MANUAL OF SUGGESTIONS FOR TEACHERS

TO ACCOMPANY

ELEMENTARY BIOLOGY

GRUENBERG

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"ELEMENTARY BIOLOGY"

BY

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PREFACE

This manual is intended to aid the teacher in organizing instruction material and ideas for effective presentation in connection with the author's "Elementary Biology." It is no substitute either for a knowledge of the subject matter or for the technique of teaching.

Since the text which the manual is to accompany is largely concerned with showing how a knowledge of living things helps human beings, the notes here offered are largely concerned with suggesting interpretations and applications. The method of treatment implied throughout assumes a changing body of knowledge for the teacher, and a changing civic and intellectual environment for the pupil. New problems and new needs calling for additional knowledge, new discoveries enlarging the horizon, new thought bringing new insight and new significance — these represent the permanent stream, to be surveyed in its main ramifications even while it flows. This means imagining as well as remembering, it means doubting as well as believing, but it means also, of course, learning much more outside the book than in it.

The references are all useful; but even the most specific and authoritative are transients. Here the intention is to guide teacher and pupil to the use of the printed page with some judgment as to relative values. It is assumed that there will be available monographs and encyclopedias, manuals for the identification of various groups of plants and animals, textbooks, and current publications of all sorts.

The teacher should be constantly on the lookout for developments that suggest new problems and new applications in which biology is significant. Many lines of publication are currently available for the mere asking; others have to be ordered as they appear. There should be in every high-school or college library the monthly circular of new publications issued by the United States Department of Agriculture; the one from the Public Health Service; and the one from the Bureau of Education. The local and state departments of health and of agriculture, the nearest Experiment Station, the Bureau of Fisheries, and similar agencies may be drawn upon for helpful and pertinent material. And every teacher should keep within hailing distance of what appears in the technical journals.

B. C. G.

MANUAL FOR TEACHERS

PART I. THE WORLD IN WHICH WE LIVE

I. INTRODUCTION

Ask pupils to report such examples as they may happen to have of *applied biology*; that is, of practical use being made of knowledge or understanding about living things. The history of civilization is a continuous record of the displacement of superstition by insight. Get examples of superstitions that have to do with health and disease; with the phases of the moon in relation to crop production; with lucky and unlucky signs in relation to fishing and hunting or the performance of other practical tasks. Why do we call these beliefs superstitions, and how do we distinguish them from our own true beliefs?

Have a committee of two or three students prepare a composite list of all the examples that have been submitted, with some classification of the material.

Have students bring together what they can of the usages of former generations with relation to epidemics and other diseases; with relation to insuring good crops, etc. Compare the average length of life and the death rates at various periods and in different countries. Compare yields per acre of various crops at different periods and in different countries. How have these changes come about? How have they *been brought about*?

References. LOCY, W. A., Biology and its Makers, pp. 1–8. WHITE, ANDREW D., Warfare of Science and Theology, chap. i. Yearbooks of the United States Department of Agriculture. Annual Reports of the State Department of Health; City Board of Health; Surgeon General, United States Public Health Service; Surgeon General, United States Army. "National Vitality," *Bulletin No. 30* of the Committee of One Hundred on National Health, Government Printing Office. Work of Vesalius. Life and work of William Harvey.

II. WHAT GOES ON IN THE WORLD

The purpose of these lessons is to acquaint the pupils with some of the common physical and chemical processes. Some of these are directly concerned in vital processes; others are helpful toward an understanding of more complex relations. Incidentally, we may lay the foundations of whatever thinking our pupils are capable of attaining by introducing the first laws of matter and motion, and the idea of *evolution* in the broad sense of continuity and causality. Where students have already studied elementary science this part may be omitted, or perhaps reviewed briefly.

The laboratory work should be in the nature of demonstrations, rather than experiments in the strict sense. The first few lessons might well be carried out with the text in the hands of the pupils, and the exercises completed, or at any rate started, in the class.

Things change. After reading section 7, have the pupils divide a sheet of paper into four columns, headed as below:

Weather	Plants	Human Beings and other Animals	Non-living Objects

In *each* column are to be listed as many kinds of changes as the pupils can think of that happen to the kinds of things suggested by the heading of the column.

Physical changes. Section 8 may be illustrated by melting a lump of ice in a pan, through applying the flame of an alcohol or Bunsen lamp. After calling attention to the change, the heat is again applied until the water is all gone. Melt a piece of paraffin or a bit of candle and continue to heat, without, however, starting decomposition or igniting.

