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The Japanese Science Education Centers

Up-to-date programs for renewing the training of teachers are closely allied to local schools.

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Science is advancing so rapidly today that knowledge is doubling in many fields, such as biology, with the passage of each 12 to 15 years. A textbook is antiquated in less than a decade, and the obsolescence of a science teacher, unless he receives adequate in-service training, is equally rapid, about as rapid as the obsolescence of an automobile. There must, therefore, be continuous reevaluation of the substance of what we try to teach, not only because much knowledge is new, but also because the very concepts and laws of science undergo modification and refinement, correction, or replacement.

An excellent example is to be seen in the field of genetics, the biology par excellence of the 20th century. The laws of Mendel are as sound and as important as ever, after a century of testing, but they are now seen to be a special case related to sexual reproduction. Many geneticists now prefer to introduce the fresh student not to the complexities of Mendelian behavior but instead to the simpler genetics of organisms that reproduce asexually—for example, bacteria or bacterial viruses. Yet the genetics of bacteria and bacterial viruses, a body of genetic knowledge now equal to that of silkworm or fruit fly, was entirely unknown a quarter century ago. Biochemical genetics scarcely existed prior to 1940. That the material of heredity is deoxyribose nucleic acid rather than protein is a basic fact that was established only in 1944 and was not generally accepted until a decade ago. In 1953 the Watson-Crick model of DNA and DNA replication opened a new era of genetics, and within a decade the decipherment of the genetic code (whereby the bases of DNA specify the sequence of the amino acids in all the 10,000 or more proteins of the ordinary cell) was virtually solved. To treat today the subjects of genetics or evolutionary theory or animal behavior or almost any other branch of biology just as they existed 25 years ago is far more antiquated than it would have been to treat biology in 1900 as if it had not advanced since 1800.

The science teacher in the elementary or secondary school is at the mercy of this rapid advance of scientific knowledge. Informal efforts to keep abreast of the newer knowledge and the changing points of view falter and break under the pressure of heavy teaching loads, extracurricular duties, inadequate time to prepare for laboratory sessions, and salaries so low that summer jobs are necessary. In the United States the declining level of science teaching in the schools has been partially met by the summer and in-service science institutes supported by the National Science Foundation, and by the reforms of the science curricula undertaken, again with support from the National Science Foundation, in physics, mathematics, biology, chemistry, and earth sciences.

The Japanese have adopted another approach, one of tremendous promise. Faced with the same problem of a shortage of well-prepared teachers, the local boards of education of some of the prefectures began to establish "science education centers" 6 years ago. These institutions provide for the local retraining of science teachers on a formal, mandatory basis. Teachers are released from classes for short courses a week long or, in some cases, for longer courses lasting a full semester. The cost is borne by the school system and supplemented by funds from the Ministry of Education. Since in Japan teachers are paid a salary on a 12-month basis, they are also on call for courses scheduled during summer and vacations. A permanent staff consisting of scientists and skilled teachers in physics, chemistry, biology, and earth sciences plans the courses and teaches them in laboratories that resemble those with which the teachers are familiar in their own schools. The emphasis in every course is on the acquisition of special skills and methods of science teaching, new and old, and upon the updating of the teacher's knowledge of the subject matter.

Local Control of Centers

It is of particular interest to Americans, whose local and state control of elementary and secondary education would seem to stand in the way of any truly national solution of the teacher-retraining problem, to observe that the Japanese science education centers were not established by central fiat of the Ministry of Education, but through the farsighted vision of the local teachers, school administrators, and boards of education of separate prefectures. The program began with the establishment in 1960 of five centers (Chiba, Toyama, Gifu, Osaka, and Yamaguchi). There are now 30 centers in the 46 prefectures that, together with Tokyo and Hokkaido, make up Japan. The cost of buildings and equipment has

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ranged from nearly 300 million yen to as little as 40 million yen (approximately 360 yen = $1). The staffs of these centers range from a maximum of 33 at Osaka to as few as 10, or even fewer, in the recently established centers. A typical number is 15 staff members, of whom 7 are in charge of research and guidance. There is a National Conference on Science Education Centers which has made recommendations for construction, equipment, and staffing at an optimal level that exceeds most current practice. The conference recommends a building area of 800 × 3.3 square meters (3.3 m^2 is a Japanese unit of area, the tsubo), the present average being 460 × 3.3 square meters, and equipment costing 31 million yen. The present average is 57 million yen for building and 18 million yen for equipment.

