THE TEACHING OF BOTANY.[1]

THE discussion was opened at great length by Prof. Marshall Ward, who reviewed the whole subject of teaching botany (1 to very young children and in schools, (2) as an academical study at the Universities, and (3) as a special subject for those who are in training for technical and other pursuits which require a knowledge of that branch of science—*e.g.*, foresters, gardeners, timber merchants, &c. He said :—

As I understand it, we may regard the study of botany as approachable from three points of view. We may speak of three ends to be attained : those of (1) elementary botany as a school subject of general education ; (2) advanced botany, as a subject of University or academic training, with a view to teaching and research ; (3) special botany, for various purposes in after life—*e.g.*, those of foresters, planters, agriculturists, horticulturists, brewers, medical men, timber merchants, &c.

This is, of course, a merely arbitrary division for the argument, and not a philosophical classification of the subject-matter of the science of botany.

The next point is the scope of the teaching in each case. I should advocate that all children pass through the preliminary training embraced under No. 1. Not only so, but I would urge the usefulness and importance of elementary botany in schools quite apart from its possible pursuit afterwards.

It seems to me that the time is gone by when we need discuss the direct applicability of teaching in elementary schools : if school training is read to mean education, in the true sense of the word, then there is no necessity for asking that a boy and girl should learn at school only those subjects of which they will make direct application as they grow older. Of course this does not preclude our keeping in mind the relative utility of the various subjects to be taught, but it does—and emphatically—preclude our falling into the error of imagining that a school-subject is of educational value only in proportion to its direct and foreseen utility in the application afterwards. In other words, educating and teaching may be, and often are, very different things.

Now, as I understand it, the nineteenth century has discovered—possibly re-discovered—the truth, that you may impart a wondrous amount of information to a boy or girl without awakening those powers of observing and comparing that lie dormant in the minds of most healthy human beings, and especially when young ; and that many a brilliant boy grows up without being able to draw correct inferences from the phenomena around him, and therefore less able than he should be to hold his own in the world he awakes in.

The peculiarity of the study of elementary botany, properly understood and pursued, lies especially in the interest it arouses in the child's mind, and the ease with which it may be taught, and I would insist and re-insist on the fact that it stimulates and cultivates just those powers of accurate observation and comparison, and careful conscientious recording of the results, which are so needed by us all ; and which, be it understood moreover, come so naturally to children who are not too much under the baneful influence of the mere instruction—the mere information—system.

What I wish to emphasize is that the educational value of this subject is no more to be measured merely by the number and kind of *facts* which the child remembers, than is the educational value of history to be measured by the dates learnt, and the lists of kings and battles committed to memory. History, reading and writing, arithmetic, and other subjects, have an educational value, if properly taught, quite apart from their value as mere accomplishments, which may be granted ; but children are naturally observers, and why this side of their hungry little natures should be starved at the expense of their usefulness in after life has always been a mystery to me.

To those who allow this, and I am happy to see that their numbers are now many, it should hardly be necessary to point out that the elements of botany afford the cheapest, cleanest, and most easily attained means of cultivating in children the powers of observing and comparing direct from Nature, and of leading them to generalize accurately.

Of course no advocacy is needed for good preliminary education in elementary botany in the case of those who are about to continue the pursuit of the subject as an academic study, or for a special purpose, as noted under the headings (2) and (3) ; but a few words may be devoted to pointing out the shocking waste of time and energy, on the part of all concerned, in the prevailing cases where students come up to a University, or other institution for higher education, insufficiently prepared for progressive study.

It is still true that boys and young men leave school without so much as a notion of the real meaning and aims of science : this applies no less to subjects like physics and chemistry, which are professedly much taught in schools now, than to subjects like natural history and botany, which, though avowedly in the curriculum of some good schools, are usually entirely ignored.

There is considerable discussion about the details, but many practical teachers regard such subjects as unfitted for school, because the boys and girls soon cease to be interested, and get lost in the masses of facts and hard names that beset their path : this, to my mind, simply shows where the whole system is wrong, and wrong because the tyrant empiricism still rules the prevailing methods of teaching in schools.

I shall go so far as to say that the only remedy for this state of things is for the teachers to lose that blind worship of facts, as facts, which dominates our school system. I am aware that this lays me open to very serious misconstructions, but I hope to make that all right in the sequel.

I would say to the teachers, therefore, do not fall into the mistake of measuring a boy's progress by the amount of dogmatic information which he imbibes, and splutters forth on to his examination papers, but look to the quality of his understanding of the relations between relatively few and well chosen facts ; and again, pay less attention to the number of facts which a boy observes and of names he remembers, and more to the way in which he directly makes his observations, and intelligently describes them, even if untechnically.

This is, I firmly believe, the only cure for the malady under consideration—*i.e.* it is the prevention of it.

Children in schools are taught most subjects from printed books, and it is not my province to criticize the necessity of this as regards those subjects ; but let a competent teacher try the experiment of making the children read directly from Nature, and he will soon see that the new exercises have a powerful effect. They will stumble, and they will even make stupid mistakes and mispronunciations ; but do they not do so when they are reading—*i.e.* observing and comparing and interpreting—printed words in a book? Of course they do, and therefore the teacher must not be discouraged by their stumbling and misapprehending when first they have to look at and compare different leaves and flowers, and give forth the articulate sounds which correspond to the impressions created on their minds.

Every weary teacher knows what a blessing is variety in the studies of the class, and it passes my comprehension why advantage is not taken of the splendid opportunity offered by the study of elementary observational botany.

We now come to the important subject of method. How should botany be taught?

Here, again, I shall consider the subject from the same three points of view referred to above.

(1) Elementary botany in schools should be confined to lessons in observation and comparison of plants, and the greatest possible care should be taken that books are not allowed to replace the natural objects themselves. Indeed, I would go so far as to advise that books be used only as an aid to the teacher, were it not that a judiciously written text-book might be employed later on by even young children as a sort of reading-book.

The chief aids should be the parts of living plants themselves, however, and, in spite of the outcry that may be expected from pedantic town teachers, I must insist that every school might be easily provided all the year round with materials for study. I even venture to think that these materials might be collected by the children themselves : at any rate there should be no difficulty about this in the country.

