primarily grouped artistically and secondarily on a systematic plan, third of natural gardens, and fourth of a limited systematic herbaceous garden. In all, selection and attractiveness of setting should be controlling principles.

W. F. Ganong

A UNIVERSITY BOTANICAL GARDEN

It requires some presumption for a mere novice to talk on this theme, after the fathers of our great botanical gardens have spoken from their ripe experience. One who neither grew up in a botanical garden already established, nor has had time to grow far with one established but a short two years ago, can hardly be expected to speak with authority. My only justification for complying with the request of your secretary to participate in this discussion is the fact that, in planning the botanical garden for the Johns Hopkins University, I have discovered what a goodly number of problems confront the beginner in this kind of work and how little detailed information is to be found in print that will aid him to overcome them.

I may therefore, perhaps, be permitted to say something of the purpose of our garden, of some of the difficulties encountered, and of such solutions of these, or part of them, as have either been worked out at Homewood or gathered from the experience of other gardens. These things are said not only in the hope of being of service to others who may be planning gardens, but also of evoking from others helpful criticism, that may be of aid to us in the work at Homewood.

That a botanical garden can be of great value to university students does not stand in need of proof to you of this audience. I desire, however, to suggest some of the particular ways in which I believe it may be most useful. If university students are what they should be, in aim and industry, it seems evident that access to a well-arranged botanical garden may advantageously replace class-room courses on certain aspects of gross morphology, floral biology and floristic geography, besides greatly enhancing the value of many of the formal courses on other subjects, given in lecture room and laboratory.

A botanical garden which is to be of use in the ways mentioned must suggest clearly what it is intended to illustrate. It must leave no suspicion of the aimlessness of a "cabinet of curiosities," but must show the purposefulness of a skilfully arranged museum—a museum in which (as an able museum director has said) the carefully selected specimens illustrate a well-devised series of labels, rather than one in which the labels are mere name-tags for more or less accidentally acquired specimens.

Such a definitely planned garden can well serve to extend the laboratory work and to concentrate the field work. For in the laboratory a student can not study enough plants minutely to comprehend them broadly; in the field he can not study any plant so thoroughly as to understand it deeply. The garden renders a larger variety of plants accessible, brings plants of different regions together for ready comparison, taxonomically, morphologically and physiologically, makes it possible to observe their activity and development more continuously and, finally, gives the most satisfactory opportunity of preserving them at critical stages for future study and comparison. The garden then does not replace either field or laboratory, but it does effectively link them.

If now we consider more specifically the functions a garden may serve we may summarize them thus:

1. It can illustrate certain phenomena of plant life which may be observed directly,

as the plants grow in the garden or the accompanying greenhouse. Because they can be observed continuously the student gains a familiarity with them and their phenomena which is not possible from a single contact with them, when they are brought out once a year, in a laboratory course.

2. The garden and greenhouse have an important use as a source for the material needed in instruction and research, in laboratory and herbarium.

3. The existence of a garden insures the presence of propagating grounds, tools and a trained gardener, all of them necessary to the carrying on of researches in plant breeding or other work involving extensive cultures, such as are often made in studies of variation and experimental morphology.

4. Not the least important feature of a garden, especially one on a university campus, is that it shall prove attractive from its design and the plants in it, entirely aside from its scientific interest.

I shall, from this on, make casual reference only to the last three of these functions, but shall dwell more fully on the first, *i. e.*, the use of a garden in botanical instruction. This is, I believe, the function which chiefly determines the arrangement of most botanical gardens now in existence, the only other potent influence being, perhaps, the artistic one.

The botanical facts and principles that can well be illustrated in a botanical garden may be grouped under the following heads: (1) plant structures, (2) plant phylogeny, (3) plant activity or physiology, (4) plant ecology, (5) floristic plant geography, (6) economic plants. We may now take these up in the order mentioned.

1. Plant structures may be illustrated by examples, first, of vegetative organs, in their various modifications, and secondly by examples of reproductive organs, such as those for vegetative multiplication, for asexual reproduction, and for sexual reproduction, including such accessory reproductive organs as flowers and fruits.

