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ART. IX.—*Forest Geography and Archæology: a Lecture delivered before the Harvard University Natural History Society*, April 18, 1878; by ASA GRAY.

. . . . IT is the forests of the Northern temperate zone which we are to traverse. After taking some note of them in their present condition and relations, we may enquire into their pedigree; and, from a consideration of what and where the component trees have been in days of old, derive some probable explanation of peculiarities which otherwise seem inexplicable and strange.

In speaking of our forests in their present condition, I mean not exactly as they are to-day, but as they were before civilized man had materially interfered with them. In the district we inhabit such interference is so recent that we have little difficulty in conceiving the conditions which here prevailed, a few generations ago, when the "forest primeval"—described in the first lines of a familiar poem—covered essentially the whole country, from the Gulf of St. Lawrence and Canada to Florida and Texas, from the Atlantic to beyond the Mississippi. This, our Atlantic forest, is one of the largest and almost the richest of the temperate forests of the world. That is, it comprises a greater diversity of species than any other, except one.

In crossing the country from the Atlantic westward, we leave this forest behind us when we pass the western borders of those organized States which lie along the right bank of the Mississippi. We exchange it for prairies and open plains, wooded only along the water-courses,—plains which grow more

and more bare and less green as we proceed westward, with only some scattering cottonwoods (i. e. poplars) on the immediate banks of the traversing rivers, which are themselves far between.

In the Rocky Mountains we come again to forest, but only in narrow lines or patches; and if you travel by the Pacific Railroad you hardly come to any; the eastern and the interior-desert plains meet along the comparatively low level of the divide which here is so opportune for the railway; but both north and south of this line the mountains themselves are fairly wooded. Beyond, through all the wide interior basin, and also north and south of it, the numerous mountain chains seem to be as bare as the alkaline plains they traverse, mostly north and south; and the plains bear nothing taller than sage-brush. But those who reach and climb these mountains find that their ravines and higher recesses nourish no small amount of timber, though the trees themselves are mostly small and always low.

When the western rim of this great basin is reached there is an abrupt change of scene. This rim is formed of the Sierra Nevada. Even its eastern slopes are forest-clad in great measure; while the western bear in some respects the noblest and most remarkable forest of the world;—remarkable even for the number of species of evergreen trees occupying a comparatively narrow area, but especially for their wonderful development in size and altitude. Whatever may be claimed for individual Eucalyptus-trees in certain sheltered ravines of the southern part of Australia, it is probable that there is no forest to be compared for grandeur with that which stretches, essentially unbroken,—though often narrowed, and nowhere very wide,—from the southern part of the Sierra Nevada in lat. 36° to Puget Sound beyond lat. 49°, and not a little farther.

Descending into the long valley of California, the forest changes, dwindles, and mainly disappears. In the Pacific Coast Ranges, it resumes its sway, with altered features, some of them not less magnificent and of greater beauty. The Redwoods of the coast, for instance, are little less gigantic than the Big-trees of the Sierra Nevada, and far handsomer, and a thousand times more numerous. And several species which are merely or mainly shrubs in the drier Sierra, become lordly trees in the moister air of the northerly coast ranges. Through most of California these two Pacific forests are separate; in the northern part of that State they join, and form one rich woodland belt, skirting the Pacific, backed by the Cascade Mountains, and extending through British Columbia into our Alaskan territory.

So we have two forest-regions in North America,—an Atlan-

tic and a Pacific. They may take these names, for they are dependent upon the oceans which they respectively border. Also we have an intermediate isolated region or isolated lines of forest, flanked on both sides by bare and arid plains,—plains which on the eastern side may partly be called *prairies*,—on the western, *deserts*.

This mid-region mountain forest is intersected by a transverse belt of arid and alkaline plateau, or eastward of grassy plain—a hundred miles wide from north to south,—through which passes the Union Pacific Railroad. This divides the Rocky-mountain forest into a southern and a northern portion. The southern is completely isolated. The northern, in a cooler and less arid region, is larger, broader, more diffused. Trending westward, on and beyond the northern boundary of the United States, it approaches, and here and there unites with, the Pacific forest. Eastward, in Northern British territory, it makes a narrow junction with northwestward prolongations of the broad Atlantic forest.

So much for these forests as a whole, their position, their limits. Before we glance at their distinguishing features and component trees, I should here answer the question, why they occupy the positions they do ;—why so curtailed and separated at the south, so much more diffused at the north, but still so strongly divided into eastern and western. Yet I must not consume time with the rudiments of physical geography and meteorology. It goes without saying that trees are nourished by moisture. They starve with dryness and they starve with cold. A tree is a sensitive thing. With its great spread of foliage, its vast amount of surface which it cannot diminish or change, except by losing that whereby it lives, it is completely and helplessly exposed to every atmospheric change; or at least its resources for adaptation are very limited; and it cannot flee for shelter. But trees are social, and their gregarious habits give a certain mutual support. A tree by itself is doomed, where a forest, once established, is comparatively secure.

Trees vary as widely as do other plants in their constitution; but none can withstand a certain amount of cold and other exposure, nor make head against a certain shortness of summer. Our high northern regions are therefore treeless; and so are the summits of high mountains in lower latitudes. As we ascend them we walk at first under spruces and fir-trees or birches; at 6,000 feet on the White Mountains of New Hampshire, at 11 or 12,000 feet on the Colorado Rocky Mountains, we walk through or upon them; sometimes upon dwarfed and depressed individuals of the same species that made the canopy below. These depressed trees retain their hold on life

only in virtue of being covered all winter by snow. At still higher altitude the species are wholly different; and for the most part these humble alpine plants of our temperate zone—which we cannot call trees, because they are only a foot or two or a span or two high—are the same as those of the arctic zone, of northern Labrador, and of Greenland. The arctic and the alpine regions are equally unwooded from cold.

As the opposite extreme, under opposite conditions, look to equatorial America, on the Atlantic side, for the widest and most luxuriant forest-tract in the world, where winter is unknown, and a shower of rain falls almost every afternoon. The size of the Amazon and Orinoco—brimming throughout the year—testifies to the abundance of rain and its equable distribution.

The other side of the Andes, mostly farther south, shows the absolute contrast, in the want of rain, and absence of forest; happily it is a narrow tract. The same is true of great tracts either side of the equatorial regions, the only district where great deserts reach the ocean.

It is also true of great continental interiors out of the equatorial belt, except where cloud-compelling mountain-chains coerce a certain deposition of moisture from air which could give none to the heated plains below. So the broad interior of our country is forestless from dryness in our latitude, as the high northern zone is forestless from cold.

Regions with distributed rain are naturally forest-clad. Regions with scanty rain, and at one season, are forestless or sparsely wooded, except they have some favoring compensations. Rainless regions are desert.

