and energies of a supervisor. It seems, therefore, probable in the light of our experiences, that some territory intermediate in extent between these two would be best for purposes of supervision of the schools and of the instruction. It may be that a representative district, in most cases, would be as near to the right size as any of the divisions existing in the State. This suggestion is made on the supposition that the work of supervision within given limits can be most efficiently done by one person. For, while I think, on the whole, that examination should be made by a board, I think also that supervision is best done by one individual.

The general examining board should probably have some power to supervise, to some extent, the supervision, so as to make the whole work, as far as possible, uniform within their district.

While the State department should have, of course, a general directing authority over the various examining boards, so as to make the school work of the entire State reasonably uniform and harmonious. Time does not permit me to inquire now as to the election or appointment of these officers.

Relation of the Superintendent of Public Instruction to the State Educational Institutions.

W. H. Payne said:

By some species of legislation the sphere of the Superintendent's active power should be considerably extended. Through the Normal School and the Institute he may now have a more or less direct influence on the education given by the State; but these cases excepted, he is limited to the giving of good advice. The State Superintendent is the nominal head of our educational system; below him there is an army of subordinates, charged with the duty of examining teachers and supervising schools. Yet, by a strange anomaly, these subordinates are released from all direct control by their superior. The Superintendent should be much more than a clerk, and much less than an autocrat. And it would not seem to be a very difficult feat of legislation to give our educational department a degree of centralization that would make it tolerably efficient, and at the same time allow the subordinate members of the system an ample field for the exercise of their versatility and individuality.

THE NEW BOTANY.

BY W. J. BEAL.

Before fully considering the new botany, let us glance at the old. Aristotle, Pliny and other Greeks and Romans paid some attention to plants. So did the Arabs of the twelfth century. Still later, Grew, Tournefort, Ray, and many others studied plants and wrote about them. A little progress, and but very little, was made in classification and description.

Not until the last century, about 1735, less than 150 years ago, did botany begin to take rank as a science. This was largely due to Linnæus of Sweden, who well earned the title "Father of Botany." His efforts were largely devoted to describing and classifying plants, and were ably continued by the four Jussieus, Robert Brown, A. P. De Candolle, Lindley, Endlicher, and their contemporaries.

Except for medical students, botany hardly found a place until within the past forty years. Even in the higher educational institutions, and as late as 1850, botany was usually only considered a pleasant and proper pastime for young school girls.

As generally pursued, the study consisted mainly in learning from a book the forms and names of roots, stems, leaves, inflorescence, and the several parts of flowers and fruits. The teacher was supposed to be a dried up old fossil. He wore odd looking clothes. He taught the class from the text-book, and preferred to pursue the study in winter, that pupils might learn the names and peculiarities of plants before they appeared in the spring. There were many hard, unfamiliar names. With no specimens to illustrate the lessons and a dry teacher, most of the pupils acquired a thorough disgust for the study, long before warm weather furnished materials for illustration. It is little wonder that botany found so little favor. Some teachers went so far as to require pupils to copy the pictures on a blackboard.

In time, spring flowers appear and the pupils are supplied with them. Each may have a cheap microscope, which he is compelled to hold in one hand. The teacher and class hastily and superficially run over the various parts of a plant. They all turn to an artificial key and wade through this part of the book till the teacher says, "We have found the order to which the plant in hand belongs." They turn to the page for the order and proceed till they come to the name, which may be *Claytonia Virginica, Hepatica triloba,* or *Ranunculus fascicularis.* And what next?

"We have found the name of the plant." The pupils have merely had an introduction to the stranger in the most formal manner. The teacher can suggest nothing further for the pupil, except that it would be a good plan for each member of the class to collect specimens, press, dry them, place in a portfolio, and give each a label on which is written the Latin and common names, the habitat and time of flowering. The pupil has been taught that it is all of botany to learn the names of all the parts of a plant, or the parts which are not too small to be easily seen with a cheap hand glass. Mysteries are still unsolved and the plant is still a stranger. We ask it no questions; we receive no replies. We have only glanced at the exterior. Such is the mode of study which can no langer be palmed off as valuable training.

From 1770, to about 1800, Wolff and Goethe of Germany and A. P. De Candolle of France developed new ideas of plant morphology. Schimper, Braun, Dunal and Rœper aided in this work; but to no one are we more indebted for accurate information in regard to the difficult problems of plant structure and affinity than to Robert Brown of England. He was the most profound botanist of this or of any age. In this country, Dr. Gray has long been foremost in developing and popularizing the subject of plant morphology, which, for twelve years beginning with 1850, may be said to have been the leading idea in botany.