2. Plant phylogeny may be illustrated by the natural system of Engler, as a modern interpretation of the kinship of plants, also by selected examples of older "natural systems" of historical importance, such as the systems of Jussieu, Braun and Eichler. Finally, examples of plant breeding may be made to illustrate the means of origin of new types of plants, such as sports, mutants and hybrids.

3. Types of plant activity that may be readily illustrated in a garden are: first, those connected with growth—showing its rate, direction and seasonal variation; secondly, sleep movements; thirdly, movements of leaves of compass plants; fourth, the movement of irritable or sensitive leaves; fifth, and finally, those movements of the flower, or its parts, which aid in the process of pollination, of which many interesting examples may be shown.

4. In plant ecology we may well illustrate certain important habitat-relations and growth-forms. Those that can be most satisfactorily shown are chiefly relations to edaphic factors, though the alpinum and the greenhouse give some opportunity of suggesting relations to climatic factors. Other ecological facts may be illustrated by examples of plant communities. Under this head, when enough ground is available, may be shown plant formations, chiefly native ones, as forest, bush, meadow, etc. Finally, ecological guilds, or types of symbionts, may be illustrated by lianes, epiphytes, saprophytes and parasites. This latter series takes but little space in the garden, but much ingenuity is required to make them develop typically.

5. Floristic plant geography may perhaps be best illustrated not merely by

groups of plants from the different formations of a general floristic region, but also, where space permits, by like formations from different regions. These should be as complete as possible and may well be selected to show similar growth-forms occurring in widely different species, genera, or even families. In Atlantic North America, for instance, bits of Alaskan, Manchurian or Scandinavian forest, in which all the elements from the herbs of the forest floor to the dominant trees are represented, would prove exceedingly interesting for comparison with our native forest and with each other.

6. Economic plants may be represented by those plants which yield the chief vegetable products of commerce, by types of ornamental plants and by noxious plants, *e. g.*, weeds, poisonous plants and fungus parasites. The practical application of plant breeding may also be illustrated here by examples showing the difference often existing between the wild parent and the cultivated offspring, together with illustrations of the methods of breeding and cultivation by which the modification of cultivated types is produced.

These, I believe, are some of the facts and principles which we may hope to illustrate in a botanical garden. The realization of these expectations demands, I am finding, persistent industry and unfailing optimism, for obstacles arise unexpectedly, and success in new fields is far from certain.

In the garden of the Johns Hopkins University, at Homewood, we are trying to do some, at present not all, of the things which I have just outlined. I wish now to try to tell you just what these are, how we have planned them and something of the practical expedients by which we have managed to get plants to grow where we wish them. I may also refer to the devices for labeling which are being used, in the attempt to make the garden intelligible not only to the student, but also to the general public, to whom the garden is open.

The area at present planted at Homewood, the new university site, is a flat-topped knoll, about two acres in extent, surrounded on three sides by a native forest of oak, chestnut, beech and tulip. The garden is laid out in a strictly formal manner, in view of the fact that it is to form the western termination of the transverse axis of the proposed group of university buildings. It will ultimately be overlooked by the terrace on which the westernmost buildings are to be located.

The boundary of the garden is marked by two parallel lines of hemlock hedge with a wide walk between them. The entire garden is divided into quarters by walks running from the middle of each side to a large pool in the center. Each quarter is broken by gravel walks into 18 beds with myrtle borders. These beds contain altogether about 500 planting spaces ($2\frac{1}{2} \times 3\frac{1}{2}$ feet), making something over 2,000 planting spaces for the whole garden. The greenhouse, physiological laboratory and an acre of ground for propagating purposes lie directly south of the garden.

The garden consists of four sections. Section I. illustrates the chief types of vegetative organs of plants. The arrangement of these types is in part a morphological, in part a biological one. Section II. is given to the illustration of the structure and biology of the reproductive organs of plants, *i. e.*, of sporangia, flowers, seeds, fruits, etc. Section III. illustrates the genealogy of plants as indicated by their classification. It includes illustrations of the various kinds and degrees of kinship, of species, genus and family, of hybrids and mutants, of a number of historically important systems of classification and of the modern system of Engler. Finally, it also illustrates in some detail the variety in structure and in geographical distribution, found among the members of a few selected families of seed plants, *e. g.,* of Ginkgoaceæ, Saururaceæ, Liliaceæ and Compositæ. Section IV. contains a selected series of useful and of ornamental plants, chiefly those native to temperate regions, though a few of the more important tropical, economic plants are shown.