The Atlantic United States in the zone of variable weather and distributed rains, and the Gulf of Mexico as a caldron for brewing rain, and no continental expanse between that great caldron and the Pacific, crossed by a prevalent southwest wind in summer, is greatly favored for summer as well as winter rain.

And so this forest region of ours, with annual rain-fall of fifty inches on the Lower Mississippi, fifty-two inches in all the country east of it bordering the Gulf of Mexico, forty-five to forty-one in all the proper Atlantic district from East Florida to Maine, and the whole region drained by the Ohio,—diminished only to thirty-four inches on the whole Upper Mississippi and Great Lake region,—with this amount of rain, fairly distributed over the year, and the greater part not in the winter, our forest is well accounted for.

The narrow district occupied by the Pacific forest has a much more unequal rainfall, more unequal in its different parts, most unequal in the different seasons of the year, very different in the same place in different years.

From the Gulf of Mexico to the Gulf of St. Lawrence, the amount of rain decreases moderately and rather regularly from south to north; but, as less is needed in a cold climate, there is enough to nourish forest throughout. On the Pacific coast, from the Gulf of California to Puget Sound, the southerly third has almost no rain at all; the middle portion less than our Atlantic least; the northern third has about our Atlantic average.

Then, New England has about the same amount of rain-fall in winter and in summer; Florida and Alabama about one-half more in the three summer than in the three winter months,—a fairly equable distribution. But on the Pacific coast there is no summer rain at all, except in the northern portion, and there little. And the winter rain, of forty-four inches on the northern border, diminishes to less than one-half before reaching the Bay of San Francisco; dwindles to twelve, ten, and eight inches on the southern coast, and to four inches before we reach the United States boundary below San Diego.

Taking the whole year together, and confining ourselves to the coast, the average rain-fall for the year, from Puget Sound to the border of California, is from eighty inches at the north to seventy at the south, i. e., seventy on the northern edge of California; thence it diminishes rapidly to thirty-six, twenty (about San Francisco), twelve, and at San Diego to eight inches.

The two rainiest regions of the United States are the Pacific coast north of latitude forty-five, and the northeastern coast and borders of the Gulf of Mexico. But when one is rainy the other is comparatively rainless. For while this Pacific rainy region has only from twelve to two inches of its rain in the summer months, Florida, out of its forty to sixty, has twenty to twenty-six in summer, and only six to ten of it in the winter months.

Again, the diminution of rain-fall as we proceed inland from the Atlantic and Gulf shores, is gradual; the expanse that is or was forest-clad is very broad, and we wonder only that it did not extend farther west than it does.

On the other side of the continent, at the north, the district so favored with winter rain is but a narrow strip, between the ocean and the Cascade Mountains. East of the latter, the amount abruptly declines,—for the year from eighty inches to sixteen; for the winter months, from forty-four and forty to eight and four inches; for the summer months, from twelve and four to two and one.

So we can understand why the Cascade Mountains abruptly separate dense and tall forest on the west from treelessness on the east. We may conjecture, also, why this North Pacific forest is so magnificent in its devolopment.

Equally, in the rapid decrease of rain-fall southward, in its corresponding restriction to one season, in the continuation of the Cascade Mountains as the Sierra Nevada, cutting off access of rain to the interior, in the unbroken stretch of coast ranges near the sea, and the consequent small and precarious rain-fall in the great interior valley of California, we see reasons why the Californian forest is mainly attenuated southward into two lines,—into two files of a narrow but lordly procession, advancing southward along the coast ranges, and along the western flank of the Sierra Nevada, leaving the long valley between comparatively bare of trees.

By the limited and precarious rain-fall of California, we may account for the limitations of its forest. But how shall we account for the fact that this district of comparatively little rain produces the largest trees in the world? Not only produces, alone of all the world, those two peculiar *big trees* which excite our special wonder,—their extraordinary growth might be some idiosyncracy of a race,—but also produces pines and fir-trees, whose brethren we know, and whose capabilities we can estimate, upon a scale only less gigantic. Evidently there is something here wonderfully favorable to the development of trees, especially of coniferous trees; and it is not easy to determine what it can be.

Nor, indeed, does the rain-fall of the coast of Oregon, great as it is, fully account for the extraordinary development of its forest; for the rain is nearly all in the winter, very little in summer. Yet here is more timber to the acre than in any other part of North America, or perhaps in any other part of the world. The trees are never so enormous in girth as some of the Californian, but are of equal height—at least on the average—three hundred feet being common, and they stand almost within arms' length of each other.

The explanation of all this may mainly be found in the great climatic differences between the Pacific and the Atlantic sides of the continent; and the explanation of these differences is found in the difference in the winds and the great ocean currents.

The winds are from the ocean to the land all the year round, from northwesterly in summer, southwesterly in winter. And the great Pacific Gulf-stream sweeps toward and along the coast, instead of bearing away from it, as on our Atlantic side.

The winters are mild and short, and are to a great extent a season of growth, instead of suspension of growth as with us. So there is a far longer season available to tree-vegetation than with us, during all of which trees may either grow or accumulate the materials for growth. On our side of the continent and in this latitude, trees use the whole autumn in getting ready for a six-months winter, which is completely lost time.

Finally, as concerns the west coast, the lack of summer rain is made up by the moisture-laden ocean winds, which regularly every summer afternoon wrap the coast-ranges of mountains, which these forests affect, with mist and fog. The Redwood, one of the two California big trees,—the handsomest and far the most abundant and useful,—is restricted to these coast-ranges, bathed with soft showers fresh from the ocean all winter, and with fogs and moist ocean air all summer. It is nowhere found beyond the reach of these fogs. South of Monterey, where this summer condensation lessens, and winter rains become precarious, the Redwoods disappear, and the general forest becomes restricted to favorable stations on mountain sides and summits. . . . . The whole coast is bordered by a line of mountains, which condense the moisture of the sea-breezes upon their cool slopes and summits. These winds, continuing eastward, descend dry into the valleys, and warming as they descend, take up moisture instead of dropping any. These valleys, when broad, are sparsely wooded or woodless, except at the north, where summer-rain is not very rare.

Beyond stretches the Sierra Nevada, all rainless in summer, except local hail-storms and snow-falls on its higher crests and peaks. Yet its flanks are forest-clad; and, between the levels of 3,000 and 9,000 feet, they bear an ample growth of the largest coniferous trees known. In favored spots of this forest—and only there—are found those groves of the giant *Sequoia*, near kin of the Redwood of the coast-ranges, whose trunks are from fifty to ninety feet in circumference, and height from two hundred to three hundred and twenty-five feet. And in reaching these wondrous trees you ride through miles of sugar-pines, yellow pines, spruces and firs, of such magnificence in girth and height, that the big trees, when reached—astonishing as they are—seem not out of keeping with their surroundings.

