REPORTS OF THE CONFERENCES ON CYCLES

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REPORT OF FIRST CONFERENCE ON CYCLES

In furtherance of researches on the problem of cycles, President Merriam, of the Carnegie Institution of Washington, called a conference of leading investigators, which was held at Washington on December 8 and 9, 1922. The first session was devoted to the nature of the problem, the methods, criteria, and conclusions in various fields; the second to a discussion of the application of the method of cycles in the fields of palæontology and archæology; and the final session was concerned with the refinement of methods and the correlation of the problems in the different subjects.

The value of the conference method in furthering the study of cycles is admirably demonstrated by the brief papers and discussions that follow. There are so many phases of the question that the correlation of the work of all the principal investigators is essential to rapid progress. In addition, there are so many specialties involved that no one person can possibly be proficient in all. The results attained up to this time promise ever-widening scope and importance to investigations of this class in their bearing on many fundamental human problems.

Reprinted from report in Supplement to The Geographical Review, vol. XIII, No. 4, pages 657 to 676, October 1923.

The Following Papers were Contributed:

Solar Radiation. Dr. C. G. Abbot, Secretary, Smithsonian Institution.

Sun-spots and Sun-spot Cycles. Dr. W. S. Adams, Carnegie Institution of Washington.

Cycles in Glacial and Postglacial Deposits. Dr. Ernst Antevs, Docent, University of Stockholm.

Nature of the Problem of the Cycle. Dr. F. E. Clements, Carnegie Institution of Washington.

Conclusions from Tree-Ring Data. Dr. A. E. Douglass, Director, Steward Observatory, University of Arizona.

General Methods in the Advance of Cycle Studies. Dr. A. E. Douglass, Director, Steward Observatory, University of Arizona.

Cycles of Health. Dr. Ellsworth Huntington, Yale University.

Causes of Cycles. Dr. Ellsworth Huntington, Yale University.

Records of Tree-Growth. Dr. D. T. MacDougal, Carnegie Institution of Washington.

Characteristics of Cycles. Dr. C. F. Marvin, U. S. Weather Bureau.

Economic Cycles. Dr. H. L. Moore, Columbia University.

Sediments and Climate. Dr. T. Wayland Vaughan, Scripps Institution of Oceanography.

Those Taking Part in the Discussion Included:

Dr. L. A. Bauer, Carnegie Institution of Washington.
Dr. Isaiah Bowman, American Geographical Society.
Dr. C. F. Brooks, Clark University.
Dr. W. J. Humphreys, U. S. Weather Bureau.
Dr. Neil M. Judd, U. S. National Museum.
Dr. Sylvanus G. Morley, Carnegie Institution of Washington.
Dr. David White, U. S. Geological Survey.
Dr. G. R. Wieland, Yale University.

PAPERS

Conclusions from Tree-Ring Data, by A. E. Douglass

The conclusions here presented include the dating and measurement of over 110,000 rings in nearly 500 trees, chiefly the yellow pine in the Southwest and the *Sequoia gigantea.* The dating has the assurance obtained by a thorough application of the principle of cross identification, in which each tree assists in correcting the errors of its neighbors. The influence of topography has been studied, and the agreement which a single tree will probably show with the average is known. More than 200 curves have been plotted and mounted for special analysis in the White Periodograph, whose flexibility in the study of undetermined variations far exceeds that of any other process known to the writer. In this analysis individual tree records may be compared with other individuals or with group averages as to cyclical characteristics.

The first group of conclusions depends upon individual characteristics, such as the width of a ring in reference to its immediate neighbors, the conspicuousness of the dark or autumn portion of the ring, the occasional division of the dark part into subordinate parts, and other individual characters. These conclusions are:

1. The dating of rings is certain when cross identification has been carefully applied.
2. In the dry climate of Prescott, Arizona, tree growth agrees with local rainfall with an accuracy of 70 to 85 per cent, depending on the use of a conservation factor.
3. The relative dating of ancient ruins in the Southwest has been accomplished by application of the principles of cross identification.
4. A relation to topography is evident. Trees having considerable soil moisture exhibit complacent rings, and trees with limited moisture exhibit sensitive rings in which a better relation to the annual precipitation may be found.
5. In the yellow pines of Arizona individual trees agree admirably with the mean of many; and the average of a small number, such as five, gives excellent results, while a still smaller number may prove of value.
6. A definite character, smallness, in one ring (1851) has been traced across 750 miles (California to Colorado).

The collective study of rings means taking them in groups whose minimum number is probably three or four. It may or may not involve smoothing the original record. But it has been found that smoothing decreases the number of short periods whose origin may be accidental. In mounting the curves for these tests the ordinates are referred to what is called a cutting or mat line and not usually to the zero line of the plot. Many tests have been made to see if this slight variation introduces error, but without finding any. The following conclusions have been formulated:

1. Scotch pines around the Baltic Sea show variations of rings in close agreement with the sun-spot numbers. This cycle therefore shows conspicuously in at least this one species of tree over a considerable area and extending back over 90 years. Hemlocks in Vermont show a similar agreement, with a phase displacement.
2. A group of cycles consisting chiefly of one about 19 years and another about 22 years (apparently the double sun-spot period) has been traced across 250 miles of country. This refers to the accurate comparison between yellow pines in northern Arizona and several groups of the same species in northwestern New Mexico and southwestern Colorado. Evidence of climatic origin is here indicated, because climate is the common factor over this large region.
3. Cycles in individual trees in the Flagstaff region have 75 per cent or more resemblance to a standard periodogram of that region. This conclusion has been reached in a series of dating tests applied to certain 125-year sequences of rings whose dating was unknown at the time of testing.
4. Cycles between 10 years and 35 in the Arizona yellow pine show a 50 per cent resemblance to sequoia cycles of similar length on the basis of comparison of large groups of trees. This result has been derived in an extensive series of dating tests between these two regions.
5. A topographic factor appears in the sun-spot cycle exhibited by the trees of Arizona and California. The yellow pines in the dry regions of Arizona show it best, the upland sequoias have it partly concealed by other cycles, while the well-watered basin sequoias show it least.
6. A striking historical confirmation of the sun-spot cycle in the Arizona pines, as well as in the sequoias, has appeared in connection with the researches of Spoerer and Maunder upon early observations of sun-spots.

Records of Tree Growth, by D. T. MacDougal

The evidence which may be obtained from the study of the growth layers of coniferous trees will doubtless be found to be much more valuable than that from any other tree trunks. The leafy mechanism and the structure of the wood has remained unchanged in some species for extended periods of geological time.

Dendrographic records have been made of the trunks of 18 species of trees in various localities from the Atlantic to the Pacific, at altitudes from sea-level to 8,000 feet. The records of 72 growth years are now available.

from the operation of the same climatic factors in evidence now. The general evidence is strongly against cataclysmic change, whether terrestrial or extra-terrestrial, and equally so against great changes in the mean annual temperature, whether due to either varying internal or solar heat.

Dr. White spoke of the significance of a study of Pleistocene forests. He recommended that in connection with climatic investigations and the attempt to establish climatic records through the study of the lamination of the Pleistocene clays or of prehistoric tree rings in the Southwest, arrangements should be made, if possible, for the systematic reinvestigation of Lake Lahontan. The work by Russell was pioneer in character, interesting and rich in results as it was. Nevertheless, in view of the great number of specialists in different lines related to such investigation at one point or another, the refinement and volume of criteria now available for comparison in such a study and the new lines of attack, with collateral ties in other branches of biology, physiography, and sedimentation, a new survey of Lahontan can not fail to develop a most profitable and instructive history, whose value to Great Basin physiography, climatic records, sedimentation, faunal and floral migrations, etc., is likely to exceed all estimates. A resurvey of Lahontan by modern methods and by specialists and criteria now available is urgently recommended.

