time and what the origin. The use of sheet-copper, manufactured and manipulated with mechanical precision, will to most minds be sufficient evidence of European agency and post-Columbian time.

This view is enforced by the presence of articles of brass and iron in the mound with one of the shell objects.

Besides this, a study of the designs themselves develops some interesting facts. Four of the designs presented, two on copper and two on shell, represent compound creatures, part bird and part man. This is a characteristic American conception, but in the execution of details there are features very suggestive of an oriental origin. The wings are, for instance, attached to the shoulder-blades behind, the arms being also present, and expand symmetrically to the right and left, resembling mediæval angels more closely than Mexican deities. We notice, also, in the delineation of the eagle, a decidedly heraldic character, a symmetrical extension of the wings, legs, and talons highly suggestive of some imperial coat of arms.

In all their leading features the designs themselves are suggestive of Mexican or Central-American work; and, if actually derived from some of the highly cultured nations of

FIG. 5. — Copper image from a mound in Georgia.

the south, it is not impossible that this derivation was through aboriginal agencies: but some of the examples in shell and copper shown in the accompanying figures bear the ear-marks of transatlantic workmen; and I believe it quite probable that they are southern works copied in favorite American mate-

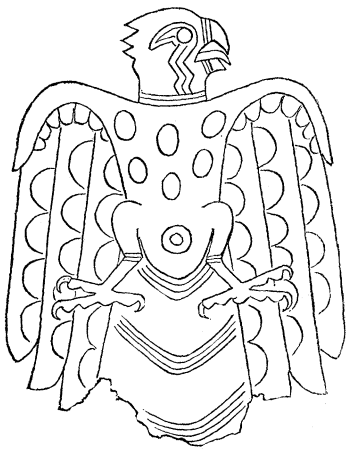

FIG. 6. — Copper eagle from a mound in Illinois.

rials by the avaricious Spanish conquerors, and subsequently used in trade with all the tribes of the Gulf states. This is well known to have been a usual practice with our early traders.

If in the end it should turn out that these remarkable objects are the unaided work of the mound-builders, we shall be compelled to recognize their standing in the manipulation of metal, and in the art of design generally, as unsurpassed by any other native American people.

W. H. HOLMES.

ADAPTABILITY OF THE PRAIRIES FOR ARTIFICIAL FORESTRY.

VARIOUS views have been entertained in relation to the treeless condition of the prairies of the interior region of the United States, some of which are rational, some partially so, and others positively erroneous. The opinion has been popularly held, that the prairies were originally covered with forests, as the region to the eastward of them was when it was first known to white men, and that from some unexplained cause these forests were destroyed. Those who entertain this view are disposed to discuss speculatively the origin of the prairies, and practically the means of reforesting them. These are views of men who lay no claim to scientific knowledge; but certain persons, even of scientific pretensions, have claimed that the character of the soil of the prairies is such,

that, although herbaceous plants may grow abundantly upon it, forest-trees cannot thrive. Others, again, suppose that the absence of trees upon the prairies is due to climatic causes, and that the growth of trees upon them by artificial planting will therefore always be precarious or impracticable. A large number of men, with no theory to support, who have made their homes in the great prairie region, have demonstrated by actual experiment that forest-trees will grow thriftily and to full maturity upon its soil.

It is my present purpose to speak of this success, and of the indication which it gives that the great prairie region of the United States may be made to produce the wood for all the needed fuel of the inhabitants, and also for other economic uses. Before doing so, however, it is desirable to describe that region briefly, as it existed when it was first occupied by white men, and to indicate in a general way its limits and its relation to adjacent regions.

It is difficult to define the boundaries of the prairie region as it existed then: first, because it merged, on the one hand, into the woodland regions, and, on the other, into the great arid plains of the west; second, its original characteristic features have been so changed by cultivation, its occupancy by homesteads and villages, and by the increasing presence of trees of both natural growth and artificial planting, that one now rarely gets sight of typical prairies as they existed over so large a region only a few years ago.