I will illustrate these remarks by a few examples. The teaching of elementary botany to children should commence with the observation of external form, and might well be initiated by a comparative study of the shapes of leaves, the peculiarities of insertion, their appendages, and so on.

The point never to be lost sight of is that if you teach a child to discriminate, *with the plants in hand and from observation only*, between such objects as the simple, heart-shaped, opposite, ex-stipulate stalked leaves of a lilac, and the compound, pinnate, alternate, stipulate leaves of a rose, you lay the foundations of a power for obtaining knowledge which is in no way to be measured

[1] Discussion at the Leeds meeting of the British Association, in Section D, on September 5.

merely by the amount or kind of information imparted. It does not matter whether the child learns the trivial facts mentioned above, or not, but it is of the highest importance that the child be taught how to obtain knowledge by such direct observation and comparison; and the beauty of it all is that, as is well known, the child will retain most of such information as mere matter of course.

For the main purpose in hand, therefore, it may be contended that any objects would do.

This is no doubt true in one sense, but it should not be forgotten that (1) the mental exercise on the part of the child is best exerted on *natural objects*, to say nothing of the admitted advantages of familiarizing him with Nature, and (2) the parts of plants are so varied, so beautiful, and so common, that he need never lack materials for his simple and pleasant work. Moreover, the parts of plants are clean, light, and easily handled—practical advantages which recommend themselves.

I feel convinced that, if the teachers were not opposed to it, the subject would ere now have been more widely taught; and I shall therefore say a few words in anticipation of difficulties. It has been suggested that materials would be scarce in winter. Not at all. Let the children be familiarized with the observation and comparison of the peculiarities of a sprig of holly as contrasted with one of ivy; or let them be shown how different are the buds and leafless shoots of the beech from those of the oak or the horse-chestnut. Show them how to observe the bud-scales, how to infer the leaf-arrangement from the scars, how to notice the colour, roughness, markings, &c., of the periderm. Or give them introductory notions as to the nature of a hyacinth-bulb as contrasted with a potato-tuber, confining their attention to points which they can make out by observation. Every nut or orange or apple that a child eats might be made interesting if teachers would dare step over the traces of convention, and introduce such ostensibly dangerous articles into class-work—and why not? The doctrine of rewards and punishments is applied more crudely than this in most children's schools!

Be this as it may, there is no lack of material at any season, for children to observe and compare, plant in hand, the peculiarities of shape, colour, insertion, markings, &c., of the leaves, stems, roots, and other parts. The difficulties are supposed to increase when the flower is reached: this is not necessarily the case in the hands of a sympathetic teacher, unless the choice of flowers is very unfortunate and limited.

There is one danger to be avoided here, however. Young children should not be troubled with the difficulties of theoretical morphology: they should be made familiar with the more obvious roots, stems, leaves, tendrils, thorns, flowers, bulbs, tubers, &c., as such, and comparatively, and not forced to concern themselves with such ideas as that the flower is a modified shoot, the bulb a bud, the tendril a leaf or branch, &c., until they have learned simply to observe and compare accurately. Later on, of course, the step must be taken of rousing their minds to the necessity of drawing further conclusions from their comparative observations in addition to recording and classifying them; but if the teacher is really capable of teaching, it will be found that the children begin to suggest these conclusions themselves, and, this stage once reached, the success of the method is insured.

Glimpses of the meanings of adaptations of structure to function soon follow, but they should be obvious and simple at first, and the mistake should not be made of entangling a child in a discussion as to more remote meanings. It should never be forgotten, in fact, that the first steps consist in learning to observe accurately and to record faithfully, comparative exercise being used in addition, both as a check and as a stimulus to the judgment.

The next step is to introduce the methods of the systematic botanist who works in the field, with flower in one hand and lens in the other; and the necessary preliminary and accompaniment of this is to exercise the tyro in describing common plants as a whole. The value of such training in the field can scarcely be over-estimated. As education it is excellent, for it inculcates neatness and accuracy of method, keenness of observation and judgment, and is, moreover, interesting to the young student, as well as healthy in every sense of the word. As preliminary training in all cases where the student will have to pursue the higher branches of botany, or other science, at a University or a technical institution, it is absolutely necessary. There is no need to enlarge on its value to the traveller, the philosopher, and even the *dilettante* who enjoys Nature in his garden, or in the country, or even merely as a reader of books on natural history: just think what enjoyment such a training would add to the lives of thousands who have read Darwin's works imperfectly, and reflect for a moment on what such intelligent appreciation of such writings means to a nation like ours.

(2) The necessities of the higher academic study demand previous acquaintance with the *facies* of a large number of plants—Cryptogams as well as Phanerogams—and it is on this account advisable also that the student has been well trained in field-work: he should, then, be familiar with terms and groups, and be able to observe and compare.

Two chief lines of instruction are open at once to the advanced student, and the first point for discussion is, how far they should be kept separate or together: they are morphology and physiology, for, say what we will, the two are separate studies in their aims and methods.

It is not improbable that the study of pure morphology may be carried too far, as an independent study, and that one-sided views of the nature of plants and their parts may result; but, however true this may be, I take it no botanist will deny that every student should know something of the attainments and aims of modern morphology. If this is admitted, the next point is not likely to be gainsaid—namely, that the study of morphology depends on the study of anatomy and histology, as well as upon that of external form. As we shall see, the same is true, but in a different way, of physiology; but I am concerned at present with morphology only.

It seems to me, in view of these facts, that the advanced teaching must presume an acquaintance with the elements of anatomy and histology; and here, again, I am convinced that if teachers fully recognized how clean, and light, and easily accessible the material is, and how excellent the training of hand and eye on the one side, and of the thinking powers on the other may be made, the difficulties of introducing this elementary laboratory work even into secondary schools would be overcome.

It has been overcome in many cases with regard to chemistry, and there is no reason why it should not be overcome with regard to botany.

