post-war advancement which may occur in medicine and allied sciences, drug manufacturing and educational centers. Success and survival will depend not only on cooperation, leadership and a shrewd business sense but on an adequate appreciation of opportunities, limitations and the value of fostering research by providing grants and fellowships. Much material assistance can be provided with mutual gain for all participants when such fellowships are established. This gain may extend past current problems into lifelong associations. If the manufacturer recognizes his opportunities and obligations and forges ahead to challenge or accept them instead of remaining on the defensive, there will be less likelihood of being fettered by purblind policies. Each one interested in research and therapeutics has responsibilities peculiar to himself, but there are few, regardless of occupation, who, at the completion of a job well done, does not feel as Pasteur, who said of the researcher:

> It is indeed a hard task when you believe you have found an important scientific fact and are feverishly anxious to publish it, to constrain yourself for days, weeks, years sometimes, to fight with yourself, to try to ruin your own experiments and only to proclaim your discovery after having exhausted all contrary hypotheses.
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> But when, after so many efforts, you have at last arrived at certainty, your joy is one of the greatest which can be felt by a human soul, and the thought that you will have contributed to the honor of your country renders that joy still deeper.

THE INTRODUCTION OF NEW VIEWPOINTS AND SCIENTIFIC CONCEPTS IN GENERAL BOTANY[1]

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IN any consideration of the approach to be utilized in presenting general botany to students of random selection and average ability, it is obviously necessary to examine with care the general aims of such an offering. It is also necessary, in this transitional period in methodology, to examine critically all current tendencies and evaluate them; one must further correlate the last named with certain recognized, sound and acceptable principles of scientific instruction at the college level. Lastly, it is imperative that we interpret and apply all controversial procedures within the limitations of personnel and equipment of the average undergraduate college.

Work at the college level is not to be confused with that of elementary grades in which the teacher is concerned with immature, plastic minds. Neither is it to be considered as similar to that offered at the secondary-school level, in which we have no selection of students whatsoever other than natural and no aim other than very generally cultural. College botany is a course offered to at least a pseudo-mature student body in which some degree of selection has operated, since only a very small percentage of high-school graduates enter college. At the worst, we are thus facing a selected group of students who should begin to divorce themselves from an immature approach to their studies. The fact that only one per cent. of the students taking general botany continue in the subject for advanced work does not change the last statement to any degree. One cogent, major aim of teaching remains fundamentally the same: a flexible and inspirationally directed assimilation of factual data and principles of proven worth with applications to those life situations within the mental scope and experience of the individual in question; factual data with which to achieve a concurrently developed, intelligent, appreciation with a concomitant curiosity as to plants, their reactions to factors in their environment, and their economic or biotic aspects, *i.e.*, plant sociology.

With these fundamentals, the fad of the moment, the latest tendency (often revived) of the professional pendulum swinger in methods, is simply incorporated into the inescapable and irreducible fundamentals of any science—namely, the assimilation of sufficient data upon which to laminate intelligent concepts; the precursors of a lasting constructive curiosity fostered by satisfaction in mature achievement rather than the immature, rambling questioning of untutored minds. Thus, whether you are striving to develop a sense of citizenship, achieve indefinite sociological aims, or direct a student in the first steps along the road to a professional scientific career, it is here in this freshman course that we must somehow bring him to see the necessity of accumulating data, developing powers of observation, achieving mental discipline, correlating factual agenda with immediate and general environment, and, finally, bring about the development of an inherent appreciation and curiosity

[1] A paper presented at the Symposium on the Teaching of Botany at Dallas in 1941 before the Botanical Society of America and the American Society of Plant Physiologists.

relative to the plant world—an inspiration for further work—a sense of the challenging problems within the field of botany and its varied fields of specialization.

College botany is in a state of flux and may it never become static. Students are adjusting themselves to a rapidly changing world; curricula are changing; progress demands a treatment of recent scientific advances as well as the more stereotyped textbook essentials—applications of new concepts to the fundamental agenda so well known to us all. It is with some of these concepts that we shall now proceed.