The year 1862 will ever be memorable as the date in which appeared the classic works of Mr. Darwin on the fertilization of Orchids. He caught the first glimpse of the subject from Sprengel, but to Darwin more than to any one else are we indebted for the light thrown on the subject of fertilization of flowers. Delpino, Ogle, Hildebrand, Bennett, Hooker, Lubbock, Kerner, Fritz

Müller and Hermann Müller and a host of others in Europe and America, aided in rapidly making new discoveries in the same direction.

In connection with this, many interesting discoveries have been made in reference to the motions of plants in climbing, catching insects, etc. Carnivorous plants have been examined and experimented upon. New modes have been discovered by which plants are distributed in various parts of the globe. From 1862 to 1875, in this country, what Gray calls "How Plants Behave," may be said to be the dominant feature in the science of botany.

In 1875 appeared the English translation of the grand text-book of Julius Sachs. In following him understandingly, one must employ a good compound microscope and considerable other apparatus. He must make many experiments to become familiar with the structure and development of cells, tissues, external conformation of plants, and their physiology. Two years later appeared the translation of another similar work by Otto W. Thomé.

Already during 1880 we have an excellent work similar to that of Sachs by an American scholar, Prof. C. E. Bessey. This is convenient in form and size and can be had at a price within the reach of students.

Original investigators keep in advance of text-books and make the materials for them. We still have all that is valuable in morphology, classification, geographical distribution and many other things, as well as all that pertains to the topics last named. The field has become too large for any but specialists. In making a selection, we should choose those topics which will afford the pupil the best training to fit him for original work.

For young pupils, object lessons are very popular for a while, but in most cases the interest soon wears away. As too often managed (I may say as usually managed), object lessons consist in short lectures with specimens in hand, with some questions plied to the pupils without time for previous study or preparation. There is too much pouring in and too little worked out by the pupil. It brings forth the combined information of all the members of a class, but it adds little or nothing by way of research. To be really appreciated, a student should earn his facts in the study of biology. What I have called

The New Botany

began to appear in this country in 1862. It includes a study of the subjects as set forth by Darwin, Sachs, and others above named in the same connection. It also includes a new or better way for students to learn the botany of our forefathers. In this we study objects before books; a few short talks are given; the pupil is directed and set to thinking, investigating, and experimenting for himself. To be constantly giving information in science makes intellectual tramps, and not trained investigators.

Teaching the new botany properly "is simply giving the thirsty a chance to drink." It also creates a thirst which the study gratifies, but never entirely satisfies. This plan, in a general way, has been again and again brought to the attention of our best teachers, some of whom are carrying it into practice. I will now enter into details as briefly as possible, and try to mark out a plan which may assist some who are always looking for the best way. Specimens are essential; a green-house or a botanic garden are useful even if they are small, but almost every neighborhood will furnish materials in abundance, which may be found in the fields, woods, and by-ways.

Before the first lesson, each pupil is furnished or told where to procure some specimen for study. If it is winter, and flowers or growing plants cannot be had, give each a branch of a tree or shrub, which may be two feet long. The examination of these is made during the usual time for preparing lessons, and not while the class is before the teacher. For the first recitation each is to tell what he has discovered. The specimens are not in sight during the recitation. In learning the lesson, books are not used; for if they are used, no books will contain a quarter of what the pupil may see for himself. If there is time, each member of the class is allowed a chance to mention any thing not named by any of the rest. The teacher may suggest a few other points for study. The pupils are not told what they can see for themselves. An effort is made to keep them working after something which they have not yet discovered. If two members disagree on any point, on the next day, after further study, they are requested to bring in all the proofs they can to sustain their different conclusions. For a second lesson the students review the first lesson—report on a branch of a tree of another species which they have studied as before. Now they notice any point of difference or of similarity. In like manner new branches are studied, and new comparisons made. For this purpose, naked branches of our species of elms, maples, ashes, oaks, basswood, beech, poplars, willows, walnut, butternut, hawthorns, cherries, and in fact any of our native or exotic trees and shrubs are suitable. A comparison of the branches of any evergreens is interesting and profitable. Discoveries, very unexpected, are almost sure to award a patient study of these objects. The teacher must not think the time is wasted. No real progress can be made, till the pupils begin to learn to see, and to learn to see they must keep trying to form the habit, from the very first, and to form the habit they should make the study of specimens the main feature in the course of training. In nearly all important cases specimens are examined, and a need is felt for a name or a definition before these are given. The use of technical names is not avoided, nor are these "thrust upon a student." They are learned as they are needed—a few at a time from the teacher or a text book. Common terms for science are usually too indefinite in meaning to answer a good purpose. The difficulty of learning technical names is often much overestimated. The discipline required to learn them is itself worth all it costs to any one.