However, be it as advanced work at school, or as elementary work at college, the student who proposes to pass on to the higher academic study of botany must face the truth that even an extensive knowledge of the outside forms of plants will not carry him far on the road to be traversed.

Now comes the question hard to answer—Should he study anatomy and histology by selecting the best known and clearest tissues, tissue-elements, &c., from any part of the vegetable kingdom; or should he choose some one plant, and explore the recesses of its structure as thoroughly as possible?

All things considered, I believe the introduction is best effected by the latter method, and for the following reasons. In spite of the drawback that no one plant can be found which shows every tissue or tissue-element at its best, one finds that, by exploring the structure of some one plant as thoroughly as possible, the thoughtful student obtains a better idea of the co-relations of the structural elements than if he seeks for xylem vessels in Maize, sieve-tubes in Cucurbita, collenchyma in one plant, sclerenchyma in another, and so on.

Moreover, the comparative survey can be better carried out, if time permits, by methods such as I advocate.

The next consideration is the selection of the type to be used as a basis. In spite of all its defects, and in anticipation of severe criticism, I maintain that the fern is, on the whole, the most useful and convenient type for the purpose.

No Thallophyte is sufficiently obviously complex in structure to give the student the necessary ideas of co-relations of parts and division of labour; moreover, the lower forms offer peculiar difficulties of observation, cultivation, &c. The moss is too specialized for some purposes, and not sufficiently complex for others. The Phanerogams, on the other hand, although they present the vegetative tissues, members, &c., in the more highly developed and specialized forms familiar to physiology, offer such stumbling-blocks to the tyro in morphology that no one will serve as a suitable type. The pine is the best of those proposed, but even it presents great difficulties to a beginner.

The disadvantages of the fern (taking *Aspidium*) embrace the following: its roots are fine, the stem is short, and the vascular bundles belong to an out-of-the-way type; the spores take a long time germinating, and the prothallus offers difficulties in the way of investigation not easily overcome by a school-boy.

On the other hand, the roots are fairly typical in structure, and introduce the student to the ideas of the root-cap, apical cell, radial bundles, and axial vascular cord. The stem, at least, shows how the vascular bundles have definiteness and continuity of course, in axis and appendages, and these bundles are so large and isolated that an introduction to the notion of their development from embryonic tissue is at least attainable; moreover, the spiral vessels, scalariform tracheides, sieve-tubes, and packing-cells suffice very well—though, of course, in different degrees—to introduce the elements of the xylem and phloem, and I regard it as an advantage to defer the complex idea of cambium.

Elementary notions of other items of complexity appear in the extra fascicular strands of sclerenchyma, while protective hairs, reserve-starch, continuity of leaves and axis, and their origin from the meristem, &c., all serve as foundation stones if properly demonstrated and discussed by the teacher.

But it is the sporophyll on the one hand, and the prothallus on the other, which make the fern so supremely useful as a type. No conceptions in the morphology of plants have been more fruitful than these, and it is of the highest importance that the student really sees and examines these and their accessories for himself.

The beauty of the fern sporophyll as a type for demonstration lies in its being so evidently a leaf, in the sense understood at once by the beginner; then the sorus, sporangium, and spore are evident and easily examined, and even the very useful ideas of the archesporium, tapetum, and the development of the spore can be mastered in the case of the fern with comparative ease.

As for the prothallus, it is admitted to be the most accessible of all, and advantages may be claimed for its independence as a chlorophyll-bearing structure, in spite of its flatttened and somewhat specialized form. The antheridia are curious, no doubt, but the spermatocytes and antherozoids and their development are easily made out so far as general features are concerned: the archegonia are not so typical, perhaps, as those of the moss, but they are sufficiently so to be very useful, and the oosphere, canal-cells, &c., are easily seen by an apt student.

Moreover, I would point out that in the hands of a properly guided student of average intelligence, the teacher can rely upon the fern prothallus for introducing some theoretical notions very difficult to acquire—*e.g.* the gradual separation of the sexual organs, and their withdrawal into the prothallus, and the eventual separation of male and female prothallia, and *their* reduction and withdrawal into the spores, leading to the final specialization of male and female spores, and *their* retention and reduced germination inside the sporophylls, which also become specialized.

I should explain here that I would not propose to carry this explanation of homologies too far at this stage, but my argument is that the foundations for much that is to follow can be laid now with better effect than at any other time. It may be contended that the elementary student cannot possibly understand the Hoffmeisterian morphology until he has mastered the structure of the ovule of the Phanerogam, and that, therefore, it makes no difference in this respect whether he begins at the one end or at the other. I grant this, but my plea is not for the crowning of the student's knowledge of morphology, but for the *foundation* of it, and I lay so much stress on his laying this foundation thoroughly—otherwise it will not bear the weight of the superstructure I should propose to raise on it—that I look for the best type for that purpose; and, bearing in mind that such a type must be convenient, and one wherein the student can find the objects and examine them himself, I believe it has been found in the fern.

It will no doubt be remarked that, in the preceding discussion, I have kept in view more especially the study of morphology as the aim of the young academical botanist, and that it is because the fern is so excellently situated midway in the vegetable kingdom that it forms so good a type for teaching purposes. If it is urged, however, that physiology is the study to be more especially kept in view, then it may be necessary to reconsider the question of a type.

But there are two reasons, to my thinking, for discarding the idea that the study of physiology should be the immediate aim of botanical teaching in schools at present, though I do not despair of its introduction in the near future.

Firstly, the appliances needed, simple as they are in most cases, nevertheless *are* appliances, and will, as matter of fact, bar the way to the study during school life for some time to come; secondly, however much we may insist that the study of the physiology of plants presents its own problems and phenomena apart from those proper to physics and chemistry—and no one can urge this more earnestly than I do myself—nevertheless it cannot be gainsaid that the student of physiology should have a fair acquaintance with elementary physics and chemistry, even at the outset. I am aware that the contrary has been asserted, and that it has been argued that a student may learn to rig up apparatus for demonstrating the respiration of germinating seeds without knowing anything about the properties of oxygen, or what happens when carbon dioxide passes into a solution of barium hydrate, and that he may perform experiments on assimilation knowing no more about starch than that it turns blue with iodine, or on transpiration without understanding anything of the physics of the atmosphere or of water; and I am not prepared to say that such training would be without benefit, but apart from the advantages of the preliminary knowledge of phenomena, every teacher knows how dull is the comprehension of the boy's mind when brought face to face with such experiments devoid of the necessary physical concepts, as they have been termed; and in any case the necessary minimum of physics and chemistry will have to be instilled at the time the experiment is performed.

