained like that in Figure 7, one may discuss what is happening at each hour. In advanced classes the amounts may be computed and compared with values in natural ecosystems (Odum and Odum, 1959).

Class 8—Controlled Experiment

In the eighth session a true scientific experiment is performed in which the teacher and class have hypotheses, but no one knows the real answer that will come from the data. Photosynthesis is measured on treated and untreated plants. The results obtained may or may not follow predictions. There may be new predictions for further experiments.

All too rarely a true experiment is not performed by a student in his education until he begins graduate work for master's or doctoral degrees. What are called experiments in most curricula are sequences of mere technique tests, measurements in which the student works to

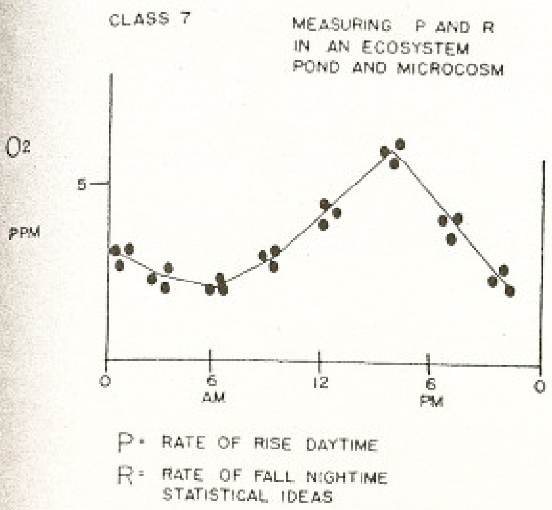

Figure 7

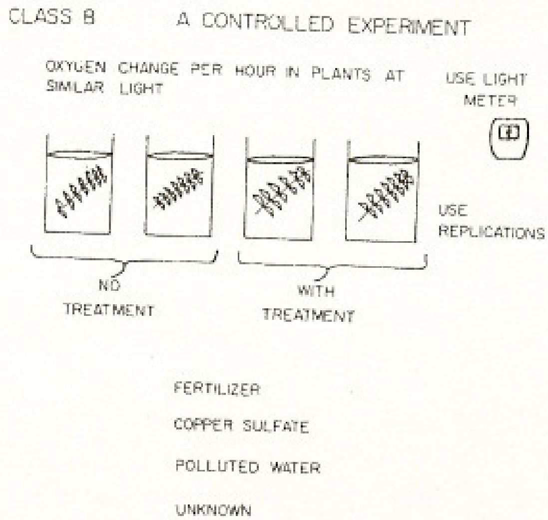

Figure 8

get a correct answer. Active science concerns instead the study of the unknown. Much in the science fairs are gadgets, devoid of adequate experimentation.

In setting up the experiment, every effort should be made to use equal sized plants, such as sprigs of *Elodea*, in equal quantities of water. Each container should be placed in similar light intensity by using the light meter. Any kind of treatment may be applied. Here is a good place for the teacher to emphasize the role of imagination in science. Students should draw ideas from their experience as to substances that ought to have some kind of effect on the plant photosynthesis. They can then test their ideas. Each set of experiments can be different.

Class 9—Geographical Aspects of Conservation

In the ninth session some of the implications of the previous measurements on ecosystems are extended with the use of scrapbook work and maps. To a large extent the distribution of fertility of nature can be related to light, the requirements for plants, or to localized accumulations of organic matter seasonally or geographically. Even the history of man's colonization and development of early civilizations may be related to the distribution of P and R on the earth. The various combinations of P and R and the various seasonal patterns of light radiation can be compared.

The teacher should include a map of the principal vegetation types of the world, a map of the rainfall zones of the world, a map of temperatures of the air and sea, and colored pictures of ecosystems. The teacher might ask which student can accumulate the most ecosystems from clipping magazine pictures. Each student may try to state something about the overall metabolism (photosynthesis and respiration). What does man do to an ecosystem when he applies such treatments as fertilization, weeding, clearing, draining, harvesting, poisoning, isolating, burning, eliminating fire, etc.?

CLASS 9 GEOGRAPHY AND CONSERVATION

BLANK MAPS OF WORLD — DRAW IN
VEGETATION ZONES, FERTILE SEA ZONE, REEFS
AGRICULTURE TYPES,

SCRAPBOOK:
CUT OUT PICTURE OF SYSTEMS AND WRITE IN
P— R STORY
P— R BALANCED
P>R PRODUCING—NEED RAW MATERIALS
P<R CONSUMING—RELEASES RAW MATERIALS

INCLUDE POLLUTION, ANIMAL HUSBANDRY, AGRICULTURE
FISHING, ARCTIC, TROPICS, WINTER, SUMMER,
SATTELLITE ECOSYSTEM

DISCUSS RAW MATERIAL STORY FOR EACH PICTURE

Figure 9

Class 10—Ecosystem Computer

One of the principal ways in which science makes progress is through the imagination of people who get an idea from one phenomenon that suggests how another situation might be