N. M. Judd and Dr. Morley discussed the archæological angle of the problem. They were agreed that the science of archæology does not now appear to be concerned with cyclic phenomena as such; that they fail to see any means whereby study of these phenomena can contribute to our present knowledge of prehistoric peoples unless it be that great influences, occurring periodically, have prompted human migrations in ancient times. Both Dr. Morley and Mr. Judd referred to the explorations which the National Geographic Society is now pursuing at Pueblo Bonito, a prehistoric ruin in northwestern New Mexico. In this ancient village, and in other ruins throughout the Southwest, beams are frequently found. An examination of the annual ring growth in these ancient beams and a comparison of these annual rings with those in trees still living will, it is hoped, help in the dating of prehistoric Pueblo Bonito. Dr. Morley expressed the hope further that it would be possible to connect the tree-ring and sediment chronology with the record dates of the Mayas of Central America.

CONCLUSION

General Methods in the Advance of Cycle Studies, by A. E. Douglass

Three practical lines of advance are indicated in the study of climatic cycles: increased reliability, development of general knowledge of climatic cycls, and extension of our chronology backward into Pleistocene times.

Increased reliability will come in at least two ways—by determination of physical causes of various aspects of the problem and by the establishment of criteria of reliability.

Reasonable criteria of reliability have to be developed by the investigators as in any other advancing line of thought. The criteria hitherto used in tree work consist in (1) the seemingly perfect obvious solar cycle in the Scotch pines about the Baltic Sea; (2) the tracing of a definite cycle through many trees and over large areas; (3) observed correlation with topography; (4) a strong historical check on the solar cycle in the Arizona and California trees; (5) a probability criterion depending on the selection of genuine from spurious records by the presence of cycles only.[1]

Development of general knowledge of climatic cycles will come by comprehensive investigation along at least three lines—the use of meteorological data, tree growth studies, and clay layers.

The greatest difficulty in utilizing meteorological data is the inadequacy of the short historical records. The compilation of much longer even if somewhat less accurate records is urgently desired. It might be possible to compile a probable or proximate record for a state or district. Then also the gathering together of all historical information from any source bearing upon wet and dry years, warm or cold, famines, floods and so forth, would give a most important check and would have to be recognized in any full solution of climatic variations.

In tree-growth studies we have 3,000 years of actual annual records, for part of which we are getting comparative meteorological comparison data; and extensive regions of the world offer to supply material. Thus, there is opportunity of extending the study of climatic cycles in time and space at the same time. It seems unlikely that the final answer to the puzzle of climatic variation will come through either time or space extension alone. The following are extensions of tree-growth study:

1. Continued use of periodograph analysis on historical and fossil tree records.
2. Determining effects of latitude, mountain ranges, oceans, and so forth.
3. Delineation of cyclo-meteorological districts.
4. Correlation with temperature and sunshine.

[1] One test of this kind had been made by the writer previous to the cycle conference, and a half dozen since then, following some suggestions of Professor Marvin. These few preliminary trials resulted in the usually immediate correct selection when the records were 200 years long and over, and mostly in failure in 50 or 60-year lengths. It shows strikingly how mere chance may produce short cycles. A single trial does not show how to recognize genuine cycles if they are present, but development of the process could, I believe, be made to do so.

5. Extensive collection of material from other parts of the world.
6. Collection of all possible prehistoric and fossil material to aid in the historical study of cycles.
7. The beginning of permanent and full records among the sequoias (*gigantea*) and temporary records on the site of specially interesting trees.
8. Identifying "storm" and "autumn" rings.

Clay layers show most remarkable sequences, reaching over 3,000 years in America and even more in Sweden. They will serve as admirable data for climatic study and are more specifically outlined below.

Extension of our chronology into Pleistocene times may be accomplished through extended sequoia records combined with the long annual records in clay layers. The latter are probably a more direct result of temperature than of any other single element. Their great extent of continuity is extremely impressive. They are limited in area and as yet of unknown date in our chronology, and we have no meteorological records to compare with them. But they do give a remarkable tape measure for Pleistocene chronology for the study of cycles. It seems well worth every effort to find buried or fossil sequoias or other trees or deposits of annual sediments which will bridge the gap between the earliest dated sequoia rings and the latest clay layers.

REPORT OF SECOND CONFERENCE ON CYCLES

In furtherance of researches on the problem of cycles, President Merriam of Carnegie Institution called a second conference of investigators which convened at the Administration Building of the Institution on Saturday, December 15, 1928. Dr. D. T. MacDougal of the Institution's staff of the Division of Plant Biology presided.

The Following Scientists were Present upon Invitation of President Merriam.

Frederic E. Clements, Associate in Ecology, Carnegie Institution.

Ernst Antevs, Docent, University of Stockholm.

Alfred P. Dachnowski-Stokes, Physiologist, U. S. Bureau of Chemistry and Soils, Washington, D. C.

Alfred H. Joy, Mount Wilson Observatory, Carnegie Institution.

Nicholas Perrakis, University of Paris.

Seth B. Nicholson, Mount Wilson Observatory, Carnegie Institution.

William J. Peters, Department of Terrestrial Magnetism, Carnegie Institution.

C. R. Duvall, Department of Terrestrial Magnetism, Carnegie Institution.

Irving W. Bailey, Professor Plant Anatomy, Bussey Institution, Harvard University.

A. E. Douglass, Director Steward Observatory, University of Arizona, Tucson, Arizona.

Earl H. Morris, Archæologist, Carnegie Institution.

A. V. Kidder, Associate in Early American History, Carnegie Institution.

Neil M. Judd, Curator American Archæology, U. S. National Museum.

G. R. Wieland, Associate, Carnegie Institution; Associate Professor Paleobotany, Yale University.

C. G. Abbot, Secretary, Smithsonian Institution.

Alice C. Evans, Bacteriologist, Hygienic Laboratory, U. S. P. H. S.

Frederick V. Coville, Botanist, Department of Agriculture.

David White, Research Associate, Carnegie Institution; Chief Geologist U. S. Geological Survey.

C. J. Whitfield, Carnegie Institution.

William Charles White, U. S. P. H. S.; Chairman Medical Division, National Research Council.

Barrington Moore, Forester and Ecologist.

E. N. Munns, in charge Forest Experiment Stations, U. S. Forest Service.

C. F. Marvin, Chief, U. S. Weather Bureau.

W. J. Humphreys, Meteorological Physicist, U. S. Weather Bureau.

H. H. Clayton, Meteorologist, retired from official work.

H. H. Kimball, Senior Meteorologist, U. S. Weather Bureau.

Watson Davis, Managing Editor, Science Service, Washington, D. C.

Edwin E. Slosson, Director, Science Service, Washington, D. C.

Charles B. Davenport, Director, Department of Genetics, Carnegie Institution.

Forrest Shreve, in charge Desert Laboratory, Tucson, Arizona.

D. T. MacDougal, Associate in Plant Biology, Carnegie Institution.

Having described the relation of this tree to the water supply I may say a word as to explorations in its reaction to other environmental factors.

Next to water supply, temperature of the cambium must be of the greatest importance, and this can not be deduced from air temperatures in useful detail, but must be observed directly.