I cannot pretend to account for the extreme magnificence of this sierra-forest. Its rain-fall is in winter, and of unknown but large amount. Doubtless most of it is in snow, of which fifty or sixty feet falls in some winters; and—different from the coast and in Oregon, where it falls as rain, and at a temperature which does not suspend vegetable action,—here the winter must be complete cessation. But with such great snow-fall the supply of moisture to the soil should be abundant and lasting.

Then the Sierra—much loftier than the coast ranges—rising from 7,000 or 8,000 to 11,000 and 14,000 feet—is refreshed in summer by the winds from the Pacific, from which it takes the last drops of available moisture; and mountains of such altitude, to which moisture from whatever source or direction must necessarily be attracted, are always expected to support

forests,—at least when not cut off from sea-winds by interposed chains of equal altitude. Trees such mountains will have. The only and the real wonder is, that the Sierra Nevada should rear such immense trees!

Moreover, we shall see, that this forest is rich and superb only in one line; that, beyond one favorite tribe, it is meagre enough. Such for situation, and extent, and surrounding conditions, are the two forests—the Atlantic and Pacific—which are to be compared.

In order to come to this comparison, I must refrain from all account of the intervening forest of the Rocky Mountains,—only saying, that it is comparatively poor in the size of its trees and the number of species; that few of its species are peculiar, and those mostly in the southern part, and of the Mexican plateau type; that they are common to the mountain-chains which lie between, stretched north and south *en eçhelon*, all through that arid or desert region of Utah and Nevada, of which the larger part belongs to the great basin between the Rocky Mountains and the Sierra Nevada: that most of the Rocky Mountain trees are identical in species with those of the *Pacific* forest, except far north, where a few of our eastern ones are intermingled. I may add that the Rocky Mountains proper get from twelve to twenty inches of rain in the year, mostly in winter snow, some in summer showers.

But the interior mountains get little, and the plains or valleys between them less; the Sierra arresting nearly all the moisture coming from the Pacific, the Rocky Mountains all coming from the Atlantic side.

Forests being my subject, I must not tarry on the woodless plain—on an average 500 miles wide—which lies between what forest there is in the Rocky Mountains and the western border of our eastern wooded region. Why this great sloping plain should be woodless—except where some cotton-woods and their like mark the course of the traversing rivers—is, on the whole evident enough. Great interior plains in temperate latitudes are always woodless, even when not very arid. This of ours is not arid to the degree that the corresponding regions west of the Rocky Mountains are. The moisture from the Pacific which those would otherwise share, is—as we have seen—arrested on or near the western border, by the coast-ranges and again by the Sierra Nevada; and so the interior (except for the mountains), is all but desert.

On the eastern side of the continent, the moisture supplied by the Atlantic and the Gulf of Mexico meets no such obstruction. So the diminution of rain-fall is gradual instead of abrupt. But this moisture is spread over a vast surface, and it is naturally bestowed, first and most on the seaboard district,

and least on the remote interior. From the lower Mississippi eastward and northward, including the Ohio River basin, and so to the coast, and up to Nova Scotia, there is an average of forty-seven inches of rain in the year. This diminishes rather steadily westward, especially northwestward, and the western border of the ultra-Mississippian plain gets less than twenty inches.

Indeed, from the great prevalence of westerly and southerly winds, what precipitation of moisture there is on our western plains is not from Atlantic sources, nor much from the Gulf. The rain-chart plainly shows that the water raised from the heated Gulf is mainly carried northward and eastward. It is this which has given us the Atlantic forest region; and it is the limitation of this which bounds that forest at the west. The line on the rain-chart indicating twenty-four inches of annual rain is not far from the line of the western limit of trees, except far north, beyond the Great Lakes, where, in the coolness of high latitudes, as in the coolness of mountains, a less amount of rain-fall suffices for forest growth.

We see, then, why our great plains grow bare as we proceed from the Mississippi westward; though we wonder why this should take place so soon and so abruptly as it does. But, as already stated, the general course of the wind-bearing rains from the Gulf and beyond is such as to water well the Mississippi valley and all eastward, but not the district west of it.

It does not altogether follow that, because rain or its equivalent is needed for forest, therefore wherever there is rain enough, forest must needs cover the ground. At least there are some curious exceptions to such a general rule,—exceptions both ways. In the Sierra Nevada we are confronted with a stately forest along with a scanty rain-fall, with rain only in the three winter months. All summer long, under those lofty trees, if you stir up the soil you may be choked with dust. On the other hand, the prairies of Iowa and Illinois, which form deep bays or great islands in our own forest-region, are spread under skies which drop more rain than probably ever falls on the slopes of the Sierra Nevada, and give it at all seasons. Under the lesser and brief rains we have the loftiest trees we know: under the more copious and well-dispersed rain, we have prairies, without forest at all.

There is little more to say about the first part of this paradox; and I have not much to say about the other. The cause or origin of our prairies—of the unwooded districts this side of the Mississippi and Missouri—has been much discussed, and a whole hour would be needed to give a fair account of the different views taken upon this knotty question. The only settled thing about it, is, that the prairies are not directly

owing to a deficiency of rain. That, the rain-charts settle, as Professor Whitney well insists.

The prairies which indent or are enclosed in our Atlantic forest-region, and the plains beyond this region, are different things. But, as the one borders—and in Iowa and Nebraska passes into—the other, it may be supposed that common causes have influenced both together, perhaps more than Professor Whitney allows.

He thinks that the extreme fineness and depth of the usual prairie soil will account for the absence of trees; and Mr. Lesquereux equally explains it by the nature of the soil, in a different way. These, and other excellent observers, scout the idea that immemorial burnings, in autumn and spring, have had any effect. Professor Shaler, from his observations in the border land of Kentucky, thinks that they have,—that there are indications there of comparatively recent conversion of oak-openings into prairie, and now—since the burnings are over—of the reconversion of prairie into woodland.

I am disposed, on general considerations, to think that the line of demarcation between our woods and our plains is not where it was drawn by nature. Here, when no physical barrier is interposed between the ground that receives rain enough for forest, and that which receives too little, there must be a debateable border, where comparatively slight causes will turn the scale either way. Difference in soil and difference in exposure will here tell decisively. And along this border, annual burnings—for the purpose of increasing and improving buffalo-feed—practiced for hundreds of years by our nomade predecessors, may have had a very marked effect. I suspect that the irregular border line may have in this way been rendered more irregular, and have been carried farther eastward wherever nature of soil or circumstances of exposure predisposed to it.

It does not follow that trees would re-occupy the land when the operation that destroyed them, or kept them down, ceased. The established turf or other occupation of the soil, and the sweeping winds, might prevent that. The difficulty of reforesting bleak New England coasts, which were originally well wooded, is well known. It is equally, but probably not more difficult to establish forest on an Iowa prairie, with proper selection of trees.

