(1) The shore plants, as some species of *Eleocharis*.

(2) Aquatic with emersed leaves (or culms) as *Scirpus lacustris*, spatterdock, water lilies and pontederia, also many *potamogetons*.

(3) Short stemmed aquatics; species near shore as *Naias* and species of *Chara* and *Nitella*.

(4) Long stemmed aquatics, in deep water, as various *Potamogetons*, *Ceratophyllum* and *Myriophyllum*.

(5) Beyond these Phanerogams, and intermixed with them, are the Algae.

The lake disseminates such winged seeds as those of elm and maple, and sows them on the beach.

Various water plants, as *Scirpus* and species of *Potamogeton*, protect the shore from waves. They also serve as points for the attachment of various organisms.

D. The Plant Ecology of Winona Lake.

Lucy Youse.

In the following discussion of plant societies and their distribution about Winona Lake, Warming's system of classification of plant societies will be used. This system of classification, now in general use by botanists, groups plants, except in the case of salt plants, on the basis of their relation to moisture. He distinguishes the following types: Xerophytes, those requiring least moisture; hydrophytes, those requiring most; mesophytes, those of medium moisture conditions; and halophytes, plants of alkaline soil or salt water.

Many things besides climate help to determine the amount of moisture. The quality of the soil has a marked influence upon the water content; clay, for instance, holds water and sand does not. Of all such factors, the topography of the country, since it plays so important a part in determining not only the drainage and the humus content of the soil, but also exposure to the wind, to light and to heat, is held by some to be more important even than surface geology in its influence upon the character of the vegetation. Dr. Henry C. Cowles, in his report upon the plant societies of Chicago and vicinity, has shown this influence to be secondary to that of topography. In his discussion of the same he says: "The flora of a youthful topography in limestone, so far as the author has observed, more

closely resembles the flora of a similar stage in sandstone than a young limestone topography resembles an old limestone topography. A limestone ravine resembles a sandstone ravine far more than a limestone ravine resembles an exposed limestone bluff, or a sandstone ravine resembles an exposed sandstone bluff. We may make the above statements in another form. Rock as such or even the soil which comes from it, is of less importance in determining vegetation than are the aerial conditions, especially exposure. And it is the stage reached by the evolution of the topography which determines the exposure."

Much might be said on this subject of the chemistry versus the physics of the soil. It is discussed by both Schimper and Warming, and even the latter says that the chemistry of the soil best accounts for the halophytes. In making observations and recording experiments both sides of the question must be kept in mind if our conclusions are to be accurate.

The soil, or edaphic influence is local, and is in direct contrast to that of climate which is widespread. To the latter are due our pineries of the north and also our own growth of deciduous trees. Beech-maple-hemlock forests, the climax type, toward which, it may be said, everything is tending, are climatic. Oak societies, on the other hand, are a predominant but not permanent feature of Winona Lake, and the conifers of the Atlantic coast are edaphic, being due to soil or local atmospheric conditions. The first plant societies of a region are the result of extreme or pronounced local conditions and are edaphic. Less pronounced conditions gradually obtain and we have climatic types. And even then the types are not permanent, for we have climatic changes. The earth is perhaps gradually growing colder and a period of glaciation may be approaching. Beech fossils in Sweden show the former existence of beech forests in a region which is now too cold for their growth.

It is the purpose of the author to indicate some of the changes which are now taking place in the region under discussion and to show how edaphic are giving way to climatic influences as the territory develops from youth to maturity.

Crustal movements and erosion, with its consequent deposition, must be taken into account. By erosion we have the constant wearing away of hills, which is retarded in no small degree by the vegetation growing upon them and the deposit at a lower level of the material carried away. By this process, which is hastened by the decay of plants, in swamp and lake, xerophytic hills and hydrophytic lowlands both become more meso-

phytic and a planation called base level is approached. This planation is interfered with by crustal movements. If the movement be upward, the mesophytic development of hills is retarded while that of the swamp is hastened. A downward movement, on the other hand, would hasten the mesophytic development of upland and retard that of the lowland. From this, it will be seen that the ultimate tendency, at least in this climate, is toward the mesophytic condition. Whether the change is slow or rapid is determined by the locality in which it occurs. A granite hill develops much more slowly than a morainic region like that about Winona Lake.