After from four to ten lessons on small branches the following points and others, or answers to them are brought out. Is there any definite proportion of active and dormant buds in any year? Where do branches appear? Is there any agreement in growth, as to length of branch, and the size of the annular ring each year? Is there any similarity of rapid or slow growth of all the limbs on a branch in each year? Is there any certain number of leaves on a year's growth, or any definite proportion between the lengths of internodes? Can the smallest old dormant buds be made to grow? Is there any order as to what buds grow, and what remain dormant? How much, and on what years did each limb grow? There are three ways of telling the age of a branch—by the bud rings, stem rings, and color of the bark. The shape, size, color, degree of smoothness and other peculiarities of buds on any branch, and the leaf scars are made out. The arrangement and position of the buds and bud scales are learned. Is there any order in the arrangement of the specks on a branch? Do the specks change as the branch grows older, and if so, how? How many leaves each year were required to build up the branch? How large were the leaves and the amount of surface exposed for a certain branch? Did the amount of growth in any year correspond to the number of leaves on the twigs and main axis? Does the ring of wood depend on the growth of the main axis? In this connection pupils may take up phyllotaxis by the study of cones, catkins, etc., not forgetting to examine a large number of specimens of one species.

The pupils are now ready for a book lesson on buds, branches, and phyllotaxis. They will read it with interest and profit, and be able to make many additions, and very likely point out some errors in the text book. Pupils must be careful about drawing hasty conclusions. Because a plant grows or behaves in a certain way in Central Michigan, it is not always safe to conclude that it will do the same in New Jersey or California.

I have gone somewhat into detail, in this case, of the lessons with branches. In like manner, any other topic or the subject of a chapter in the book may be first taken up by the study of some specimens, as roots, seeds, fruits, stamens, petals, sepals, leaves. For beginners the following flowers, if they can be had, will be excellent: buttercup, cranesbill, trillium, berberry, flax, pink, violet, mustard, potato, sage, bergamot, lilac, cherry, apple, serviceberry, Missouri currant, snapdragon, pea, vetch, strawberry, rose, iris, the flowers of poplars, willows, maples, oaks, hazels. After a day, two, three, or more of study of the specimens pertaining to one topic, then comes the study of the book. Even with the shortest and most elementary course, a study of some of the specimens by all of the class should precede a study of the text.

I place very little stress on investigating a number of chapters in the definite order as given in a text book on botany. For example, it makes little difference whether a pupil begins with a study of petals or stamens, buds or roots, leaves or pistils, but it is quite desirable after beginning, not to abandon any one of of these topics till many of the various forms have been thoroughly studied. It is possible to classify and divide a topic till you take all the life out of it. A young man of eighteen will begin and pursue the same course as a child of ten, only he will progress faster and go deeper. Almost any of the above topics, and hosts of others are admirably well adapted for descriptive compositions. I usually give each student one or more of them each term. For the youngest students this year, the following topics will serve as examples: Compare the leaves and young branches of the Scotch pine with those of the Austrian pine; or black spruce and Norway spruce; sugar maple and red maple; butternut and black walnut; any two species of poplars. I have here on the table the compositions prepared last year by the young beginners in botany. I made no corrections in the spelling or grammar, but met each student and heard him state his main facts before writing them out.

(See American Naturalist, January, 1881.)

As students advance in morphology and systematic botany, topics for other themes are assigned, of which the following may serve as examples: He studies the living plants, and makes his notes. To him it is just the same as original research, and not unfrequently young students, in this way, make discoveries new to science. For example, he studies the arrangement and development of the parts of the flower with reference to its self-fertilization, or fertilization by insects, birds, wind, or by other means. Here are plants suitable for such study: Moth-mullein, dog-bane, sage, thyme, red clover, plantain, milk-weed, mallow, thistle, cleistogamous flowers of the violet, campanula, iris, lobelia, martynia, Indian corn, wild balsam. One studied the vines of dodder; one, the climbing of Virginia creeper; one, the twining of the wild morning-glory; one, the tendrils of the cucumber; one, unequal lobed leaves; one, the time of opening and closing of flowers; several, the development of some irregular flower; one, the order of dehiscence among anthers of a flower; one, the honey glands of some flower; some, the glands in other parts of plants than flowers; one grew beans in pots containing all sorts of soil, and with more or less light; one experimented on the germinating power of weevil-eaten peas; one, the relative order of development of stamens and pistils of many plants of Indian corn; one, for what do ants visit plants? In most cases it was necessary to give brief hints to the students to set them to work intelligently. The theses were made up from original observations and experiments, and drawings, and were read in the class room. Here they are on the table, with all the imperfections, just as they wrote them. Teachers can well make use of such topics for the pupils to write about. In some respects, topics like these are better for theses than those usually assigned, in which students must consult books for information. A study of such topics for theses is equivalent to enlarging a library.

During five-sixths of the academic year in which our students have daily lessons in botany, full three-fourths of the time is given to the study of plants in some form or other. The books serve for reference and reviews.