Make three lists of substances with which you are acquainted. In the first list place the names of those that may exist in all three states; in the second, those that exist in only two states; and in the third, those that exist in only one state.

Note that the metal mercury is liquid at ordinary temperatures, and that practically all metals may be volatilized at high temperatures.

Demonstrate *solution* by placing sugar, salt, marble, starch, etc. in tumblers of water.

Chemical changes. Prepare three large test tubes or tumblers, a solution of washing soda (about four tablespoons to the pint), a solution of barium chloride, a solution of phenolphthalein, and some dilute hydrochloric acid. Before the class call attention to the similarity in appearance of the four solutions. That they are not really the same kind of stuff is to be demonstrated. Place the soda solution in the three test tubes; in succession add portions of the three other solutions. You will obtain a precipitate, a change in color, and an effervescence. The three distinct reactions indicate the occurrence of *chemical changes*.

Have the pupils describe these examples of chemical change, not in terms of the materials used and the materials produced, but in terms of the phenomena observed. Two apparently similar liquids produce, when mixed, a solid, insoluble substance and a new liquid, — one that can be shown to have properties different from those of either of the two used in the first place. Two others produce some gas, and so on. It is possible in each case to show that some distinct kind of substance has disappeared and that some new kind of substance has been formed.

Demonstrate the reversibility of the chemical changes manifested when a solution containing litmus or phenolphthalein is alternately changed from acid to alkali and the reverse. Use dilute HCl and dilute $NaOH$ solution. Have students suggest all the examples of color changes with which they are familiar; some of these will be chemical changes.

Have students give examples of chemical changes that have not yet been brought to the attention of the class. Make as complete a list as possible of physical changes and one of chemical changes.

Get a committee of students to compile the lists of the whole class, indicating the number of times each particular kind of change is mentioned and bringing in for class discussion and conclusion all doubtful cases.

Complexity of matter. Use magnifying glasses and bits of granite, gneiss, marble, and other minerals to get the idea of *heterogeneity*, — not necessarily the word.

Milk may be analyzed, to show that it is made up of several distinct parts. The specimen of milk is allowed to stand overnight in a four-ounce wide-mouthed bottle, covered against dust. The cream, or *fat*, separates out. In regions that are acquainted with dairy processes, the time may be shortened by the use of a centrifuge, or separator. If the milk has not soured, and there is nothing to be gained by delaying the demonstration, the milk may be immediately curdled by the addition of a few drops of acetic or some diluted mineral acid. (The casein is held in solution by the natural alkalinity of the milk, and is precipitated on neutralizing or acidifying.) Separate the *curd* and the *whey* by filtering through paper. The whey may be further analyzed by evaporating over a flame, in a porcelain dish. This shows the whey to be made up of *water* and *solid*. The solid residue may now be further broken up by ignition, showing that it is made up of a part that can burn and a part that cannot burn, — the *ash*.

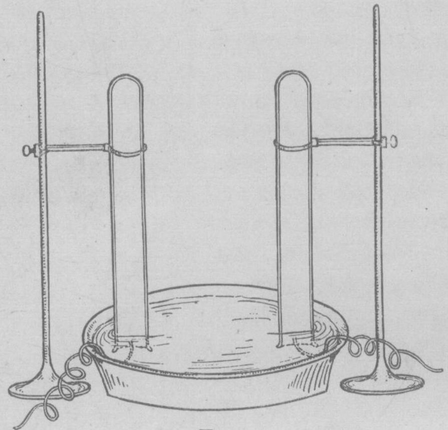

FIG. 1

Have pupils make a list of the fractions of the milk that can be readily recognized as distinct, — as fat, curd, water, solids-in-whey-that-can-burn, ash.

Have ready for inspection specimens of alcohol, ether, benzine, gasoline, etc. as examples of liquids that appear to be homogeneous;

and rock candy, a lump of glass, and a clear crystal of quartz or alum as examples of solids that appear to be homogeneous.

Wherever it can be managed, it is worth while to demonstrate electrolysis of water, with a test of each of the two gases produced. If a eudiometer is not available, set up two large test tubes, filled with the acidulated water, over the two poles of a direct-current system (see Fig. 1).

If you have a eudiometer, burn the hydrogen from a small glass jet and collect the vapor in a cold bell jar or battery jar held above the flame.

Elements and compounds. Have a collection of elements; these can usually be borrowed from the chemical laboratory. The pupils should see elementary sulfur, phosphorus, carbon, sodium or potassium, iodin, iron, magnesium, and silicon. It is not difficult to get specimens of platinum, gold, silver, nickel, aluminum, lead, tin, copper, and zinc.