Here we have the "knob and kettle hole" lake and swamp of the terminal moraine. The soil is that attendant upon such a region, a mixture of sand, gravel and clay, with here and there a predominance of sand or clay, the whole being varied by stretches of the muck of the swamp and the sand of the beach.

There are probably three main types of vegetation—the hydrophytic or semi-hydrophytic societies of lake and swamp, the xerophytic or semi-xerophytic of the morainic uplands, and the mesophytic along the streams. In reality we have various combinations of these types and the different plant societies are not limited to the respective topographic forms as indicated, since the region shows marked evidence of development toward the climax type.

1. The Lake.—There are all gradations in the "kettle hole" in the immediate vicinity of Lake Winona, from the lake itself to the various undrained and half-drained swamps scattered here and there about the margin of the lake and representing old ponds which have gradually become filled up by the encroachment of vegetation upon them.

Where the vegetation in the lake is most luxuriant, we find, in the outermost zone, Nymphaea odorata and Nuphar advena (the white and yellow water lilies); next, Pontederia cordata (pickerel weed), and nearer the shore the bulrushes (Scirpus lacustris and Scirpus pungens). A number of species of Potamogetons are found among all of these, in some places reaching far out into the lake. At the mouth of Cherry Creek Potamogeton fluitans predominates, with Potamogentons pectinatus, Potamogeton zosteraefolius and one or two other species nearby, together with Hydrophyllum (water milfoil) and Ceratophyllum (hornwort). In this society Chara has a place by no means unimportant. It is especially prominent in the northwest arm of the lake, which, in its luxuriant growth

of vegetation, beautifully illustrates the ultimate fate of the entire body of water. The outlet, which flow from this arm at its southern end, has become so thoroughly choked up with vegetation at its beginning that the water has grown almost stagnant and the lake flora is gradually working its way up the stream. Fig. 1 shows part of this arm in the left foreground and the lilies at the entrance to the outlet. With the exception of this arm the lake vegetation is most luxuriant near the southwest shore.

Fig. 1. View across the lake to the east. The general basin form is distinguished. The highlands can be seen in the background. Tongues of land are seen being reclaimed from the lake bottom. On the right is the outlet to the Tippecanoe. Zones of white and yellow water lilies in the foreground, followed by cat-tails and sedges. Zones of willows, Carolina rose and osier dogwood are in the center, while to the right is an oak and hickory forest. On the left is a swamp meadow.

This is perhaps explained by the fact that the winds in this region are from the southwest. The greatest wash of the waves is toward the east and northeast, and here, as we might expect, we find the greatest dearth of plants and plant growth. This southwest beach is overlaid with muck, a natural result of the decay of plants along its margin.

At some places around the lake, notably in the same arm, the bulrushes are followed by the cat-tails (Typha latifolia) with sedges and grasses on the shore beyond. This is shown in Fig. 1, at the left. On

the south shore, however, where the land is raised by an ice beach, the lake is bordered by the button bush (Cephalanthus occidentalis), osier dogwood (Cornus stolonifera), Rosa Carolina, Cottonwood (Populus monilifera) and willow. A region similar in vegetation is shown in Fig. 2. This succession of societies is carried a step further on the west shore of the lake southwest of Yarnelle's landing. In addition to the foregoing are swamp white oak (Quercus bicolor), silver maple (Acer dasycarpum),

Fig. 2. View across lake from Yarnelle's landing. The basin effect is more apparent here. The transition in vegetative types is very rapid at this point, owing to the somewhat abrupt rise in the topography. It quickly passes from hydrophytic through the marsh stage to mesophytic. On the shore, zones of the button bush and osier dogwood are followed by those of Carolina rose, willow and, lastly, elm. The coming of this tree means permanent conditions looking to the mesophytic types.

