width can be as short as 65 mm., as the width of the projected image on the 45° sloping surface is not as great as the vertical dimension.

A thin, metal collar is bolted or soldered at right angles to the horizontal mirror housing in order to clamp it around the ocular and draw tube of the microscope. A rubber ring placed above the ocular keeps it from being scratched. Lining the metal collar with felt or three layers of tape will protect the draw tube.

A concentrated light source, such as that produced by standard condenser type microscope lamps, will produce adequate illumination for 10× and 20× objectives. A carbon arc or other intense light source should be used for greater magnifications. The room must be darkened and shields are used to prevent light from reaching the drawing paper. Matte black paint or paper can be used inside the mirror housing to eliminate stray light reflections.

Knowledges of Botany Possessed by High School and College Students*

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This study was not undertaken originally for determining achievements of any group or groups of students in the field of botany. Rather, the conclusions herein were drawn from data obtained for a number of other studies.

During the last three years the author has engaged in a number of research projects involving the use of tests in the different areas of science. The tests have contained, of course, many questions other than those dealing with botany. The tests and the research projects in which they were used were these:

1. Over 4000 Regents Examinations in Biology of the University of the State of New York completed by high school students during 1949 and 1950. They were used in a major investigation concerning certain characteristics of the Regents Examinations.
2. Over 1000 Minnesota State Board Examinations in Biology for 1947 that were administered to students in five midwestern colleges and universities.
3. Over 180 comprehensive examinations in science taken by student teachers in six midwestern teachers' colleges and colleges of education, whose major field was science.
4. Over 80 comprehensive examinations in science and mathematics used by Western Michigan College of Education to award science and mathematics scholarships to superior students from high schools in the State of Michigan.
5. Over 100 classroom tests of subject-matter in biology given to students who were enrolled in the author's methods courses.

The questions found on these tests that dealt with botany were listed on a sheet of paper together with the passing percentages made by the students. Scores obtained on questions that dealt with the same topic were compared with one another, the types of errors made by the students were noted, and the types of questions that seemed to cause the greatest difficulty were listed. Also, whenever questions were found for which the passing percentage was the same for students in the upper and in the lower half of the score range, they were listed for further attention.

The data thus obtained were analyzed carefully. Two facts were noted immediately:

1. The *types* of errors found on the papers of college students and on the papers of the high-school students were much the same.
2. The major errors that appeared most frequently could be grouped under three major headings, (1) errors involving "psychological ownership," (2) those involving "absolutism and relativism" and (3) those involving "selectivity." Each of these categories of errors will be treated separately below:

I. Errors Involving Psychological Ownership. The term "psychological ownership" refers to the extent to which a student has an adequate perception of a topic of subject matter, the extent to which he can recognize the implications of that topic when they ap-

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pear in unique contexts, and the extent to which he can apply and make use of the knowledge when needed.

Unfortunately, the evidence reveals that both high-school and college students have a verbal knowledge of subject matter far greater than psychological ownership. A few illustrations will make this clear.

On one examination a group of college students was given the task of drawing and labelling the cross-section of a woody stem. The average score received for the drawings was about 90%. The drawings they produced consisted of a series of neat concentric circles demarking the xylem, cambium, phloem and cork. On another section of the examination was an illustration of a quarter section of a woody stem as it would ordinarily appear. The students were asked to label the parts. The average score was about 45%. Obviously, the students had learned the woody stem in terms of a series of verbal symbols, but had not established an adequate perceptual pattern of the woody stem in their minds.

On an informal test students were asked three questions. The first was to define and describe the sporophyte and gametophyte generations of the "common moss." The second was to list the characteristics of roots, stems and leaves. The third was to define and give examples of the term "photosynthesis." Nearly all the students who had taken courses in botany were able to muster a satisfactory answer to the first question. Yet less than 50% were able to differentiate between the sporophyte and gametophyte generations when handed samples of the moss.

The task of defining "root," "stem" and "leaf" proved to be no problem. Yet less than half were able to classify correctly the "stalks" of a bunch of celery.

Nearly all the students defining photosynthesis stated correctly that "the green plant *manufactures its food* from CO_2 and H_2O in the presence. . . ." Yet when asked to name the food of green plants about eighty per cent stated CO_2 and H_2O.

In another interesting experiment, a methods class in biology developed a list of the basic characteristics of plant, animal and mineral substances. When the list was accepted as being satisfactory, the students were shown the black, dry embryo cases of the dogfish (skate). They were asked to decide, according to the list that they had prepared, whether the object was animal, vegetable or mineral in origin. Only 10% suggested that it was animal in origin, and these suggested that it was the exoskeleton of an insect! More interesting, however, was the way the students altered their observations so that they would fit the characteristics in the list.

While all students did not so err, the vast majority did. The question is whether they read about botany, or know botany.