I have as yet no practicable method for continuous registration of cambium temperatures. However, mercurial thermometers with thin bulbs have been kept in position to take temperatures of the growing layer in several trees. Such an instrument on Redwood No. 6 has been read on random

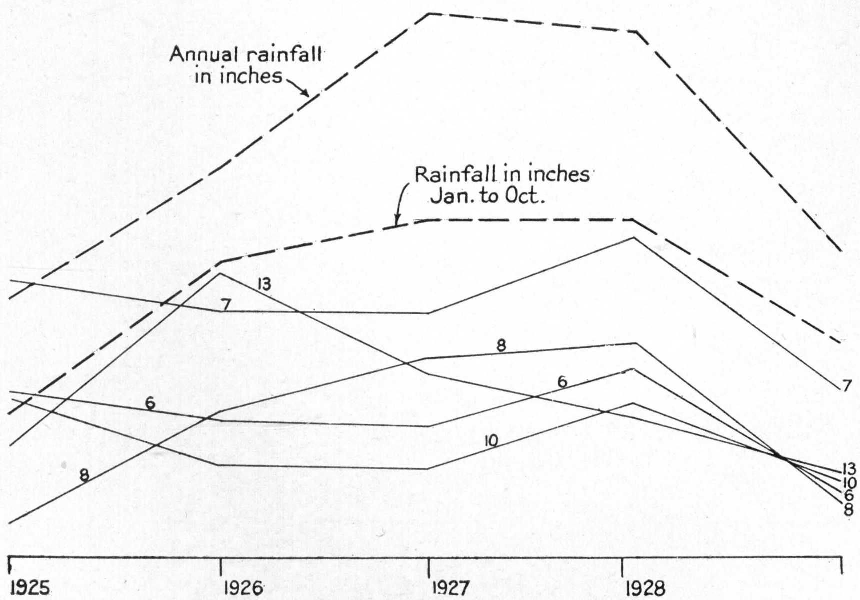
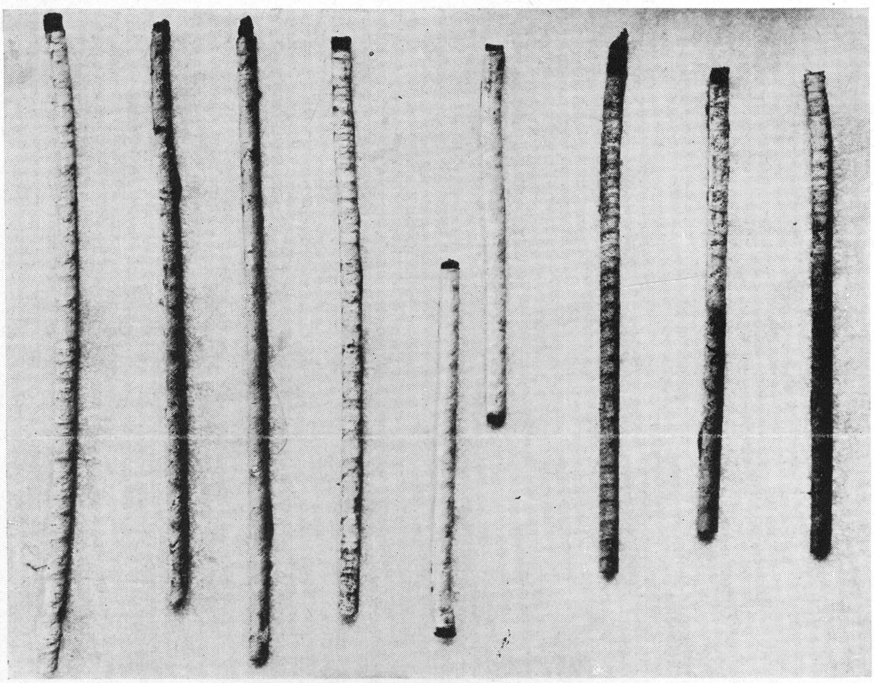


FIG. 9. Records of growth of redwoods 6, 7, 8, 10 and 13, annual rainfall, and rainfall, January–October are given for comparison.

occasions about 300 times in 1926, 1927 and 1928. It is notable that these readings plot as a good parallel to the amount of growth during these three years; otherwise expressed, the annual layers in these trees would seem to record the course of temperature more nearly than that of rainfall in the three years mentioned.

The possibility of using certain trees as recorders of temperature and of rainfall greatly increases the prospective value of the tree trunk to the student of past climates.

In most of this work slices or cores taken from living and dead trunks furnish the material brought into the laboratory. It is no easy matter to distinguish the separate layers in many cases. After trials of many solutions and stains for bringing out the boundaries of layers, cores from pines and redwoods, including the individuals of which the records have been discussed above, were photographed by X-rays. Under the intensities and



1A 1B 17 28 O O_1 6 7 8

FIG. 10. X-ray photographs of cores of Pines Nos. 1A, 1B, 17, 28, and O, O_1 and redwoods Nos. 6, 7, 8 delimit layers sharply.

exposures used, the carbohydrate components are transparent and an image of the infiltrated calcium and perhaps magnesium only was obtained. It may be seen by reference to figure 10 that the annual layers are much more sharply delimited than by any scheme for direct vision. The employment of the X-ray may be expected to facilitate the study of many features of wood sections and to yield information of especial value to the student intent on deciphering the course of past climates as recorded by tree trunks.

Cycles in Tree Growth, by A. E. Douglass

THE CYCLOGRAPH: VARIABLE GRATING TYPE

Search for periodic characters in curves of rainfall, tree growth, sun-spot numbers and other data have been made by the writer since 1914, by a cyclograph method specially developed for the purpose. The principle involved depends upon the interference of two sets of parallel lines adjusted at a small angle of about 15° to each other. For purposes of description let us consider these lines to be nearly vertical. If these two sets have the same spacing throughout, the points of intersection will form straight lines perpendicular to the mean direction of the sets, that is, in a horizontal direction. If one set can be varied with respect to the spacing between the lines, the line of intersections can be made to incline one way or the other as the intervals between become larger or smaller. Suppose one set remains uniform throughout, while the other shows a certain spacing, for the time represented by the left quarter of the pattern, then diminishes for the second quarter, then increases for the third quarter, till in the last quarter it takes a size equal to that in the first and in the same phase with it. In such a series of changes the line of intersections will take first the horizontal direction, then bend down (or up) in the second quarter, change its direction back again in the third quarter till it reaches and maintains the continuation of its direction and position in the first quarter.

An exactly analogous combination of changes took place in the Wolfer sun-spot numbers after about 1700. The spacing was constant at a little over 11 years to 1750, then reduced nearly to 9 years till 1788, then increased to approximately 15 years to 1830, and after one interval of about 7 years reassumed its value of the early 1700's and in the same phase. This constitutes typical data for analysis.

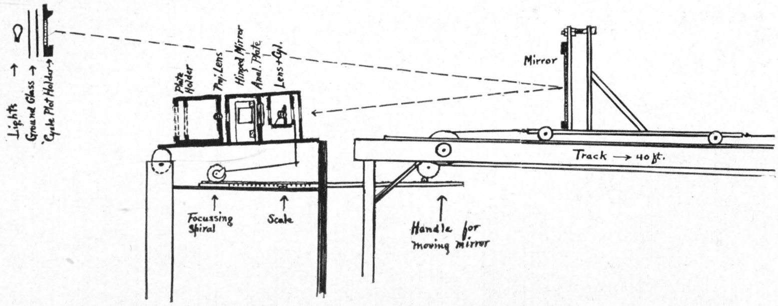


FIG. 2. Arrangement of White cyclograph, in which long range is obtained by varying the size of image falling upon a fixed grating.

In order to get these sun-spot numbers into form for cyclograph analysis, they are plotted in the usual manner at a standard horizontal time scale of 2 mm. to the year, or other unit, and in such ordinates that their variations (not their full ordinates) cover between one and two inches in the vertical. By carbon paper, the curve is carried through on to a strip of heavy brown paper, using a slight smoothing in some approved way. Then the maxima are cut out in such manner as to leave them somewhat isolated. To offset this preference for the maxima, the curve is then usually inverted and the minima treated in the same way—results that are common to both are used. There is rarely any important difference between the two analyses.