I have been quite particular to indicate the course pursued, because some think it is difficult. Aside from collecting specimens, which can often be entrusted to an advanced student, it is an easy way for a teacher when he knows how to proceed. But little time need be occupied with lectures; short talks of ten, fifteen, or twenty minutes are occasionally given. I have taught zoölogy and physiology in the same manner. Students are thus at once put in the way of becoming independent and reliable observers and experimenters. They are trained more than they are taught. As the New York Tribune says: "Teaching communicates ideas; training forms habit. Teaching imparts knowledge; training develops power. In teaching, the adult explains words; in training, he shows methods. Under teaching, the child hears what is said; under training, he sees what is done." And I may add, he learns to do it himself. "Training is food which gives strength to run."

In the whole course in botany I keep constantly in view how best to prepare students to acquire information for themselves with readiness and accuracy. This is a training for power and is of far more value than the mere information acquired during a course of study in natural science.

Of all the natural sciences, botany is the best for beginners. The materials are everywhere abundant and inexpensive. Many parts of plants are more interesting than minerals; less complicated and pleasanter to handle than animals.

For the benefit of young teachers, I will now give in an informal way a large number of topics which are suitable for students to investigate. A teacher can select such as he likes, not all, of course, and after using some, others will suggest themselves to him. Any text-book should suggest many topics to a teacher. In connection with these topics I will make comments or give hints as to mode of procedure.

Set pupils to raising or collecting seedlings of maples, oak, basswood, beans, peas, morning-glory, sun-flower, radishes, wheat, flax, squashes, onions. Let each study one species at all ages, then another or more and carefully compare. Most seeds can be neatly started for this purpose between folds of thick paper or cloth kept warm and damp. Boxes of clean sand are also good. To learn whether the different parts of a seedling, as radicle, ascending axis and roots elongate alike, prick with ink a row of spots at equal distances along the side and let them grow a while longer for further comparison. Grow seeds suspended over water with roots in water. In beans, peas, peanuts, cut off much or all of the cotyledons at different ages to see the result. Cut off tip of plumule to see whether buds will come in the axils of cotyledons.

Dig very carefully to trace the depth and extent of roots of clover, wheat, corn, any weed or cultivated plant in various soils, light or heavy, wet or dry.

The structure of the seeds may well be studied and compared in connection with their germination in any young plants. To the above seeds, I will add seeds of catalpa, trumpet-creeper, milk-weed, apple, violet, cockle, wheat, oats, barley, chess. See carefully where the smallest roots come from in corn and in squash or pumpkin, bean or pea. It is a good plan for a beginner to repeat some simple experiment which he finds described in some book. Let one or more compare the runners of strawberries of many varieties, potentillas, buttercup, beef-steak saxifrage, and any other plant which has runners. Work out the morphology of the tendrils of grape-vines, Virginia creeper, smilax, cucumber, pea, etc. Work out the morphology of spines of various sorts by hunting up intervening forms. Compare the diverse forms of stipules in prickly ash, locust, dock, sorrel, clover, tulip tree, beech, oak, and trace the stipules from very small rudiments to maturity. Observe the position of flowers in the bud while open and when dead; also the position of the fruit, as peas, violets, columbine, etc. Compare two or more rhizomas, as Solomon's seal, iris, blood-root, sweet flag, quack grass or June grass. Compare the tubers of artichokes and potatoes; the bulbs of a lily and onion; the chips of any two kinds of wood, or sections of wood made in different directions, as any oak, ash, beech, maple, pine. Collect and press sets of leaves, arrange and paste on to cards. Give each a name and name the shape. Study and draw many kinds of leaf scars. Study the development of some leaf from a very small rudiment to perfection, as pea, ash, basswood. Study leaves of arbor vitæ, pines, spruces, larches. In spring clip off the ends of young branches of pines and see how and where buds develop during summer; the same with peach, beech, maple, poplars. With the aid of a stage microscope, study and draw the position of scales and leaves in a bud, as cherry, violet, basswood, etc.; also the buds of flowers, as mustard, spiræa, asclepias, evening primrose, fuchsia, baswood, oxalis, phlox, violet, lobelia. Do not forget to notice the tip of the bud before opening. Examine a large number of specimens and make drawings of a cross section of each distinct mode or form. Let a young pupil study all the parts of a head of flowers of dandelion, aster, or coreopsis; also double flowers of roses, fuchsias, petunias, geraniums, flowering almond. Compare the fruit of a strawberry with a rose hip and a geranium; the anthers of some two species of compositæ, lobelia, mallow, obutilon, lupine, berberry, spice bush, sassafras, huckleberry, squash, sage, lily, grass, violet, tulip, spring beauty, buttercup, milkweed. Compare the pistils or fruits of some two of the following: mandrake, cowslip, columbine, cherry, bloodroot, trillium, flax, portulacca, iris, melon, pea, bean, maple, ash, elm, acorn, horse chestnut, plum, apple, cranberry, huckleberry, gooseberry, currant, raspberry, blackberry, fig, wintergreen, mulberry. Try to trace out the morphology of each.