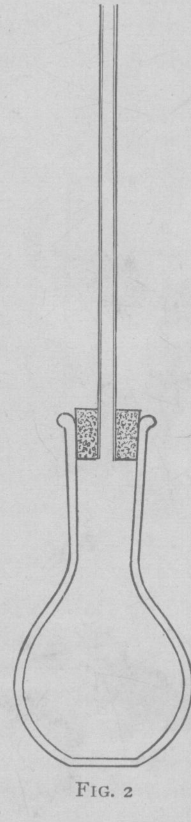

FIG. 2

Energy; energy and matter. Reëxamine the first list of changes prepared, or the list of physical and chemical changes; next to each item of change have students write the name of the kind of energy that brings the change about. Heat has already been shown to cause changes in state; it produces *motion*, as in the thermometer. This can be demonstrated on a large scale by gently heating a flask full of water closed by a pierced stopper carrying a glass tube (see Fig. 2). A little red or blue ink may be added to the water to make it visible in all parts of the room. Magnetism may be demonstrated with an electromagnet or with a permanent magnet (bar or horseshoe). The other forms of energy mentioned, with the exception perhaps of the X rays, have either been studied before or may now be demonstrated, so far as needed.

Students should get the idea that all events are connected in series, and this study may well end by having them describe, in writing, one or two chains of happenings, in which the change in energy as well as the change in matter is indicated for each link.

Conservation of energy. Many children come to school with the superstition that machines are devices for increasing the amount of energy. It is well to clear up any misgivings or misunderstandings on this point. Machines vary as to efficiency, — that is, as to the proportion of all the energy they receive that they make available in the special work for which they are intended, — but in all machines the output of energy is exactly equal to the income.

References. PEARSON, KARL, Grammar of Science, chap. i. Have students report on readings in any accessible textbooks in physics, chemistry, or general science on such topics as physical changes, chemical changes, work, states of matter, conservation of matter, conservation of energy, elements, compounds, forms of energy, transformation of energy, perpetual motion, the philosophers' stone, efficiency, etc.

III. FIRE

The concern of the student of life with fire is sufficiently indicated in the text. The experiment suggested in section 17 is not practicable for the ordinary laboratory, and would not in any case convince the skeptic.

Air and fire. Here we meet problems that lend themselves readily to experimental treatment, and the opportunity should be utilized to make clear *the method of the experiment*. A candle flame furnishes the most convenient "fire" for these experiments, and a Bunsen or an alcohol flame, or both, will be convenient to have at hand.

The *flicker* of the flame suggests that burning liberates motion in addition to light and heat, but it may well be that this motion is imposed upon the flame by air currents, as is the case with the trembling of leaves, for example, or the movement of the shirt on the clothesline. Here we may find out *by trying*, that is, by experiment. Emphasize the important fact that we have here a problem the solution of which we shall seek not in authorities, or in the records of other people's beliefs and opinions, but in the materials and forces at hand. Have the problem formulated clearly by the pupils, that there may be no ambiguity as to just *what* we are trying to find out. *How*, then, shall we find out? A second item involves the use of various materials. Record should be made of the *things used*. Then what is *to be done* with the things? The generalized scheme for the experiment is, *to shut off air currents*. Many suggestions may be made by the pupils, and the suggestions will in turn be criticized. There should be substantial agreement on the most reasonable or the most convenient method to be pursued or material to be used. A lamp chimney[1] has the advantage that it may surround the flame on all sides, and that it is transparent. Produce the lamp chimney and set it over the burning candle. The flickering stops, and this *result* may be sufficient to satisfy the pupils with the *conclusion* that the flicker is due to outside disturbances. If there is any disposition to discuss the matter further, be careful to remove the chimney before the flame is extinguished; it may be put on and taken off several times before the question is closed. As the discussion nears its end, leave the chimney over the candle, and the flame will expire. This will at once suggest new issues, and many of the pupils will be prepared to explain that it is the exclusion of the air that resulted in the dying out of the flame. But before that can be taken up, make

[1] In general it is well to have the materials to be used in the day's work readily accessible in the laboratory or recitation room, but *not laid out*. When you — that is, the teacher *and* the pupils — decide that a lamp chimney would be desirable, the teacher's resources must be equal to the occasion. But no matter how carefully the teacher has prepared the day's demonstration, the procedure should never give the impression of being "cut and dried" in advance. Exception should be made for demonstrations that involve rather elaborate arrangements, or that take more time for setting up than the usual session allows. In that case, however, there is either no pretense that the experiment is performed in response to a problem that has arisen in the class, or, if you have led up to the problem, the *plans* for the experiment may be agreed upon at one session, with the understanding that the preparations will be made in anticipation of a future meeting of the class.

a complete record of the first experiment, insisting upon the logical sequence and clear analysis rather than upon the mechanical form of the record. These points should stand out clearly, whatever designations may be used:

1. *The problem:* the question to be solved.
2. *Materials and apparatus:* what was used.
3. *Operations performed:* what was done.
4. *Results:* what happened, what phenomena were observed.
5. *Conclusion(s):* the answer to the *question*, so far as it may be inferred from the *results*.