and sycamore (Platanus occidentalis). The land adjoining this on the west, which is slightly elevated and better drained, and which might show a still higher stage of development, has been cleared and cultivated. So we must look toward the south where the hand of man has not interfered with the work of nature. Here, as we might expect, in the same relation as to position, that is a step further from the lake, higher, drier, and well drained, we find the hazel (Corylus Americana), the grape, Mayapple (Podophyllum peltatum), Catnip (Nepeta Cataria), Smilacina

racemosa, and the Elder (Sambucus Canadensis). This mesophytic strip forms a zone of tension between the more nearly hydrophytic beach and the semi-xerophytic hill adjoining on the west. At Yarnelle's landing, north of the dredge, where the land rises quite suddenly from the water's edge, joining the hills a short distance beyond, there are comparatively few willows. The sycamores and cottonwoods of the shore are accompanied by the aspens (Populus tremuloides), the elm (Ulmus Americana), black haw (Viburnum prunifolium), the hickory and Sassafras officinale. Closely adjoining are the mayapple, grape, red bud (Cercis Canadensis), and prickly ash (Xanthoxylum Americanum). This evolution of plant societies on the lake shore is perhaps shown even more beautifully in the vegetation of the two long points of land projecting out into the northwest arm. These are shown at the left in Fig. 1, the one in the foreground showing the more advanced stage.

2. The Swamp.—The encroachment of vegetation upon the lake, with its death and decay, makes the water shallower and finally unfits it for the plants themselves. This filling up process is aided by the deposition of material carried in by the streams that feed its waters, and ultimately we have a swamp taking the place of the lake. These may be found in various stages of construction and destruction in the region about Winona which was at one time itself a part of the lake.

One of the youngest of these, near the east shore of the lake and bordering upon Cherry Creek, has its surface covered with duckweed (Lemna, Spirodela and Wolffia) with arrowhead and yellow water lilies near the shore in some places, followed by grasses, the Iris (Versicolor) and sedges (Carex vulpinoidea and Carex lupulina). Surrounding these are the button bush, osier dogwood, willows, swamp white oak and elm and the fern (Aspidium thelypteris). In some places where the swamp is becoming filled up, a dense growth of Polygonum is found in the center.

At many places about the lake is the swamp meadow, a wide stretch of flat land with rich muck soil. One of the most interesting of these lies just north of the lake. Here are grasses, sedges, Salix amygdaloides, the shield fern (Aspidium thelypteris), Potentilla fruticosa (shrubby cinquefoil), Eupatorium purpureum, osier dogwood, Carolina rose, Joe-Pye-Weed, Solidago lanceolata, Campanula aparinoides (marsh bellflower), Lycopus lucidus (water horehound), Asclepias incarnata (swamp milkweed), Pycnanthemum lanceolatum (mountain mint), Boehmeria cylindrica (false nettle), Betula pumila (low birch), Steironema longifolium, Osmunda regalis,

Convolvulus arvensis (bindweed), Apocynum androsaemifolium (spreading dogbane), Verbena urticaefolia (white verbena), Rudbeckia hirta (cone flower), and Lythrum alatum (loosestrife), together with the following mesophytic pioneers: Eupatorium perfoliatum (boneset), Pilea pumila (rich weed), and Impatiens.

At places where the swamp is better drained its ultimate tendency is indicated, notably at a point about a quarter of a mile south of the southeast corner of the lake. We see here black oaks (Quercus coccinea tinc-

Fig. 3. View showing rich mesophytic meadow reclaimed from the lake bottom. This area is rapidly becoming more mesophytic and the remaining hydrophytic plants are dying out. In the background, on the morainic upland, is seen an oak-hickory forest, with the white oaks at the base and black oaks on slope. It is probable that the meadow has never been forested.

toria), white oaks (Quercus alba), silver maple (Acer dasycarpum), sycamore (Platanus occidentalis), walnut (Juglans nigra), hickory, poison ivy (Rhus Toxicodendron), richweed (Pilea pumila), Indian turnip (Arisaema triphyllum), May-apple (Podophyllum peltatum), Viola palmata, Viola pubescens. These patches of mesophytic woods are sometimes found in the very center of the swamp at places where the land is somewhat higher. The soil contains a larger amount of moisture than

that of the mesophytic woods on the lake shore spoken of above, and the vegetation represents a higher type of mesophytic society.