There is a wide gap between formal research—pure science—and the mental set of the average freshman. It is possible, however, to adapt modern concepts to the course of study and thereby bring to the student not only a greater appreciation of plant science and its ramifications but also the awakening of curiosity and the awareness of plants as entities—as complex organisms in a living world.

We can then consider the plant as a whole, as an entity, and interpret morphology, physiology, etc., as intergrading biotic, dynamic living forces. This work may be simplified greatly if the student himself actually grows and tends plants over a period of time. The Chicago Teachers College is fortunate in having available greenhouse facilities so that each student actually has the experience of tending seven square feet of soil from the preparation of the seed bed in the benches to the harvesting of fruit and seeds. Seeding, transplanting, potting, rooting of cuttings, soils and fertilizers, and factors of growth may be considered in one situation and the writer has yet to see the student who does not feel a just glow of pride in his achievements. In this particular institution this practical, horticultural experience is a part of the required course of study for every freshman and is thus carried into their ultimate professional activities.

It is thus possible for the student to observe, with proper suggestions, that the life cycle of a typical flowering plant is really a series of phases. From the germination of the seed the vegetative phase is observed with growth and accompanying activities. Buds arise and flowering proceeds with the stoppage of growth common to this phase as shown clearly in recent work with tomatoes. Then follows the production of the fruit with a quickened pulse, so to speak, and ultimately the senescence of this individual plant or its parts. Even though a student may not realize or grasp fully all the details in the limited time available, the seed of an idea is fixed; namely, the plant as a whole with integrating, though definite, phases of development. With even a low ebb of interest, the most negative student may note his mistakes in tending the plants, observe variations in the growth of different species, see aberrations in certain phases of growth due to critical factors, become sensitized to factors in general and thus conceive of plants as living, changing complexes passing through definite phases in their development and reacting accordingly. It isn't difficult for a student to understand germination, embryos and the origin of tissues when he sees them unfold before his eyes. He may even think of a plant as a result of its past rather than its present in having presented to him facts relative to induced phenomena at certain stages in its embryology; for example, light and temperature effects in photoperiodism and vernalization. One may gradually perceive that the study of growth is a study of the differences developing from similar cells arising in meristems and growing into various structures. Physiological changes in these cells can then be considered in terms of environment and heredity. The firing and stimulation of the imagination and the correlation of varied factual data in the mind of the student are of the greatest value in these considerations.

Germination of seeds in glass containers may be used as illustrative material for many of these phenomena; at least a cotyledon and plumule become realities. In lieu of greenhouse experience, if space is available, even a potted plant or an experiment in hydroponics is feasible. The latter is particularly appropriate in the light of common usage both commercially and in the home. An understanding of the simple requirements for fertilizers can be included, although more practical knowledge is gained from a study of soils. In any event, the actual growing of plants is a vital requisite for successful work in general botany and certainly for the introduction of much colorful and challenging data.

In connection with the morphology of seedlings and growth a student can comprehend the sensitive loci of stimulus and response in plants by the use of simple experiments. Simply placing a box over a plant or stringing a few light bulbs brings a vivid appreciation of the phenomena of photoperiodism, and the seasonal blooming of common garden plants becomes significant to the student. Shading a part of a plant definitely connotes transport of a hormonal stimulus or inhibition in plants. Seasonal variations are clarified and gardens become something more than simply aggregations of miscellaneous plants. The student again thinks of a plant as an individual with loci of responses and transport of chemical determiners; thus, subsequently, some form of concept relative to meristems, primordia and manner of growth gradually evolves. With mitosis as a

requisite, the use of colchicine is introduced and, if successfully applied, evolution occurs in the morphological change of the tissues reacting and the vista of future economic possibilities spreads before them. Further types of induced mutations are but another step in the line of thought, and variations in turn are assimilated with enlarged understanding of progressive development; at least to a greater degree than before.