From spring and during summer examine every few days to see how the bulb of adder-tongues is formed. Grow young roots on clear glass to see if they corode the surface. Carefully pull or take up stools of wheat or chess or oats to find, after washing, the kernel from which the stool grew.

Remove stamens before the buds open, and by protection for a day or two get ready and cross-fertilize or hybridize two sorts of strawberries, raspberries, gooseberries, currants, apples, wheat, corn, etc.

The Fertilization of Flowers.

Remarks on this topic have already appeared on the previous pages, with some subjects for study. Most botanists believe, whether it is true or not, that honey is placed in flowers to attract insects which are needed to fertilize them. Flowers are the advertisements to draw insects. Honey is the wages received and compensates insects for their visits. "The lines and circles on the corolla guide them to the right spot. To them we owe the beauty of our gardens, the sweetness of our fields. To them flowers are indebted for their scent and color, nay, for their very existence, in its present form."—[Lubbock.] No topics are more attractive to the young student than some under this heading. Watch insects on the flowers of melons or pumpkins to see how they behave and transfer the pollen. Tie up or cover the pistillate flowers to see if fruit will form without pollen on the stigma. Cut the petals from some flowers to see if bees or other insects can find them readily. In many cases, a crossing of flowers has been found necessary for the production of seeds; in most, it is very beneficial. Try it and see. Try a flower with its own pollen and another with pollen of another flower. For experiment and observation our native plants are the best if we study them with reference to our native insects.

The wind aids in the transfer of pollen in some cases. Study pines, spruces, larches, birches, oaks, hazels, hickories, grasses. Are these flowers showy, or do they secrete honey? Always notice the condition of the pollen, whether dry, in grains, strings, etc. What parts of a flower secrete honey? See pæony, buttercups, hellebore, pulsatilla, caltha, pointsettia, and others. Observe stigmas after pollen has been applied and where none has been applied. What do insects gather, nectar, pollen, or both of these? Observe time of day when certain flowers open and close, and see whether they open more than once. See the dandelion, white water lily, evening primrose, oxalis. What insects visit each flower? Study flowers of willows, poplars, and see what attracts insects. In every case, observe whether the stamens and pistils are ready for each other on any flower at the same time, or whether one set of these organs precedes the other. With this hint study epilobium, angustifolium, thyme, lobelia, compositæ, companula, mallow, amorpha, scrophularia, plantago, pink, geranium. In some violets and oxalis look late in the season for flowers without petals above ground and below ground. Examine carefully for pollen, seeds, etc. Look in flowers of the closed gentian for bumble bees. Any flowers of the mint family are excellent for study in relation to fertilization by insects. What insects visit flowers of the umbeliferæ, as parsnips, carrots, and the like, and how do they behave?

Some species are dimorphous. They have plants, different specimens of which have different forms of flowers. Some have two forms of flowers, so far as their stamens and pistils are concerned. In some cases it has been found that the long stamens are best to fertilize the long pistils, the short stamens to fertilize the short pistils. Try this on primula, mitchella, houstonia, bouvardia, polyanthus, auricula, and look elsewhere for flowers with the same peculiarity. A few are trimorphous. See Lythrum salicaria and Pontederia cordata. Hunt for others. Experiment by crossing a pistil with pollen from stamens of different lengths.

In geranium pratense there are two sets of stamens. They advance and retire from the stigmas at certain times. See Tropæolum, and also whether this is true of any other flowers. Valisneria spiralis and anacharis grow in the water. In a still place look for pollen below water in the flowers and the stigma at the surface. Study up the whole subject.

Study the structure and modes of fertilization of all the species to be found of any large or small genius, as viola, rosa, spiræa, epilobium, lobelia, ranunculus, aquilegia, berberry.

See and study the sensitive stamens of the berberry. See whether the weather or time of day affects the supply of honey in any flower. In shade or damp air honey may appear when not seen in dry air or in the sun. Study the changes which take place in the development of different parts of a flower with reference to its fertilization by insects or otherwise. Changes sometimes occur in a very short time. Quickly brush the stamens of portulacca to see them move in the opposite direction. Try to find other flowers which will behave in like manner. See where and how an insect alights on a flower, how it gets in and gets out, and where it begins and leaves off on a cluster of flowers, as peas, amorpha, mullein, veronica virginica. How does pollen get out of flowers of compositæ, lobelia, etc.? Are the stigmas of a head or spike all ready at once? Is the pollen all ready at once? See also dipsacus and scabiosa. Is nodding any benefit to flowers? Look for appendages to anthers and inside of corolla, and study their use. Where are the holes in an anther when at rest and when visited by insects? See many ericaceæ, as vaccinium and kalmia. Study sensitive stigmas to see how they can be of any use in aiding a cross. See utricularia, pinguicula, catalpa, martynia, tecoma, begonia, mimulus.

