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AGRICULTURAL BOTANY IN SECONDARY EDUCATION[1]

THE advance of physical science during the past century, and the application of the results gained therein to industry, and especially to the means of transportation and intercommunication, have made desirable and available, areas of the earth's surface hitherto unsought or inaccessible. Because of the development of mechanical agencies through science, the present age, more than any other, is characterized as an age of economic exploitation. The freedom and mystery of the older earth are departing, and soon will be gone forever. Never again will there be another Odyssey. The spirit of the new Age of Steel is over us—the spirit of exploitative and capitalized industry, that is reaching with magnificent ease out to the remotest confines of the planet, uncovering all the secret places, and blazing plain bare trails athwart the earth, straight to the very capitals of the ancient fairylands of geography. What mystery is there left in Peking or Timbuktu, in Samarkand or Candahar? To commerce, the names of the nations are but words in a game; their habitations but the squares of red and black on the chess board upon which the game is played; their remoteness a mere relativity of cost of communication.

In a sense that is far from Emerson's this spirit is embodied in the words:

> Far or forgot to me is near,
> Shadow and sunlight are the same,
> The hidden gods to me appear,
> And one to me are shame and fame.

The first exploitation of new territories has always been made by adventurers driven by the primitive Wanderlust; by men impatient of sitting in sodden security, but ever eager

[1] Address before the Iota Chapter, Sigma Xi, University of Kansas.

to voyage on and try the hazard of new fortunes. It is to men like these that we owe the opening of new regions to settlement. In them through all ages has spoken the soul of Odysseus:

> Push off, and sitting well in order, smite
> The sounding furrows, for my purpose holds
> So sail beyond the sunset and the baths
> Of all the western stars, until I die.

The world, however, has passed through this epoch. No new lands lie under the sun waiting discovery, for the earth's surface, in all its essentials is roughly known. The home of El Dorado, the Fountain of Perpetual Youth, the Seven Cities of Cibola, Bagdad, the Land of Ophir, Cipangu, Lhassa, the country of Prester John and the city of the Great Khan, like the Poles of the Earth and the "Old Moon Mountains African,"—all these have faded out of the romanticism of twilight obscurity into the daylight monotony of the commonplace. Magical names that once lured mankind, have vanished like the Wagnerian gods, over some rainbow bridge into the Valhalla of their own romance.

We will do well to pause for a moment to contrast the modern movement that is enmeshing the earth in a net of industrial enterprises, with the spirit of the Age of Discovery just closing, that we may better orient educational work with respect to future necessities and present demands. Especially is this required of the sciences, upon the development of which industry depends. In the field of biology, the extent to which botany becomes an effective factor in modern education, depends very largely at the present time, whether we will it so or not, upon the degree to which it can be brought to efficiently cooperate in practical affairs.

For our greater and our lesser happiness, the boyhood of the human race is past. We are growing up socially and economically, and the inevitable outcome is going to be the mastery of the globe by means and for ends that are scientifically economic, and in the long run unquestionably altruistic. If this development means the elimination of mystery and glamor so far as the earth's surface is concerned, it yet remains for biologists to exploit the deeper mystery and the more thrilling story of life itself in all its protean forms upon that surface. If this transformation means the elimination of the poetry of the naïve childhood of the race, we may yet, perchance, find a higher poetry in the grander rhythm of a developing social life and a more harmonious evolution of wider racial ideals. Such at least are the deeper reflections of science—science that has come both to destroy and to fulfill.

In no other field of industry is the scientific age working greater changes than in agriculture. The oldest, the most primitive and the most necessary of occupations, agriculture, has been, until the last centruy, the field most neglected by science. In the older countries of Europe, a sharp social stratification, involving contempt for manual labor among the so-called upper classes, has been one of the retarding factors in agricultural development. Agriculture there is still largely the occupation of the peasant, and for the most part, the university and the peasant never meet. While this is rather a bald and radical statement of the situation, it holds good in its general outlines for most of the European states operating under the aristocratic systems of the past, while in the rest, the prejudice referred to still survives as a social memory.