[To be continued.]

ART. XVII. — *Forest Geography and Archæology; a Lecture delivered before the Harvard University Natural History Society*, April 18, 1878; by ASA GRAY.

[Continued from p. 94.]

THE difference in the composition of the Atlantic and Pacific forests is not less marked than that of the climate and geographical configuration to which the two are respectively adapted.

With some very notable exceptions, the forests of the whole northern hemisphere in the temperate zone (those that we are concerned with) are mainly made up of the same or similar *kinds*. Not of the same species; for rarely do identical trees occur in any two or more widely separated regions. But all round the world in our zone, the woods contain *Pines* and *Firs* and *Larches*, *Cypresses* and *Junipers*, *Oaks* and *Birches*, *Willows* and *Poplars*, *Maples* and *Ashes* and the like. Yet with all these family likenesses throughout, each region has some peculiar features, some trees by which the country may at once be distinguished.

Beginning by a comparison of our Pacific with our Atlantic forest, I need not take the time to enumerate the trees of the latter, as we all may be supposed to know them, and many of the genera will have to be mentioned in drawing the contrast to which I invite your attention. In this you will be impressed most of all, I think, with the fact that the greater part of our familiar trees are "conspicuous by their absence" from the Pacific forest.

For example, it has no Magnolias, no Tulip-tree, no Papaw, no Linden or Basswood, and is very poor in Maples; no Locust-trees—neither Flowering Locust nor Honey Locust—nor any Leguminous tree; no Cherry large enough for a timber-tree, like our wild Black Cherry; no Gum-trees (Nyssa nor Liquidambar), nor Sorrel-tree, nor Kalmia; no Persimmon, or Bumelia; not a Holly; only one Ash that may be called a timber-tree; no Catalpa, or Sassafras; not a single Elm, nor Hackberry; not a Mulberry, nor Planer-tree, nor Maclura; not a Hickory, nor a Beech, nor a true Chestnut, nor a Hornbeam; barely one Birch tree, and that only far north, where the differences are less striking. But as to Coniferous trees, the only missing type is our Bald Cypress, the so-called Cypress of our southern swamps, and that deficiency is made up by other things. But as to ordinary trees, if you ask what takes the place in Oregon and California of all these missing kinds, which are familiar on our side of the continent, I must answer, nothing, or nearly nothing. There is the *Madroña* (Arbutus) instead of our Kalmia (both really trees in some places); and

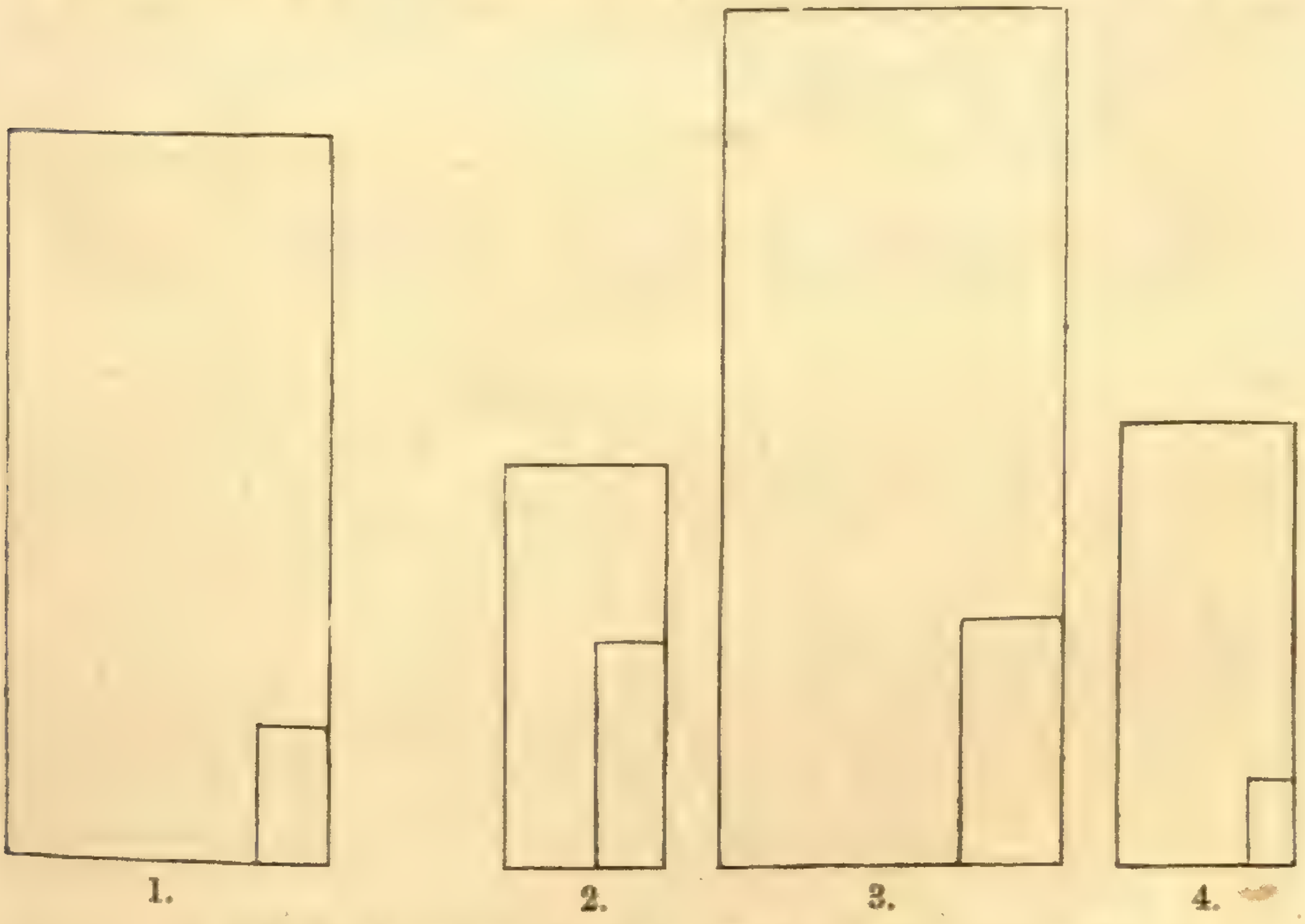
there is the California Laurel instead of our southern Red Bay tree. Nor in any of the genera common to the two does the Pacific forest equal the Atlantic in species. It has not half as many Maples, nor Ashes, nor Poplars, nor Walnuts, nor Birches, and those it has are of smaller size and inferior quality; it has not half as many Oaks; and these and the Ashes are of so inferior economical value, that (as we are told) a passable wagon-wheel cannot be made of California wood, nor a really good one in Oregon.