Do any insects gnaw into flowers? See bumble bees in pedicularis and flowers of labiateæ. Orioles sometimes pinch flowers of Missouri currant for honey. Do any flowers catch and hold or otherwise torture insects, and is it in any way an advantage to either? See asclepias, apocynum, drosera, martynia, vinca, cirsium, oltissimum, nemophila. Study carefully the date and length of time of flowering of timothy, June grass, Indian corn, or other plants. Besides those named, the flowers of the following are also excellent for study with reference to the agency of insects or birds in fertilization, viz.: nymphæa, nuphar, sarracenia, poppy, polygala, silene, chickweeds, hypericum, flax, basswood; all cruciferæ, mignonette, euonymus; all rosaceæ, as apple, pear, quince, plum, cherry, strawberry, spirœa; also œnethera, ribes, parnassia, rhus, acer, staphylea, aesculus, cornus sambucus, lonicera, cephalanthus, vibernum, galium, campanula, convolvulus, pulmonaria, ipomæa, scrophularia, snap dragon, linaria, fox glove, and all other scrophulariaceæ. All leguminosæ are excellent; all verbenas, phlox, physalis, petunia, datura, buckwheat, hydrophyllum, sassafras, benzoin, gladiolus, iris, smilax, lily, tradescantia.

Through a season look for humming birds on flowers; make inquiries of others, and keep a list of such plants. See especially fuchsia, impatiens fulfa, trumpet creeper. Examine the flowers and the birds for small insects, pollen and honey.

The Unwelcome Guests of Flowers.

There are many truly wonderful contrivances in flowers by which a cross is secured. Certain insects are not only welcome but allured to make visits. Other insects which from any cause can be of no advantage in fertilizing plants are often kept away by various means. Dr. A. Kerner of Innsbruck has written a very suggestive book on "Flowers and their unbidden guests." This has been translated into English by W. Ogle. He has in many cases observed the presence of differently directed hairs and viscid glands which prevent the access of certain insects and not of others. He took the hint for all of his book from a single suggestion of Erasmus Darwin, and perhaps also from Mr. Belt. Many of our native plants have never yet been studied in reference to this part of the subject. The closed gentian admits the bumble bee, which can benefit it, but keeps out ants and many others which would be of no advantage. Pedicularis keeps unwelcome insects away by a narrow corolla, by hairs and awns on the stamens. Small snails and slugs are often kept away by bristles on the plant or flower. Experiments could be made by removing hairs in some place and placing a snail on the plants. A few snails could be placed inside a Wardian case and certain plants in flower introduced. Aphides or plant lice may be studied in this connection. They like sweet. Do they get it from flowers?

Of all wingless insects, ants are perhaps the most active and the fondest of sweet; yet they seldom get much honey from flowers. Look over many kinds of plants and watch the manœuvers of ants to see where they go, what they do and why they go no further. Remove some nectar from flowers and place near ants; take away some obstructions and watch the ants. See if ants can enter some wilted or old flowers, as snap dragon. Prop open fresh flowers of snap dragon and watch for ants. Thrips are small, slim, active insects which cannot fly. Watch them about flowers, as in compositæ.

Large animals avoid some plants on account of an unpleasant taste, leathery foliage, prickles, or thorns. Do cattle eat the fresh flowers of plants the leaves of which they are fond? Will they eat flowers dried, as in hay?

See isolated plants in water; make a bridge to them for lice or ants. See dipsacus lacinatus and silphium perfoliatum, with water in the axiles of the connate leaves, which serves to keep unwelcome insects from the flower; also a cluster of flowers arising from water held in the leaves of many bromeliaceæ. See if dew keeps any insects away, or if some flowers are open only when the dew is on? Study polygonum amphibium grown in water and out of water to see if all have protecting hairs alike. Study viscid gum to learn the use on buds of populus, alnus, betula, iuglans, æsculus. Study robina viscosa or any others with viscid glands.

Kerner holds "that the position, direction, and shape of the leaf is of just as great significance for the preservation of a species, as form, color, and smell of the flower; and that no hair is meaningless, whether found on the cotyledon on the leaf, on the stem, or the blossom; that it is rare that any part of a plant is so shaped as to be suitable for the attainment of but one end. Usually 'two birds are hit with one stone;' nay, often three or more." See the viscid secretion on the internodes of lychnis viscosa. What insects are caught? Place bridges over for ants. Look for glands or nectar on the leaves or petioles of pteris aquilina, ricinus, gossypium, poinsettia, helianthus, viburum opulus, cow pea, acacia, vicia sativa, runus, cassia, the fruit of tecoma radicans.

