Cycles in Natural Phenomena.

IN December 1922, Dr. Merriam, president of the Carnegie Institution of Washington, called a conference to discuss the question of 'cycles'. The report of this, and of a second conference held in December 1928, have now been published by the Carnegie Institution,[1] and the two reports form a stimulating contribution to the subject. The members took a very broad view, which was set out by F. E. Clements in an introductory paper as follows: "It seems desirable to use cycle as the inclusive term for all recurrences that lend themselves to measurement, and period or periodicity for those with a definite time interval, recognising, however, that there is no fixed line between the two. On this basis there can be no question of the existence of climatic and other cycles, though there may be the gravest doubt of the reality of periodicities in climate beyond that of the year."

The greatest emphasis naturally falls on cycles of climate, which underlie most known cycles of other terrestrial phenomena, such as crops and prices, growth of plants, and fluctuations in numbers of animals, while climatic cycles are themselves most probably reflections of cycles of solar activity. Unfortunately, however, the systematic observation of climate is of comparatively recent growth, and very few homogeneous series of meteorological records exceed one hundred years. This is sufficient for the accurate study of weather periodicities of a few years in length, but is quite inadequate for the determination of longer cycles, from twenty or thirty years upwards. The meteorological records, for example, have hitherto proved insufficient to determine the real nature and extent of the well-known Brückner cycle of about 35 years.

On the other hand, there exist several natural agencies which have the power to integrate the meteorological conditions during a period of a few months or a year, and register the results in some permanent form. The two most notable of these agencies are trees, which by the width of their annual rings show their rate of growth during each of a long succession of years, and melting glaciers, which leave behind them records of the volume of thaw water.

The investigation of the annual rings of trees has found its home in the United States, where it is associated especially with the name of A. E. Douglass, who in 1922 was able to present conclusions based on the dating and measurement of more than 110,000 rings in nearly 500 trees, all carefully collated and compared. It has been generally accepted that in the dry climate of Arizona and California the redwood, *Sequoia*, grows most rapidly in relatively rainy seasons, but the nature of the relationship between tree-growth and weather is examined more closely in a paper read at the 1928 conference by O. T. MacDougal. Since 1918, MacDougal has been obtaining measurements by means of the 'dendrograph', an instrument which makes a continuous record of the diameter of a tree between two contact points on opposite sides of the trunk.

The trees chiefly examined were the Monterey pine and the coast redwood. From the records illustrated, it seems that the pine grows most rapidly in late spring; the tree forms no reserve of starch, and in a dry situation the growth is closely related to the rainfall of the preceding winter. If abundant soil moisture is available, however, growth is greatest in dry years with few fogs, abundant sunshine, and high temperature. The meaning of the record made by the pine, therefore, depends on its situation. On the other hand, the redwood accumulates a reserve of starch, and moreover, it grows only in situations where the soil moisture does not fall below a certain percentage. Hence the correlation between the width of the annual rings and the rainfall in individual years is smaller than with the pine, but the redwood gives an excellent measure of the long-period fluctuations of rainfall. It also seems probable that temperature plays a more important part in the growth of the redwood than that of the pine.

On the whole, the pine is probably the better index of rainfall, but it is relatively short-lived. Four of the Sequoias measured began their existence more than 3000 years ago, but few pines go back more than 500 years, the oldest covering a period of 640 years. This difficulty has been partly overcome by the use of historic and prehistoric material, and the available pine records now cover two nearly equal periods, totalling about 1255 years, but unfortunately separated by a gap of unknown duration. When this gap has been filled, the whole series will become a continuous climatic record of the highest value.

The harmonic analysis of a very long series of data is a laborious occupation, and for the purpose of studying the variations of his tree measurements, in 1913 Douglass invented an ingenious optical instrument for determining the lengths of periodicities. A large instrument with photographic attachment was constructed with a fund given by Mr. Clarence G. White, and the instrument has been termed the 'White Cyclograph'. The earlier form suffered from the disadvantage of a rather limited range, the longest periodicity which could be determined being only seven times the shortest, but in an improved form described at the 1928 conference a device is incorporated which more than doubles this ratio. The principal result obtained up to the present is that most of the cycles of growth shown by the western tree-rings are probably simple fractions of a Brückner cycle of 34 years.

Another series of data which may prove of value is that relating to waves of infectious diseases, discussed by Dr. W. C. White. These may be related to cycles of solar radiation of various wavelengths, but very little is yet known as to the nature of the relationships, and the conclusion

[1] "Reports of the Conferences on Cycles." Pp. 83. (Washington, D.C.: Carnegie Institution, 1929.) Free on request.

reached is that there is a greater likelihood that a knowledge of weather cycles will help the study of preventive measures against disease than that a knowledge of the history of epidemics will further the study of weather cycles.