This poverty of the western forest in species and types may be exhibited graphically, in a way which cannot fail to strike the eye more impressively than when we say that, whereas the Atlantic forest is composed of 66 genera and 155 species, the Pacific forest has only 31 genera and 78 species.* In the appended diagrams, the short side of the rectangle is proportional to the number of genera, the long side to the number of species.

Now the geographical areas of the two forests are not very different. From the Gulf of Mexico to the Gulf of St. Lawrence about twenty degrees of latitude intervene. From the southern end of California to the peninsula of Alaska there are twenty-eight degrees, and the forest on the coast runs some degrees north of this; the length may therefore make up for the comparative narrowness of the Pacific forest region. How can so meagre a forest make so imposing a show? Surely not by the greater number and size of its individuals, so far as deciduous (or more correctly non-coniferous) trees are concerned; for on the whole they are inferior to their eastern brethren in size if not in number of individuals. The reason is, that a larger proportion of the genera and species are coniferous trees; and these, being evergreen (except the Larches), of aspiring port and eminently gregarious habit, usually dominate where they occur. While the east has almost three times as many genera and four times as many species of non-coniferous trees as the west, it has slightly fewer genera and almost one-half fewer species of coniferous trees than the west. That is, the Atlantic coniferous forest is represented by 11 genera and 25 species; the Pacific by 12 genera and 44 species. This relative preponderance may also be expressed by the diagrams, in which the smaller enclosed rectangles, drawn on the same scale, represent the coniferous portions of these forests.

* We take in only timber trees, or such as attain in the most favorable localities to a size which gives them a clear title to the arboreous rank. The subtropical southern extremity and Keys of Florida are excluded. So also are one or two trees of the Arizonian region which may touch the evanescent southern borders of the Californian forest. In counting the Coniferous genera, Pinus, Larix, Picea, Abies and Tsuga are admitted to this rank, but Cupressus and Chamæcyparis are taken as one genus.

Indeed, the Pacific forest is made up of conifers, with non-coniferous trees as occasional undergrowth or as scattered individuals, and conspicuous only in valleys or in the sparse tree-growth of plains, on which the oaks at most reproduce the features of the "oak openings" here and there bordering the Mississippi prairie region. Perhaps the most striking contrast between the west and the east, along the latitude usually traversed, is that between the spiry evergreens which the traveler leaves when he quits California, and the familiar woods of various-hued round-headed trees which give him the feeling of home when he reaches the Mississippi. The Atlantic forest is particularly rich in these, and is not meagre in coniferous trees. All the glory of the Pacific forest is in its coniferous trees: its desperate poverty in other trees appears in the annexed diagram.



1. Atlantic American Forest.
2. Pacific American Forest.
3. Japan-Manchurian Forest.
4. European Forest.

These diagrams are made more instructive, and the relative richness of the forests round the world in our latitude is most simply exhibited, by adding two or three similar ones. Two will serve, one for Europe, the other for N. E. Asia. A third would be the Himalay-Altaian region, geographically intermediate between the other two as the Arizona-Rocky Mountain district is between our eastern and western. Both are here left out of view, partly for the same, partly for special reasons pertaining to each, which I must not stop to explain. These four marked specimens will simply and clearly exhibit the general facts.

Keeping as nearly as possible to the same scale, we may count the indigenous forest trees of all Europe at 33 genera and 85 species. And those of the Japan-Manchurian region, of very much smaller geographical area, at 66 genera and 168 species. I here include in it only Japan, Eastern Manchuria, and the adjacent borders of China. The known species of trees must be rather roughly determined; but the numbers here given are not exaggerated, and are much more likely to be sensibly increased by further knowledge than are those of any of the other regions. Properly to estimate the surpassing richness of this Japan-Manchurian forest, the comparative smallness of geographical area must come in as an important consideration.

To complete the view, let it be noted that the division of these forests into coniferous and non-coniferous is, for the

European	non-coniferous,	26 genera,	68 species.
"	coniferous,	7 "	17 "
		33 "	85 "
Japan-Manchurian	non-coniferous,	47 genera,	123 species.
"	coniferous,	19 "	45 "
		66 "	168 "

In other words, a narrow region in Eastern Asia contains twice as many genera and about twice as many species of indigenous trees as are possessed by all Europe; and as to coniferous trees, the former has more genera than the latter has species, and over twice and a half as many species.

The only question about the relation of these four forest regions, as to their component species, which we can here pause to answer, is to what extent they contain trees of identical species. If we took the shrubs, there would be a small number, if the herbs a very considerable number, of species common to the two New World and to the two Old World areas respectively, at least to their northern portions, even after excluding arctic-alpine plants. The same may be said, in its degree, of the North European flora compared with the Atlantic North American, of the Northeast Asiatic compared with the northern part of the Pacific North American, and also in a peculiar way (which I have formerly pointed out and shall have soon to mention) of the Northeastern Asiatic flora in its relations to the Atlantic North American. But as to the forest trees there is very little community of species. Yet this is not absolutely wanting. The Red Cedar (*Juniperus Virginiana*) among coniferous trees, and *Populus tremuloides* among the deciduous, extend across the American continent specifically unchanged, though hardly developed as forest trees on the Pacific side.

There are probably, but not certainly, one or two instances on the northern verge of these two forests. There are as many in which eastern and western species are suggestively similar. The Hemlock-Spruce of the Northern Atlantic States, and the Yew of Florida are extremely like corresponding trees of the Pacific forest; indeed the Yew-trees of all four regions may come to be regarded as forms of one polymorphous species. The White Birch of Europe and that of Canada and New England are in similar case; and so is the common Chestnut (in America confined to the Atlantic States), which on the other side of the world is also represented in Japan. A link in the other direction is seen in one spruce tree (called in Oregon Menzies Spruce) which inhabits Northeast Asia, while a peculiar form of it represents the species in the Rocky Mountains.

But now other and more theoretical questions come to be asked, such as these:

Why should our Pacific forest region, which is rich and in some respects unique in coniferous, be so poor in deciduous trees?

Then the two *Big-trees*, Sequoias, as isolated in character as in location,—being found only in California, and having no near relatives any where,—how came California to have them?

Such relatives as the Sequoias have are also local, peculiar, and chiefly of one species to each genus. Only one of them is American, and that solely eastern, the Taxodium of our Atlantic States and the plateau of Mexico. The others are Japanese and Chinese.

Why should trees of six related genera, which will all thrive in Europe, be restricted naturally, one to the eastern side of the American continent, one genus to the western side and very locally, the rest to a small portion of the eastern border of Asia?

Why should coniferous trees most affect and preserve the greatest number of types in these parts of the world?