In the further development of the botanical garden it is planned to illustrate various types of plant communities, some of the important facts of geographical distribution and the habitat relations of various growth-forms. It is expected that the general planting of the Homewood grounds may be carried out in such a way that the groups of shrubs and trees so used shall have scientific as well as an ornamental value.

The efficiency of a garden as an educational factor is determined, in large degree, by the design and arrangement of the labels used to designate the individual plants and the plant groups shown.

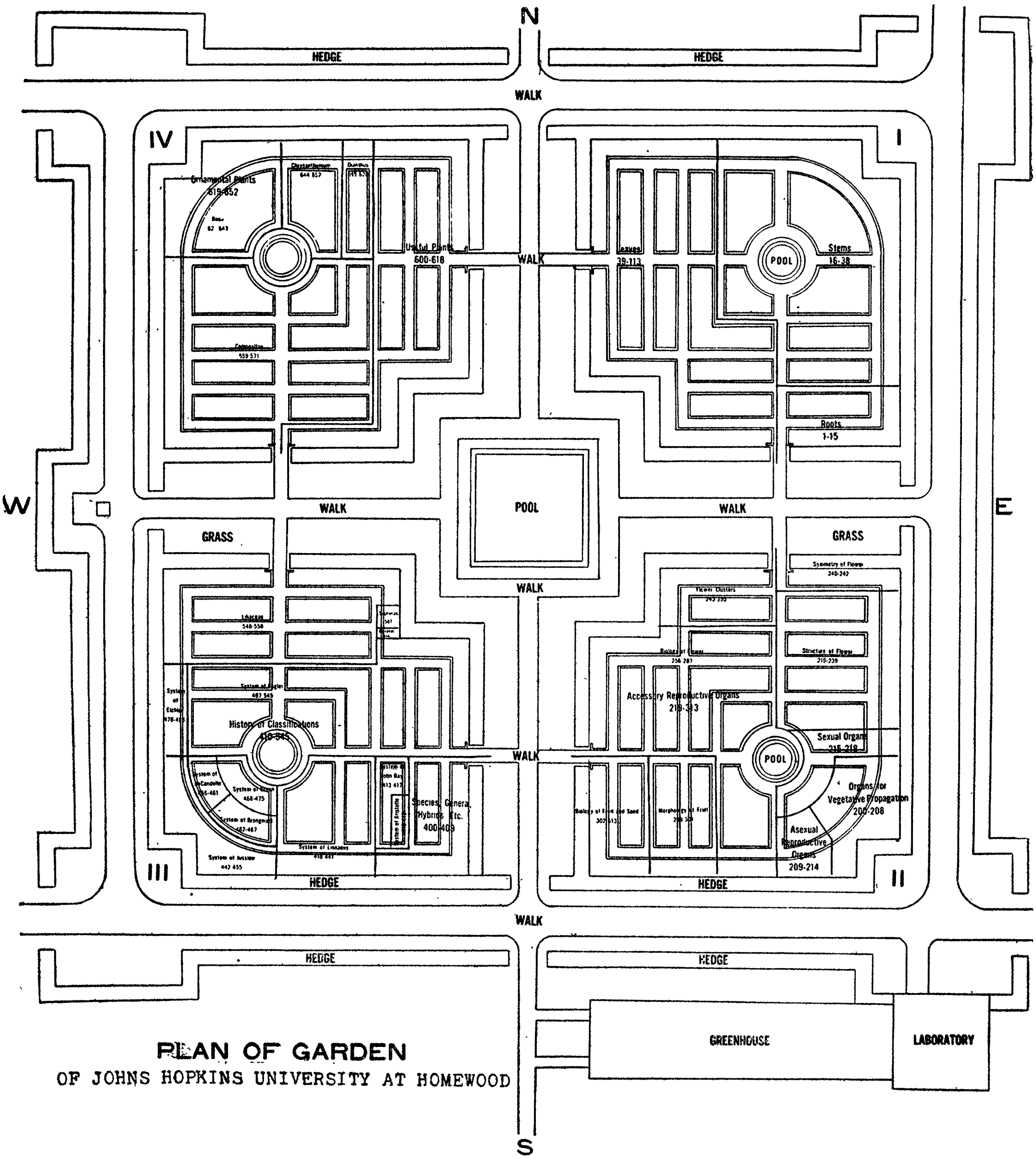
The series of types of structure, relationship, etc., shown in each section of the garden at Homewood, is divided into successively subordinate groups. These groups are: division, subdivision and groups without names but designated by letters and signs.