For viscid glands or hairs see thistles, mulleins, geranium, ribes, circæa, eryngium, calyx of labiateæ, scrophulariaceæ, phlox, verbenas, mallows, physalis, menyanthus, vinca, tropoeolum. Force ants or other insects to crawl up a panicle of flowers of asclepias and lettuce and see the milk exude; also hieracium, nabalus, and sonchus. On the inside of flowers see how far it is true that hairs, etc., act as path-finders to welcome insects. What parts of flowers produce the hairs?

In some cases access to flowers is impeded by parts of the plant or flower being bent, dilated, or crowded together. In this connection study linaria, cynoglossum, antirrhinum, solanum, ericacæ, campanula, cactaceæ, potentilla, geum, œnethera, aconitum labiateæ, calceolaria, convolvulus, cruciferæ, scrophulariaceæ, many leguminosæ.

Carnivorous Plants.

Some plants have been found to be carnivorous or insectivorous, as drosera, dionæa, pinguicula, martynia, and perhaps pelargonium, primula, tomato, tobacco, petunia, verbena, several pitcher plants, the small bladders of utricularias. Verify any of the above suggestions by experiment. Irritate tentacles on the leaves of drosera, dionæa. Apply to any of the above, water, sand, meat, milk, acid, salt, ammonia, chloroform, starch, sugar, etc. Apply heat and cold.

Motions of Plants.

All plants move more or less, while parts of some move quite rapidly. The leaves of leersia in a warm day close up quite rapidly if stroked between the thumb and finger. The stamens of portulacca move when brushed suddenly. Observe the details of movements and repeat the jarring of the sensitive plants (*Mimosa pudica*). Observe the position of the leaves of any other plants day and night, as in tripolium, melilotus, oxalis, robinia, cassia, desmodium. See if these can be made to recognize artificial light and darkness. Turn some plant occasionally in front of a window and note carefully the results. Make drawings.

Climbing by Roots.

Carefully study the climbing by roots of English ivy, poison ivy, trumpet creeper, etc. Where do roots first appear on a young stem? Experiment with small mirrors placed in different positions about the stems. Look for liquid or mucilage on roots. Let them stick to glass to see if it is coroded. See how some plants are held up by hooks or bending of the stem or leaf, as tomato, some species of galium, polygonum, rubus, leersia, rose.

A good twiner is said to always turn one way only. Look at many specimens for exceptions. In a twiner observe the twist of stem and where it twists, at what age or part. See what the stem does when it arrives at the top of a straight stick, and stick inclined at various angles. Observe the revolutions at different times of day, warm and cold. Make diagrams of movements. What does it do when it hits an object? How far does it reach? How many internodes are active in the movements? Try to reverse the motion. Wind up a part while young and study the rest. Study some one certain internode from the time it is very small till fully grown. Unwind a twiner to some extent and study. See if an old stem is uniformly twisted when the stake is straight and when inclined. Study the shape of the young tips of a vine. Take the support out of a coil to see what it will do. See how large a smooth stick a vine can climb. Make a cross section of the stem. Examples of plants are tomato, hop, honeysuckle, morning-glory, bindweed, beans, wax-plant, wistaria, celastrus, aristolochia, lygodium, menispermum, apios, jasmine, solanum dulcamara. In case of

Leaf Climbers,

see how they climb, what part of the leaf moves and clings. Do the leaves move so as to be seen? Experiment on small and large sticks. Make diagrams of cross section of the petiole of a leaf. Observe the changes in any part of a leaf after it sets. Examples of leaf climbers are clematis, tropœolum, solanum jasminoides, tomato, nepenthes, cobæa, pea, vetch, fumaria, adlumia. In case of

TENDRIL CLIMBERS,

trace out the morphology of the tendril, whether it is a flower cluster or a real stem axis. Irritate in some way a tendril and study the result. Observe the shape of a tendril when young, its length, size, how long before it coils if it reaches nothing, how fast it coils if it reaches an object. What does the end do? If a tendril begins to coil back of the top, how does it perform? Observe the coils of many tendrils and draw them after they have coiled. What is the advantage of such coils? How much weight will a *set* tendril hold? Do tendrils in shade and damp air secrete a gum? Why do not tendrils coil on their own main stem from which they branch? The latter alone is worth much observation. Observe the tendrils of a squash vine after it has spread out on the ground. Tear it loose and see what happens. In case of Virginia creeper, use bits of glass to see if a tendril can stick. Look for a gum. How long will it remain sticky? What becomes of a tendril if it catches hold, or if not? How many branches has each sort of tendril? How do young and old tendrils of smilax behave? Irritate a young tendril of a squash or wild cucumber in a warm part of a warm day and see if it moves. Wait and repeat several times. Observe any other points. Examples of plants are bignonia, wild cucumber, melons, squash, pumpkin, grape, Virginia creeper, passion flower, mikania, smilax.