The curve thus treated, called a cycle plot, is mounted with a strong light behind it, whose beam is, at proper distance, passed through an ordinary lens to which a negative cylinder has been added, eliminating refraction in the vertical direction. A lens without the cylinder would give a simple image of the cycle plot in the focus. Adding the cylinder causes the illuminated

A

B

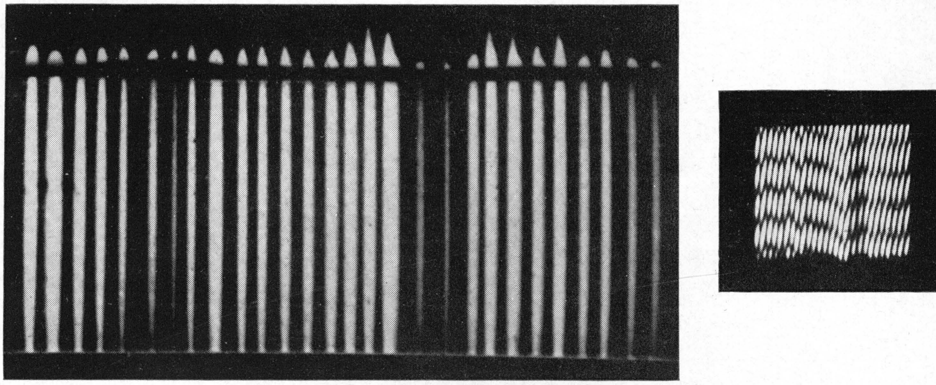


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FIG. 1. Cyclograph analysis of sun-spot numbers, 1610 to 1910: *a*, cycle plot; *b*, cylinder plot of same (formerly called "sweep"); *c*, cyclogram produced by passing *b* through a grating of equally spaced transparent lines; variations in the 11-year cycle become evident quantitatively in the bending of the interference fringes.

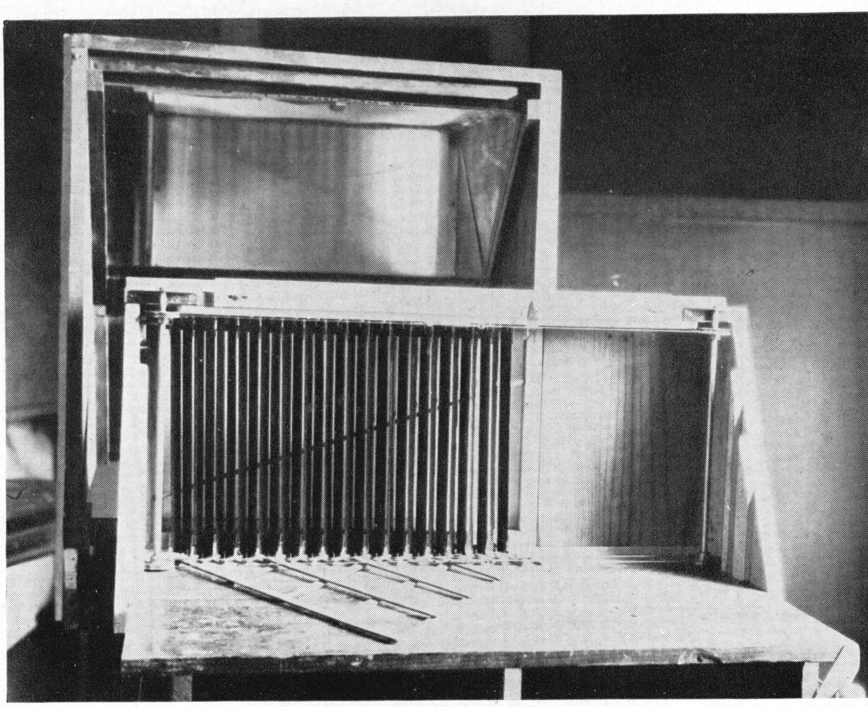

FIG. 3. Direct reading variable grating cycloscope; range is here obtained by varying the distance between the lines of the grating. The scale is directly above the right end of the grating; a frame at the back carries two mirrors which make the transmitted pattern visible to the audience. A "cylinder" plot of the original data is thrown on this grating by a lantern. (Photograph by James Stokley.)

maxima to extend themselves into a vertical set of parallel lines whose horizontal spacing is the relative spacing of the maxima in the original, and whose photometric intensity is proportional to the ordinates. Thus a two-dimensional curve has been changed into three dimensions.

The other set of parallel lines is supplied by an analyzing plate or grating, whose spacings are the same throughout. It is thus a standard with which the observed data are compared. It consists of transparent lines whose width is about one-fourth of the center-to-center distance. Of these two sets of parallel lines, the one giving the observed data is thrown upon the standard grating and the pattern that passes through is observed. The equalized spaces of the grating pick out the cycle effects in the data, and any features that come too early or too late are thrust out above or below the line of a true period. The pattern thus becomes an ordinary graph of the differential between a true period and the cycle under observation. But in this graph the ordinates are quantitative and it follows that any apparent alignment of intersections in any direction is an actual cycle in the data examined. Thus one pattern may give several different cycles, the length of time over which each has prevailed whether concurrent or not, whether they are simple or composite or variable, when variations took place and how great they are.

In actual practice one will find that a single pattern does not have a large range, say 1:2 or 1:3. That is, the longest cycle plainly seen in it is only two or three times the shortest. This range is not enough for practical purposes, for in long use of this instrument the desired range has proved to be at least 1:5 and even a little more. The White cyclograph has a range from a minimum cycle of 6 years or less to a maximum of over 42 years. The complete analysis of a long curve consists first of a test at standard plotting (2 mm. to the year) and then at $\frac{1}{5}$ of that scale, $\frac{1}{25}$, and so on. Thus the different cyclical characters are brought out.

The increased range may be produced either by varying the size of the pattern passed through a constant grating or by varying the size of the grating through which a constant pattern is passed. The first form with the variable pattern is preferable. It has a greater range and the number of interference fringes in the pattern watched is constant, and therefore subdivisions and harmonics can more quickly be recognized. The disadvantage is the larger floor space covered and that only one person can view the pattern at a time. This form has been in use since 1914. Variation in size of pattern is produced by a movable mirror reflecting the beam of light from the cycle plot back to the lens and grating. As the mirror is moved away the effective distance between the curve and the lens is increased and the scale of the pattern thrown on the grating is diminished.

The necessary characters of any variable grating are that the spacings, however varied, shall remain equal throughout and that the ratio of transparent to opaque part of each line in the grating shall be constant and equal

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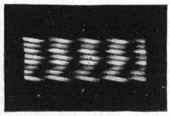

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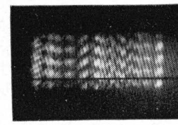

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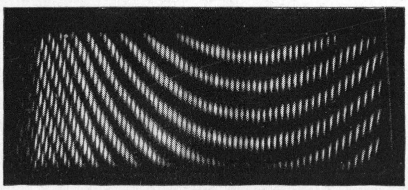

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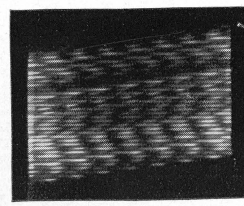

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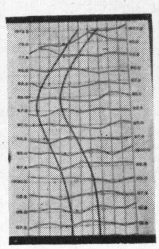

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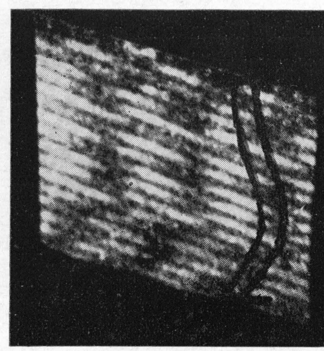

FIG. 4. Cyclogram of European trees, 1825 to 1910, showing sun-spot cycle alone.

FIG. 5. Cyclogram of Flagstaff trees, 1425 to 1910, with the horizontal thread set at a cycle of 14 years; it shows a 14-year cycle in most of these centuries, an 11-year cycle in the left (first) half, one of 9 or 10 years in the third quarter, and so on. In the first century (left) the 11-year divides into halves.

FIG. 6. Logarithmic variation in a cycle; the values represented change from 5 to 10 years by a constant ratio.

FIG. 7. Apparent variable cycle of 2.3 years in Windsor, Vermont, rainfall; 1835 to 1912, as published in Astrophysical Journal, April 1915; 1835 is at top.