In our own country, settled at the outset by immigrants who chiefly came from a body of land-loving and free-holding people, social prejudice toward agriculture is a comparatively minor matter, economically speaking. Strange to say, however, the very favoring conditions of our environment have hindered agricultural development along scientific lines. Our land was originally boundless and seemingly inexhaustible. It was impossible not to make a living on a farm, and anybody could become the possessor of one. There were no agricultural economic problems to solve, beyond the question of markets for the surplusage of the farm. What wonder that agriculture awakened scant interest in the scientific world. If the soil began to yield less as the years went by, under a wasteful, extravagant one-crop system, there was always more cheap land farther west, to which emigration could proceed. Furthermore, although social prejudice was largely eliminated in America, the utter ease and simplicity with which a living could be gotten out of the land on the one hand, and the relatively small cash returns and the severe discomforts of farm life on the other, have correspondingly continually operated to tempt the more ambitious minds away from the farm. Something that anybody can do, does not appeal to the more enterprising and gifted individuals. Not only that, but the youth who ventured his fortunes in business or the professions, embarked the more confidently perhaps, because of the feeling that if he failed elsewhere, he could still always go back to the farm as a last resort and make his living. Conditions, however, have radically changed. Not only is agriculture no longer the simple occupation it once was, but the greater portion of the best land is now under the plow. No new soil resources remain to be drawn upon, except in the dry plains area, and the arid regions of the west, upon the development of which nature has imposed severe limitations which can never be entirely removed. The torrent to the west has dwindled to a trickling stream, and from now on we must bend our energies toward the building up of the lands that have already been exploited in a pioneer way.

The population of the country is now under present methods overtaxing the cultivated land for its support. It has been said that we are consuming thirteen months of wheat every twelve months. The ratio of those engaged in agricultural pursuits, to those engaged in all other occupations, in the decades since 1870 is as follows:

TABLE I

Year	Ratio of Those Engaged in Agriculture to Those in Other Occupations
1870	1: 2.10
1880	1: 2.24
1890	1: 2.65
1900	1: 2.80
1910	1: 3.01

In other words, whereas in 1870 one person engaged in agriculture represented two persons engaged in other occupations, in 1910 there were three persons in other occupations to one in agriculture.

In respect to percentage of the population, the following relationship is found to exist:

TABLE II

Year	Per Cent. of Total Population Engaged in Agriculture
1870	15.43
1880	15.38
1890	13.68
1900	13.66
1910	13.76

In the forty-year period up to 1910, the percentage of the total population engaged in agricultural pursuits fell off 1.67 per cent. while the percentage relation of the ratio of the number engaged in agriculture to those in the other classified occupations, meaning thereby largely, effective young and adult males, has widened by 30 per cent. since 1870.

If we now turn to the rate of production in agriculture for the same period, dividing the United States into more or less homogeneous districts, we find the acre-value of all agricultural products raised in the different crop-growing regions of the country to be as follows:

TABLE III

Region	Year					
	1910	1900	1890	1880	1870	Average
North Atlantic	$19.03	$11.70	$9.90	$7.85	$12.83	$12.26
Middle Atlantic	14.06	9.75	9.21	9.99	16.00	11.80
S. Atlantic and Gulf	16.17	8.85	8.44	7.82	12.27	10.71
Central	11.62	7.09	6.69	7.63	12.46	9.10
North Central	11.35	7.15	7.34	8.64	16.02	10.10
Plains	8.48	5.56	4.50	5.15	15.27	7.79
Rocky Mountain	6.56	6.14	6.58	7.98	18.24	9.10
Pacific	12.75	7.50	6.82	5.78	7.85	8.14
Average	$12.50	$ 7.97	$7.44	$7.63	$13.87	$ 9.88

From the above table, there appears to be no consistent, consecutive increase in the acre-value of farm products for any of the regional divisions in the United States during the period in question—something more than a generation. The vertical columns show a remarkable harmony of acre-values over the whole United States for the same census year. This fact, coupled with an entire absence of any uniform upward trend of values for the period, either for the regions individually, or for the United States as a whole, clearly demonstrates that the acre-values of American farm products for the past generation have been entirely dependent upon accidental years of good crops or good prices or both.

The situation is still more strikingly set forth when we compare the percentage increase or decrease in improved acreage from one decennial census period to another, with the percentage increase or decrease in the acre-values of agricultural products for the same period, as shown by the following table.