In the middle and Gulf states there were originally numerous treeless areas, which were, properly speaking, prairies; but to these I do not now refer. It is sufficient for my present purpose to say that the states of Illinois and Iowa lie in the heart of the region I shall discuss, and that it also embraces large adjacent parts of Wisconsin, Minnesota, Dakota, Nebraska, Kansas, and Missouri.

Although this region occupies a central position upon the continent, its average elevation is not great, a part of it being less than five hundred feet above the level of the sea. The general surface has an approximately level aspect; but it is often undulatory, and sometimes cut by deep valleys. It is traversed by two great rivers, the Mississippi and Missouri, and also by many of their tributaries. The valleys of these streams are cut down somewhat abruptly from the general level, to depths varying from a dozen feet to two or three hundred feet. The streams are bordered by level 'bottom-lands,' varying in breadth from a few rods to several miles.

These bottom-lands and the adjacent valley-sides, together with the contiguous ravine-broken land, contained all, or nearly all, the forest-trees which grew in that great region when white men first knew it; and even these surfaces were then largely destitute of trees. All the broad intervening spaces were covered with a dense growth of grass, mingled only with other herbaceous plants. So small was the aggregate of the timbered as compared with the grass-covered surfaces, that, from a long and early acquaintance with it, I estimate the former to have been not more than five per cent of the whole. In many parts of the region it was certainly less than this.

The early settlers found the Indians in the habit of burning the prairies annually; and they seemed to have practised that habit from time, to them, immemorial. The grass of this great region was largely burnt off every year, either by accident or design; so that from October until May the settlers were seldom out of sight of the lurid light of the burning grass by night, or the towering volumes of smoke by day. The next spring brought an equally abundant growth of grass from the unharmed roots, to fall, in turn, a prey to the devouring flames.

Although that condition of things prevailed within the memory of thousands of persons now living, the present prevalence of artificial groves, and the rapid natural encroachment of trees upon the before treeless surfaces, which followed the discontinuance of the annual fires, have nearly destroyed all the distinguishing characteristics of a prairie region. So rapidly is this change now taking place, that the next generation of those who are to occupy it will probably know of its original prairie character only from tradition or history.

The prairie region in question lies almost wholly within that over which the great northern drift is distributed; and its soil and subsoil are largely made up of the drift material, together with the silt deposit to which the name of 'loess' is now generally applied by geologists. The soil is therefore quite uniform in character over large portions of the region, and yet there is a good degree of variation in different localities. It is generally a rich, deep, dark loam, often without a stone or pebble in sight for many miles. But sometimes drift pebbles and bowlders are scattered plentifully upon the surface; and, in the valley-sides, escarpments of the underlying stratified rocks often appear.

To the westward of the Missouri River the prairies pass gradually into the great plains; and these continue westward to the base of the

Rocky Mountains. The general surface of the plains is similar to that of the prairies; and the character of the soil is also similar, except that it has not been so completely leached of its soluble salts, which are known by the popular name of 'alkali.' There is, in fact, no line of demarkation between the prairies and plains except a climatic one, and there is no other reason for giving them each a different designation than that which has resulted from climatic causes; that is, westward from the Missouri River there is such a gradual diminution of the annual rainfall, that in western Kansas and Nebraska it is insufficient for the purposes of agriculture, while in the eastern part of those states respectively it is ample. In a general way, the line between the arid and humid regions may be said to pass northward medially through the two states just named, swerving somewhat to the westward as it passes through Dakota Territory to the British line.