II. Errors Involving Absolutism and Relativism. It was quite surprising to note the number of students whose minds accepted botany in terms of "pigeon-holes" or "honeycombs." Few students seemed to accept the fact that characteristics in the botanical world fall on a continuum.

One could infer from the answers in the area of classification that the Deity had manufactured a box with a neat number of little compartments. Over the top of each was placed a neat typewritten card which listed the characteristics the inhabitant of the compartment was to receive. The characteristics of all compartment dwellers were mutually exclusive. An organism was then fashioned completely independently from all other organisms. It was then deposited in the compartment to reproduce its kind.

Few seemed to comprehend the significance of the evolution of characteristics in biological history. The answers to many questions seemed to indicate that students construed evolution as the emergence of a rabbit from an apparently empty hat. The need for learning botanical differences in terms of relativism rather than absolutism is clear.

Another question stated that seeds of a certain flower were planted in a container of soil. The ratio of the color characteristics that appeared was 193 to 61. The students were asked to identify the probable genotype of the parents. About 38% correctly indicated that both parents were probably hybrids. Most of the others protested that the offspring of hybrids have the characteristics in a ratio of 3 to 1. Since this ratio was not exactly 3 to 1, it was impossible to state what the parents were!

The need for developing the idea of relative rather than absolute appearance of characteristics, and the chance assortment, is clearly evident.

III. Errors of Selectivity. The inability of students to differentiate between pertinent and impertinent factors, to select from many pieces of evidence those that are significant, and to discern the elements in an experimental situation is quite marked.

In one problem the college students were given the following materials: a geranium plant, $2\frac{1}{2}$ inch disks of cork, 1 pin, alcohol, iodine solution and phenol. They were asked to describe an experiment, from purpose to conclusion, that could be performed with the materials. Only one of 93 students failed to suggest that the experiment involved photosynthesis. Yet 72 found some way for using the phenol, obviously an inappropriate one.

On another test given to over 1000 college students, the answers suggested by 420 of these students who had taken botany to a question involving transpiration were analyzed. Less than half of the students were able to distinguish between the control and the experimental factors. Further, the experiment was to be carried out in a series of steps with the information obtained in one step to be used in the next. Less than one-third of the students were able to select from the one step those elements necessary to carry out the next step successfully.

It seems apparent that the meaning of experimentation to botany students is very nebulous and not well understood. The fundamental experimental skill of being able to examine evidence, and to select that which is pertinent, seems to be woefully weak. Interestingly enough, the students receiving the higher grades on these examinations did not do commensurately better on the thought and relationship types of problems than did those who received the lower grades. The increment by which the better botany students exceed the poorer ones seem to be gained on factual type questions.

Of course, it is easy to state weaknesses in a smug fashion without recommendations. Yet it does seem to be a responsibility to make some suggestions for the alleviation of these weaknesses. Hence a few are here made:

1. Teachers of biology at both the high school and college levels need to ask themselves the question, "Is the purpose of our teaching to enable the students to assemble a mass of botanical facts to be disgorged at test time, or is it to enable them to search for and recognize botanical truths, to recognize botanical relationships, and to make use of botanical facts?" The first purpose has the implications of the story of the woman who baked pancakes merely for the purpose of storing them in the cellar in trunks. The second objective is, of course, the one which biology teachers accept, or to which they give lip service, and which research evidence has shown to be eminently justified.

2. No purpose can be attained maximally by any means other than direct teaching. Hence, the abilities and skills implicit in the second purpose are not natural concomitants of the dissemination of facts. The student will not learn to think critically in a laboratory unless the design of the experiments forces him to do so. Too often we have assumed that if a student performs the same experiments as did those great botanists who did think critically and who did discern relationships, then he will do likewise. Unfortunately, there is no evidence to support such an assumption and a good deal of evidence to negate it.

Thus the passive *hope* that students will learn to discern, to relate, and to select must be translated into an active *demand*. We must be less willing to accept neat drawings and be more desirous of building in the student the ability to interpret his findings by means of laboratory exercises that require such interpretations.

3. The implications herein mean one thing especially. There may be a need for reducing the quantity poured out to the student with an increase in quality. Any good farmer knows that the Holstein gives volume, while the Jersey gives fat. There is a biological principle here that cannot be ignored. Perhaps we are being driven to making our choice. The results of this study, however, indicate that too much of our botanical teaching is a veneer rather than solid wood. We had better make the choice of our objectives and then implement that choice.

His many NABT friends may want to extend get-well wishes to genial Pres. Blair Coursen of General Biol. Supply House, who met with a serious accident while on a trip West and has been recovering at Teton Memorial Hospital, Chateau, Montana. Best wishes from the ABT staff, Dr. Coursen!

A rubber band will substitute for a broken steel spring drive belt on aerator pumps and such until a new belt can be obtained.