A typical building is not very different from a Japanese high school, except that it is somewhat smaller. Besides administrative offices, it contains four teaching laboratories each to accommodate groups of about 20 to 24 teachers, for physics, chemistry, biology, and earth and space sciences. The recommended staff is 25 persons, of whom about 15 should be in research and guidance. Only one existing center (Niigata) has reached this level of staffing. It is further recommended that about half the research and guidance staff should have had experience teaching in the upper secondary school. Each teaching laboratory is flanked by an equally commodious room for the research activities and preparations of the staff, as well as for storage. The laboratories are well equipped (tables with water and electricity; gas sometimes centrally supplied) but are not intended to be too different from the laboratory facilities to be found in local high schools. There is usually a small library of books useful in science education, especially those from the American curriculum studies. Generally there is a machine shop and a greenhouse. Some centers have a separate auditorium. Three of those visited, Osaka, Gifu, and Matsuyama, have astronomical observatories with 20-centimeter telescopes. Two have donated electron microscopes. There are good collections of minerals and sometimes of fossils. Consistent effort is made to maintain collections of materials and types of equipment beyond the resources of the ordinary high school, so that not only can teachers become familiar with these, but can subsequently bring visiting groups of students to see them. Thus the center serves the secondary function of advising teachers about the improvement of equipment and the value of collections. It may also serve as a place where teachers can exhibit various kinds of original teaching devices, methods, and students' research papers.

The major function of the science education centers is to provide courses organized by the permanent staff for updating science teachers. A typical well-balanced staff includes two or three persons for each of the four sciences. Ideally, this would include one Ph.D. and one or two experienced teachers who have specialized in the subject. I was greatly impressed by the enthusiasm and the qualifications of the staff members in biology whom I met in the six centers I visited recently. In Osaka an active individual research program is being carried on by one Ph.D. staff member. All of the staff members seem to have studied the BSCS program extensively, but they were also utilizing Physical Science Study Committee (PSSC), Chemical Education Material Study (CEMS) and Chemical Bond Approach Study (CBAS), and Earth Science Curriculum Project (ESCP) materials in their special work.

The Ministry of Education at present meets about one-third of the cost of operation of the centers. Already, in scarcely 6 years, the science education centers have proved so successful in improving the quality of teachers that the program is being extended to include other subjects, such as the social sciences, mathematics, and foreign languages. The new centers, henceforth, will be called Education Training Centers. One of the first of these was approaching completion at Mito. The new building includes a dormitory for 40 persons, where teachers can be housed and fed while attending the courses, as well as offices and classrooms, a library, and an auditorium.

I visited the science education centers at Mito (established in 1962), Sendai (1964, still under construction), Gifu (1960), Osaka (1960), Takamatsu (1961), and Matsuyama (1962). In Sendai I met for a day with a biology teachers' conference, but the center itself was not yet in operation. In Osaka I visited the facility, examined the laboratories, and talked with the members of the staff, but at the time of my visit no biology course happened to be scheduled. In all the other places active biology courses for teachers were in progress, and I observed in detail the methods which were used.

The work I observed at Mito is typical of that at most of the centers. Two courses were in progress, biology and chemistry. In the former, 22 upper secondary teachers were spending 2 days studying some of the laboratory teaching methods of the American BSCS program, and in the latter, 10 teachers were spending a week reviewing parts of the CHEMS program. The center serves 78 schools (65 public, 13 private), and about 2800 elementary and secondary teachers attend the 18 courses scheduled at various times through the year. There are both short courses, usually lasting 4 days to a week, and long courses lasting a full month. The latter are usually for groups of 10 teachers, since it is difficult to find adequate replacements for many teachers during prolonged periods of absence from their classrooms. The short courses involve larger groups, usually 20 to 24 in the secondary school courses, and still larger numbers in the classes for elementary school teachers. At times as many as 240 teachers at once attend classes and laboratories. There are also many evening lectures and seminars. The teachers were a most enthusiastic and serious group, keenly interested in improving their own command of the subjects they were teaching. In fact, the teachers themselves probably aided the establishment of the science education centers. But retraining all the science teachers in one prefecture is a long process. Mutsuji Sato, director of the Mito center, estimated that it would require 10 years before all the teachers, elementary as well as secondary, had participated in the programs.

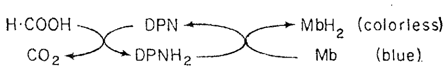
The study of BSCS laboratory methods occupied three periods. In the first of these, while the other teachers were observers, one biology teacher conducted a demonstration class of 10th to 12th grade students selected for their interest in science. As the class took place during the school vacation period, the students participated without interrupting any school work. The experiment concerned the properties of an enzyme, as exemplified by catalase (BSCS Blue Version, Investigation 15). The students had been told to bring various kinds of living materials to the laboratory, and did so: earthworms, caterpillars, a frog, a small fish, a mantid, and leaves of various plants. The instruction sheets, in Japanese, provided a modified, fuller set of directions and questions than those given in the BSCS Blue Version. The students were divided into seven teams, each with three persons. The study began with preparation of potato cubes, each of which was to retain the skin of the tuber on one face. Consequently, when the cube was placed in the test tube and water and hydrogen peroxide were added, it was at once apparent that the bubbles which appeared came from all faces of the cube except the one with the skin on it. Control tubes of hydrogen peroxide solution without the potato cubes released no bubbles of gas. This observation created a vigorous discussion and led, later in the investigation, to various experimental attempts to find out the reason for the reaction.