TABLE IV

Region	1870–1880 Per Cent. Increase or Decrease		1880–1890 Per Cent. Increase or Decrease		1890–1900 Per Cent. Increase or Decrease		1900–1910 Per Cent. Increase or Decrease		Acreage Av. Net Increase Per Cent.	Acre-Val. of Farm Products
	Acerage	Acre Value of Farm Products	Acreage	Acre Value of Farm Products	Acreage	Acre Value of Farm Products	Acreage	Acre Value of Farm Products	1870–1910	Average Net Inc. Per Cent. 1870–1910
North Atlantic	8.75d	32.91d	18.32d	28.64i	24.25d	10.50d	10.81d	32.52i	15.53d	4.44i
Middle Atlantic	12.32i	28.80d	4.16d	7.48d	2.02d	9.34d	4.76d	27.21i	1.38i	6.14i
South Atlantic and Gulf	17.11i	23.04d	16.88i	22.96i	10.44i	14.55i	8.94i	5.17i	13.34i	2.33i
Central	32.60i	9.21d	10.25i	22.31d	11.11i	16.19i	27.95i	40.63i	20.48i	6.33i
North Central	46.09i	9.57i	19.75i	55.21i	16.91i	23.81i	6.52i	41.15i	22.31i	32.44i
Plains	81.28i	44.49i	57.37i	51.22i	23.85i	38.37i	31.68i	55.17i	48.54i	47.31i
Rocky Mountains	73.97i	40.47i	58.47i	50.87i	35.01i	30.31i	47.20i	66.60i	53.91i	47.06i
Pacific	43.63i	23.43i	23.96i	35.55i	6.36i	14.90i	14.91i	49.94i	22.21i	30.96i
General Average Net Increase									24.71%	22.12%

In the table above, the increase and decrease of both acreage and acre-yield, are placed on a percentage basis, and are therefore comparable each to each. If, therefore, the acre-yield from one decennial period to another had kept step with the acreage yield, the percentages of increase and decrease would be harmonic. This, however, is not the case. There is little or no correspondence between the two. If any harmony existed, it would certainly be shown in the general average net increase for the four decennial periods, as shown in the last two columns. Here however, the fact is demonstrated, that in practically every agricultural region in the United States, the average net percentage increase in the improved acreage for the forty-year period, has out-distanced and in most cases greatly outstripped the corresponding percentage increase in acre-value of production upon that acreage. Surveying the figures in more detail, we find that in the most typical agricultural regions of the country—in the South Atlantic and Gulf and in the Central region—the manner in which the percentage increase in acre-value of farm products falls behind the percentage increase in the improved land under cultivation, gives just cause for consideration. When we consider that in the Central region, the states of Arkansas, Illinois, Indiana, Iowa, Kentucky, Missouri, Ohio, Tennessee, and West Virginia, comprising the upper Mississippi drainage basin, certainly pre-eminently the typical agricultural part of America, the average net percentage increase in farm acreage for the entire past generation has outstripped the corresponding net percentage increase in acre-products upon it by 14.15 per cent., it would seem proper for science to give the matter serious consideration and attention. In the Plains region, where improved methods of farming on dry-land areas, and the introduction of better crops, such as alfalfa and the sorghums, and in the Rocky Mountain and Pacific regions, where irrigation is practised and higher-priced crops are grown, the percentage increase in acre-value of the products, equals or surpasses the percentage increase in acreage of the improved land.

Taking the evidence as a whole for the entire country, it appears from the general average at the foot of the last two columns, that in forty years the net increase in food production in the United States ran behind that of the land brought under cultivation by about two and one half per cent. In other words, the people on the farms failed to raise enough more products per acre, as measured by the average selling price, to correspond with the amount of land they were cultivating. That this is partly due to a falling off of agricultural labor is probable; that it is partly due to diminishing fertility from continuous cropping is measurably certain. It is likewise evident that this general situation has been arrived at in spite of the fact that the period in question, covers nearly the whole period of the rise and growth of the state agricultural colleges and experiment stations, and the development of the enormous activities of the United States Department of Agriculture, through all of which agencies, new and better systems of tillage, cropping and rotation, and feeding of farm animals, have been introduced and disseminated, all of which should contribute to operate toward counter-balancing the losses from the other sources.