Each individual type of structure, etc., is designated, in this guide and on the labels, by a number. All species used in the garden to illustrate a given type bear the number of this type on their labels. In the guide this number is found at the extreme left of the page, opposite the name of the group. In the garden these numbers are at the bottom on the group labels and at the top on the species labels.

The numbers at the bottom of a group label indicate the kinds and number of types of structure included in the group. For example: the numbers 16–19 on the label for subterranean stems indicate that the types included in this category are those bearing these numbers, in the guide and on the labels, *i. e.,* rhizomes, tubers, corms and bulbs; the numbers 288–290 on the label for indehiscent fruits indicate that this group includes the achene, nut and caryopsis.

The number at the top of a species label indicates the type of structure, relationship or economic plant illustrated by this species. A reference to this number in the guide, or in the garden, to the nearest group-label bearing this number, shows what is illustrated by the species. For example: any species label bearing the number 8 indicates that the plant illustrates the use of the roots as tendrils; the number 529 indicates that the species belongs in the series Rosales of Engler; the number 600 designates the species as a cereal.

The location in the garden of the illustrations of any particular group of structures or relationships may be readily seen by a comparison of the outline of the chief groups (p. 653) and the plan showing the arrangement of beds in the garden (figure, p. 652). On the latter the area devoted to each division is indicated by heavy lines between beds. Section I. is in the northeast quarter of the garden, the types being numbered from 1 to 113. Section II. is in the southeast quarter (Nos. 200–313). Section III. is contained chiefly in the southwest quarter (Nos. 400–558), but partly in the northwest quarter (Nos. 559–571). Section IV. is also contained in the northwest quarter (Nos. 600–652). The sequence of the types within each quarter is readily seen from the numbers on the labels. These are arranged in regular succession along the beds as far as possible,



PLAN OF GARDEN
OF JOHNS HOPKINS UNIVERSITY AT HOMEWOOD

and, where this succession has been broken, an index label has been used to show where the next following numbers are to be found.

By means then of the continuous series of numbers, one for each ultimate unit of structure or relationship shown, it is believed that confusion may be avoided and the visitor be at liberty to note as much or as little as he desires of the assembling of these units into successively larger groups, which are indicated in the guide, and by group labels in the garden.

With such a definite series of structures

BOTANICAL GARDEN AT HOMEWOOD

Chief Groups in the Garden

SECTION I. VEGETATIVE ORGANS.
- Division I. Roots. 1–15.
  - Subdivision I. Subterranean Roots.
  - " II. Aquatic Roots.
  - " III. Aerial Roots.
  - " IV. Parasitic Roots.
- Division II. Stems. 16–38.
  - Subdivision I. Leafless Stems.
  - " II. Foliage Stems.
  - " III. Branch Systems.
- Division III. Leaves. 39–113.
  - Subdivision I. Cotyledons.
  - " II. Foliage Leaves.

SECTION II. REPRODUCTIVE ORGANS.
- Division I. For Vegetative Propagation. 200–208.
- " II. For Asexual Reproduction. 209–214.
- " III. For Sexual Reproduction. 215–313.
  - Subdivision I. Sexual Organs.
  - " II. Accessory Reproductive Organs.