Secondly, the study of histology—practical acquaintance with the microscope—is a necessary preliminary to physiology, and I am doubtful whether we are at present in a position to demand more than the beginnings of these matters from the schools, though the time will come when it will be disgraceful for a boy to leave school quite ignorant of them.

The study of the fern should be followed by that of the *pine*, and I am not prepared to demand a continued adherence to the type-system beyond this point, except under special and favourable circumstances, such as need not here be discussed. Indeed, I should be quite satisfied if we could depend on school-children learning how to describe plants fairly accurately, and on the boys and girls in secondary schools knowing something more of field botany and how to use a flora, and having a satisfactory acquaintance with the life-history and structure of a fern and a pine. When I speak of field botany as above, it is not intended to exclude an acquaintance with the external appearance of common Algæ, Fungi, lichens, and mosses, &c., though the extent of that acquaintance would necessarily depend upon circumstances.

It must not be overlooked, however, that somewhere between this stage and that of further progress to the higher departments of academic botany, the student will have to do some comparative anatomy and histology, on the one hand, and to master the details of the life-history of certain types of Algæ, Fungi, and Lichens, Muscineæ and Vascular Cryptogams, and look more deeply into that of the Phanerogams.

It depends on circumstances whether the type-system should be followed here or not. If the student is going to specialize in the direction of morphological botany, I am inclined to the opinion that he should steadily pursue the type-system, supplementing his work with comparing special structures selected from allied types as he proceeds. For instance, after working through the life-history of a *Pythium*, he should not need to devote his attention to actually exploring all the details in the life-history of *Mucor* and *Peronospora*, but he should see the sporangia of these, and the haustoria of *P. parasitica*; and again, having worked through the chief stages in the life-history of *Marchantia* and *Funaria*, say, there is no need to insist on the same pursuit of detail in the case of other Muscineæ, but the student might compare with the corresponding structures in his types the sporangia of *Anthroceros* and *Jungermannia*, &c., the leaves of *Sphagnum* and *Polytrichum*, and so on.

If the student is more inclined to the pursuit of physiology, I should prescribe a different course as soon as he has examined a few types of Algæ and Fungi, a moss, and a few Vascular Cryptogams, and I should, moreover, direct his attention at once to the highest plants—the Angiosperms—instead of leading up to them as in the case of morphological studies.

In fact, the system to be pursued for a training in physiology, is to select the best illustrations of the organs, the tissues, and the histological elements of which the functions are to be studied. For the typical root I should go to one plant, but it might be necessary to employ quite another plant for showing root-hairs or root-cap: while selecting the vascular bundles of *Ranunculus repens* or of *Aristolochia* to show certain facts about the bundles as a whole, I might take those of *Cucurbita* for sieve-tubes, those of *Linum* or *Vinca* for bast-fibres, and those of quite other plants for spiral or pitted vessels, &c.

So also with other structures, the training is designed to familiarize the student with the best examples of each structure, and although he must acquire a sufficient insight into the relations of these structures and parts to be able to understand how they work together, and how the functions of some depend on those of others, still his aim is not to follow out their development and relations in space and time, but to deal with their behaviour now and in the mature plant.

Up to a certain point both morphologist and physiologist must work along the same lines: they then diverge, and it is at this period that the more extensive use of books must come in; for the student should now have so *real* a knowledge of the things discussed, that illustrations and information are clear to his understanding. The intending physiologist must put himself in possession of sufficient histology and anatomy to be able to follow the work of the specialists in this domain, and to see what bearings their discoveries have on his branch of investigation: no less must the morphologist follow the special literature, but with his own very different end in view. Both will, of course, have their special literature also.

However, it is obvious that we have now reached a point where no very rigid rules can be laid down, since the advanced academical student is in a position to strike out his own lines, and if he does not display some originality now in his methods, aims, &c., the presumption is that no amount of training on the part of teachers will lead to it. Nay, more than this, it is highly desirable that he should be left alone, for the dormant originality is as likely as not being kept down by the pressure of prescribed studies.

(3) In illustration of what is required in special branches of botanical study, I cannot do better than take the case of the properly-educated forest-student: go where you may, you are not likely to meet with a more representative "practical man" than the trained forest-officer, and consequently his case is peculiarly well adapted for my present purpose.

No one will be so rash as to argue that the botanical training of a forester should err in subordinating a knowledge of trees and wood, the phenomena of germination and nutrition, of growth, &c., to transcendental hypotheses and discussions on the nature of morphological conceptions or on abstruse questions as to the significance of movements of irritability, or the ultimate mechanism of reproduction and the molecular forces concerned in heredity: on the contrary, most people will concur in agreeing with me that the teaching of forest botany should be directed to laying down in the student's mind a good foundation of facts of observation, and showing him how to acquire others, and, further, to training his mind to reason accurately from these facts, so that he may apply his reasoning to the practice which is to be his life's pursuit.

On the other hand, there is a danger which very few people escape when talking on this subject, and that is the danger of supposing that the attention of the forest-student should be confined simply to acquiring and remembering aphoristic statements of facts, and that his accomplishments in this connection measure the fitness of his training. In other words, many so-called "practical men" argue that it is the *quantity of information* which tests the student's progress, and neglect the truth that progress is much more adequately represented by the *quality of the instruction.*

Let us put the case in another way. It is granted that the forest-student must be made acquainted with certain facts of observation, and that he must be informed of important conclusions derived after comparing these facts: it is also granted that his time for training is limited—there is no getting over this, and we need not discuss what the limits are, or why they are so. Now, the problem is, Shall the student devote the whole of this period of training to simply acquiring as many of these facts as possible, the conclusions being limited to those directly applied in the forest; or shall more attention be devoted to the methods of acquiring these facts and of drawing the conclusions from them, and the facts themselves be utilized rather in so far as they are necessary for the training, than as the ultimate aim of that training?