If the agricultural situation has been thus detailed at some length, it is in order to bring out the vital fact that there is a definite demand upon science, and especially upon that part of science that is capable of dealing scientifically with at least some of the factors underlying plant production, to lend its aid to the relief of a situation that is becoming worse instead of better. This is the matter with which the agricultural colleges have to deal and which bears a vital relation to the teaching of botany.

So far as botany is concerned, the main problem from the educational standpoint is, how can the young people in the public schools receive such a training and discipline as will be of scientific value, and at the same time be of vital economic use in their every-day life.

As a general social question, the problem is, how can this subject which can unquestionably be made of economic value, be so handled as not to destroy its integrity as a part of the teaching of science, and at the same time contribute its maximum help to agriculture. Now our principal business with secondary school pupils is not merely to give botanical discipline in an abstract sense, but to give such students as broad and as scientifically accurate a knowledge as possible of the only plants with which they are ever likely to deal, and from which the world gets its living. About ninety-five per cent. of high-school graduates go no further. Should effort be devoted to giving these immature minds a hasty and inadequate sketch of a botanist's realization of the plant world, or should we rather be contented with giving them that part of botany that will be most useful and necessary in their probable occupations. I think unquestionably the latter. We are certainly not precluded thereby from making botany a subject of disciplinary value. Charles Darwin was not a superficial student of plants, for the reason that he directed his studies to those phenomena which the seed plants alone offer to the unaided eye. After the pupil has thus built up a solid and substantial knowledge of the way in which the higher plants are constructed in their more obvious aspects, and how they perform their work, time should then be devoted to widening this plant horizon, by bringing in the lower groups in succession. But even here it is wise to avoid a strenuous attempt at a scientific discussion of the alternation of generations. The object, at this juncture, should mainly be to give the student an alga concept, a fungus concept, a fern concept and so on, that he need not go through life entirely ignorant of what these lower forms of plant life are, how and where they live, and their economic relation to the earth, especially of course to man.

It is not impossible to make plant evolution the central axis around which to swing a high-school course in botany. High-school pupils can be trained in this sort of discipline, but it usually involves the wooden adherence to a few "types" illustrating a supposed evolutionary series, and imposes severe limitations upon a student's conceptions of plants, no less detrimental in its effect upon his mind than the rigid conceptions of "typical" plants, and the stereotyped leaf and flower forms of the pseudomorphology of the older school. The phylogenetic method of teaching botany to elementary students, is not only objectionable because it deals with plants which are almost throughout entirely unrelated either to their previous experience and observation, or to their future necessities, but because, as ordinarily handled, the data are confined to a comparatively few type plants because of the time restrictions imposed. The result is, that instead of widening his horizon of the plant world, the succession of forms worked upon, serve chiefly as mnemonic beads in a botanical rosary, the telling of which serves to call up memorized facts for examination purposes, chiefly concerning reproduction.

At the present time, the teaching of botany in secondary schools is quite generally morphological in character, a survey of the general morphology and reproduction of the great groups of plants in succession. This is done partly by virtue of tradition, and partly because the subject is most easily handled in that way under average conditions. In too many cases however, this sort of teaching degenerates into a sort of stereotyped routine, revolving around the peculiar relations of the alternating generations in plants—the tragic story of the decline and fall of the gametophyte and the triumphant rise of the sporophyte. This rather extensive and various history has become condensed and standardized for teaching purposes into an orthodox version, to the correct rendition of which a few selected forms of plant life are annually consecrated. Beginning with the microscopic, unicellular forms of green algæ, we proceed, with side excursions into the equally microscopic blue-greens, up through colonies, flat, globular, and in chains and filaments, until we finally get to a real alga that we can plainly see with the 1/6 objective. From here on, the pathway leads finally to where *Fucus vesiculosus* and *Polysiphonia violacea* are waiting to tell their tale of the alternation of generations and heterospory. Once in the clutches of these two ideas, botanical anxiety for the student begins, for he is there to stay.