In insisting upon a correct record of the first experiment, we must shift the emphasis from the performance, as an interesting "stunt," to the *argument* involved in formulating the problem, in selecting materials and operations, in selecting the significant elements from the results, and in drawing conclusions.

When we have established this routine of *thinking* about experiments, less time will be required in the matter of form of records etc.

The second experiment, suggested by the expiration of the flame, centers on the question whether the flame *uses up* something in the air or *gives off* something that interferes with burning. The air being invisible, we must have some means of showing the increase or decrease in the volume of air. It may be that after several suggestions from the pupils, it will devolve upon the teacher to find a feasible plan. A cylinder large enough to go over the candle, and closed at one end, inserted over the lighted candle standing in a dish of water, will meet all the conditions. If the flame gives off gas(es), bubbles should be forced through the water, out of the cylinder; but if the flame uses up part of the air, what would happen? The possible results should be anticipated as part of the argument, before the operation is actually performed, but with the apparatus in hand.

Some of the pupils will probably jump to the conclusion that the flame uses up part of the air. But we must not be too sure. It is quite conceivable that both processes are going on at the same time, but at different rates. Here is a problem for the chemist — to identify the gases concerned.

When the cylinder is finally placed over the lighted candle, the flame begins to fade, it flickers a few times, and finally expires. In the meantime the level of the water inside the cylinder changes in a way that indicates a reduction in the amount of gas included. We may also observe the condensation of moisture on the inside of the cylinder, and the ascent of the thin column of smoke from the wick. Which are the phenomena that are significant in relation to our problem? Obviously, the change in level of the water. What does that show? Probably that something in the air has been removed by the action of the flame. By means of a ruler held alongside the cylinder it may be possible to get an approximate idea of what proportion of the air has been thus used up.

But let us not overlook the possibility that something may be present in the jar (the air) that was not there before. We shall have to come back to the question whether the flame gave off something. There is the smoke, for example; and perhaps there are some *invisible* fire products. We may need the assistance of the chemist to answer the question. At this time we may be certain only that *something has been taken from the air by the burning.*

Now as to the chemical nature of the remaining gas (or mixture of gases), we should need some knowledge of chemistry to proceed farther. It is futile to test this air further with relation to fire, as some of the students are almost sure to suggest; for the failure of a flame to burn in this residual air cannot tell us anything that we did not already know. The teacher, drawing upon his fuller experience, produces a *reagent*, a substance that reacts distinctively with the various gases — in this case limewater. Yes, it is the same kind of limewater as is sometimes used in the baby's milk bottle. It is prepared by shaking up some calcium oxid (unslaked lime) with water, and filtering through paper. This should be kept in tightly stoppered bottles (cork is better than glass; but if glass-stoppered bottles are used, smear a little vaseline on the stopper, to make sure of an air-tight joint that will not become caked). A little limewater is placed in the bottom of a cylinder similar to the one used in the experiment. Place a glass plate or the palm of the hand over the open end of the cylinder and shake up vigorously. The limewater does not change its appearance perceptibly. A little limewater is placed in the cylinder in which the flame had expired, the cylinder being quickly turned up and then quickly covered. When the limewater is shaken up, it turns cloudy or milky. This shows us at least that the two masses of air are *different*, although it does not tell us just what the difference is. We may therefore conclude that the burning process not only removes something from the air but also sets free something that was not there before.

The question may here be raised as to the relation between the products of combustion to the fuel, on the one hand, and to the materials removed from the air, on the other.

Burning a synthesis. It is a reasonable hypothesis that the product, like the visible ash of some other fires, is either some portion of the fuel thus set free, or a portion of the fuel or of the air modified in some way, or a *new combination* of materials, containing elements from the fuel, from the air, or from both.

The technique of testing these variations of the hypothesis is rather too complex for the schoolroom. We can, however, test the supposition that the product of a burning contains fuel substance plus air substance. For this purpose we must have a fuel the burning of which gives us a product that is easily gathered and weighed. We use magnesium ribbon, — magnesium because the product of its combustion is solid, and ribbon because it is convenient to handle.