CLASS 10 ECOSYSTEM COMPUTER

USE IRON, WIRE, AND MILLIAMMETERS TO CONSTRUCT P—R SYSTEM WHERE ELECTRIC CURRENT IS THE FLOW OF CARBON

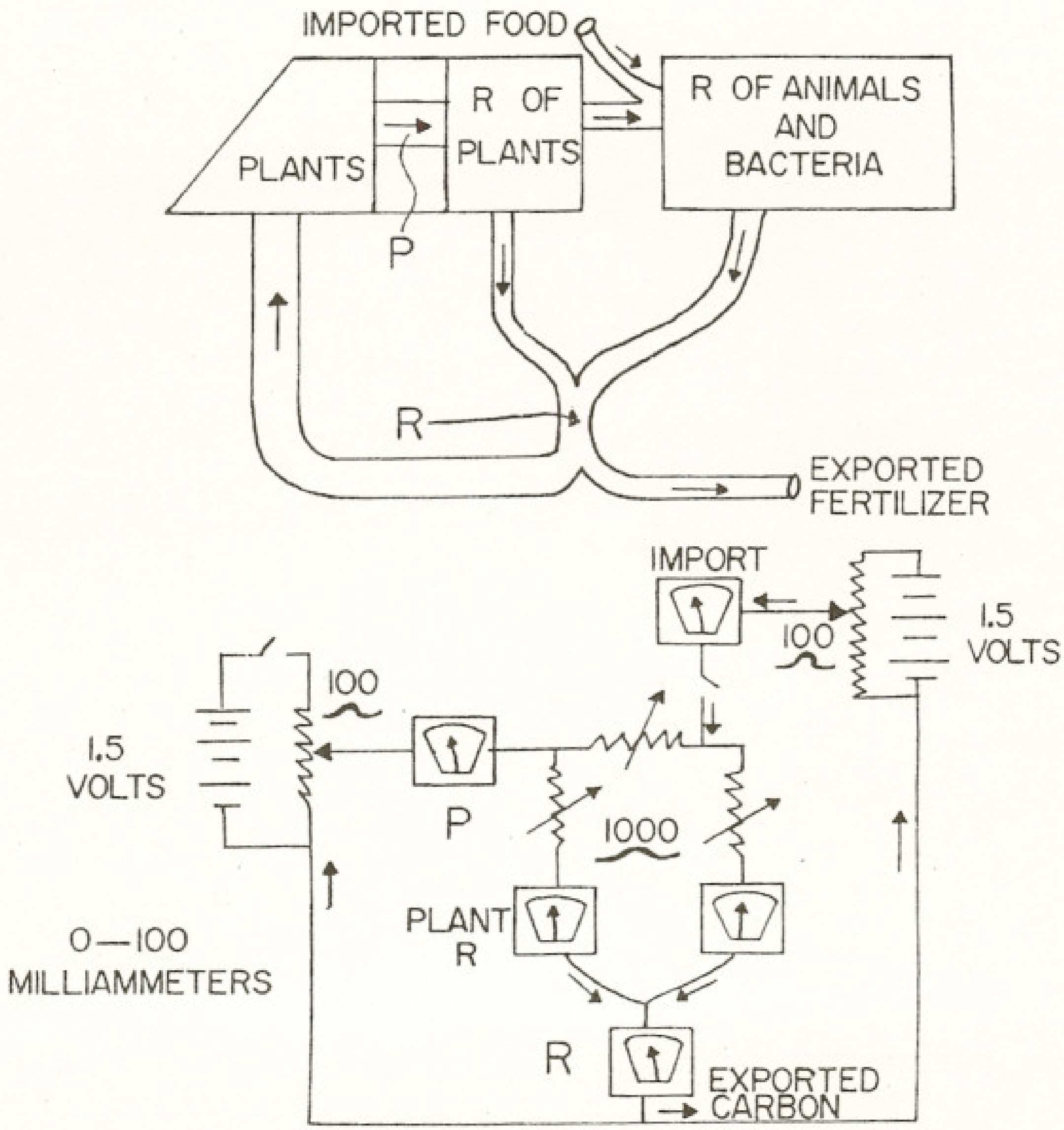

Figure 10

observed. In the tenth session we see how an electrical system can serve as an analogue suggesting things about ecosystems. Students with a yen for the soldering iron can be utilized in combining physical and biological science to make a gadget, which mimics in some ways the flow of materials in the ecosystem.

A flow diagram for materials in a simple ecosystem is pictured in Figure 10 along with an electrical analogue computer to match. The flow of electrons in the wires may be compared to the flow of carbon in the food chain and biogeochemical cycle. Batteries represent two energy sources, (a) the sun's energy for the plants, and (b) the organic matter imported from outside as in the example of the stream ecosystem when leaves fall in. By varying the resistances, one may vary the amounts of electricity in the circuits. By adjusting the circuits, one may illustrate the interactions in the ecosystem. Increasing import increases respiration; decreasing plant respiration increases the amount available to animal respiration, for example. The voltage in the electrical circuits may be compared to the concentations of food that occur in nature. An accumulation of plants in high voltage in driving food through snails, for example. The system in Figure 10 is a simple case for an ecosystem in a steady state, without seasonal or other changes. With some ingenuity, with electrical condensers and with the help of the physics classes much more elaborate arrangements are possible. Student projects may study further the ecosystem in nature, in the classroom, and in electrical analogues. Ecosystem science is new and these things have yet to be done by anybody. Thus the ten sessions on science can end with some vision of the future and the possible control of nature when the circuits of the ecosystem can be controlled.

Reference Cited

Odum, E. P. with collaboration of H. T. Odum. *Fundamentals of Ecology*. 1959. Saunders, Philadelphia.