HOW NATURE SOWS SEEDS.

If grains with awns in the chaff can be had of any species of stipa, aira, trisetum, danthonia, avena, andropogon, sorghum, alternately moisten and dry them and watch the motions. Erodium (found in California) is also excellent. In a dish of loose sand stick in close together a lot of straws to imitate stubble; place the seeds on the surface; alternately wet and dry them. Erodium, stipa, and avena hirsuta, and perhaps others may work into the sand, *i. e.*, bury themselves.

SEED DISTRIBUTION.

Make notes of any cases of distribution of seeds or fruits actually seen. Some examples are given for study: impatiens, brasenia, seeds of pines, spruces, tulip tree, maples, ashes, elms, thistles, dandelions, basswood, birch; those with hooks, as bidens, burdock, coreopsis; seeds of tecoma, catalpa, desmodium, echinospermum, cynoglossum, geum, circæa, clematis. See how fleshy fruits distribute seeds by aid of animals which eat them, as seeds of apples, hawthorns, cherries, haws, cranberries, blackberries, raspberries, huckleberries, strawberries, gooseberries, currants. See how nuts are carried, as acorns, walnuts, butternuts, hickorynuts, hazelnuts, beechnuts. Watch some fruit of witch hazel as it is dried near a stove to hasten drying; also pods of the pea, bean, wistaria, geranium, violet, oxalis, etc. Observe seeds of milkweed, poplar, willow.

In studying up any topic great stress should be placed on good drawings. Count all the parts. Examine many specimens. Examine young and old as well as mature specimens. Observe the relative size of the parts. Observe the relative order of parts. Make many comparisons of specimens of the same species with those of kindred species.

For further topics and suggestions a teacher can consult any of the following works:

How Plants Behave—A. Gray.

Concerning a Few Common Plants—George L. Goodale.
British Wild Flowers in Relation to Insects—Sir John Lubbock.
Climbing Plants—Charles Darwin.
Insectivorous Plants—Charles Darwin.
Nectar, Its Nature, Occurrence, and Uses—Wm. Trelease.
Flower Object Lessons—M. Emm. Le Maout.
On the Mode of Distribution of Plants—Albert N. Prentiss.
Flowers and their Unbidden Guests—A. Kerner, translated by W. Ogle,
Numerous articles and notes in the American Naturalist, and the American Journal of Science and Arts.

To enter into details in reference to the method of learning morphological and physiological botany as treated in the text-book of Julius Sachs would carry me much beyond the limits of this essay. For such work each student needs a good compound microscope, with some other apparatus. My favorite method is to require each pupil to study all the parts, or all that his time will permit, of some one plant, to make accurate drawings and notes. A good plant for this purpose is the common pumpkin. If there is time after this course, let the pupil work up some one topic, investigating the corresponding part of many plants as the stomata, trichomes, spiral or reticulated vessels, starch, crystals, nucleus, streaming motions of protoplasm, grains of pollen, seive tubes, glands, fibro-vascular bundles, tips of roots.

GENERAL DISCUSSION.

To What Extent do the Strictures of Charles Francis Adams* Apply to Michigan Superintendents?

W. H. Payne said:

Mr. Adams's remarkable article in a late number of Harper's Magazine is inspired by Mr. Walton's report on the condition of the schools in Norfolk county, Mass., or rather on a review of this report in the Chicago Times. Mr. Walton makes it appear that these particular schools are shockingly bad, and Mr. Adams not only attributes their extreme badness to incompetent supervision, but on the *ab uno disce omnes* principle he makes the schools of Norfolk county the type of American public schools in general, and then proceeds to discuss school supervision as it has been, as it is, and as it ought to be.

Mr. Adams's style of wholesale denunciation is deserving of attention. He characterizes the country school of the past as "the beastly old common school," and he speaks of the modern graded schools as "huge mechanical, educational machines," and describes the modern superintendent as sitting "in his central office with the time table, which he calls a programme, before him, by which one hour twice a week is allotted to this study, and half an hour three times a week to that," etc., etc. That in the past there may have been some country schools that were "beastly," is possibly true, and that there are to-day some graded schools that "are organized, as nearly as possible, as a combination of the cotton-mill and the railroad with the model state prison," is also possibly true, but to insinuate, as Mr. Adams does, that these descriptions are anything more than very gross caricatures, is a libel.

* See Harper's Monthly for November, 1880.