The view has often been expressed that by far the greater number of weather cycles will prove to be intimately related to cycles of solar variation. Unfortunately, only one of the latter can be regarded as fairly established, namely, the double sunspot period of $22\frac{1}{2}$ years. The shorter cycles which are believed to exist in solar radiation are not well shown by the sunspot numbers, and reliable measurements of solar radiation do not yet cover a sufficiently long period to give conclusive results. At the second conference, C. G. Abbot presented the results of the harmonic analysis of 100 months of data ending in October 1928, but probably the only periodicity so found which has any claims to reality is that of 25 months (an inspection of the author's diagram suggests that the real periodicity is slightly longer, perhaps 26 months). It seems that we shall have to wait many years for a full study of the periodic variations of solar radiation based on a sufficiently long series of observations.

The greatest mass of material awaiting systematic periodogram research is to be found in the deposits left by the waters issuing year after year from the ends of the glaciers. These waters deposit a fine clay, but the winter deposit, when the glacial streams are at a minimum, differs in colour and texture from that of the streams swollen by the summer thaw. Hence the layer added each year can be readily detected and its thickness measured, giving what is essentially a representation of the average summer temperature. These glacial deposits have been carefully studied by de Geer, Antevs, and others in Scandinavia, Finland, North America, the Argentine, and the Himalayas, and in Scandinavia it has proved possible to connect up the deposits with those forming at the present day and so obtain an accurately dated series of measurements covering a period of more than 20,000 years.

Hitherto, statisticians have quailed before the immense task of analysing this record for periodicities, and in his paper Antevs quotes only two determinations, both rather casual. In the Argentine series periodicities of 5·1, 10·4, and 51 years were found, while in the North American series there is a strongly marked periodicity of two years, besides others of three to eight years. Neither investigation discovered the eleven-year sunspot cycle, a remarkable result which is at variance with the claim of de Geer, embodied in his title "the solar curve", that the series of clay thicknesses is a measure of the variations of solar radiation from year to year.

This does not exhaust the possibilities of wresting from Nature detailed evidence of her past vicissitudes. Peat bogs in many countries enshrine the history of post-glacial vegetation, and though by its nature this record cannot be made to give numerical annual values comparable with those from the trees or the glacial clays, it should—when it is fully understood—provide valuable information as to the longer sweeps of climate, which will form a base-line for the variations of shorter period revealed by the more detailed sources.

From the reports as a whole, it appears that on all sides forces are being marshalled for a combined attack on the weather changes in post-glacial times, which cannot but throw much light on the changes in process at present. As Dr. White phrased the problem in the discussion, "Surely it should be possible by careful planning and coordinated study to construct relatively complete records from the present year backward into Pleistocene time, though that is but a beginning of the baffling if not insuperable task of constructing a continuous record that will reach back into the Tertiary". C. E. P. B.

Recent Work on Yellow Fever.

THE opening address of the Cambridge Philosophical Society on Nov. 11 last was delivered by Prof. E. Hindle, the Beit research fellow in tropical medicine, who gave an account of recent work on yellow fever. The paper for the most part was a description of experiments on yellow fever which have resulted in his discovery of a method of vaccination against this disease.

West Africa is now the main endemic centre of yellow fever, although serious epidemics have occurred in Brazil during the year 1929. A new era in the study of the disease was opened by the discovery in 1927 by Stokes, Bauer, and Hudson, that Asiatic monkeys, and especially *Macacus rhesus*, can easily be infected with yellow fever. Afterwards, Dr. Adrian Stokes working at Lagos, and also Drs. Young and Noguchi at Accra, died of yellow fever acquired in the course of their investigations. Prof. Hindle described how he succeeded in getting the virus of the disease brought back to London. Pieces of the liver of an infected monkey in Senegal, killed at the height of the disease, were kept frozen during the voyage to London, a period of 12 days, and with this material the disease was reproduced in England at the end of March 1928. Since that date, the strain has been maintained by Prof. Hindle at the Wellcome Bureau of Scientific Research and has been distributed to laboratories in Paris, Berlin, and Amsterdam. The method consists of keeping the virus frozen, in which form it will survive for three to four weeks, or preferably to dry infected blood or tissues *in vacuo*, and keep it in the presence of a desiccating agent, when the virus will survive for 3-4 months. Monkeys can easily be infected by the inoculation of blood or liver from an infected animal, and 1/1000000 c.c. of infected blood has been found sufficient to produce infection.