SECTION III. PLANT RELATIONSHIP.
- Division I. Degrees of Relationship. 400–409.
- " II. History of Classifications. 410–545.
  - Subdivision I. System of Aristotle.
  - " II. " " Ray.
  - " III. " " Linnæus.
  - " IV. " " de Jussieu.
  - " V. " " de Candolle.
  - " VI. " " Brongniart.
  - " VII. " " Braun.
  - " VIII. " " Eichler.
  - " IX. " " Engler.
- Division III. Selected Families. 546–571.

SECTION IV. ECONOMIC PLANTS.
- Division I. Useful Plants. 600–618.
- " II. Ornamental Plants. 619–652.

Outline of the Types of Plant Organs, of Plant Relationships and of Economic Plants Illustrated in the Garden*

SECTION I. VEGETATIVE ORGANS.

Division I. Roots.

Subdivision I. Subterranean Roots.

1 Tap Roots.
2 Fascicled Roots (clustered roots).
3 Fibrous Roots.

Subdivision II. Aquatic Roots.

4 Bottom Roots.
5 Floating Roots.

Subdivision III. Aerial Roots.

6 Prop Roots.
7 Protective Roots (root-thorns).
8 Tendril Roots.
9 Attaching Roots (of air plants).
10 Attaching and Absorbing Roots (of air plants).

Subdivision IV. Parasitic Roots.

11 Water-absorbing Roots.
12 Food-absorbing Roots.

Subdivision V. Symbiotic Roots.

13 Mycorhizal Roots (with fungus threads instead of root hairs).
14 Bacterial Roots (with bacterial tubercles).
15 Nostoc-holding Roots.

Division II. Stems.

Subdivision I. Leafless Stems (*i. e.*, with scale-like leaves).

A. Subterranean Stems.

16 Rhizomes.
17 Tubers.
18 Corms.
19 Bulbs.

B. Aerial Leafless Stems.

20 Cactoid Stems (fleshy green stems).
21 Phyllocladia (leaf-like stems).

* All types illustrated in the garden are indicated in this list. Each type is given a number here, which also will be on the top of the label of every species used to illustrate that type.[1]

and systematic sequences to be illustrated in a set of formal beds, we encounter at once the very practical difficulty of making plants grow in proximity in the garden that occupy quite different habitats in nature. Under these conditions one is tempted to do what one of my correspondents has done—*i. e.*, rearrange the families of plants in such a way that families with like habitat-requirements come near together. This correspondent, a landscape gardener, points out the horticultural inconveniences of the Engler system, and suggests that the Eichler, and Bentham and

[1] This page is reprinted from "Guide to the Botanical Garden at Homewood."

Hooker systems are—to quote—"better adapted to the artistic ensemble of a hardy garden." He then proceeds to give—to quote again—"a revision of the Hookerian cohorts that is adapted to copyrighted garden plans of the author previously published."

If, however, one is not bold enough to remodel the whole natural system to suit his particular garden scheme he must find other means of making system and soil fit—and this often presents considerable difficulties.

To make aquatic and bog plants grow beside related forms inhabiting drier soils, we tried several devices. The first of these was the small brick pool common in European gardens. But these are expensive to build and are liable to be burst and rendered useless by freezing. We have, therefore, substituted two-gallon earthenware kitchen bowls, with sloping sides inside and out. These can stand freezing, and can be made invisible in the garden by sinking them to the rim in the soil. Well-developed specimens of many aquatic plants were made to grow in these during the past summer. By the use of these bowls it is possible to have a miniature bog at any point in the garden where it is needed.

Provision for larger aquatic plants is made by three concrete pools. For swamp plants there is a bog bed, 15×30 feet, filled with peaty soil. This has a watertight brick border, two feet deep, and a water supply from taps at both ends. In this bed fine specimens of *Woodwardia virginica, Rhododendron viscosum, Hibiscus moscheutos, Decodon verticillatus* and others have flourished finely.

In a bed of sand, with a slight admixture of humus, fine clumps of *Opuntia vulgaris* are spreading vigorously and other xerophytes promise to do well.