We are now, however, compelled to divert our attention for a time from green evolution in order to pick our way over the fungi, after which we duly return to our duty of securing the transition in the laboratory from water to land life, whereby there emerges, with dripping rhizoids, a liverwort upon the mud.

The Bryophytes, unfortunately, are still very small plants, and usually do not of their own motion excite undue interest among young people. However, this is not for us to discuss, to be sure, since it becomes our responsibility for the next few weeks, to make the curious and rather minute relations of the gametophyte and sporophyte series in this group the chief object of our ambition. There is many a beginning student who has been led during this period of his life to suppose that botany thinks a great deal of *Marchantia polymorpha*. Bidding farewell at length to the Hepaticæ, we become greatly obliged to the botanical supply company for its fruiting *Sphagnum* and its *Polytrichum commune,* whereby we are enabled to continue the ever-lengthening story of the everlengthening sporophyte and its ever-diminishing spores.

The leafy gametophyte of the Bryophytes has now to roll up its foliar organs and be born again like unto a liverwort, re-emerging before the student as the prothallium of the ferns. We have now at last gotten roots on the sporophyte, and its future is assured, so that we can henceforth proceed to devote our remaining attention to prosecuting our favorite microscopic pursuit of the luckless and reticent gametophyte, as it elusively recedes from form to form, through *Marsilia, Salvinia* and *Pinus Laricio,* until its final recondite demise in *Lilium Martagon,* and the last "slide" is "drawn."

Is this a caricature? No more so than many such a course is a caricature of reality in the plant world. The question is, does it pay, with the limited time usually available, to sketch hastily through a syncopated genetic series in secondary school work. The primary object in following such a series through, is to get before the student a picture of the upgrowth of the sporophyte form, which is the final stage in morphogenetic evolution in plants, and through the facts in reproduction, throw light upon the evolutionary relationship of the various phyla.

To this end, beginning students who have usually observed little with their eyes, have to be armed at the very outset with the dubious weapon of the compound microscope, and their first weeks in botany are consecutively devoted to an examination and study, almost entirely through the microscope, of organisms that the most favorably disposed among them are hardly prepared to appreciate as plants. From the pedagogical standpoint this is a weak approach. If however, instead of the groups of the Thallophytes, and the succeeding members of the evolutionary series, the seed plants are made from the outset the center of gravity of the teaching, the interest and sympathy of the students is more easily impounded. If this method is followed, it is desirable, instead of beginning with a study of seeds and seedlings and so on, to commence with a complete life-cycle exercise covering the entire life history of the species, from the seed on to maturity and seed reproduction. This can be done by means of a serial succession of plantings made in advance, whereby the student gets at once at a given laboratory period, an immediate present view of all the stages through which the plant has had to pass. Lima beans, for example, handled in this way, will give satisfaction, and, in the final stages, will furnish a complete series in the plant's reproduction, from unfertilized flowers on to well-grown seed pods upon the same plant. All the morphological details of structure of all the different organs may be worked out at once upon such a plant, and many species may be introduced in series in the same manner for comparative study of types of development. The morphology however, it ought to be emphasized, should be accompanied step by step, by experiments in the physiological behavior of the same organs. Osmosis experiments should accompany the study of roots and root-hairs, and not be postponed to some future exercise in physiology Transpiration and photosynthesis experiments should be conducted simultaneously with the study of the leaves as such. Conduction should be studied experimentally, at the same time with the study of the structure of stems. The rate of growth of stems and roots, and of the floral organs before and after fertilization, should be determined while the students are engaged at the same time upon the morphology of those structures.