And why should the Northeast Asian region have, in a comparatively small area, not only most coniferous trees, but a notably larger number of trees altogether than any other part of the northern temperate zone? Why should its only and near rival be in the antipodes, namely, here in Atlantic North America? In other words why should the Pacific and the European forests be so poor in comparison, and why the Pacific poorest of all in deciduous, yet rich in coniferous trees?

The first step toward an explanation of the superior richness in trees of these antipodal regions, is to note some striking similarities of the two, and especially the number of peculiar types which they divide between them. The ultimate conclusion may at length be ventured, that this richness is normal, and that what we really have to explain is the absence of so many

forms from Europe on the one hand, from Oregon and California on the other. Let me recall to mind the list of kinds (i. e. genera) of trees which enrich our Atlantic forest but are wanting to that of the Pacific. Now almost all these recur, in more or less similar but not identical species, in Japan, North China, etc. Some of them are likewise European, but more are not so. Extending the comparison to shrubs and herbs, it more and more appears, that the forms and types which we count as peculiar to our Atlantic region, when we compare them, as we first naturally do, with Europe and with our West, have their close counterparts in Japan and North China; some in identical species (especially among the herbs), often in strikingly similar ones, not rarely as sole species of peculiar genera or in related generic types. I was a very young botanist when I began to notice this; and I have from time to time made lists of such instances. Evidences of this remarkable relationship have multiplied year after year, until what was long a wonder has come to be so common that I should now not be greatly surprised if a Sarracenia or a Dionæa, or their like, should turn up in Eastern Asia. Very few of such isolated types remain without counterparts. It is as if Nature, when she had enough species of a genus to go round, dealt them fairly, one at least to each quarter of our zone; but when she had only two of some peculiar kind gave one to us and the other to Japan, Manchuria, or the Himalayas; when she had only one, divided these between the two partners on the opposite side of the table. The result, as to the trees, is seen in these four diagrams. As to number of species generally, it cannot be said that Europe and Pacific North America are at all in arrears. But as to trees, either the contrasted regions have been exceptionally favored, or these have been hardly dealt with. There is, as I have intimated, some reason to adopt the latter alternative.

We may take it for granted that the indigenous plants of any country, particularly the trees, have been selected by climate. Whatever other influences or circumstances have been brought to bear upon them, or the trees have brought to bear on each other, no tree could hold its place as a member of any forest or flora which is not adapted to endure even the extremes of the climate of the region or station. But the character of the climate will not explain the remarkable paucity of the trees which compose the indigenous European forest. That is proved by experiment, sufficiently prolonged in certain cases to justify the inference. Probably there is no tree of the northern temperate zone which will not flourish in some part of Europe. Great Britain alone can grow double or treble the number of trees that the Atlantic States can. In all the latter

we can grow hardly one tree of the Pacific coast. England supports all of them, and all our Atlantic trees also, and likewise the Japanese and North Siberian species, which do thrive here remarkably in some part of the Atlantic coast, especially the cooler-temperate ones. The poverty of the European sylva is attributable to the absence of our Atlantic American types, to its having no Magnolia, Liriodendron, Asimina, Negundo, no Æsculus, none of that rich assemblage of Leguminous trees represented by Locusts, Honey-Locusts, Gymnocladus, and Cladrastis (even its Cercis, which is hardly European, is like the Californian one mainly a shrub); no Nyssa, nor Liquidambar; no Ericaceæ rising to a tree; no Bumelia, Catalpa, Sassafras, Osage Orange, Hickory, or Walnut; and as to Conifers, no Hemlock Spruce, Arbor-vitæ, Taxodium, nor Torreya. As compared with Northeastern Asia, Europe wants most of these same types, also the Ailantus, Gingko, and a goodly number of coniferous genera. I cannot point to any types tending to make up the deficiency, that is, to any not either in East North America or in Northeast Asia, or in both. Cedrus, the true Cedar, which comes near to it, is only North African and Asian. I need not say that Europe has no Sequoia, and shares no special type with California.

Now the capital fact is, that many and perhaps almost all of these genera of trees were well represented in Europe throughout the later Tertiary times. It had not only the same generic types, but in some cases even the same species, or what must pass as such, in the lack of recognizable distinctions between fossil remains and living analogues. Probably the European Miocene forest was about as rich and various as is ours of the present day, and very like it. The Glacial period came and passed, and these types have not survived there, nor returned. Hence the comparative poverty of the existing European sylva, or at least, the probable explanation of the absence of those kinds of trees which make the characteristic difference.

Why did these trees perish out of Europe but survive in America and Asia? Before we enquire how Europe lost them, it may be well to ask, how it got them. How came these American trees to be in Europe? And among the rest, how came Europe to have Sequoias, now represented only by our two Big trees of California? It actually possessed two species and more; one so closely answering to the Redwood of the Coast Ranges, and another so very like the *Sequoia gigantea* of the Sierra Nevada, that, if such fossil twigs with leaves and cones had been exhumed in California instead of Europe, it would confidently be affirmed that we had resurrected the veritable ancestors of our two giant trees. Indeed, so it may probably be. "*Cœlum non animam mutant*," etc., may be

applicable even to such wide wanderings and such vast intervals of time. If the specific essence has not changed, and even if it has suffered some change, genealogical connection is to be inferred in all such cases.

That is, in these days it is taken for granted that individuals of the same species, or with a certain likeness throughout, had a single birthplace, and are descended from the same stock, no matter how widely separated they may have been either in space or time, or both. The contrary supposition may be made, and was seriously entertained by some not very long ago. It is even supposable that plants and animals originated where they now are, or where their remains are found. But this is not science: in other words it is not conformable to what we now know, and is an assertion that scientific explanation is not to be sought.

Furthermore, when species of the same genus are not found almost everywhere, they are usually grouped in one region, as are the Hickories in the Atlantic States, the Asters and Goldenrods in North America and prevailingly on the Atlantic side, the Heaths in Western Europe and Africa. From this we are led to the inference that all species closely related to each other have had a common birth-place and origin. So that, when we find individuals of a species or of a group widely out of the range of their fellows we wonder how they got there. When we find the same species all round the hemisphere, we ask how this dispersion came to pass.

Now, a very considerable number of species of herbs and shrubs, and a few trees, of the temperate zone are found all round the northern hemisphere; many others are found part way round,—some in Europe and Eastern Asia; some in Europe and our Atlantic States; many, as I have said, in the Atlantic States and Eastern Asia;—fewer (which is curious) common to Pacific States and Eastern Asia, nearer though these countries be.

We may set it down as useless to try to account for this distribution by causes now in operation and opportunities now afforded, i. e., for distribution across oceans by winds and currents, and birds. These means play their part in dispersion from place to place, by step after step, but not from continent to continent, except for few things and in a subordinate way.