Another difficulty encountered in garden-making of this sort is that of getting shade plants to grow in the open beds. To accomplish this we have been using small dogwoods, which can readily be kept within bounds, and in the shade of which many mosses, ferns, orchids and other plants of the forest floor are growing well.

Finally, a very important detail of the management of a garden is the selection of labels that shall be inexpensive and at the same time legible and durable. Profiting by suggestions from older gardens we have devised three types of zinc labels that are proving very satisfactory. The simplest of these is a stake label an inch wide and six inches long. On this the accession number is stamped across the top with a steel stamp, and the name is written directly on the metal with platinum tetrachlorid. These labels are used for all plants not provided with show labels. Another type of label is $1\frac{3}{4}$ inch wide and 8 inches long. It is painted gray, the name is then stamped on it with printer's ink by means of a rubber stamp. After the ink is dry the label is covered with spar varnish. These are used for show labels on pot plants in the greenhouse. The show labels used for all group and species labels in the garden are rectangular zinc labels, of various sizes from 3×5 inches up to 5×12 inches. These are hung by a fold of the upper edge, to a heavy wire staple, the name is printed and the varnish used for protection as in the show labels in the greenhouse.

The advantage of these labels is that they can be made readily, of any size, by any tinsmith, since they do not involve the use of expensive dies.

Such are some of the practical devices which contribute toward making the garden useful. Some of these are probably used in other gardens, but I have thought it worth while to mention them here because I have not been able to find information of this sort in print.

It is to be expected that what now seem satisfactory devices for carrying on the work of the garden will prove capable of much improvement in the future, aided by experience gained from other gardens as well as in our own. It will always be one of the chief aims of the garden at Homewood to discover what a garden is capable of doing for the botanical student and investigator and how it can do this best.

DUNCAN S. JOHNSON

THE RELATION OF APPLIED SCIENCE TO EDUCATION[1]

THE dative of indirect object is used with most Latin verbs compounded with ad, ante, con, in, inter, ob, post, pre, pro, sub and super, and sometimes circum; the elements essential for the growth and maturity of the plants which furnish, directly or indirectly, the food and clothing for the human race are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, magnesium, calcium, iron and sulfur, and possibly chlorin, and I think I am expected to discuss the general question whether there may be as much educational development in a study of these elements, for example, and of their application to the preservation of American soil and to the preservation of American prosperity, civilization and influence, as in learning a like number of Latin prepositions and their application to language development, and to philological research.

The question is, whether the culture of corn roots and the investigation of corn-root insects and diseases or the culture of clover roots, with their millions of symbiotic bacteria and their wonderful power to transform much of the impoverished lands of that part of Illinois whose name is "Egypt," and much of the exhausted and abandoned lands of India, whose fame is famine, into fruitful and valuable lands, may serve as well for the development of the mind and for the advancement of education and civilization, as the culture of Greek roots, and Sanskrit roots, and Hindu roots, from which we learn that the people of India, of whom only one man in ten, and only one woman in a hundred, are able to read and write—from which we learn that these people are our own cousins; that many words still live in India and in America that have witnessed the first separation of the northern and the southern Aryans; and, in the words of Max Müller:

> These are witnesses not to be shaken by any cross examination. The terms of God, for house, for father, mother, son, daughter, for dog and cow, for heart and tears, for axe and tree, identical in all the Indo-European idioms, are like the watchwords of soldiers. We challenge the seeming stranger, and, whether he answer with the lips of a Greek, a German or an (East) Indian, we recognize him as one of ourselves. There was a time when the ancestors of the Celts, the Germans, the Slavonians, the Greeks and Italians, the Persians and Hindus, were living together beneath the same roof.

Why has the southern Aryan civilization developed but one school for every five villages, while the northern Aryan, save in Russia, opens to every child the door of the school which leads on, for those who will, to the college and university? Why? Because only a prosperous nation can afford the trained intelligence or education of its people.

Education in America is not the cause, but the product, of our prosperity; and, thus far, the prosperity of this nation is due to our conquest of the former inhabitants and to the consequent acquisition of the great natural resources of this country,

[1] One of the papers presented February 19, 1910, before the Illinois State Academy of Science in the symposium on the "Relation of Pure and Applied Science."