The concept of control of plant development by internal forces is one of fundamental significance. Hormones have become a by-word of the layman and vitamins are a part of the average vocabulary. Auxin, as a collective term, is used quite freely and will soon become a part of all courses. While it is not practicable to utilize auxin as such, there is no dearth as yet of synthetics. With the varied phenomena attributed to these complicated chemical factors—growth promotions, growth inhibition, differentiation of tissues, flowering, fruit development—the concept of hormonal control assumes significant proportions as a causative factor. The interrelations of plant parts may be stressed in this connection; this is a further approach to the concept of plants as entities.

Bud dominance is easily introduced in varied ways. Apical dominance in potatoes, for example, and its importance in planting can be stressed and in some instances chemicals may be used to break such dominance. Apical dominance and inhibition of later growth as illustrated in tree form are easily seen and the simple procedure of pinching back a plant grown in the greenhouse with the subsequent development of buds indicates a change in the hormonal balance; for example, a reversal of the floral to the vegetative phase with its concomitant growth as compared with the more static phase of flowering.

The rooting of cuttings with the appearance of adventitious roots brings the attention once again to hormones and vitamins. It is of never-failing interest to the student to observe the formation of roots on various plant parts by means of the rooting hormones. Synthetic hormones in lanolin paste brings roots from stems and with proper application brings prototropism into clear focus as shown by the bending of stems when hormones are applied. The action of hormones in geotropism then becomes more clear. To see roots growing and covering stems by adding a few milligrams of an acid to the soil is also striking. Once the concept of hormones is established, parthenocarpy may be introduced with varied materials in keeping with the latest findings. From this approach, pollination and fertilization assume realistic proportions since basic understanding is present. A seedless tomato—a swollen ovulary—and then economic applications and the experimental work on premature fall of fruits and the delay of opening of blossoms to avoid killing frosts. The plant sciences begin to assume significant aspects in the eyes of the student—a necessary and vital prerequisite for positive and challenging interest with a fixation of facts rich in either professional or cultural connotations.

In addition to these modern approaches, the subject of vernalization and dormancy is always of interest; all students respond to the unusual, and certainly the explanation of these reactions can not fail to fall into this category. In addition, it is not at all difficult to stress the economic aspects of such work; either the latter or its application and relationship to man as the perpendicular pronoun will achieve the same result. Common bulbs may be treated and certain aspects of dormancy in general may be clarified. Dormant twigs are always potent illustrative material with morphological applications. Many misconceptions born of extravagant claims relative to vitamins and hormones may be corrected in such studies.

In general, these engrossing applications, in addition to experience in the actual growing of plants as practiced in the greenhouse, have caused the plant as a whole to assume a colorful significance in the life of even a casually interested individual. An integration has occurred; roots, stems, leaves, flowers, fruits, seeds—the student has run the gamut of them all—has observed the plant in all its phases of growth from the first cotyledons to the achievement of its ultimate goal—the seed. Perhaps even a casual understanding of vernalization and respiration has brought to him a sense of the living qualities—the reactions of dormant embryos or partly stimulated embryos to factors in the environment. Primordia are not simply morphological units or divisions; they are regions from which develop the resultants of heredity and environment, shaped by factors controlled by hormo-vitamin combinations, possessed of a phasal ontogeny and in a constant stage of change —an individual living through the infinitesimally short interphase of an evolutionary sequence.

Perhaps none of us can achieve all these correlations; not all instructors, for example, can provide actual, continuous, hands-in-the-dirt experiences. This brief presentation is by no means complete; the instructor may add others in respective fields of specialization and adapt them to presentation of material. All of us can, however, amplify our fundamentals with modern approaches and concepts—glorify our essentials with inspirational explanation of observed phenomena and thus achieve in a mature fashion, in a manner in keeping with the intelligence of our students at the college level, those aims so briefly entertained in the opening paragraph.