Fortunately we are not obliged to have recourse to overstrained suppositions of what might possibly have occurred now and then, in the lapse of time, by the chance conveyance of seeds across oceans, or even from one mountain to another. The plants of the top of the White Mountains and of Labrador are mainly the same; but we need not suppose that it is so because birds have carried seeds from the one to the other.

I take it that the true explanation of the whole problem

comes from a just general view, and not through piecemeal suppositions of chances. And I am clear that it is to be found by looking to the north, to the state of things at the arctic zone,—first, as it now is, and then as it has been.

North of our forest-regions comes the zone unwooded from cold, the zone of arctic vegetation. In this, as a rule, the species are the same round the world; as exceptions, some are restricted to a part of the circle.

The polar projection of the earth down to the northern tropic, as here exhibited, shows to the eye—as our maps do not—how all the lands come together into one region, and how natural it may be for the same species, under homogeneous conditions, to spread over it. When we know, moreover, that sea and land have varied greatly since these species existed, we may well believe that any ocean-gaps, now in the way of equable distribution, may have been bridged over. There is now only one considerable gap.

What would happen if a cold period were to come on from the north, and were very slowly to carry the present arctic climate, or something like it, down far into the temperate zone? Why, just what has happened in the Glacial period, when the refrigeration somehow pushed all these plants before it down to Southern Europe, to Middle Asia, to the middle and southern part of the United States; and, at length receding, left some parts of them stranded on the Pyrenees, the Alps, the Appenines, the Caucasus, on our White and Rocky Mountains, or, wherever they could escape the increasing warmth as well by ascending mountains as by receding northward at lower levels. Those that kept together at a low level, and made good their retreat, form the main body of present arctic vegetation. Those that took to the mountains had their line of retreat cut off, and hold their positions on the mountain-tops under cover of the frigid climate due to elevation. The conditions of these on different continents or different mountains are similar, but not wholly alike. Some species proved better adapted to one, some to another, part of the world; where less adapted, or less adaptable, they have perished; where better adapted, they continue,—with or without some change;—and hence the diversification of alpine plants, as well as the general likeness through all the northern hemisphere.

All this exactly applies to the temperate zone vegetation, and to the trees that we are concerned with. The clew was seized when the fossil botany of the high arctic regions came to light; when it was demonstrated that in the times next preceding the Glacial period—in the latest Tertiary—from Spitzbergen and Iceland to Greenland and Kamtschatka, a climate like that we now enjoy prevailed, and forests like those of New

England and Virginia, and of California, clothed the land. We infer the climate from the trees; and the trees give sure indications of the climate.

I had divined and published the explanation long before I knew of the fossil plants. These, since made known, render the inference sure, and give us a clear idea of just what the climate was. At the time we speak of, Greenland, Spitzbergen and our arctic sea-shore, had the climate of Pennsylvania and Virginia now. It would take too much time to enumerate the sorts of trees that have been identified by their leaves and fruits in the arctic later Tertiary deposits.

I can only say, at large, that the same species have been found all round the world; that the richest and most extensive finds are in Greenland; that they comprise most of the sorts which I have spoken of, as American trees which once lived in Europe,—Magnolias, Sassafras, Hickories, Gum-trees, our identical Southern Cypress (for all we can see of difference), and especially *Sequoias*, not only the two which obviously answer to the two Big-trees now peculiar to California, but several others; that they equally comprise trees now peculiar to Japan and China, three kinds of Gingko-trees, for instance, one of them not evidently distinguishable from the Japan species which alone survives; that we have evidence, not merely of Pines and Maples, Poplars, Birches, Lindens, and whatever else characterize the temperate-zone forests of our era, but also of particular species of these, so like those of our own time and country, that we may fairly reckon them as the ancestors of several of ours. Long genealogies always deal more or less in conjecture; but we appear to be within the limits of scientific inference when we announce that our existing temperate trees came from the north, and within the bounds of nigh probability when we claim not a few of them as the originals of present species. Remains of the same plants have been found fossil in our temperate region, as well as in Europe.

Here, then, we have reached a fair answer to the question how the same or similar species of our trees came to be so dispersed over such widely separated continents. The lands all diverge from a polar center, and their proximate portions—however different from their present configuration and extent, and however changed at different times—were once the home of those trees, where they flourished in a temperate climate. The cold period which followed, and which doubtless came on by very slow degrees during ages of time, must have long before its culmination have brought down to our latitudes, with the similar climate, the forest they possess now, or rather the ancestors of it. During this long (and we may believe first) occupancy of Europe and the United States, were deposited in pools and shallow

waters the cast leaves, fruits, and occasionally branches, which are imbedded in what are called Miocene Tertiary or later deposits, most abundant in Europe, from which the American character of the vegetation of the period is inferred. Geologists give the same name to these beds, in Greenland and Southern Europe, because they contain the remains of identical and very similar species of plants; and they used to regard them as of the same age on account of this identity. But in fact this identity is good evidence that they cannot be synchronous. The beds in the lower latitudes must be later, and were forming when Greenland probably had very nearly the climate which it has now.

Wherefore the high, and not the low, latitudes must be assumed as the birth-place of our present flora;* and the present arctic vegetation is best regarded as a derivative of the temperate. This flora, which when circumpolar was as nearly homogeneous round the high latitudes as the arctic vegetation is now, when slowly translated into lower latitudes, would preserve its homogeneousness enough to account for the actual distribution of the same and similar species round the world, and for the original endowment of Europe with what we now call American types. It would also vary or be selected from by the increasing differentiation of climate in the divergent continents, and on their different sides, in a way which might well account for the present diversification. From an early period, the system of the winds, the great ocean currents (however they may have oscillated north and south), and the general proportions and features of the continents in our latitude (at least of the American continent) were much the same as now, so that species of plants, ever so little adapted or predisposed to cold winters and hot summers, would abide and be developed on the eastern side of continents, therefore in the Atlantic United States and in Japan and Manchuria; those with preference for milder winters would incline to the western sides; those disposed to tolerate dryness would tend to interiors, or to regions lacking summer rain. So that, if the same thousand species were thrust promiscuously into these several districts, and carried slowly onward in the way supposed, they would inevitably be sifted in such a manner that the survival of the fittest for each district might explain the present diversity.

Besides, there are re-siftings to take into the account. The Glacial period or refrigeration from the north, which at its inception forced the temperate flora into our latitude, at its culmination must have carried much or most of it quite beyond.

* This takes for granted, after Nordenskiöld, that there was no preceding Glacial period, as neither paleontology nor the study of arctic sedimentary strata afford any evidence of it. Or if they were any, it was too remote in time to concern the present question.