It is a useful and practical thing, when dealing with the structure of leaves, for example, to take plants in which there is a considerable deposition of reserve food, such as corn, potato, sweet potato, etc.; in warmer regions, taro, sugar cane and banana, and have the pupils determine for the entire plant, the total percentage amount of combustible dry matter, taking the storage regions separately as such. By separately determining the total percentage amount of water, dry matter and ash, the work of the plant as a machine in the manufacture of carbohydrates can be plainly seen. If the area of the leaves is now measured, the number of grams of carbohydrates produced per unit of leaf surface can be calculated, and this in turn can be converted into terms of energy in calories. If such an exercise as this, together with field work in leaf ecology, accompanies the study of palisade cells, stomata and conduction tissues in leaves, the latter will be seen in the light of functioning organs, and not as static structures. There seems to be no disputing the fact that the study of the structure of organs will be vitalized, by experimental work alongside at the same time upon their functions. It is correspondingly useful, for example, while engaged in the study of the structures of reproduction, to have the pupils demonstrate for themselves, as with such plants as corn, wheat, beans, or the more common prolific weeds, the volume and extent of their reproductive energy, as measured by the number and amount by weight of their seeds. The relative prolificacy of representatives of tested varieties of the same cultivated species, such as soy beans and cow-peas, may be used for a comparative study of the relative expenditure of vegetative and reproductive energy. If plants in flower are accessible, such as can easily be hand-pollinated, such as corn, cotton or tobacco, many of the fruit trees, garden geraniums, etc., the time elapsing between pollination and the first signs of fertilization should be ascertained experimentally. Such experiments as these, combined with field experiments in cross and close fertilization and in the study of the adaptations thereto, vitalize for the pupils the whole study of the structures of reproduction, and of the scientific aspects of the reproductive process.

In fact, throughout the whole elementary botany course, every possible effort should be made to illustrate immediately, structure by function and function by structure, and to bring out the variations in structure which accompany variations in function under different habitat conditions. Students should be led especially to study the biological adaptations of plants to their environment in their own neighborhood. If some study of plant evolution is lost in doing this, the gain will be compensatory, since the pupils will come to realize that plants are vital and very variable biological organisms, with various dynamic activities, and not "typical" static structures, chiefly engaged in reproduction.

In any event, a beginning course in botany should strive to give students some conception of the luxuriance, richness of material, riotous abundance in color and form, and marvellous complexity of structure and adaptation which is the reality of fact in the plant world, instead of leaving him with a conception of pettiness in the materials offered, of triviality in the functions performed, and of dryness and stiff formality in the relationship, of the organisms. One way in which to avoid the sense of pettiness which well-grown students not infrequently experience in being set to work upon the lower and smaller forms of life, is to increase greatly the number of forms and types for general comparative habit-study. In working with algæ for example, a considerable supply of a wide variety of fresh-water forms collected locally, supplemented from a marine supply company, by as large an assemblage of species of the larger marine algæ as can be afforded, coupled with a study of the use of the latter for food, fertilizers, etc., will do more for the student educationally than an intensive study of a few, unfortunately for the most part, species of insignificant size and of lesser economic importance. In the study of the lower forms, *it should be made a general policy throughout,* to secure for habit study a large variety of species of the forms worked with, in order to give the students, to some extent at least, a comparative, conception, a broader mental idea, of the groups taken as a whole.

In the study of the fungi, a secondary school course in botany should consist mainly in a study of plant diseases, with enough experimental work in growing cultures of important pathogenic organisms at least, to teach the student the nature of the invading fungi. That such a course can comprise all the forms necessary to include the various types of fungus morphology and spore reproduction, is sufficiently manifest. A course of this kind should leave the pupil knowing most of the commoner diseases of the ordinary farm, orchard and garden plants, and their means of prevention.

Such a rapid survey of the lower groups of plants, systematic rather than morphological in character, should likewise be followed by a systematic study of the more important orders and families of the seed plants. The work should here be more intensive than with the lower groups, for here is the opportunity to present in orderly sequence, in something of a connected series, the extraordinary array of the economic plants. All of the principal agricultural, forest and garden plants, the wild flowers, the poisonous species, the drug plants, and the weeds of the farm and the wayside, can now be thrown into orderly sequence, as their representatives are brought into the laboratory for study. No course in botany for high-school students ought to be considered satisfactory, that does not give a tolerably good idea of the relationships of the principal families of the seed plants, of the place of the economic plants among them, and of their geographic and ecological distribution.