In the evolution of the swamp of Turkey Lake, the first vegetation is of water plants. These are followed by bulrushes or sedges, and next come shrubs and trees, in some cases those noted above, but in others Cassandra calyculata which is followed by the tamarack (Larix Americana). These swamps are destined to become forests, while in the case of the lake like Lake Calumet, near Chicago, Ill., the destiny of which

Fig. 4. View of a portion of the beach in Cherry Creek Embayment. The slope is gentle, rising from the low channel of the creek on the right to over 20 feet on the left. The soil is very boggy and most of the bogs are associated with mineral springs. Rows of willows in the right center, with sycamores and oaks on left. The rich nature of the soil is apparent in the heavy herbaceous vegetation. Semi-fossilized bivalve shells were found here.

is the prairie, the bulrush stage is followed by grasses. It is suggested by Dr. Cowles that this difference in the ultimate development of the swamp may be due to the depth of the kettle and consequently the depth of the muck, the forest type being found by him to have originated from deep kettles and the prairie type from shallow ones. The muck in the swamps spoken of above is deep and their destiny is evidently forest, as has been pointed out, but there is very little evidence of the Cassandra and the Tamarack stages. There are a few tamarack swamps in the

vicinity of Lake Winona containing some of the plants typical of the tamarack stage, such as the pitcher plant (Sarracenia purpurea), and the peat moss, Sphagnum. But in the old Winona Lake bed there are barely three lone tamaracks, standing in the bottom of an old arm of the lake, with nothing to indicate the share they took in the development of the swamp. Further data obtained by a comparison with other specimens of this kind of swamp are necessary before a definite conclusion can be reached concerning its evolution.

Quite an interesting type of swamp is found in a narrow belt of lowland which adjoins the lake and represents an old arm of it, lying like a ditch between the hills there. It contains Ludwigia polycarpa, Ludwigia hirtella, ditch stone-crop (Penthorum sedoides), manna-grass (Glyceria fluitans), Polygonum acre, Polygonum hydropiper, Polygonum sagittatum and Polygonum Muhlenbergii. The flora of the margin is swamp white oak, black alder (Ilex verticillata), sour gum (Nyssa sylvatica), Carolina rose, and the swamp, white or silver maple (Acer dasycarpum). Riccia fluitans carpets the wet soil.

A swamp in the hollow of the hills is filled with Polygonum hydropiper, Iris, skunk cabbage (Symplocarpus foetidus), and Rosa Carolina. Around the margins are dying willows, elm and ash. Fossils of ferns point back to former days when moisture was more abundant. Withering Mnium and flourishing Polytrichum, the relict and the pioneer, show past and future. To the south, the hill has been cleared and xerophytic conditions are being hastened in the margin of the swamp. Dying Iris and vigorous Canada thistle grow side by side. On the east, west and south are the morainic hills covered with oak-hickory forests. The fate of this swamp is gradual filling up by dead vegetation and downwash from the surrounding uplands and the ultimate encroachment of the neighboring plants upon its territory.

3. The Morainic Uplands.—The sand-gravel-clay hills are even more numerous about the lake than are the swamp meadows and their vegetation is only slightly varied at different places, this being usually in clearings. The oak-hickory stage prevails. Near the summit of the hill is the black oak (Quercus coccinea tinctoria), with the white oak (Quercus alba), on the lower slopes. These are accompanied by the hickories (Carya alba and Carya sulcata), wild oats (Danthonia spicata), wire grass (Poa compressa), plantain-leaved everlasting (Antennaria plantaginifolia), Polytrichum, New Jersey tea (Ceanothus Americanus) and Silene stellata. At

the base of the hills, on the tension line adjoining the swamp, is the black huckleberry, Gaylussacia resinosa. (See background of Fig. 3.) The oak stage has required so long a time to develop and has been in existence so long that we have only the result and little evidence of what preceded this type. In the north the coniferous forest comes first. Clearings give some intimation of the order of succession, and they are numerous, though somewhat deceptive, as the stages in this case follow one another much more rapidly than they would in a virgin soil in which