FIG. 8. Enlargement of portion of figure 7 between dates 1873 and 1912, to correspond with figure 9, and slight turning to bring a cycle value of 2.5 years into the vertical, as in figure 9.

FIG. 9. Variable cycle of mean value 2.3 years, observed by Clough (Monthly Weather Review, September 1924) with vertical line representing a cycle of 2.5 years. Slightly foreshortened in photographing.

throughout. Such a grating was constructed in the spring of 1928. This was accomplished by high narrow vertical pieces of thin metal attached perpendicularly to "lazy tongs." Each strip was made of two narrower pieces of light galvanized iron soldered together in a slightly overlapping position, to give them great stiffness without thickness. The lazy tongs are crisscrossed pieces of metal riveted so as to turn on each other at center and each end. The grating so arranged was not workable until similar lazy tongs were placed at the top of the strips and a guide of the same type was made to distribute the movement equally in all parts of the grating. This can be seen in the illustration.

The grating as illustrated has 32 strips, 0.75 inch wide by 13 inches high, and may be readily expanded from about 14 to some 30 inches by a handle and gearing and flexible wire belt at top and bottom. A scale is placed at the top with an index attached to the moving end of the grating. The left end in the illustration is fixed. Beyond the grating is an inclined stick to serve as a standard direction necessary to get scale readings. Back of that is a tracing paper screen. Beyond that is a separate frame carrying two large mirrors at 45° inclination facing each other, to lift the view of the pattern on the screen up over the grating and turn it back toward the audience.

For working with this apparatus a photograph is made of the cycleplot through a camera with cylindrical lens. The negative is then enlarged into a lantern slide at a standard scale. When this slide is placed in a lantern and the scale of the picture so produced is given a definite relation to the grating and the standard direction, then any fringe in the transmitted pattern that is brought parallel to the standard direction gives a scale reading that is its own cycle length. The instrument is thus a direct reading variable grating cycloscope.

In connection with all cycle analysis simple standardizing curves are thrown in from time to time to check the accuracy of adjustments and scale. The best form of calibration curve is a mixture of several periods such as 7, 9, 11, 13 and 17 years plotted on standard scale. In this way one checks the scale at several different points and at the same time becomes accustomed to the appearance of cyclograms showing the sort of interference produced by mixture of cycles, as is common in tree records. Some tree curves give single well-defined cycles, as in the European trees shown in figure 4, but by far the larger part show mixture as in figure 5, which gives the Flagstaff tree record from about 1425 to 1910. Here a number of different cycles from 10 to 28 years may be distinguished.

[In answer to a comment on varying periods (raised by Professor C. F. Marvin) the capacity of the cyclograph to show variable and broken cycles, as well as constant ones, was emphasized.]

Figure 6 shows a cyclogram of a varying period in which each interval is increased by a constant ratio over the preceding. Figures 7, 8 and 9 show the often observed cycle of something over 2 years. In figure 7 it is in the compiled rainfall near Windsor, Vermont, 1835-1912. It has been found by Clayton, Arctowski, deGeer, and Abbot as well as by the authors in these figures. The cycle and its variation were observed by the writer in 1915, but were called a "broken" cycle and interpreted as the result of interference of other cycles as seems so often to be the case in tree records.

Cycles in Western Trees: A Check

A study has recently been made of 305 trees taken in 42 groups over the western area between the eastern edge of the Rocky Mountains and the Pacific Coast and lying between the Columbia River on the north and the Mexican border on the south. This area was divided into three zones, Coast, Arizona and Rocky Mountain, with approximately an equal number of groups in each and about 17,000 ring measures to the zone. In 1926 three complete analyses were made of the 42 group curves, two of the ordinary upright curve and one of each curve inverted to bring out the minima. Only those cycles were listed which appeared in two of the three analyses. The cycles in each zone were then plotted in the periodogram form and published (1928). However, before that publication went to press, a complete check had been made by having the entire 84 curves, one upright and one inverted of each group, replotted on scales unknown to me. A complete analysis was made of these and then the cycles found were corrected back to true scale. Only those cycles were listed which appeared in both upright and inverted curves. These were then plotted as before in periodogram form. Figure 10 shows a comparison by zone of the two results. The maxima are darkened to enable the eye to catch more readily the agreements and disagreements. In the interpretation of the writer the agreements are sufficiently strong to give evidence of the reality of the cycles appearing in both curves.

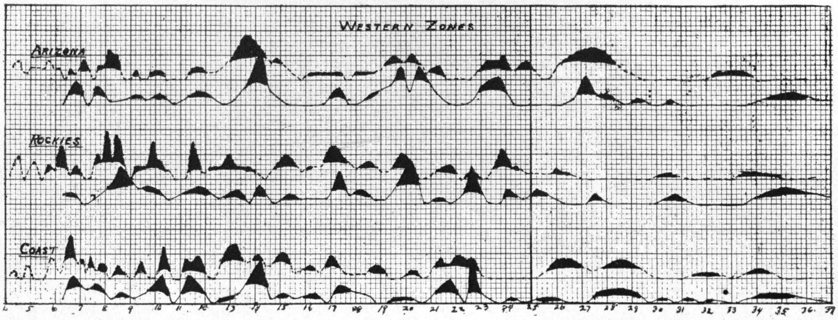

Fig. 10. Western zone cycles by two independent analyses; about 100 trees in each zone; tree record after 1750 is used throughout except in a few cases in earlier analysis (lower line in each pair).

The cycles found show a strong resemblance between the three zones with, however, some difference in emphasis. They have been combined into

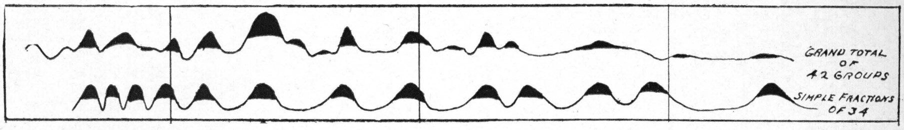

FIG. 11. Comparison of summary of western cycles with simple fractions of Bruckner period, here taken as 34 years.

one curve which is shown in figure 11, together with the simple fractions of the Bruckner period which is here taken as 34 years, a figure derived from study of the sun-spot cycle as it appears in pines and sequoias of the southwestern area. The resemblance is perfect, but it seems to the writer to give considerable expectancy that the western tree cycles are closely related to the Bruckner cycle and therefore to solar variations.

Long Records in Annual Rings

Four 3,000-year sequoias are now known, three of them in a grove east of Springville and one, the oldest, extending 3,233 years into the past, near the General Grant National Park. Three were found by Huntington about 1911 and one was identified by the writer in 1928. The record in these trees is very clear and its appearance in similar form throughout the sequoia area indicates a close climatic connection. Strong evidence has been found that precipitation plays an extremely important part in the growth of these trees, but other factors enter also and the complete interpretation of these valuable records will be somewhat more complex than those of the yellow pine of Arizona. It should be added that to the present time the coast redwood is not found to be its equal. In two carefully selected groups of the latter, one at Santa Cruz and the other at Eureka, the center of the redwood industry, not enough similarity has been found between different trees to lead to the belief that climatic effects were being recorded. Further effort will be made to find coast redwoods that give climatic effects.

The western yellow pine, growing in the plateau area of northern Arizona and adjacent states, gives a more direct record of rainfall since its situation is in a much drier region. Excellent records of recently cut trees carry this ring record back 500 years. A single tree secured for me by Director G. A. Pearson, of the Southwest Forest Experiment Station, has 640 rings and is the oldest yellow pine tree so far discovered. The inner part as a record, however, is somewhat complacent and therefore less easy to interpret in climatic terms. But it has been supplemented by collections of early historic and prehistoric material made in behalf of the National Geographic Society and thus we have available today pine records covering some 1,255 years, divided into nearly equal portions by a gap of unknown duration. When this interval is filled, the whole series will become a continuous climatic record of the highest value, both for exactness and for the correlation possibilities between it and the longer sequoia record above mentioned.