The trees which grew originally within the great prairie region were, with few exceptions, of the same kinds that grew in the wooded regions to the eastward of it; the more important of the missing kinds being the beech, chestnut, tulip-tree, and the common locust-tree. The more common kinds of trees which grew there were oaks (four kinds), hickory (three kinds), maple (two kinds), elm, cottonwood, black walnut, and linden. Among those which were less common were ash, honey-locust, sycamore, white walnut, mulberry, hackberry, Kentucky coffee-bean, and pecan. Besides these, a few pines and cedars grew upon the rocky cliffs of the valley-sides, and a few other trees were also scattered through the region; but the conifers, as compared with angiospermous trees were rare and of little importance. I use here only the common names of the trees, as given in Gray's 'Manual of botany.'

Traversing the prairie region from east to west and from south to north, it has been found that certain of the kinds of trees above named did not grow so far westward and northward, respectively, as others did. As regards the northern limitation of some, it was probably due mainly to temperature, and the western limitation of others was perhaps due, in part, to approaching aridity; but I think that to about the 98th meridian it was due to the only partially accomplished natural distribution of forest-trees from the eastward, which began at the close of the second glacial epoch. The first of the suggested causes of limitation has an important bearing upon the proper selection of trees for artificial planting in the northern portion of the prairie region. For example: while we may regard the oaks, maples, elm, cottonwood, linden, and others as practically without northern limit in the region under discussion, there are others, but fortunately they are mostly of less comparative value, which have their northern limit within this region. Among the latter may be mentioned the mulberry, honey-locust, Kentucky coffee-bean, and pecan. The hickories and black walnut were plentiful in the immediate region of the Mississippi and eastward, when the country was first known; and those trees seem to be the natural associates of the oaks.

Now, there are two general physical conditions which are inimical to forest-growth; and, wherever either of them is fully established, forests cannot exist. One of these conditions is an arctic climate, whether produced by high latitude or high elevation above the sea; and the other is an arid climate, or one where the annual rainfall is insufficient for the purposes of agriculture. I hold, that, in all regions of the earth which are not affected by either of these great climatic conditions, the foresting and reforesting of the surface, which is covered by a soil suitable for vegetable growth, is practicable for certain kinds of trees.

Neither of these conditions exists within the great prairie region as I have indicated its boundaries. It should therefore be expected that forest-trees would grow there, even if no experimental proof of the fact had ever been made. As one goes westward from this region, however, he finds the country incapable of supporting a growth of forest-trees for the same reason that it will not support a farm-crop; namely, because of its aridity. Both trees and farm-crops can and do grow successfully upon the prairies, because they have sufficient moisture from rainfall. Also, if one should go northward far enough, he would, of course, come to a limit of the successful growth of trees, and also to a limit to the growth of any farm-crop; but that limit is far beyond the northern boundary of the region here discussed.

The experiments of the dwellers upon the prairies have demonstrated that not only may all the indigenous trees of the adjacent valleys be made to grow on all varieties of its soil, but also that many kinds of eastern and exotic forest-trees, as well as most of the common fruit-trees, will grow there equally well. They have shown that the owner of any productive farm in that great region need not be deterred from planting any of those trees upon it, from any other consideration than he would give to the planting of a farm-crop.

These experiments show that certain kinds

of trees grow from artificial planting much more readily and rapidly than others, the cottonwood exceeding all others in these respects. Next, perhaps, comes the common locust, which, however, was not indigenous within the prairie region; but the cultivation of this valuable tree, which was formerly practised there with great success, was suspended, some twenty years ago, in consequence of the ravages of the 'borer.' Then follow certain trees which I name in the order of the apparent readiness and rapidity of their growth; namely, white maple, elm, black walnut, linden, oaks, and hickories.

The greater readiness and rapidity with which some of the trees named will grow by artificial planting do not imply that they have any greater vitality or permanence after their growth is established than the others: it only implies that they have greater promptness of vitality in establishing their growth. For example: the cottonwood may be grown with almost equal facility from the seed or from cuttings; but the oaks, hickories, and walnuts can be successfully grown in practical forestry only from the seed. Even the transplanting of these trees is not usually successful, but their cultivation from the seed is easy and natural.