A trip balance has a large funnel, closed with cotton wool in the stem, on one platform, with a strip of ribbon about eight inches long. This is counterbalanced until the platforms are level. A wire loop or hook may be hung into the funnel before adjusting the balance. The magnesium ribbon is hung from the loop and ignited with an alcohol or Bunsen flame, and the funnel is immediately replaced upon the platform of the scale. If the operation has been carefully conducted, the accumulated smoke or ashes will be found to *weigh more* than the original ribbon of magnesium.

Since the addition to the solid matter on the scale platform could have come only *from the air*, we are tempted to conclude that the air stuff that takes part in burning combines with something in the fuel.

The gases in the air. The three principal gases of the atmosphere may be prepared for laboratory use as follows:

Carbon dioxid. A wide-mouthed bottle or flask is fitted with a two-holed stopper. Into one hole is fitted a glass "thistle" tube reaching nearly to the bottom of the bottle. Into the other hole is fitted a bent glass tube reaching only a fraction of an inch below the cork or rubber and having a rubber tube attached to the outside arm (Fig. 3). This apparatus, or gas generator, may be used for generating hydrogen and for other purposes. To make carbon dioxid, place some marble chips (calcium carbonate) or limestone bits in the bottom of the bottle; insert the stopper with the tubes and pour water through the thistle tube until the chips are covered. Pour dilute hydrochloric acid (commercial will do) slowly into the thistle tube until effervescence begins. Place the free end of the rubber delivery tube in a pneumatic trough or in a dish of water. The bubbles coming through the water indicate the rate at which gas is being liberated. Carbon dioxid can be collected either with the help of a pneumatic trough or with a large dish of water, the tubes or bottles to be filled being held in the hand over the delivery-tube opening, after being filled and inverted. Be careful not to raise the mouths of the vessels out of the water while the gas is being collected. Four-ounce wide-mouthed bottles are

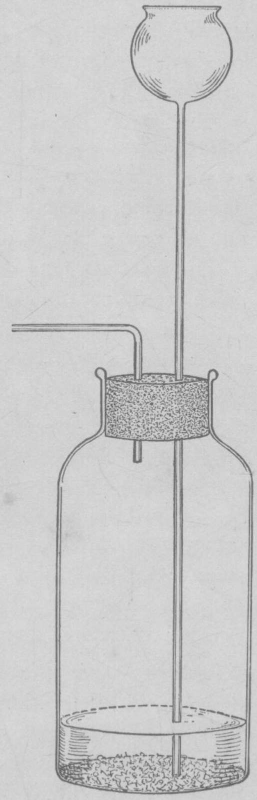

FIG. 3

convenient for these experiments. Glass squares smeared with vaseline may be used as covers for these containers; and if there is not too much water left in the bottles after the gas is collected, several bottles of gas may be prepared in advance and may be relied upon to react properly when wanted.

Nitrogen. To produce this gas there are needed a Florence or an Erlenmeyer flask, 250 cc. or 500 cc.; a rubber stopper with one opening carrying a short glass tube with a long rubber delivery tube; some ammonium chloride (sal ammoniac) and some sodium nitrite, $NaNO_2$. (Be careful not to use sodium nitrate, $NaNO_3$.) There will also be needed a pneumatic trough or other means of collecting gas over water, bottles with glass covers smeared with vaseline, and an alcohol or Bunsen flame. Place about a teaspoonful (level full or less) of sal ammoniac and about an equal volume of sodium nitrite in the flask; pour in just enough water to cover the salts, and insert stopper carrying the delivery tube. Warm the mixture gently over the flame, holding the flask in the hand all the time so as to be able to regulate the heat by moving the flask nearer to or farther from the flame. When the chemical action begins, a great deal of heat is generated within the flask; then it is necessary to apply only enough heat from the outside to keep up a steady action. After some gas has escaped from the delivery tube, displace the water in one or two bottles to make sure that there is no more air in the generating flask. Then collect the gas in the usual way. At the conclusion of the work, or when the generation of gas is stopped for any reason, be careful to take the delivery tube out of the pneumatic trough. The teacher should try out the making of nitrogen before attempting it in the classroom.

Oxygen. This gas can be produced by hydrolysis, if there is available a direct current of electricity, or by chemical methods. For small quantities, the decomposition of red oxid of mercury in a small tube by the application of heat is convenient. For making larger quantities to be used in experiments, the decomposition of potassium chlorate is the best method. A mixture of about equal parts of potassium (or sodium) chlorate and manganese dioxid