Toward the close of the year, and after the systematic work referred to, some simple work in the study of variation, and of the results of selection should be taken up. There is no better way of developing observation in young people, than by setting them to work collecting all the so-called "variations" they can find of a number of species of plants. A little simple work in plotting variation curves is also easily possible with high-school students. A school garden can be made to afford a series of plants to be used in hybridization, and the pupils can readily be taught the necessary technique in plant breeding. Curiosity once aroused as to the outcome of crosses, and interest awakened in the possibility of originating new forms of plants, the high-school teacher will find such a summer occupation for the brightest pupils as may lead to serious and important results. Many a student in a farm neighborhood will be aroused thereby to undertake valuable work in the improvement of staple crops, such as will bring about economic results of value to an entire neighborhood. It is also perfectly easy to convey to pupils of this age a working knowledge of the elementary principles of breeding, sufficient to serve for a considerable range of practical purposes.

We may therefore conclude that a course in agricultural botany for secondary schools should differ from the ordinary academic course in the same subject in the following respects:

First, in the aim of the course, which is the economic advantage of the pupil rather than the professional array of the subject from the standpoint of discipline.

Second, in the means used for botanical instruction, the seed plants being largely employed as teaching material for practical purposes.

Third, in the extensive use of plants of economic value as the means through which to study plant structure and functions.

In the hundreds of cultivated forms of grasses and forage plants, in the multitude of varieties of the grains, in the horde of the vegetables, in the manifold fruit-bearing plants of the orchards and gardens, in the wealth of valuable forest trees, ornamental garden plants and shrubbery, in the array of plants grown for fibers, for drugs, gums, resins, rubber, beverages, condiments, and spices in the parasites, poisonous and noxious plants and weeds, there exists a vast botanic garden of species, varieties and biotypes of plants. wild and cultivated, in which every modification of form, and every biological adaptation of structure to environment is found. There is no type of root, stem, flower, or seed structure, generalized or specialized, that is not to be found among them. There is no mode of securing or preventing cross or close pollination which they do not exhibit. There is no mode of performance of a single physiological function in any type of habitat that they do not display. In this maze and medley of plants cultivated by man, and which carry the initial intrinsic interest of economic value, are limitless opportunities for developing in a beginning course in botany, fresh and interesting types of material for the study of the organs and tissues of plants, their work and their relation to soil and climatic environment. Here is the high school's, and especially the rural high school's opportunity in botany.

In all communities, and especially in rural communities, a course in botany should have three fundamental objects—to stimulate observation, to give such botanical knowledge and training as will be most useful, and to impart culture. Let us briefly consider these three leading motives.

First, as to the matter of observation. Our public school system is overburdened with second-hand learning. Ideas are furnished ready-made in books. The written word becomes a fetish. The child gets most of his notions of the universe by reading what somebody else has said about it. Everything has to be subordinated to getting large masses of pupils "through the grades." The simplest way to do this is to cause large quantities of ready-made, predigested information to be memorized, recited upon and "passed" in examination. Originality, curiosity, spontaneity, are all effectually stamped out by this process, and the child, who is naturally an investigator to begin with, becomes in the end a mere passive recipient of prescribed orthodox information.

It is the duty of the biological sciences to step into the school room, reawaken this latent curiosity, and fan the sparks of originality into the flame of investigation. Can this best be done by a course in botany that is "scientific" from the adult standpoint, but that is totally lacking in vivid human interest from the point of view of young people. Shall we stimulate observation in eyes already grown accustomed to looking for the world in print, by carrying them still farther away from the domain of sense experience. we must compel young people to realize the vast range of nature about them that their eyes should be open to see. We must lead them first up to the plants, and only afterward inside of them. Does any one who has ever worked with young students, doubt for a moment that one of the surest ways of arousing and holding their interest in the plant world, is to open up new vistas of knowledge to them in those many plants which already claim the world's interest because of their usefulness or beauty.

So far as the teaching of botany as an observational subject is concerned, it is possible to say from personal experience, that the use of the straight observational method in an ordinary laboratory of elementary botany, conducted entirely without the use of any laboratory guides or outlines whatsoever, has proved an entirely successful experiment. The plants were placed before the students, with instructions to find out, first with the eyes, then with the simple microscope, and finally with the compound microscope, all that they could discover about them that seemed in any way characteristic, and afterwards to describe what they had observed, both in writing and by sketches, in extent, measure and proportion as they saw fit, being held responsible for getting results, but not for the manner or form of getting them. It is surprising what an amount of spontaneous observation, original in form and substance, was evoked by this method. It can be confidentally asserted that public-school pupils just entering the high school, or high-school students just entering college, and spoiled for original thinking and observation by the continual taking of notes and following of outlines, can be taken in hand by this method and trained to observe nature.