To what extent displaced, and how far superseded by the vegetation which in our day borders the ice, or by ice itself, it is difficult to form more than general conjectures—so different and conflicting are the views of geologists upon the Glacial period. But upon any, or almost any, of these views, it is safe to conclude that temperate vegetation, such as preceded the refrigeration and has now again succeeded it, was either thrust out of Northern Europe and the Northern Atlantic States, or was reduced to precarious existence and diminished forms. It also appears that, on our own continent at least, a milder climate than the present, and a considesable submergence of land, transiently supervened at the north, to which the vegetation must have sensibly responded by a northward movement, from which it afterward receded.

All these vicissitudes must have left their impress upon the actual vegetation, and particularly upon the trees. They furnish probable reason for the loss of American types sustained by Europe.

I conceive that three things have conspired to this loss. First, Europe, hardly extending south of latitude 40°, is all within the limits generally assigned to severe glacial action. Second, its mountains trend east and west, from the Pyrenees to the Carpathians and the Caucasus beyond, near its southern border; and they had glaciers of their own, which must have begun their operations, and poured down the northward flanks, while the plains were still covered with forest on the retreat from the great ice-wave coming from the north. Attacked both on front and rear, much of the forest must have perished then and there. Third, across the line of retreat of those which may have flanked the mountain-ranges, or were stationed south of them, stretched the Mediterranean, an impassable barrier. Some hardy trees may have eked out their existence on the northern shore of the Mediterranean and the Atlantic coast. But we doubt not, Taxodium and Sequoias, Magnolias and Liquidambars, and even Hickories and the like were among the missing. Escape by the east, and rehabilitation from that quarter until a very late period, was apparently prevented by the prolongation of the Mediterranean to the Caspian, and thence to the Siberian ocean. If we accept the supposition of Nordenskiöld, that anterior to the Glacial period, Europe was "bounded on the south by an ocean extending from the Atlantic over the present deserts of Sahara and Central Asia to the Pacific," all chance of these American types having escaped from or re-entered Europe from the south and east, is excluded. Europe may thus be conceived to have been for a time somewhat in the condition in which Greenland is now, and, indeed to have been connected with Greenland in this or in earlier times. Such a

junction, cutting off access of the Gulf Stream to the polar sea, would, as some think, other things remaining as they are, almost of itself give glaciation to Europe. Greenland may be referred to, by way of comparison, as a country which, having undergone extreme glaciation, bears the marks of it in the extreme poverty of its flora, and in the absence of the plants to which its southern portion, extending six degrees below the arctic circle, might be entitled. It ought to have trees, and might support them. But since destruction by glaciation, no way has been open for their return. Europe fared much better, but suffered in its degree in a similar way.

Turning for a moment to the American continent for a contrast, we find the land unbroken and open down to the tropic, and the mountains running north and south. The trees, when touched on the north by the on-coming refrigeration, had only to move their southern border southward, along an open way, as far as the exigency required; and there was no impediment to their due return. Then the more southern latitude of the United States gave great advantage over Europe. On the Atlantic border, proper glaciation was felt only in the northern part, down to about latitude 40°. In the interior of the country, owing doubtless to greater dryness and summer heat, the limit receded greatly northward in the Mississippi Valley, and gave only local glaciers to the Rocky Mountains; and no volcanic outbreaks or violent changes of any kind have here occurred since the types of our present vegetation came to the land. So our lines have been cast in pleasant places, and the goodly heritage of forest trees is one of the consequences.

The still greater richness of Northeast Asia in arboreal vegetation may find explanation in the prevalence of particularly favorable conditions, both ante-glacial and recent. The trees of the Miocene circumpolar forest appear to have found there a secure home; and the Japanese islands, to which most of these trees belong, must be remarkably adapted to them. The situation of these islands—analogous to that of Great Britain, but with the advantage of lower latitude and greater sunshine—their ample extent north and south, their diversified configuration, their proximity to the great Pacific gulf-stream, by which a vast body of warm water sweeps along their accentuated shores, and the comparatively equable diffusion of rain throughout the year, all probably conspire to the preservation and development of an originally ample inheritance.

The case of the Pacific forest is remarkable and paradoxical. It is, as we know, the sole refuge of the most characteristic and wide spread type of Miocene Coniferæ, the Sequoias; it is rich in coniferous types beyond any country except Japan; in its gold-bearing gravels are indications that it possessed, seemingly

down to the very beginning of the Glacial period, Magnolias and Beeches, a true Chestnut, Liquidambar, Elms, and other trees now wholly wanting to that side of the continent, though common both to Japan and to Atlantic North America.* Any attempted explanation of this extreme paucity of the usually major constituents of forest, along with a great development of the minor, or coniferous, element, would take us quite too far, and would bring us to mere conjectures.

Much may be attributed to late glaciation ;† something to the tremendous outpours of lava which, immediately before the period of refrigeration, deeply covered a very large part of the forest area; much to the narrowness of the forest belt, to the want of summer rain, and to the most unequal and precarious distribution of that of winter.

Upon all these topics questions open which we are not prepared to discuss. I have done all that I could hope to do in one lecture if I have distinctly shown that the races of trees, like the races of men, have come down to us through a pre-historic (or pre-natural-historic) period; and that the explanation of the present condition is to be sought in the past, and traced in vestiges, and remains, and survivals; that for the vegetable kingdom also there is a veritable Archæology.

Art. XVIII.—*Notes on Antimony Tannate;* by Ellen Swallow Richards and Alice W. Palmer.

In the course of some work on the determination of tannic acid, we tried Gerland's method of direct estimation by means of a standard solution of tartar emetic in presence of ammonium chloride. Gerland's formula, in which the old atomic weights are used (Zeitschrift für Analyse, 1863, ii, page 419), is given as $SbO_3(C_{18}H_3O_{12})_3$ [or in the new nomenclature $Sb_2O_3(C_{18}H_{16}O_{12})_3$] which requires

Sb, 15·60 per cent, C, 41·43 per cent, H, 3·07 per cent.

The formula that we have been led to adopt, is $Sb_2(C_{14}H_8O_9)_2 + 6H_2O$ which requires

Sb, 18·59 per cent, C, 38·41 per cent, H, 2·74 per cent,

in which tannic acid is considered as di-gallic acid,‡ with, possi-

* See, especially, Report on the Fossil Plants of the auriferous gravel deposits of the Sierra Nevada, by L. Lesquereux; Mem. Mus. Comp. Zoology, vi,. no 2.—Determinations of fossil leaves, &c., such as these, may be relied on to this extent by the general botanist, however wary of specific and many generic identifications. These must be mainly left to the expert in fossil botany.

† Sir Joseph Hooker, in an important lecture delivered to the Royal Institution of Great Britain, April 12, insists much on this.

‡ H. Schiff, Bull. Soc. Chem., II, xvi, 198.