While these facts concern the practical cultivator especially, they also have an important bearing upon the question of the original distribution of forests. The experiments referred to also show that not only will certain of the indigenous trees of the prairie region, which preferably grew upon the moist soil of the river-valleys, grow thriftily upon the upland prairie-soil, but that all kinds of the indigenous trees, as well as many others, will also grow thriftily upon all varieties of that soil. It is true that some of the soils — those of the loess of the Mississippi valley, for example — were more ready than others to receive tree-growth by the natural process of distribution; but this does not alter the fact, that all varieties of prairie-soil will receive and support an abundant forest-growth, when easily available artificial conditions are applied, and controllable unfavorable conditions are removed.

I have so far spoken of the facility with which trees will grow upon prairie-soil by artificial planting. I have now to speak of another phase of the subject of the propagation of forest-trees; namely, that of their natural encroachment upon prairie surfaces.

The borders of the primitive prairies, where woodland and prairie joined, were usually occupied by thickets of hazel and other shrubs, mingled with stunted trees. Also, for considerable distances out upon the grassy surface, there were numerous dwarfed stubs of oaks, hickories, and other trees, sometimes putting out small branches, only to be destroyed in a year or two by the fires; sometimes burnt to the ground, but their roots remaining alive, and sending up vigorous shoots next year, only to be burnt off by the next fire which should sweep across the adjacent prairie. The prairie borders were thus kept stationary year after year by the fires. It was a perpetual contest between vigorous and progressive vegetable life and its deadly enemy, with material conquests upon neither side.

As soon as the annual fires were stopped by the increasing inhabitants, which they did as a necessary provision for safety, the natural encroachment of the forests upon the prairie borders went on so vigorously, that it required the preventive means of agricultural occupancy to check it.

There are now many thousands of acres of land in the great prairie region, which are densely covered with a full variety of mature forest-trees, which were parts of grass-covered prairie borders when the country was first settled. In many cases, cultivated farms, which were originally established upon the open prairie borders, are now surrounded by woodland, which has become such by natural means since the fires were prevented. Doubtless, local conditions have varied the rate of encroachment of forest-trees upon the prairie borders; but it is plain that the natural tendency is, and always has been, in that direction. This tendency is, in fact, the leading element in original forest distribution, — a process, which, in the present case, beginning with the close of the second glacial epoch, probably progressed mainly from the eastward and south-eastward. This process of distribution was only partially accomplished in the prairie region when it was first known to white men. No doubt, the uncompleted state of the distribution was primarily due to the want of necessary time for its accomplishment since the distribution began; but it was certainly long held in check by the annual prairie fires.

It is not my present purpose to discuss geological questions with regard to the prairies; but since the remains of trees, which have not unfrequently been exhumed from beneath the surface in that region, have been supposed to afford proof of the former forested condition of the prairies, it is desirable to refer briefly to that subject. It is no doubt true, that the great prairie region was formerly occupied by a forest-

growth, as many other now treeless parts of North America have been, not excepting at least a large part of the present arid region; but those forests existed in other geological epochs, and they have been destroyed by subsequent unfavorable physical changes. The region of the great prairies has also been shorn of its forests once, and perhaps twice, since the tertiary period: that is, in the tertiary period, and even before, an extensive arboreal flora prevailed in North America, which was closely related to that which now exists; but, with the accession of the glacial epoch, the forests of the region here discussed were necessarily wholly destroyed, except, perhaps, along its southern borders.