The second phase of the investigation involved the release of bubbles from hydrogen peroxide solution in the presence of a small quantity of manganese dioxide as catalyst. A test with a glowing splint demonstrated that the gas supported combustion; hence, from chemical knowledge, it was presumed to be oxygen. After these two preliminary parts of the investigation, which together required about 15 minutes, the instructor said: "Now you have 7 minutes to devise an experiment of your own to study further properties of the postulated enzyme that releases oxygen from living tissues." Each of the seven teams participated in animated discussion. At the end of the 7 minutes they were ready, and a spokesman for each team reported what they wished to do. One team proposed to compare the activity of the organic and inorganic catalysts at *p*H 10 (alkaline) and *p*H 2 (acid). A second proposed to study the activity of the enzyme at room temperature, 50°, 55°, and 60°C. A third proposed to study the enzyme activity in various animal and plant tissues, whole and crushed. A fourth group suggested the comparison of dried versus moist tissues (mushroom, yeast), and of plant in contrast to animal tissues. The fifth group proposed to use potato cubes of various sizes and to compare the respective duration of the evolution of gas. So it went. The teacher then said: "All right, you now have 20 minutes to perform your experiment. Make your results as quantitative as you can. At the end of the time each group will report to the class what results have been obtained." I have never seen such effective activity in the teaching laboratory as that which ensued. Each team set to work with speed but without confusion. One student would perform the manipulations; another would take the readings; the third member of the team would record the data and, if possible, graph them. In exactly 20 minutes the teacher called time, and asked the groups to begin their reports. Group 1 had found that pig liver is more active than manganese dioxide, but that MnO_2 is more active than the potato cube. Boiling the potato destroyed its activity but did not affect the activity of the MnO_2 as catalyst. MnO_2 was active both at *p*H 10 and *p*H 2, whereas the potato enzyme was inactive at both departures from neutrality. Group 2 found that a marked decrease occurred in the activity of the enzyme in the potato cubes between 55° and 60°C. Group 3 confirmed the results of Group 1 in respect to the relative activities of pig liver, MnO_2, and potato when comparable quantities were used. Quantitative results were obtained and graphs were drawn on the blackboard showing that heated potato cubes had no activity in readings taken over a 5-minute period; leaf tissue, a whole earthworm, and a whole caterpillar each demonstrated activity maximal at 1 to 2 minutes; a mashed caterpillar revealed about three times as great activity, and the maximum was not obtained until 3 minutes. Group 4 found that both dried and active mushroom tissue and yeast possessed activity. Much more activity was found in the animal tissues tested than in plant tissues, but the results were not quantitative. Clams, fish, frog muscle, and insect tissues were tested. Frog muscle was about as active as potato, which was the most active plant tissue among those tested (radish and carrot). The fish evolved oxygen only along the lateral line of the body, a fact which aroused considerable curiosity. The insect was negative in enzyme activity until crushed. Group 5 used 1 centimeter and 1/16 centimeter cubes of potato. Duration of the activity was found to be much longer in the larger cubes. The small cubes, when mashed, reached peak activity in 1 minute, but when whole only after 13 minutes.

Following the reports, the teacher explained the activity of the enzyme in chemical terms, relating it to the presence of the bonded duet of oxygen atoms in $H-O-O-H$ and similar compounds, such as $CH_3 \cdot O-O-H$ and $C_2H_5 \cdot O-O-H$. A student asked, "Is there any other enzyme that can do the same thing?" This question led to a brief discussion of peroxidase. It was pointed out that some animals may have peroxidase but no catalase. I was able to interject that in Japan a hereditary condition, catalasemia, has been discovered. Persons with catalasemia lack catalase but are protected from the toxic effects of peroxides because they still possess peroxidase. With this general discussion the class terminated, approximately 75 minutes, a double period, after beginning.

This was by far the best demonstration class in biology (or in any other science) I have ever witnessed. I was suspicious that the entire performance had been rehearsed, but was assured both by the teacher and by the director that such was definitely not the case. Beyond the usual advance assignment of the exercise no warning had been given of what was to be done. To be sure, these students were not average 10th graders. Many of them had already studied chemistry and physics, as well as biology, in high school courses. Some, however, had not; and these students did not appear to be distinguishable from the more advanced students. What I found most admirable in the entire performance of teacher and students was the complete understanding of the explicit philosophy of the BSCS program, namely, that science is essentially *investigation* of unknown phenomena and a critical, controlled analysis of causes. The "open-endedness" of the investigation was superb. The teacher himself did very little beyond getting the class started upon the preliminary investigations with the potato cubes and manganese dioxide. From that point the students themselves devised the experiments, performed them, and reported their results to the other groups, who discussed and criticized both methods and conclusions with real understanding. Even though the investigations were on the level to be expected of secondary school students, it was nevertheless an outstanding performance, and it fully validates the sometimes disputed idea that team activity in the high school laboratory is perfectly feasible and is an excellent way not only to cover the study of phenomena more broadly, but also to develop more scientific insight in and cooperative activity among the students.