Life Cycles in Disease, by William Charles White, M.D.

We have much evidence which relates diseases in both man and animals to certain well-known cycles in nature. I think we have never yet in the study of disease cycles swung out toward their relation to the great cycles of nature, such as those occurring in the great cosmic cycles, or even in relation to the sun-spots in the sun cycles. We have, however, very definite evidence of the relation in such a disease as rickets to the influence which various wave-lengths of the sun and its emanations have to a definite chemical substance known as sitosterol. These emanations from the sun and other luminous bodies at least occur in cycles of intensities, but so far as I know little study has been given to this phase of the subject, and very little study has been given to the seasonal occurrence of such a disease as rickets.

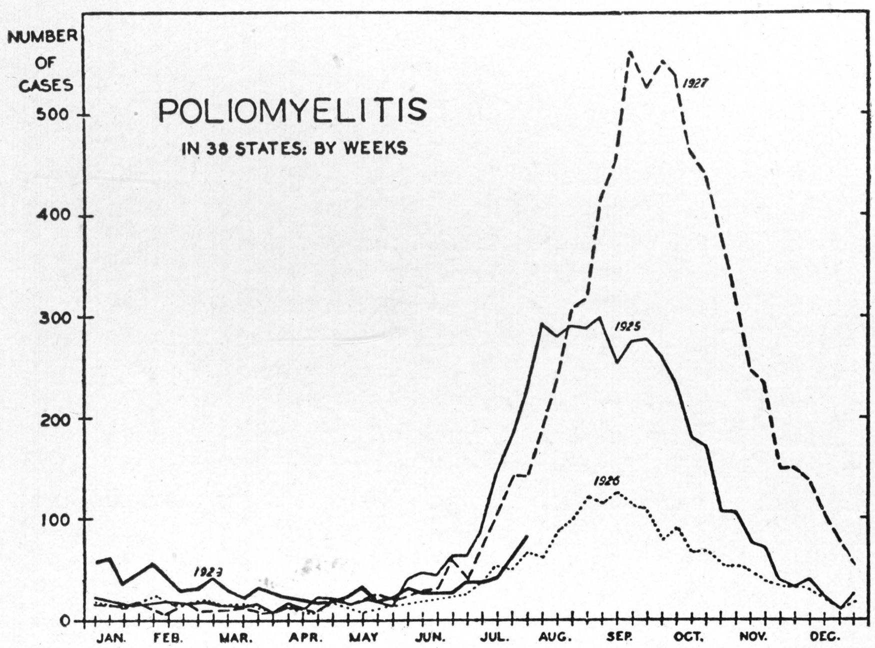

CHART 1

Perhaps the most prominent cycles with which diseases are associated are what we know as seasonal cycles. The influence of these is evident in such diseases as poliomyelitis (see Chart 1 for 1925-26-27), Rocky Mountain spotted fever (see Chart 2 for 1922-23-24-25-26-27), influenza and, in fact, most of the so-called infectious diseases.

Some diseases and their relation to cycles, so far as man is concerned, are known to be due to cycles in other forms of life, and a number of these have been worked out definitely. Probably one of the most striking examples is the occurrence of Rocky Mountain spotted fever determined entirely, in its occurrence in man, by the life cycle of the tick. This will be apparent from differences in this country than in Europe. But on the whole the remains of conifers and shrubs as a more or less definitely woody layer or "Grenzhorizont" in the east-west belt of European highmoors, and the abundance of conifers in the bottom woody layers of peat that occupy the younger Atlantic coastal terraces (9) and extinct glacial lakes in this country (7) point to environmental conditions essentially like those of forested regions. During this period the western grasslands or black prairie soils developed probably well-defined zones of carbonate accumulation and the characteristics of tschernozems, while sand dunes were again being built up by wind activity along the sea coast.

(6) Thereafter, in the Sub-Atlantic period of recent postglacial times, sphagnum mosses once more encroached on the forested peatlands. In the younger peat profiles of central and eastern United States, the secondary pond and lake stages as well as the layers of reed and sedges and peat with admixture of sedimentary materials are probably of the same age. Futhermore it appears quite possible that, through the action of increased moisture, podsolization was brought about in the forest soils of the cool moist eastern United States, and that westward in the black prairie soils the change from dry to wet conditions brought about a certain degree of degradation in that region under the influence of increased moisture. According to Marbut (13) the prairie soils have been podsolized to a slight extent, but the evidence is considered too meager as yet to ascribe the characteristics to a change of climate.

(7) As has been already pointed out elsewhere (5) the present period is somewhat drier than the Sub-Atlantic. The visible natural reforestation of many peat areas along the ocean coast as well as inland in the Great Lakes states and in southern peat deposits of this country, the dying out of the sphagnum mosses in the northern peatlands and their replacement by fruticose lichens, shrubby heaths and conifers, is very common and a consequence of diminished precipitation or humidity. The formerly abundant reed marshes are disappearing more or less completely, and dunes are becoming more and more mobile. The extent of the northward movement of deciduous hardwood forests over peat deposits and the chemical expression of these changes have been studied but very little. There exists a richer vegetation on the peat deposits of today than at any time in the past, and crops as well as civilizations show a more ample spread and movement farther northward. While the evidence is perhaps not altogether tenable from the standpoint of the meteorologist, the current stratigraphic interpretation by workers in peat investigations as to climatic changes from wet to dry periods will doubtless stand until the records of American peat deposits have been much more systematically studied.

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Climatic Cycles and Changes of Vegetation, by Frederic E. Clements

From the synthetic and dynamic nature of its approach to the problems of life in its environment, ecology deals constantly with cycles and with climatic cycles in particular. The sun-spot cycle is taken as the typical example of cycles in general and its variability in duration, intensity and phase is thought to be sufficient warrant for using the term to apply to a wide range of continuous recurrences, in accordance with scientific usage. While the average duration of the sun-spot cycle has been 11.4 years for the 180 years of record, the interval between maxima has varied from 17 years (1787-1804) to 7 years (1830-1837). In addition to the more or less regular progression from minimum to maximum that characterizes it, its intensity varies much at these times. The highest maximum recorded was 154.4 for 1778, the lowest 45.8 for 1816; for the minimum the respective numbers were 11.4 for 1766 and 0.0 for 1810. The five maxima from 1750 to 1787 ranged from 83.4 to 154.4, and the three from 1804 to 1830 from

45.8 to 70; the highest successive maxima were 138.3 for 1837, 124.3 for 1848, 95.7 for 1860 and 139.1 for 1870. From this date relatively low and high maxima have alternated, viz, 63.7 in 1883, 84.9 in 1893, 63.5 in 1905, 103.9 in 1917 and 76.5 in 1928, indicating a double cycle. Furthermore, the sun-spot cycle differs in its phases, the interval from minimum to maximum being but once the same as that in the opposite direction.

The initial interest of the ecologist in cycles was an outcome of the study of succession, itself a cycle, but it was much stimulated by the investigations of Douglass (1909, 1914) and Huntington (1914). These lent support to the working hypothesis that the sun-spot cycle might be employed for anticipating changes in rainfall and hence in vegetation. The approach of what was thought might prove a zero minimum in 1913 gave additional impetus to this view. The minimum turned out to be 1.4 rather than zero, but it was followed by excessive precipitation, such as had marked the absolute minimum of 1810. Since the maxima of 1883 and 1905 had been low, alternating with high ones for 1870 and 1893 with coincident periods of intense drought, it was assumed that the next maximum might well be high. This proved to be true, the sun-spot number being 103.9, the highest for half a century, and this was accompanied by a major drought period lasting for 2 to 4 years throughout the West. As a result of these coincidences, a compilation was made of the plus and minus departures from the mean rainfall for all stations in the western United States for the five-year period centering on the maximum. These showed little correlation with the sun-spot maximum as such, but gave a striking one with those maxima of 80 numbers or more. Since this was practically half of the highest maximum known, namely, 154.4, and since historical accounts supported the rainfall record in indicating drought at all major sun-spot maxima, it suggested the hypothesis that drought periods were to be anticipated at each maximum of 80 numbers or over (Clements, 1921).