Accumulating evidence seems to show, that there was an interglacial epoch of temperate climate, during which that great region was again covered with forests, and that these were in turn destroyed by the second glacial epoch. It is the remains of these interglacial forests that have been so frequently found in excavations made in the prairie region, and which have excited so much local interest. Those forests were evidently extensive; but, unlike those now living there, they seem to have consisted largely of conifers. I do not doubt, that, at the close of the second glacial epoch, the present prairie region of the United States was as completely destitute of trees as any of its present prairies were when white men first discovered them. The opinion also seems a reasonable one, that the foresting of the prairies has been slowly in progress, ever since the close of the second glacial epoch, by the process of natural dispersion, and, furthermore, that this dispersion of trees progressed mainly from the south-eastward. Not only were the interglacial forests necessarily destroyed by the icy visitation of the second glacial epoch, but the whole, or nearly the whole, surface was rewrought, and practically a new soil was produced by the glacial action and the subsequent physical conditions.

Such a new soil would naturally be first occupied by herbaceous plants, whose abundant and annually matured seeds are so readily distributed by natural means. So, also, the pioneer occupants of the new land among the trees would doubtless be those whose light and abundant seeds are capable of being distributed by the winds, and whose most congenial habitat is upon the moist grounds which border the streams: such are the cottonwood, willows, and elm, for example. It is especially the first two that are found to be the most advanced of the western arboreal pioneers upon the borders of the great plains, and which were doubtless the pioneers in the primitive foresting of the prairie region. Other trees followed those pioneers more slowly, for their methods of propagation were slower; but still the methods of natural propagation of the majority are sufficiently vigorous to suggest, that, if the prairie fires had never been introduced, the early settlers would have found that great region a forested instead of a prairie one.

How long the battle of the fires against the trees continued is not known; and by what successive steps the latter succeeded in gaining and holding even the small strips of land along the borders of the streams of so wide a region, hundreds of miles from the place of their original departure, it is difficult to say. It is probable that the pioneer trees effected their occupancy there, to a large extent, before the fires prevailed, and that their presence favorably modified the immediate conditions for the occupancy of other trees. The streams also seem to have favored their occupancy, not only by the additional moisture which they gave to the adjacent soil, but by acting as checks to the fires which alternately swept the prairies on each hand, lessening the average frequency of fires upon their bordering bottom-lands by perhaps one-half of what it otherwise would have been.

The subject, as I have attempted to present it, may be summed up briefly as follows: in the natural geographical distribution of faunas and floras, nature necessarily fixes the potential boundary of such distribution at a greater or less distance in advance of the boundary of actual occupancy; and, when these two boundaries come to coincide, there is necessarily an end to distribution. When the prairie region was first known, the potential boundary-line of forest occupation was at least five hundred miles westward from that of full occupancy.

At the close of the glacial epoch the whole of the great prairie region was practically destitute of vegetation, but its new soil was capable of supporting an abundant and varied growth. Herbaceous vegetation first occupied the soil, and trees followed more slowly. The obstacles to the occupancy of the new soil by forest-trees at the close of the glacial epoch were, first, the slowness of the process of natural distribution; second, the pre-occupancy of the soil by herbaceous vegetation, preventing or retarding the effective germination of the seeds of trees; third, the subsequent prevalence of annual fires upon the grassy surfaces, which retarded forest-growth.

The conditions favorable to the natural dis-

tribution of trees in that region were a fruitful and congenial soil and a favorable climate. If the fires had never been introduced, the two first-named obstacles to forest-distribution in the prairie region would probably have been practically overcome by the time when the country was first settled; but, upon their introduction, an equilibrium of the retarding and accelerating forces was established and long continued. With the final cessation of the fires, and with the favoring conditions incident to agricultural occupancy, that equilibrium was destroyed, and the vigorous natural tendency to forest-distribution again asserted itself. It is now in full force except where it is checked by human agency; and it is greatly accelerated where such agency is exerted in its favor. It therefore only remains for the inhabitants of the great prairie region to decide whether their land shall be forested or treeless.