The second laboratory period observed at Mito was one in which the biology teachers who constituted the class performed and discussed an investigation of a second enzyme. A now discarded BSCS investigation of malic dehydrogenase formed the basis of the study, but because of some technical difficulty in obtaining the malate substrate, formic dehydrogenase had been substituted by the staff. The substrate used was sodium formate, the test system methylene blue, which when reduced becomes colorless. The crude enzyme was obtained from peas or beans germinated for 1 to 2 days. A phosphate buffer was used, and the effect of boiling the enzyme preparation was examined. The reaction was explained to the class in the form of a simple diagram:



It was indicated that the reaction must take place in the absence of air. For this purpose a Thunberg apparatus could be used, but the high cost of these units had led the staff to devise a substitute apparatus at a cost of 300 yen (83 cents). This was a test tube fitted with glass stopper and stopcock. The stopper was continuous with a glass bulb in which the enzyme preparation could be placed, to be tipped into the solution in the test tube (substrate + methylene blue + buffer) at the right time. The stopcock, by attachment to a faucet aspirator, could be used to create a partial vacuum in the system. Another useful piece of cheap apparatus developed in Japan and suitable for this exercise was the Komagome pipette. This is like a medicine dropper with a very long, fine tip and a reservoir bulb. The stem of the pipette is graduated in two places to indicate a 2-milliliter volume. The cost is a mere 50 yen, or 14 cents.

The experiment did not work very well. Three tubes were prepared by each team in the class, tube A complete, tube B without substrate, and tube C with boiled enzyme. Tube C remained blue, as expected, but tube B in each case became colorless. The discussion that followed included suggestions that the enzyme preparation itself might contain a substrate, but then it would have to be a heat-labile substrate, since tube C did not exhibit reduction of methylene blue; or that there might be in the pea another enzyme and substrate that would reduce DPN, for example, malic dehydrogenase and malate. The general conclusion was that the exercise was not suitable for inclusion in the program in its present form.

The third laboratory period involved a study of the BSCS Green Version Exercise 9.2, Succession in Freshwater Communities. Eight members of the class of biology teachers had conducted long-term studies of freshwater ecological succession of microorganisms in their high school classes. Because of time, only four teachers reported. The starting materials had usually been hay infusions or leaves from the bottom of dried-up ponds. The objective was to enable the students to develop the concepts of the food web, succession, and the encystment of microorganisms. The succession was followed in large beakers, some kept in the sun, some in the shade. Examinations of the populations in the beakers were made by the students every 3, 4, or 5 days. They also measured the temperature and *p*H of the microcosms. One of the eight schools used the exercise as classwork; the other seven, because of the long duration of the study and the necessity for many repeated observations, did it as club work. School 1 used an infusion prepared from moss that had been dried up to 1½ years. School 2 used hay, dead leaves, pond mud, rice paddy mud, and gutter mud in separate populations. School 3 used dried leaves; School 4 used leaves taken from the bottom of a pond and then dried 20 days. In all cases a good succession of forms was observed. According to the students, who were usually unable to see the bacterial flora, the smaller protozoans appeared first. Larger protozoans and diatoms came later, nematodes last. But in the mud from the rice fields, diatoms and other algae were observed first, then rotifers. In the school in which the exercise was tried as classwork, four 100-minute periods were allowed for it, but examinations of the communities were made every 2 days, up to a total of 30 days. Fifty minutes of the total 400 minutes were taken for discussion of the observations and deductions. The teachers in general agreed that various types of succession were readily demonstrable, that the students showed great interest, but that their conclusions were not very perceptive. Confusion might result from the emphasis in class discussions that the food web starts with *producers*, whereas if hay or decayed leaves, the best readily available materials, are used to start the infusions the community, of course, begins with a flora of *decomposers*. Difficulties with this exercise were pointed out by the teachers. One lies in the identification of types. How far should the students go in trying to identify classes and species? How much time should be permitted for learning to classify the types? In general, the teachers felt that the investigation was interesting and worthwhile but required too much time. Further study devoted to clarifying the methodology of the exercise so as to bring out more clearly the nature of the food web, the succession of types, and the occurrence of encystment would be valuable. A small manual which illustrated the principal types and simplified and standardized identification problems would be particularly useful.

At Mito I addressed the combined study group of biology and chemistry teachers and discussed the revolution in modern biology, its increasingly molecular character, and the great need for curriculum reform and development and for periodic renewal of training of science teachers. I described the philosophy of the BSCS programs, especially the three-dimensional matrix of ideas (kinds of organisms, levels of organization, and great biological and scientific themes). I emphasized the reasons for presenting science as inquiry and investigation rather than as solely an authoritative body of facts, concepts, and principles, and the consequently central place of laboratory and field investigations in the BSCS programs.

The questions asked by the teachers reveal especially well the status of biology teaching in Japan:

1) What percentage of high schools in the United States are using the BSCS textbooks? Is the percentage increasing steadily? If not, why?

2) In the Blue Version, great emphasis is placed on the molecular level, but not in the Yellow or Green versions. How much biochemistry is actually taught in class?

3) Do you think that biology today is concerned mostly with physiology and biochemistry? How deeply are such metabolic processes as the citric acid cycle, ornithine cycle, and Calvin cycle actually taught in American high schools?

4) How do you rate the present science curriculum in the United States? Who or what organization is responsible for making up the curricula in the United States?

5) Why is human reproduction treated in detail in the BSCS textbooks rather than in physical education, as in Japan?

6) In studying heredity, mathematical principles such as probability and

statistics are included in the BSCS books. How are these related to the high school courses in mathematics?