A further investigation of this possible relation is now under way for all stations west of the 90th meridian, as well as those in the East with long-term records. With this has gone an attempt to forecast the intensity of the present maximum, based partly upon the monthly and yearly course of the sun-spot numbers since the minimum of 5.8 in 1923, but chiefly upon the assumption that the high maximum of 1917 would be followed by one lower than 80 numbers, as was the case in the two preceding double cycles. This has been verified by the provisional figure for 1928, which is 76.5.

The Water Cycle

This is the fundamental cyclic process in which the action of rainfall and the reaction of vegetation assume preponderant rôles. For convenience, the cycle of events may be considered to begin with evaporation and to end with the return of the water to the reservoir from which it came. The major features are evaporation, precipitation, runoff and percolation, all of which are profoundly modified by the plant cover, as well as by land-form and soil. Evaporation takes place from ocean and lake, forest and grassland and from the soil surface, much modified in the last instance by the vegetation that covers it. In all its forms, precipitation is also influenced by the presence and nature of the plant cover, which may condense moisture, intercept rain or snow, or divide the water that reaches the soil into runoff and absorbed. It further apportions the latter into water-content and gravity water, this being conserved in underground supplies or finding its way into stream, lake and ocean. Of all these reactions exerted by vegetation, evaporation from plants or transpiration and the reduction of runoff and erosion by means of shoots, roots or leaf-mold are the most significant.

The nature of the permanent or climax plant community determines in a great measure the kind of reaction and even more its intensity. This is equally true of the successional stages that lead up to the climax, though the effect of the pioneer communities is relatively small compared with that of the final stages and the climax itself. It has long been recognized that the transpiration of a deciduous forest, such as that of the East, might equal or even exceed the evaporation from a water-body of the same extent, but few exact measurements of water-loss from trees have been made, and it is but recently that the transpiration of grassland has been determined. Since the early settlement of the West, a feeling has prevailed that the breaking of the prairie and the growing of crops have led to an increase in rainfall, in spite of the fact that the records show no such difference for the two halves of the period. Experimental studies carried out with native grasses and field crops have demonstrated that tall-grasses may lose practically twice as much water as oats for the same area and period or nearly as much as alfalfa, while mid-grasses may transpire 90 per cent as much as millet. When the longer growing season of the grasses is taken into account, it becomes evident that they contribute as much moisture to the air as most crops, and that cultivation could not have produced an increase of rainfall in the Middle West.

The rôle of forest and grassland in reducing runoff and erosion and correspondingly increasing the water absorbed by the soil has been a matter of repeated observation for centuries, but the lack of definite measurements of this reaction has led to an occasional challenge of its existence. All doubts on this score have recently been settled by Lowdermilk (1925) in his studies of runoff and erosion from cultivated fields and temple forests in China, in which a ratio of 59:1 was sometimes found. In still more recent studies of the influence of the chaparral of southern California upon runoff and erosion, Lowdermilk and his associates have found a ratio as high as 100:1 between a slope denuded by burning and one with the natural cover. The annual pioneers of the first successional community reduced this ratio to approximately 10:1 the first season, owing largely to the favorable conditions for growth on a north slope.

In the endeavor to evaluate the significance of transpiration in rainfall, Brückner (1905) estimated that 78 per cent of the rainfall over a continent was derived from transpiration and evaporation from plant and soil and that only 22 per cent came from the ocean. Though this is a bold generalization in the present state of our knowledge, it has been accepted by Zon (1912) and by Lowdermilk in this country, and is in harmony with the ecological results obtained in several climaxes. It is evident that fire, clearing, overgrazing and most cultivation hasten the return of water to the ocean basins and correspondingly reduce the contribution made by transpiration to the rainfall of a region. This relation appears to be so fundamental that it has been proposed as the major reason for the depopulation of much of central Asia (Lowdermilk, l. c.).

Climatic and Biotic Cycles

The basic relation of life to its environment is summed up in another cycle of processes, composed of the action of environment upon plants and to a less degree upon animals, the response of both to this, the reaction of plants upon the environment and the coaction of organisms upon each other. Out of this complex springs the development of the climax community, which is known as succession and constitutes the simplest and most visible cycle in vegetation. Wherever a climax is destroyed or new territory becomes available through other causes, its development begins again as soon as the disturbing agency ceases to act, community following community until the climax is reestablished. Such cycles are repeated again and again as long as the climate endures, but an effective climatic shift brings in a new climax better adjusted to it. It thus follows that each climax is an indicator of its particular climate, and in much the same way each successional community indicates the set of conditions for its stage in the development. When a series of climatic changes occurs, as during an ice age, a corresponding cycle of climaxes, called a clisere, is constituted in a particular region.

However, all regions exhibit more or less topographic diversity and local climates to match. In these, fragments of original climaxes may persist as relicts for thousands of years and serve as keys to unlock the past in terms of climax migrations and the causative climatic shifts. Every great climax on the North American continent contains many such relicts of former climaxes, the individual examples often running far into the thousands. Nevertheless, all of these fall into two major groups termed preclimax and postclimax, which bear a definite relation to the climax in possession. The primary relation is one of rainfall, the preclimax being drier than the climax and the postclimax wetter in terms of water requirements. In consequence, relicts of the one will be found on dry ridges and southerly slopes, of the other in moist valleys and northerly slopes, while the climax occupies the middle levels between. In the case of an effective shift toward dryness, the preclimax will replace the climax; if the change is to greater rainfall, the postclimax will invade the climax area. Where climates lie in close juxtaposition as on a great mountain range, each climax bears the relation of preclimax to the one above and postclimax to that below.

During the past decade the method of relict indicators has been applied to all the climaxes of the continent north of the tropics, and to the three great types of vegetation—forest, grassland and desert. This method has been employed in Death Valley and the Mohave Desert to yield a series of communities ranging from desert scrub to mixed prairie on the margin, corresponding to rainfalls of approximately 3, 6, 9, 12 and 15 inches. These represent the climates and climaxes that succeeded each other in the cyclic spiral of desiccation from the Miocene to the present. The existence of grassland under a rainfall of 15 to 20 inches is further attested by the fauna described by Merriam for this region in the Barstow beds of the late Miocene (1919); this contained several species of grazing horses, camels, mastodons, merycodonts, etc.

The structure of the great prairie formation also bears witness to changing cycles of climate and migration. The original matrix was composed of genera of circumpolar origin, such as *Stipa, Agropyrum, Kœleria, Poa* and *Elymus*. A later change caused *Andropogon, Sporobolus* and *Panicum* to sweep in from the Southeast, and a relatively recent shift toward dryness brought in *Bouteloua, Bulbilis* and *Hilaria,* the typical short-grasses of the Mexican highlands. These dominants had evidently become associated before the Pleistocene, since members of each group constitute the great prairie wedge driven into the deciduous forest as far east as Ohio.

The shifting of climaxes due to glacial cycles is recorded by relicts of deciduous forest well within the limits of the boreal and lake climaxes of conifers, and by reciprocal outposts of spruce and fir, white pine and hemlock far to the south of their present climax areas. The last persists as a postclimax relict on a steep north exposure in southern Ohio (Braun, 1928), and the pine-hemlock climax once extended even farther south, as shown by relicts in the Alleghany Mountains as far as Georgia and Alabama. Though a circumpolar tree, the beech moved to the shores of the Gulf, probably at the time of the maximum glacial phase, and many relict communities of it still exist in the valleys of Louisiana.