The answer to this question is of the highest importance. If we decide that the chief object of the forest-student's training is to make himself acquainted with the facts themselves, then his whole time will have to be given to such matters as learning the names of plants; the peculiarities of the roots, bark, wood, buds, leaves, &c., of the various trees; the empirical facts as to the relative amount of light, moisture, &c., and the degrees of temperature that each species will bear, and so on; the ascertained growth in height of each species, and the annual increment it exhibits, and so on. It is obvious that, if the student worked continuously for his two years or so of probation, he could make himself or be made acquainted with an enormous mass of such information, but it is equally obvious that he could not nearly exhaust the catalogue of facts. The latter truth becomes still more apparent, however, when we remember that he has to devote his attention to several other branches of study in addition to botany.

But is this the right decision to come to in face of the problem I put before you? I say no! emphatically no! On the contrary, it should be recognized at once that the forest-student cannot acquire more than a small proportion of the facts of his subject while he is in training, and even if he could they would be of no use to him in this shape. The selection being limited, then, it should be the aim of the teacher to direct the student's attention to a selected number of facts (you need have no fear that the list will be a short one) such as throw light upon matters that the student will not be likely to explain for himself, unless he is directed. The facts of the forest will be before him always; why, then, occupy the valuable time of training with an incomplete catalogue of them? There are thousands of other points, however, that he will never know anything about if he does not learn how to observe and infer them while he has the chance with a competent teacher by his side.

Let me give an example. The details of the different modes of germination of the various seeds of trees are numerous, but they can be collated under a few heads. Some seeds, like those of the beech, raise their cotyledons above the surface of the soil, and they become green and expand; others, like those of the oak, remain underground, and devoid of chlorophyll, and do not expand. As sown, however, the beech-mast and acorns are not seeds, but fruits, for each is enclosed in its pericarp. Both agree in having two cotyledons to the embryo; and although the beech seed contains a thin remnant of endosperm, both are usually termed exalbuminous; moreover, the cotyledons have their cells crowded with food-materials consisting chiefly of starch-grains and oil.

The seed of a date-palm, on the other hand, is provided with large stores of food-material in the form of cellulose, as thickening materials to the cell-walls of the endosperm, and it contains a relatively minute embryo, furnished with one knob-like cotyledon only; while the seed of a Scotch pine has a large, fatty endosperm, and a poly-cotyledonous embryo in its axis. The details of germination of the palm and the pine differ, and both in different ways from those of the beech and the oak.

Now it is unquestionable that the forester ought to understand what are called the phenomena of germination; but the inquiry arises, Do we mean by this that he ought to learn the details of the germination of these and a large number of other seeds, or do we mean that he should be made acquainted with what research has shown to be common to all seeds, and then with the chief classes of difference in detail? In other words, is he to be taught generalizations, and shown by a few well-selected examples how they have been and are being arrived at; or is he to be burdened merely with the details themselves, as stated in the words of and on the authority of others? Undoubtedly the former is the true method: the latter is simply empiricism.

Let none fear that the student who is thus taught will learn too few facts—the fetish of the "practical man."

In the first place he cannot proceed without sufficient information to enable him to understand the physiological value of such bodies as starch, cellulose, oils, and proteids; and, without troubling him with the refinements of micro-chemical methods, he will at least have to be made acquainted with the better-known changes which these bodies undergo in the presence of water and oxygen, and with the metamorphoses comprised under metabolism; and here his botanical knowledge comes into intimate relations with his information on elementary chemistry.

But, further than this, how is he to proceed to an understanding of even the outlines of the physiology of germination until he knows the leading phenomena of fermentation on the one hand, and of respiration on the other?

I will not enlarge upon this part of my subject however, but simply assure those unacquainted with the full bearings of these remarks, that there is no paucity of facts in this connection, and that, simply to make himself acquainted with the more salient ones, the student has to devote many hours of careful study in the laboratory.

But he will not understand the process of germination unless

he is acquainted with the structure of the seed. Here, again, it is not the details of structure of the seed-coats, the nucellus, and the embryo, which differ in each seed taken, that are to tax his memory and disgust his mind, but he must be made familiar with the leading features common to all seeds, and illustrated by a few selected examples. The nature of the seed-coats, the structure of the embryo and its relations to the endosperm, &c., are easily taught, if the teacher knows his art, and the pupil is properly led up to his work; otherwise, I fail to see how the latter is to gain any idea of what a seed is on the one hand, or of how a tree arises from the embryo on the other, and if he does not understand what a seed is, he will never comprehend the process of germination, and he thus misses the best chance of elucidation as to the development of the complex structures of the root, stem, and leaf, &c., which follow.

I have said nothing of the phenomena of growth, moreover, and yet the problems of germination will remain obscure and unintelligible until the student knows something about growth; and this presupposes at least some notions as to the phenomena of cell-division in the embryonic tissue, and of cell-growth and development.

Why say more? It is obvious that these studies lead the one to the other, and the real difficulty is to select the best illustrations and use them to the best advantage.

The forest-student's curriculum, therefore, is not to be regarded as a *narrow* one because he needs only a catalogue of facts, but as a *special* one because the exigencies of his professional time demand his attention to certain classes of phenomena. His early training—would that it began at school—should be in the observation and comparison of plants and their organs: he should then proceed to more comprehensive field-work, and exercises in the description of plants and systematic botany. In selecting his examples special attention should be paid to trees and shrubs, which are commonly neglected by students, and the lens should be always at hand.

Studies in the elements of anatomy and histology must follow, otherwise his progress will be hampered when he has to deal with the subjects of germination, nutrition, growth in thickness and formation of wood, cortex, bark, &c.