7) How much identification of species is done in biology classes in the United States? Are many reference books supplied in the laboratory?

8) How much field observation is done in the high school biology course in the United States?

9) What science is taught below the high school level? Are there any local facilities, such as science education centers, in the United States?

10) Are the public high schools in the United States well equipped for scientific education laboratory work?

11) Is a great deal of homework given in the American high school biology courses?

12) Why is biology in the United States given in the tenth grade, before the study of physics and chemistry?

13) How fully are the BSCS materials utilized in in-service training of biology teachers in the United States?

14) What measures are taken to increase the use of the BSCS teaching materials?

Sendai

At Sendai, in northern Japan, the biology teachers' institute comprised approximately 139 persons, including staff. Shimizu, professor at Tohoku University, has worked effectively with the biology teachers in the development of new methods of teaching, modernization of the curriculum, and trial inductions of BSCS materials in the Japanese secondary schools. In addition to lectures on the BSCS by Shimizu and by me, there was a showing of several BSCS technique films, a general discussion of biological education in Japan and the role of the adapted BSCS materials in modernizing it, conducted by Dr. Nakayama of International Christian University and Professor Komatsu of Sophia University, as well as reports on field trials of BSCS programs in the Japanese schools of the prefecture, by teachers, supervisors, and professors, and a guided tour of the botanical gardens of Tohoku University.

The reports compared the BSCS textbooks with current Japanese secondary school biology textbooks and, in greater detail, the BSCS Blue Version with a recent Japanese *General Biology* text written by Tametake Nagano, dean of Tohoku University, as well as a critique of the use of the tetrazolium test for viability of seeds, according to the BSCS Laboratory Block on Plant Growth and Development. The relative proportion of subject matter devoted to ecology in the Japanese textbooks is about the same as in the Blue and Yellow Versions of BSCS but only about one-fifth as much as in the BSCS Green Version. Reproduction and development were presented much as in the Blue and Yellow Versions, using about 4.5 to 7.5 percent of space, but since the Japanese book typically is about 250 to 280 pages in length and the BSCS books are about 700, the treatment of most subjects in the BSCS books is 2½ to 3 times as extensive as in the Japanese books. Another report compared the classification systems used in the BSCS books and in Japanese texts. The increased attention devoted in the BSCS books to molecular biology and to genetics was emphasized. Good results were obtained by nine classes of students who performed the tetrazolium test. Quantitative data for seeds stored at different temperatures, at different degrees of dryness and moisture, or for different lengths of time, were graphed or tabulated. Tetrazolium is expensive for the Japanese, so questions were raised about the extent of dilution which could be made without impairing the accuracy of the test, and how much reagent is needed for each test. The BSCS directions are not adequate to answer these questions. (The group had the BSCS Laboratory Block Student's Manual but not the Teacher's Manual which provides information on such matters.)

Gifu

The Gifu science center and the center at Osaka were the oldest and most developed of those visited. The main three-story, structural-steel building, begun in 1960, was completed in the summer of 1961, and an extension doubling its size was begun immediately thereafter. The Gifu building cost between 10 and 11 million yen (about $30,000) and was equipped at an expense of over 8 million yen ($22,000). The annual operating budget of the center from 1962 to 1965 was about 5½ million yen ($15,000). There is a staff of seven persons in administration, nine in teaching, two each in physics, chemistry, biology, and earth sciences, and one for the manufacture of teaching materials.

A course in BSCS biology was being conducted for the second year under the direction of T. Kawasaki, who had prepared an impressive text and laboratory manual for this special course. The first portion of this book discussed the movement to improve science teaching in the secondary schools of the United States and refers to the reports by James Bryant Conant on the comprehensive American high school and to the initiation of the curriculum studies of PSSC, SMSG, BSCS, CBA and CHEMS, and ESCP. There followed a fairly detailed consideration of the BSCS, its aims and philosophy, its organization of materials, and its emphasis on science as investigation. The conceptual matrix of (i) the major groups of organisms, (ii) the levels of organization, and (iii) the unifying themes listed, and the tables of contents of both Blue and Yellow Versions were reproduced by photo-offset. Chapter 10, "The Evolved Cell," translated from the BSCS Blue Version into Japanese, served as background for the laboratory investigations. The laboratory part of the paperback volume consisted of 12 translated and expanded exercises, 11 taken from the BCSC Blue Version and 1 from the BSCS Yellow Version. These were: (Blue Version) 3, A Controlled Quantitative Experiment; 15, Catalytic Activity of Enzymes in Living Materials; 17, Activities of the Cell Membrane; 24, Effects of Various Factors on the Rate of Photosynthesis; 25, Cell Duplication; 30, Reproduction in Flowering Plants; 31, Development of the Chick Embryo; 39, Stomata and Photosynthesis; 45, Effects of Variables on the Heartbeat Rate of Daphnia; 47, Measuring Carbon Dioxide Production in Animals; 49, Detection of Organic Nutrients; (Yellow Version) Cells as Robert Hooke First Saw Them. The choice of exercises indicates that the instructor was primarily interested in introducing the teachers to more experimental sorts of laboratory work in biology, in order to divert them from simple observation of structure and memorization of terminology. The discussion of each investigation is much fuller than it is in the BSCS sources, and the abundance of graphs indicates that many kinds of quantitative study of the effects of varying one condition or another have been made. Actual results obtained by trial classes are included. Twenty-three teachers, selected as leaders in the schools of the prefecture, composed the class. They were divided into seven groups, each of which performed two of the BSCS laboratory experiments and reported the results to the others. The critiques were excellent.