Cycles in animal populations are less directly related to climate; they are fewer in number and have been little studied. Apart from a few cases, such as that of the 17-year "locust," they had received little or no ecological attention, until the investigations of Elton (1924). He has confirmed the existence of such cycles at the present time, though these are relatively unimportant by comparison with the great cyclic migrations of the Pleistocene. Since animals are to be regarded as intrinsic members of the climax community, it appears certain that they migrated as a part of it, a view that derives further support from the fact that food rather than climate is the primary control.

Paleo-ecology

The application of the methods of the climatic and biotic cycle to the past has led to the point of view embodied in paleo-ecology. The latter rests upon the doctrine of uniformity enunciated by Hutton and developed by Lyell, and has profited correspondingly from the trinity of modern ecology—development, measurement and experiment. The community bond in the climax, its developmental processes and its basic dependence upon climate have supplied the guiding principles of paleo-ecology and contain the promise of a changed outlook upon paleo-climatology. The investigation of peat deposits and their correlation with climatic cycles has been of the first importance in this connection, since they place beyond question the uniformity of the relation between succession, climax and climate from the present to the past (Steenstrup, 1842; Blytt, 1876; Sernander, 1894; Dachnowski, 1921, 1922).

The paleo-ecological method has been applied by Chaney (1925) to the fossil deposits of the John Day Basin, and with signal success. The principles laid down for paleo-ecology (Plant Succession, p. 362) had made it appear highly improbable that forests of the Oligocene and Miocene could have comprised such unlike life-forms as the determinations of the older paleobotanists required. The method of the community bond indicated that the abundance of *Sequoia* should provide the clue to its associates and an examination of the relict forests of *Sequoia sempervirens* confirmed this assumption. The majority of its modern associates were found to have lived with it in Oligocene times, while all the supposed tropical genera disappeared as a consequence. Similar results were obtained with the Mascall flora of Miocene age, the dominants being generically much the same as those of the oak-madroño woodlands of California today. With these two modern communities as a basis, it was possible to extend the present-day climatic correlations to the past and thus closely approximate the rainfall of the region during these two periods.

In another field, the relation between a series of climates and the clisere, both of which are potential cycles, has been invoked to give definiteness to the concomitant evolution and migration of grassland and ungulates. More than a half century ago, Kowalevsky (1873) pointed out the general correlation between grassland and the graminivore animals, but there was at that time no knowledge of the climatic succession of grasslands or of their composition and structure. The progress of paleo-ecology in recent years has made it possible to reconstruct the grassland climaxes of the different periods and from these approximate the climates under which they flourished. While the details of the correlation are still to be worked out, it appears probable that the height and density of the community, the structure of stem and leaf, and the content in terms of fiber, silica, starch and other food-stuffs will be reflected in the transition from such omnivores as *Eohippus* and

Orohippus to such intermediate graminivore types as *Mesohippus* and from this to the highly specialized *Pliohippus* and *Equus*.

In reply to Dr. Antev's question as to the present trend in the climate of North America, it may be stated that there is some evidence to indicate that the tendency is toward desiccation. It is possible, however, that this phase has reached its term and that the evidence really points to a maximum of dryness that has passed. It appears certain that the most xeric communities, such as desert scrub, sagebrush and short-grass, have extended far beyond their climax limits, first in response to dry phases of the climatic cycle and then in consequence of fire, overgrazing, or both factors combined. Under the operation of these and similar disturbances wrought by man, the effective influence of climate is removed and it is becoming increasingly difficult to find climax areas sufficiently natural to serve as trustworthy measures of climatic trends.

Moreover, this question is still further complicated by the telescopic relation of cycles, the minor fitting into major and these into grand climatic cycles and the latter into still larger deformation cycles. The tendency at any time in a lesser cycle may be directly opposed to that in a larger one without affecting materially the general course of the latter. As a consequence, we can deal accurately with the matter of climatic trends only with reference to a particular cycle, and this requires more knowledge of the major ones than we possess at present.

With reference to Dr. White's statement, the paleo-ecologist has a lively faith that the rings of fossil trees, varves, and other types of lamination will reveal cycles similar or identical with those disclosed by the work of Douglass, Huntington, DeGeer (1912), Antevs (1922) and others. However, it appears quite impossible that these should ever yield a continuous chronology through the Tertiary, to say nothing of the vast eras that precede. On the other hand, there is good reason to believe that the use of the climax as a universal indicator of climate will permit the reconstruction of past climates in clisere sequences that correspond to major or grand cycles.

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DISCUSSION

Remarks by H. H. Clayton following paper by A. E. Douglass:

I have studied weather cycles for a long time and the most serious difficulty I have encountered in analyzing solar and meteorological cycles is that the same cycle varies rapidly in amplitude and occasionally inverts in phase. This inversion in phase is not produced by a slow change in the length of the cycle; but frequently occurs suddenly. This change of phase is particularly noticeable in the cycles depending on solar rotation; but is found in every meteorological cycle that I have investigated. It is even found in the sun-spot cycle, if the relative numbers preceding the year 1800 can be trusted. Beginning with the sun-spot maximum in 1761, a sun-spot minimum is found in 1784—two sun-spot periods later; and beginning with the sun-spot maximum in 1787 a minimum is found in 1798 showing a complete inversion of phase in a single sun-spot period.

The assumption made in the Schuster method of cycle analysis and in most methods used in physics and astronomy is that the cycles remain constant in amplitude and phase. The assumption of a constancy of phase is also involved in the analysis by means of the formulas of correlation used successively by Clayton, Abbot and Alter and in the cyclograph used by Douglass. This change of phase does not necessarily prevent the discovery of the cycles by these methods, but greatly reduces the amplitudes of the periods found and renders futile any efforts at forecasting from the data. The occasional changes in phase and the rapid changes in amplitude of meterological periods, I think, explain the small amplitudes found by D.

Brunt and other investigators of meteorological cycles and the failure of the results in having forecasting value.

In reply to a remark of Dr. Antevs that the trees of Europe did not show periods of growth corresponding to rainfall, Mr. Clayton pointed out that the trees of Europe were like the tree described in the paper by Dr. MacDougal, which had an abundant supply of water and in consequence growth responded to changes in sunshine and temperature rather than to rainfall.

Remarks of H. H. Clayton following the paper by F. E. Clements:

Mr. Clayton, replying to an inquiry by Dr. Antevs as to whether the climate of North America was growing warmer and drier now, said that if Dr. Antevs meant by *now* a change during the last century, he thought the reply should be in the affirmative. In the eastern United States meteorological records extend backward for more than a century; while in the western United States and Canada they cover an interval of from 40 to 80 years.

If the temperatures are averaged in five or ten year groups they show a distinct trend upward in the northern United States and Canada, so that the temperatures are averaging some 1° to 3° higher than they were a half century ago. The glaciers in Alaska have been retreating since the first observation made many years ago. The evidence of desiccation is less certain because rainfall is more difficult to measure accurately than temperature; the level of the Great Lakes has shown a trend downward since the earliest observations more than a half century ago, and while this fall may be due in part to artificial causes it is apparently also due in part to decreasing rainfall.

Remarks of H. H. Clayton following the paper of C. G. Abbot:

The cycle of 25 months in solar radiation referred to by Dr. Abbot was discovered by me in meteorological conditions more than forty years ago and is described in two papers published in the American Meteorological Journal, one in August 1884 and the other in April 1885. A period of nearly the same length in sun-spots was described by A. E. Douglass in 1912. Both these papers precede the references given by Dr. Abbot.

Discussion and Comments by E. N. Munns:

Foresters are much interested in the study of climatic cycles. Their interest arises along two lines: First, the influence of these climatic changes upon the growth of forests and their reproduction; second, their influence upon protection, including protection from fire and protection from insects. Droughty conditions over extended periods of years may result in great difficulty in obtaining reproduction and may retard seriously the growth rate of forests over extended areas, making forestry as a practice almost impossible commercially. During the drought period, fires are more common,