Secondly, with regard to the imparting of such botanical knowledge as will be most useful, it would scarcely seem to demand discussion, that for the majority of secondary-school pupils, that botanical training is most desirable which gives them the greatest possible amount of knowledge which can be made practically serviceable. The relation of plant physiology and structure to agriculture and horticulture, plant diseases, medicinal plants, weeds and their eradication, plant breeding, the botanical relationships of the chief families of the seed plants, and especially of the economic plants, are fields in botany that can be drawn upon for teaching purposes with the greatest profit.

A broader knowledge of the species and varieties of economic and ornamental forest and fruit trees, wild and cultivated, and of the wild and cultivated ornamental flowering plants, will also lead to an interest in introducing and growing many new and attractive forms of plant life in the community, and in the consequent adornment of homes monotonously devoid of variety and beauty.

Finally, as a means of enlightenment and of imparting culture, botany is a sadly neglected field. Between the teachers with ultra-scientific proclivities and propensities, and those who are frank agronomists, the obvious opportunities of botany in the humanistic field have been extensively overlooked. The history of the origin and migrations of the cultivated plants, and the discovery and use of plants in primitive culture for food, clothing and household purposes, leads directly into the domain of human history and anthropology.

The study of the origins of the names of plants and their folk-lore, in connection with the literature of wizardry, magic, necromancy, the healing art and poetry, furnishes an abundance of material of decided human interest and value.

The study of the plant as a machine, in the light of its adaptations of structure to habitat, to secure survival, and to effect fertilization and the distribution of seeds and spores, in its economy in the use of material, and in its conservation of resources, is a field of distinctively cultural value. Certainly the field study of the struggle of plant societies with one another for existence and for supremacy, and with their general biological and physical environment, furnishes material for thought, analogous to the study of social evolution, and from which social lessons can be derived.

Without in any way cheapening its disciplinary value as science, a great opportunity is thus open to elementary botany, of becoming a subject of far more practical value, interest and importance, both in the field of education, and in the development of agriculture.

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GRANTS FOR RESEARCH OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

AT the annual meeting of the association in 1918 the Committee on Grants for Research was organized for the year 1919 as follows: Henry Crew, Chairman; N. L. Britton, W. B. Cannon, J. McK. Cattell, R. T. Chamberlin, L. I. Dublin, G. N. Lewis, G. H. Parker and Joel Stebbins, Secretary. The sum of four thousand dollars from the funds of the association was assigned by the council to the committee for distribution in support of investigations. The committee did not hold a formal meeting, but transacted all of its business by correspondence, and by the middle of June had distributed the entire sum at its disposal in the following grants.

Astronomy

Five hundred dollars to Professor E. B. Frost, of the Yerkes Observatory, for the securing, measurement and reduction of stellar spectrograms. Additional assistance in this work with the 40-inch telescope will greatly increase the mass of results being accumulated concerning the motions of stars.

Physics

One hundred and fifty dollars to Professor A. L. Foley, of Indiana University, for experiments on the speed of sound very close to the source. This investigation is in extension of the important and rather remarkable results which Professor Foley has recently published in the *Physical Review*.

One hundred dollars to Professor Orin Tugman, of the University of Utah, to meet the cost of a monochromatic source of light to be used in finding the change of conductivity in a thin metallic film when exposed to ultra-violet light—a problem which has acquired new importance in view of the rapidly developing electronic theory.

One hundred and fifty dollars to Professor E. M. Terry, of the University of Wisconsin, for work on the modulation of radio-energy employed in wireless telephony.

One hundred dollars to Professor F. C. Blake, of the Ohio State University, for aid in prosecution of a study of electric waves and dielectric constants.

Chemistry

Three hundred and fifty dollars to Dr. Gerald L. Wendt, of the University of Chicago, for the investigation of the photochemical reactions of hydrogen and chlorine. He has been able to show that under the action of alpha rays and in the vacuum discharge tube hydrogen forms a chemically very active form, which probably has the formula H_3. From a valence point of view