During the course of the year about 250 biology teachers attend the courses given in the science education center at Gifu. Unlike Mito, here no dormitory is provided, since there appear to be sufficient cheap living quarters in the neighborhood of the center for housing the participants. The school from which each teacher comes pays the living costs of the participant and is reimbursed in part by the board of education of the prefecture. The Parent-Teachers Association also pays part of the expenses.

At Gifu we were privileged to see the famous cormorant fishing in the Niagara River by torchlight. The regurgitation of the undigested fish caught by the birds supplied a vivid parallel to our usual methods of teaching and examination, an analogy which I was able to use in subsequent lectures with humorous and apparently telling effect.

Osaka

The science education center at Osaka lies in the southern suburbs of the great city. It is the largest and best equipped of all the centers visited. Biology occupied half a floor of the three-story building, with five biological laboratories, instead of the usual two. There were two laboratories for biology, one for botany, one for zoology, and one for physiology. In the biology laboratories the tables were simple Formica-covered tables, but they were supplied with water, gas, and electricity. Each table had a lower shelf. The number of Ph.D. scientists on the staff was greater than elsewhere (there are three in biology, for example), and one or more of them carried on independent scientific research work in small separate laboratories.

This center serves 32 upper secondary schools, 102 lower secondary schools, and 252 elementary schools, all within the city, and an additional 65 schools in the prefecture outside Osaka. Osaka City is planning to construct its own municipal science education center in the immediate future, in order to relieve the heavy pressure on the present center. Seminars in science laboratory work are conducted for short periods throughout the year. For example, in biology, lower secondary school teachers make observations of the giant salivary gland chromosomes of dipterans, study methods of collecting protozoa, observe the behavior of chromosomes during cell division, perform blood typing, and study the enzymatic conversion of starch into sugar. "Science research schools" are conducted on such topics as the use of instruments in experiment and observation; problem-solving; science education to develop thinking ability; the proper science facilities in the schools and their effective utilization; field experiments and observations; the use of movies and slides in science education; and the school garden for science teaching. Longer seminars run through the year for elementary and lower secondary school teachers. In one of these, 40 teachers meet once every 2 weeks; in another, 40 teachers meet every day for 6 months, their places being supplied in the schools by substitute teachers. For upper secondary school teachers a course meets once a week for 15 weeks with the class limited to 10 persons, because the aim is to provide thorough training for small groups who can thereafter function as leaders in local seminars of a similar type conducted in their own neighborhoods. The course of study for these teachers included lectures by professors from Osaka City University, Nara Women's College, Kyoto University, Osaka University, Konan University, Mukogawa Women's University, and Osaka Gakugei University. The laboratory programs were conducted by the staff. The topics were cell structure and electron microscopy; photosynthesis; respiration; water economy of plants; freezing and cold resistance of plant cells; plant growth regulators; the productivity of the plant community; animal carbohydrate metabolism; animal protein metabolism; osmoregulation in animals; structure of the eye, and rhodopsin; the morphology, physiology, and reproduction of paramecium; embryogenesis in the chick; heredity of *Drosophila;* and the phylogeny of cormophytes. Although some of these topics seem rather advanced and overly specialized for secondary school teachers to profit from directly, it is again significant that the college and university professors of the vicinity are participating freely in the work of the Center. For the most part, subject matter essential to an understanding of modern biology is being stressed.

The primary aim of the Osaka center is the improvement of elementary school science teachers. As the present center grows to include non-science subjects such as languages, the new municipal center will remain strictly organized for the improvement of science education and will be attached to the Osaka Science Museum.

Takamatsu (Kagawa Prefecture)

The tour of science education centers was concluded by visiting two on the island of Shikoku, which though large and heavily populated is out of the way of most Western visitors. The two science education centers on this island were established earlier than or simultaneously with the one at Mito, and are in no way inferior to it.

At Takamatsu the four-story building accommodates chemistry, physics, biology, and earth sciences on three floors. The ground floor is used for administrative purposes. There is a plan to add an auditorium and to accommodate a telescope in an observatory on the roof.

At the time of our visit, 79 secondary school biology teachers were engaged in a 3-day BSCS course. Each person apparently had a different assignment, relating to eight investigations adapted from the BSCS Blue Version and supplied in translation. The exercises were: 16, Effects of Various Factors on Enzyme Activity; 18, Permeability of Yeast Cells; 24, Effects of Various Factors on the Rate of Photosynthesis; 26, Behavior of a Slime Mold; 31, Development of the Chick Embryo; 46, A Comparison of Metabolism in Animals; 47, Measuring Carbon Dioxide Production in Animals; 52, Effects of Reproductive Hormones on Secondary Sex Characteristics. It is significant that five of these eight investigations represent different choices from those which were being used at Gifu. The choices therefore are independent, and will provide a basis for future intercenter comparisons. The time at Takamatsu was spent in discussions with the biology teachers about the philosophy and methods of BSCS. Their questions evinced both interest and sharpness.