Refined histology, special anatomy, and speculative morphology will have to be neglected, nor must he aim at becoming a specialist in taxonomy. His laboratory work must be directed to the end that he may understand the general structure and relations of tissues and organs, otherwise he cannot understand what is known of their functions; that he may have clear ideas as to the parts which yield economic products, otherwise he becomes lost in the long catalogue of these; that he may grasp the salient features in the structure of the different kinds of wood, otherwise he cannot attempt to classify and identify them; that he may know something of the biology of fungi, otherwise he cannot hope to understand the diseases of timber which they cause, or the important scavenging and other work which they perform in the forest, and so on.

It would take too much space and time to enlarge on the pity of the fact that young forest-students come up for training almost totally unprepared for such a curriculum, and especially devoid of the elementary knowledge and powers of observation which they should have received at school: the consequence is, much of their valuable probation period is occupied with acquiring the elementary facts and methods without which they cannot possibly make progress in more special work. Now I should like to see all this altered, and the only way to effect the necessary salutary changes is to have some guarantee that such probationers have a suitable training in elementary botany while they are in the receptive condition of school life.

Let me now suppose the case of a young man destined for a career as a brewer. No one will deny that an essential part of his training should consist in a thorough schooling in the methods of cultivating and separating the various forms of yeast, bacteria, and moulds which are met with in every corner of a brewery, and some of which are the agents on the proper action of which he depends directly, while others are his enemies—for I need not remind you that the fermentation industries all depend on various yeasts, and that the diseases of wine and beer, &c., are due to the interfering action of other microscopic organisms of the nature of yeasts, moulds, and bacteria.

This is all clear, and generally accepted, but I am not so sure that everyone recognizes the fact that the proper study of these fungi and allied organisms is a department of botany; though I am quite sure that many people suppose that it is the province of the chemist to clear up the mysteries of these agents of fermentation and putrefaction.

It requires long practice with the microscope and with botanical methods of investigation to trace the vagaries of even the largest of these ferment-organisms, however; and without implying in the least that some of the methods and results of modern chemistry are not essential in such investigations—for the contrary is really true—I would urge the absolute necessity of a botanical training before the student can grasp the meaning of the problems to be solved.

It is surely childish to reply that the special technical methods of the brewer's microscopist can be acquired without the preliminary training in botany which is here pleaded for. I know they can be acquired, as merely technical processes, and I do not deny that relatively good work has occasionally been done under such conditions by men of genius and industry, who have acquired the botanical knowledge as they proceeded; but the point is that the technologist who has had no training in botany is found groping over problems in a manner he would never have had to do had he a proper view of the nature of plants and plant-life such as a suitable training in the elements of botany would give him.

This training, if commenced at school with exercises on observing and describing plants, and then pursued far enough to give him correct ideas of structure, of the nature and grouping of the histological elements, and of what is best known as to their functions in the physiology of nutrition, growth, and reproduction, would at least save the student from those crude notions as to the so-called physics and chemistry of a yeast-cell or of a fungus-hypha which one so commonly meets with.

I am not in any sense implying that a brewer's technologist should be a botanist, in the accepted meaning of the term: I only urge that he has to confront problems of *physiology* and of *morphology*, over and above his every-day riddles of chemistry and physics; and that even if we concede that physiological actions are nothing more than complex and conditioned physical and chemical actions (and I do not deny this), it is still true that he should be quite clear that this implies much more than it is commonly supposed to imply, and have at least an inkling of what we know as to the complexity of metabolic and other processes.

Now he cannot be clear on this subject unless he knows something of modern plant-physiology; and he cannot follow the teachings of physiology unless he is familiar with what is best known as to the structure of plants, and their general nature. How far he should go in these studies is not for me to limit, but he must at least be able to grasp enough to enable him to understand the progress of the science, and to see how far he is justified in drawing inferences from phenomena observed in other plants and applying his conclusions to the plants he is studying. To attempt to study the behaviour of a yeast-cell, or of a bacterium or mould, without clear ideas as to what is known of the plant-cell generally, seems to me very like obstinately attempting to open a lock in a dark room when you are ignorant of the whereabouts of the lock and have not found the right key.

What I have said with respect to the study of ferment-organisms holds good with regard to the study of what is called bacteriology, and to an even greater extent. For no one is likely to gainsay that such extremely difficult and delicate investigations as those made in the domain of pathology cannot be properly conducted without an intelligent acquaintance with the physiology of parasitic and saprophytic fungi and bacteria, and this being conceded the rest follows as a matter of course.

Yet it is in just this region of special scientific investigation that the grossest sins are committed. It is pitiable to see the wild struggles with facts that have been carried on in the name of bacteriology, and which might have been avoided had the investigators been properly trained in botanical science.

Bacteriology, however, is only one special branch of what is popularly known as the study of germs, and the truth of what has been above stated comes out with yet more startling clearness when we recognize the benefits that have arisen from the study of parasitic fungi and their relations to the diseases of plants. Taking the latter as a special pursuit, it is very difficult to say what should be omitted in a training designed to fit the botanist for investigation. It is only quite lately that pathologists have clearly recognized that the study of the diseases of plants (so important to horticulturists, planters, and foresters) implies by no means a mere acquaintance with the forms of fungi and their

systematic relationships, but that it demands, on the one hand, the most patient and refined researches into the life-history of these organisms, and the variations in their biology due to changes in the environment, and, on the other hand, as deep an insight as can be obtained into the normal physiology of the host-plants, and the variations in this due to changes in the environment. In other words, not only must the investigator attack the question of the mutual relations between parasite and host (and he cannot understand these without studying the normal biology of both), but he must also look into the relations of each to a varying physical environment.