Fig. 5. View of the channel and abutments of the upper or lesser dam. From the condition of the vegetation in the foreground, it is evident that the stream's gradient is small. Upon the left and right the surface rises abruptly to 12 feet, and is covered with heavy mesophytic trees. The soil is sandy. This is a place where vegetation is capable of closing the drainage lines.

there had been no foundation laid for later types. Where the soil has been cleared the first plants that follow, as shown on the north and west sides of the lake, are Xerophytic annuals and perennials, such as poke weed (Phytolacca decanda), mullein (Verbascum thapsus), Canada thistle (Cnicus arvensis), hounds-tongue (Cynoglossum officinale), Leonurus Cardiaca, Arctium lappa, Echinospermum lappula. These seem to be followed by elm and hickory. The beech-maple forest is working its way in so slowly around Winona that at first glance there seems to be no

Fig. 6. View across the valley from the left abutment of the lower or greater dam. The width of the valley is here about 165 feet, with the earth walls rising abruptly 22 feet on either side. The soil is a glacial deposit, sand predominating.

Fig. 7. View up the channel of the outlet at the greater dam. The depth of the valley is shown by the altitude of the right abutment in the background. The evidence of the ascending erosion line is in the foreground.

indication of it whatever. It has made its appearance in only one region in the old lake bed, namely, within a mile of the present lake shore around Clear Creek. The beech forest west of the lake is outside of the territory covered by this report. Why this type has lagged so far behind is perhaps due to the large percentage of gravel in the soil, as its development is much slower in gravelly soil than in that in which we have a large percentage of clay. The presence of beeches depends upon the amount of humus in the soil. Then, too, both beech and maple seedlings can grow in the dense shade these trees themselves make or in the lighter forests of oak and hickory. The plants of the latter type, on the other hand, do not flourish in the deeper shade of the beech.

Accompanying the beech (Fagus ferruginea) which is yet somewhat rare in this type of forest about the lake, and the sugar maple (Acer saccharinum) are the tulip tree (Liriodendron tulipifera), the walnut, the pawpaw (Asimiua triloba), Hepatica, Trillium, Virginia Creeper, Mayapple, skunk cabbage, various species of ferns, together with the older oaks and hickories, which point back to the past.

4. The Stream.—The territory over which now flows the lower part of the two streams that feed the lake was once the lake bed and is now a flood-plain. Cherry Creek, the largest of these, is a pre-erosion type in what is apparently an erosion valley. Along the lower course of this is a mixture of influences which results in a "hodge podge" of vegetation not easy to unravel. Lake and swamp, spring and stream, all combine their forces to produce this effect. Near the mouth of the stream Potamogeton fluitans is abundant. In that part most often submersed are the rice cut grass (Leersia oryzoides), cat-tails, bulrushes and sedges, among them Scirpus atrovirens, Carex lupulina, and Carex vulpinoidia. Many plants characteristic of springs and spring brooks are found, such as swamp milkweed (Asclepias incarnata), skunk cabbage (Symplocarpus foetidus), Eupatorium purpureum, Eupatorium perfoliatum, Lycopus lucidus (water horehound), and several other species of mint, Lobelia leptostachys and Lobelia syphilitica. Salix longifolia and Salix nigra are common (see Fig. 4), and in the locality west of the creek and bordering upon the lake seedlings of the river or silver maple (Acer dasycarpum) and the aspens (Populus tremuloides) form a marked feature of the landscape. Other plants characteristic of this flood-plain are the ash (Fraximus Americana), the walnut (Juglans nigra), the red-bud (Cercis Cana-

densis), the sycamore (Platanus occidentalis), the mulberry, the hazel (Corylus Americana), the hornbeam (Carpinus Caroliniana), poison ivy (Rhus toxicodendron), Virginia creeper (Ampelopsis quinquefolia), grape (Vitis), greenbriar (Smilax), Indian Turnip (Arisaema Dracontium), ground ivy (Nepeta Glechoma), nettles, blue grass (Poa pratensis), meadow rue, strawberry (Fragaria), Impatiens, Aspidium thelypteris, Onoclea sensibilis and Osmunda regalis.

Looking forward to the future of this stream we expect greater erosion, retrogression toward the xerophytic, and, as the ultimate base level is approached, progression again toward the mesophytic.