Matsuyama (Ehime Prefeeture)

At Matsuyama the physical facilities were most impressive: a good three-story building with an astronomical observatory on top, adjacent to the local university, whose professors were participating in some (if not all) of the courses being given. There were an auditorium and a machine shop, in addition to the usual laboratories for physics, chemistry, biology, and earth sciences. A biological museum had been developed, and the biology preparation room contained a chamber for controlled temperature and humidity experiments, plant tissue culture facilities, a Kubota refrigerated centrifuge, a small autoclave, an ion-exchange column, a Warburg apparatus, a soft x-ray machine (18 kv), and ten stereoscopic dissecting microscopes in addition to the usual supply of compound microscopes. I learned that the stereoscopic dissecting microscopes cost 50,000 yen ($140) apiece, whereas the regular classroom compound microscope costs 30,000 yen ($83).

The Ehime prefecture science education center serves about 1200 teachers annually, of whom 320 are upper high school teachers and 500 are lower secondary school teachers. There are about 7000 elementary school teachers in the prefecture, all of whom must teach science. The center is consequently in very heavy use throughout the year, with both short seminars, of a week's duration, and long courses simultaneously in progress. There is a 3-month course for 20 elementary school teachers, a 6-month course for 10 lower secondary school science teachers, and a full-year course for four upper secondary school science teachers. In Ehime prefecture substitute teachers seem to be more readily available than elsewhere in Japan, partly because the Board of Education strongly wishes to promote the use of the science education center, and partly because of the teachers' own initiative. One of the short seminars represented an interesting pioneer approach to the study of local island conditions and rural communities. Ninety teachers were involved in that seminar.

A study of BSCS methods and programs was in progress, with approximately 200 teachers working for a week, while a 23-week course proceeded simultaneously (17 April to 25 September). In the BSCS course, Blue Version laboratory investigations 15, 46, 47 and Green Version 14.3 (A Heart at Work) were being used in English in Xerox form. The critique of Investigation 46, A Comparison of Metabolism in Animals, was sharp. The expected temperature difference was found in the case of the frog's respiratory quotient at 19° and 25°C, but when a mouse was used the rate at 29° was actually below that at 18°C. Was the cooler mouse more active, or perhaps shivering, in order to maintain its body temperature? It was suggested that spreading the soda lime over the floor of the jar, even when covered with fine wire net, as directed, was inadequate to keep the animal away from the chemical. There was also sharp criticism of Investigation 47, Measuring Carbon Dioxide Production in Animals. Why was phenol red used? The range it covers (*p*H 6.6 to 8.2) is not suitable, especially since at lower *p*H the carbon dioxide will diffuse out of solution. It was suggested that phenolphthalein (range *p*H 8.2 to 10.0) or some other indicator in the alkaline range be used. The average value for six groups performing the experiment was 1/20 of that found by the barium carbonate precipitation method. Something must be wrong with the suggested technique of the experiment. On the other hand, the exercise from the Green Version on rate of heartbeat of *Daphnia* went very well, as did the study of catalase.

The center at Matsuyama sends out a 16- to 20-page monthly or bimonthly bulletin describing the local activities of the center, new experiments suitable for the high school laboratory, and improvements in science education. The bulletin contains frequent references to PSSC experiments, CHEMS and CBA, BSCS, and ESCP, which are all widely and intensively used by the Japanese.

Conclusions

These six Japanese science education centers signify a sweeping reform of elementary and secondary school science teaching. They achieve their striking results because they are established on a permanent, local basis and are supported mainly by the local boards of education. They have avoided control by pedagogues and specialists in "education." Instead, they are operated by trained scientists and experienced school teachers who work together to devise programs specially suited to the needs of their teachers. With small and practicable steps, the teachers improve their understanding of methods which they can readily test in their own classrooms and laboratories. The laboratory equipment in the science education centers is only slightly superior to that which the teachers have in their own schools, but superior enough to make them desire to improve their own facilities. Major facilities, such as x-ray machines, electron microscopes, telescopes (15-cm), and machine shops, as well as good working collections of minerals and fossils, and adequate greenhouses, permit the teachers to work with more expensive equipment, to gain a first-hand knowledge of its operation, and to bring groups of students to the center to observe what such instruments make possible.

The use of American experimental course content improvement programs is widespread. Every science education center I visited is using PSSC, CHEMS, CBA, BSCS, or ESCP materials and studying the philosophy of these programs. Yet no center is entirely dependent on these programs, but uses them critically to supplement and improve its own courses. The emphasis is on good laboratory and field teaching as a basis for understanding scientific methods and concepts. Science as investigation and inquiry, instead of treatment solely as an authoritative body of facts, is coming into its own.