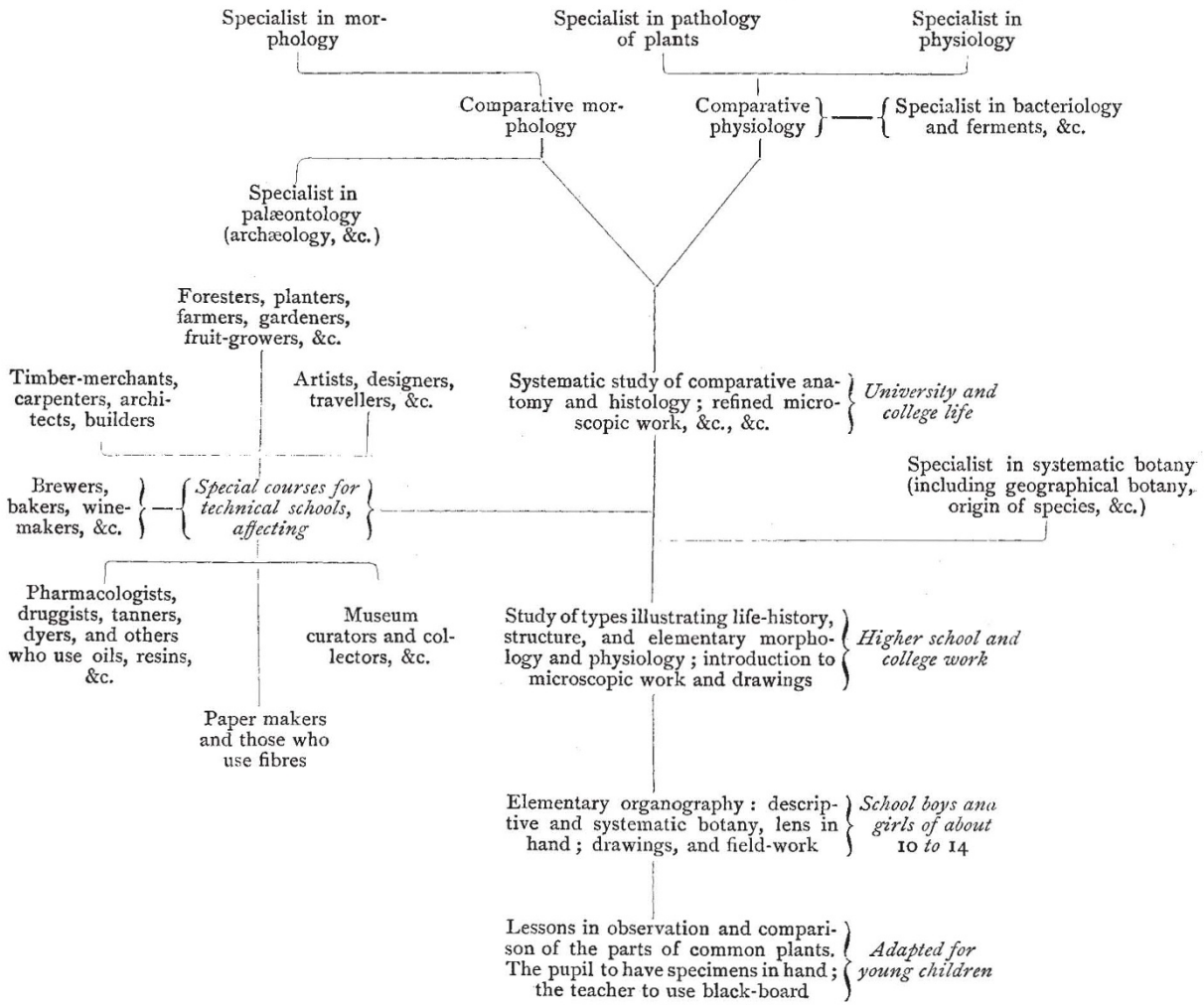
As I said before, it would be hard to say what botanical information can be superfluous in such a training.

But there are other technical pursuits which demand a training in elementary botany, and among these that of the timber merchant, and those of the builder, carpenter, and architect may be grouped together.

It is admitted that these people should understand the nature and properties of timber in the wide sense, and especially of certain kinds of wood in particular. My case is made out quite clearly by the efforts one meets with in various articles and books on timber, designed for the information of those engaged in the trades and professions referred to, and by the lamentable failures in conveying clear instructions, owing to the want of acquaintance with the elements of botanical science.

I maintain that no one can properly understand the markings,

Tabular Résumé of the Various Branches of Botanical Study, as grouped for the preceding argument.



colour, texture, and other technological peculiarities of timber who is ignorant of its structure; and I have had abundance of proof afforded me of the interest taken in this subject by individuals connected with the numerous callings centred around that of the timber merchant—*e.g.* wood-carvers, turners, cabinet-makers, wheelwrights—as well as by archæologists and geologists, who are brought face to face with problems which require an acquaintance with the structure of timber for their solution.

Now, the structure of timber is a very interesting subject if properly approached, but it is a very complex and hopeless subject for one who is unacquainted with the meaning of the four or five histological elements which compose wood, and of their development from the cambium-cells; and, to comprehend these things, the student should know the elements of botany.

But it is not only the properties of timber that have to be understood by the workers and dealers in wood. An important subject, which is coming more and more to the front, is that of the classification and identification of timbers. It is astonishing how cleverly practical experts can find their way through the difficulties which beset those who have to decide upon the value of timber, and the suitability of different pieces of wood for various purposes; but even more astounding is the vagueness of their replies to the very natural question, How do you decide in difficult cases? One thing is clear—the expert bases his conclusions on keen observations of minute details, and yet these observations are not recorded: the whole system is one of empiricism and blind rule-of-thumb guess-work. It serves the purpose in many cases, just as rough measurements by an expe-

rienced eye and hand are often said to serve the purposes of those concerned at the time; but will anyone doubt that scientific accuracy and system would be more reliable? I am aware that "practical men" doubt this, but repeated contact with "practical men" assures one that they pay a heavy penalty in loss of time for their triumphs.

It is repeatedly observable that the "practical man"—the man of experience, in other words—has to spend long periods of time in the acquirement of his unsystematized powers, and the conviction forces itself upon the observer that he could do much more if he were systematically and logically observant, instead of being merely spasmodically so. In other words, he is scientific in so far as his successes go, for in the end it all resolves itself into keenness of observation and comparison; and he would save himself many failures if he were properly trained. How often is it pointed out that such and such a man is unscientific but practical! Well, this resolves itself into a fallacy, for he is really practical in so far as he is scientific in his methods—clumsily so, it may be, and the science in him has been unconsciously acquired and pursued; but it is there, and it is just where his science breaks down that he becomes a mere bungler. This truth need not blind us to the further one that even a bungler occasionally stumbles upon success, but my argument is that his conclusions would be more constantly trustworthy if he pursued a consistent and recorded course of methodical observation and comparison, instead of trusting to the unsystematized impressions from which his keen mind draws the conclusions of of which he is so vain.