C. A. WHITE.

THE APPLICATION OF PHOTOGRAPHY TO THE PRODUCTION OF NATURAL HISTORY FIGURES.[1]

FROM the accuracy and rapidity of its delineations, photography has proved itself an invaluable aid to science, although in natural history its use has been somewhat limited from the difficulty or impossibility of putting many of the objects in a vertical position. To make photography applicable to all classes of objects, it is simply necessary to have the camera so arranged that it may be placed at any angle from horizontal to vertical. The object to be photographed may then occupy its natural position, whatever that may be. For the last ten years, there has been in constant use, in the anatomical department of Cornell university, an apparatus constructed on this principle. It consists essentially of a camera fastened to a board that may be swung from horizontal to vertical, and clamped firmly at any angle.

With this instrument have been photographed, not only objects ordinarily photographed with a vertical or horizontal camera, but delicate embryo brains and other objects that would collapse if removed from liquid. Living salamanders (Necturi) have been photographed under water, their gills remaining completely outspread.

[1] Papers on this subject were given by the writer at the meeting of the American association for the advancement of science in 1879, and at the meeting of the Society of naturalists of the eastern United States in 1883. The only other persons employing a vertical camera in photography, known to the writer, are Dr. Theo. Deecke of the State lunatic-asylum at Utica, N.Y., and Dr. Dannadieu of Lyons, France. (For the last, see Anthony's *Photographic bulletin*, December, 1883, p. 404.)

A photograph answers the requirements of a scientific figure in but few cases; as the object usually is to bring out with diagrammatic clearness a few details, subordinating or omitting others: hence the photograph is used as the basis of the figure; that is, the object is delineated of the desired size, all the parts being in their proper relative position. From this photographic picture may be traced all the outlines directly upon the drawing-paper; thus avoiding the tedious labor of measurement by

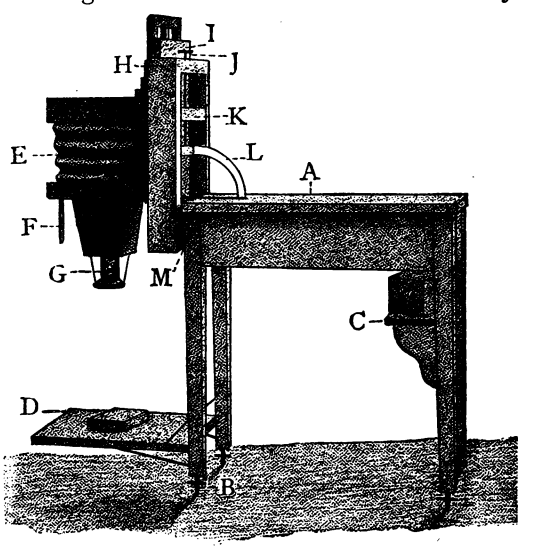

FIG. 1. — Side view of a vertical camera. *A*, the table supporting the camera; *B*, levelling-screws; *C*, shelf for holding a box of sand as counterpoise; *D*, stage upon which the object is placed (it is made parallel with the top of the table); *E*, camera with cone; *F*, slotted brass guide (see fig. 2); *G*, the photographic objective (its cap is made of card-board, and covered with black velveteen; it is held in position by two rubber bands); *H*, frame hinged to the table, and supporting the camera; *I*, movable board to which the camera is clamped; *J*, head of the focusing-screw; *K*, block fastened to the movable board *I*, and containing the nut which receives the focusing-screw; *L*, semicircle by which the frame bearing the camera is set at any angle; *M*, thumb-screw pressing against the semicircle *L*, and serving to fix it at any point.

the artist, and leaving all of his time available for artistic work proper.

While, however, the use of the photograph for outlines diminishes the labor of the artist about one-half, it increases that of the preparator; and herein lies one of its chief merits. The photographs being exact images of the preparations, the tendency will be to make them with greater care and delicacy, and the result will be less imagination and more reality in published scientific figures; and the objects prepared with such care will be preserved for future reference.

In the use of photography for figures, several considerations arise: 1°. The avoidance of distortion; 2°. The adjustment of the camera to