The few defects of the science education centers of Japan inhere in the educational situation itself. The centers are at present inadequate to reach even a reasonable proportion of the science teachers within a 5-year, or even a 10-year cycle. The shortage of substitute teachers causes most of the courses to be far too brief for maximum effectiveness. Staff programming tends to be rather spotty instead of comprehensive.

A major difficulty, frequently expressed, lies in the grim hold of the university entrance examination system over the science curricula of the lower schools. The university is the goal of every able student, for economic as well as intellectual reasons. To enter a university he must pass the examinations, which are established separately by each institution. The professor who makes out the examination questions therefore controls what must be taught and learned in the lower schools. This same rigorous control is in part reflected in the Ministry of Education syllabi, which must be followed by the teachers. Nevertheless, I found the men in the biological section of the Ministry of Education very enlightened and pressing for change. Many professors in the universities are also in the full current of modern biological thought, participate gladly in the programs of the science education centers, and would write examinations that emphasize interpreting data, applying tests to hypotheses, and drawing valid conclusions instead of merely memorizing and regurgitating facts. On the other hand, in many universities the upper positions are still filled by men to whom biology means classification rather than experimentation, morphology rather than biochemistry, organ physiology rather than cell biology. We cannot afford to discard taxonomy, morphology, or gross physiology—they are important parts of biology and will remain so. But they do not comprise all of biology—they are only a diminishing proportion of it. In Japan, as in the United States, the examination system must become more flexible. It must change with the development of science itself, must encourage scientific attitudes and cease defeating the introduction of new disciplines, new outlooks, new subject matter. The universities and the examining boards in some educational systems indeed exhibit a rigor mortis.

On balance, the science education centers in Japan may well represent the most significant educational experiment of our time. Their vitality, which springs from their local relationship to the prefectural schools and their permanent staffs, far exceeds in my own estimation that of most of the summer science institutes held in the United States, which lack that close relation to the local schools and which by their impermanency countenance ill-planned and ill-taught programs that are often little different from the usual summer school sessions. The best summer institutes in the United States are indeed very good, but far too few of them reach a passable standard. That is because, for the most part, their staffs are recruited quickly, teach their favorite subjects without much consideration of their appropriateness or suitability for improving science education in the lower schools, and depart without much contact with other members of the staff. What is needed is serious, continuous, prolonged, hard work devoted to the development of the right sorts of courses for renewing the training of science teachers. The Japanese seem to be achieving just that. We would do well, with our vast resources for the improvement of education, to emulate them. As they have profited by employing and improving upon our NSF-supported programs in science education, we may likewise profit through the establishment of science education centers modeled on theirs.

Ionospheric Topside Sounding

Satellite observations of radio echoes are providing a picture of structure in the upper ionosphere.

W. Calvert

Above an altitude of 300 kilometers, the density of the earth's atmosphere (less than 10^{-10} that at sea level) corresponds to a good laboratory vacuum. Nonetheless, the region still exhibits important physical properties, particularly for the propagation of radio waves.

Solar ultraviolet radiation and particle bombardment ionize the constituents of the upper atmosphere and produce the *ionosphere* (*1*). Extending upward from around 70 kilometers, the ionosphere is usually described in terms of the density of free electrons (Fig. 1). The electron density increases in a series of regular layers (D, E or E_s, F_1, and F_2) up to a peak in the vicinity of 300 kilometers. Above the peak, in the *topside* of the ionosphere, the electron density continuously decreases to very great heights. The fraction of the particles which are ionized is minute at the base of the ionosphere, but increases with height and reaches the order of 10 percent at 1000 kilometers.

Because it is ionized, the ionosphere exhibits the properties of a plasma and profoundly affects the propagation of radio waves (*2*). At times it can reflect back to the earth frequencies as high as 60 Mcy/sec, thus making possible shortwave radio communications over long distances. This practical application enhances the importance of understanding the ionosphere.

The neutral atmosphere, held to the earth by gravity, tends toward an equilibrium distribution in which the density decreases exponentially with height. The scale of the variation (that is, the change in height for an e-fold change in density) is called the *scale-height*. It is proportional to the absolute temperature divided by the mean molecular mass. At the earth's surface the scale-height is about 8 kilometers. Above the peak of the ionosphere, where the mean molecular mass is less and the temperature greater, the scale-height may be tens or hundreds of kilometers.

Except for two factors, similar considerations apply to the ionized components of the topside ionosphere. First, the ions and electrons are bound together by strong electrical forces which prevent their gravitational separation. The two act as a composite gas with a scale-height about twice that of the ions alone. Second, the equilibrium situation pictured above is not always encountered. Dynamic processes (such as the production of ion-electron pairs competing with the loss by recombination or the diffusion of the ionized component through the neutral gas) can control the situation. Nonetheless, in the topside of the ionosphere the electron-density distribution is still essentially exponential, with the scale-height reflecting the temperature and mean ionic mass (*3*).

Furthermore, thermodynamic equilibrium does not always apply. The temperature of the ions and the temperature of the electrons may differ not only from one another, but also from the temperature of the neutral gas. During the day the ions at the peak of the ionosphere may be somewhat hotter than the neutrals, and the electrons may be twice as hot as either the ions or the neutral particles. Toward greater heights in the topside the neutral temperature and the electron temperature

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