It is, to my thinking, one of the most curious problems of the human mind that "practical men" can persist in upholding empiricism, on the grounds that such knowledge as the above is most real and useful. Of course, it is real and useful in so far as it has been acquired during long years of experience in contact with facts; but look at the opportunities lost in this expensive and wasteful training—at the mistakes made and the wrong lines pursued, until correction comes, sharp and merciless because it involves failure. Surely, a better method is to prepare the man to gain his experience at least cost, and to profit to the utmost by his mistakes; and, when all is done, see the equivocal position the "practical man" is put into—his only real knowledge is scientific, and the wild hypotheses and ignorant fallacies to which he is a slave might have become fruitful thoughts, leading him to far higher attainments had he learnt to observe and record, and compare and judge when he was young. Personally, I know no more contradictory being than the one who prides himself on being a "practical man," and is continually throwing at one's head the adage, "An ounce of practice is worth a ton of theory," for at every turn one finds him involved in endless tangles of error, and his ignorance of this is only equalled by the obstinacy with which he contends the contrary.

The second speaker was Prof. F. W. Oliver, who considered the question of botanical teaching only so far as it bears upon the training of medical students. He argued that, since all scientific medicine is based upon elementary biology, it is necessary to bear in mind that, in a course of say fifty lectures, designed for the requirements chiefly of medical students, some things must be sacrificed in order that certain fundamental truths may be driven home. The only questions are, What must go? and what must be retained? And the reply is that much of the study of types, and of such transcendental subjects as the alternations of generations, and so forth, as found in the schedule of the London University, for instance, should be sacrificed in order that the teacher may concentrate his attention on such parts of the subject as are of real importance and interest to the medical student, and others composing large classes. He would go so far as to say that about thirty out of the fifty lectures should be devoted to the organography and elementary physiology of the higher plants; for in that case the teacher is dealing with beings of which everybody knows something, and there is more human interest to the student when the *facies* of the organism is so familiar as is that of common flowering plants. In conclusion, Prof. Oliver pointed out that the responsibility of these matters rests with the examiners and those who draw up such schedules as that of the London University, and laid some stress on the importance of this responsibility.

Prof. F. O. Bower followed, and directed his remarks chiefly to the subject of teaching mixed and elementary classes in a University. He wished especially to deplore the threatened divorce between morphology and physiology, and advocated that such a divorce should be prevented at all hazards. In regard to this, and to some other points, he must differ from Prof. Marshall Ward's conclusions, though he heartily concurred with most of what he had said. He thought that, taking into account the value of the mental exercise, so useful a study as that of morphology should be introduced early, and that the teaching of the main homologies should be insisted upon. With regard to the cut-and-dried schedules now so universal, Prof. Bower was of opinion that, while they protect the weaker teachers, they hamper the strong ones, and he wished very much that more individual freedom should be allowed to lecturers.

Mr. Forsyth was especially interested in Prof. Marshall Ward's remarks on the teaching of botany to children in schools, and described an experiment now being tried in the Leeds Higher Grade School. The children are being taught to bring plants themselves, and to observe them in the field, and the speaker was of opinion that the new departure is a signal success.

Prof. Green spoke very strongly against the "type-system" as now pursued in the teaching of botany. Not only does it occupy too much time, but it is quite a mistake to begin with an unknown and minute object like the yeast plant: not only is the *Saccharomyces* plant a strange object, but the student obtains no adequate notions of its size or properties. He advocated less section-cutting and less work with the compound microscope, and more observation with the simple lens, at any rate until the student is familiar with common objects.

Prof. Hartog differed from previous speakers in thinking it a mistake to be afraid to teach children technical terms, and pointed out that children take very readily to hard names, and are very proud of having acquired them. He also differed entirely from those who advocate that the fern is a good type to begin with: the fern is a difficult type, abnormal in its phloem, its stomata, and other respects, and should be avoided for some time. He thought it much better to select the various tissues and elements from the first, and then pass on to the study of types.

Prof. Hillhouse agreed with Prof. Marshall Ward that technical terms should be introduced carefully and not too early, and considered that botany has suffered in the past from being regarded as associated with hard words. He also advocated that botany affords the best means for introducing students to the use of the microscope.

Prof. Geddes has often found that schools are detrimental to the observing powers of children, and that the real way to interest the pupils is to let them make discoveries for themselves. He advocated the establishment of a botanical garden for every school, and pointed out that very useful notions of geometry can be taught from flowers. Prof. Geddes objected to the type-system for children, and urged that the life of the plant, and not its destruction, should be the aim of teaching. He would interest students in such subjects as insectivorous plants, and so infuse general interest into their studies.

Prof. Johnson remarked that at South Kensington, the home of the type-system, they have for some years past tried varying the order of teaching the several types, and have found that it is best to work down from the higher to the lower plants.

Prof. Marshall Ward having briefly replied, the discussion was then closed by the President.

THE PRESENT POSITION OF THE HYDRATE THEORY OF SOLUTION.[1]

IT is but four years since this Section devoted a day to the discussion of the nature of solution;[2] since then, however, the general aspect of the question and the position of the advocates of the two rival theories have undergone such a complete change, that in renewing the discussion we shall run but little risk of going over the same ground which we then trod. At Birmingham, Dr. Tilden opened the discussion by passing in review all the well-known and long-known facts which might by any possibility throw some light on the nature of solution, and those who followed him in the discussion each gave the interpretation of these facts which harmonized best with his own views, and, as the facts themselves were susceptible of several different interpretations, the not surprising result followed that

[1] Paper read before Section B, at the Leeds meeting of the British Association, as an introduction to a discussion on the nature of solutions and the theory of osmotic pressure.

[2] B. A. Report, 1886, p. 444.