have derived from the applications of science, they are nothing as compared with those which will and do accrue to us from the acceptance of scientific habits of thought. That is coming already, and it will come more in a not remote future. We have many things in this age and country of which we cannot boast, but we may boast that in science England has done something more than hold her own. The great name of Darwin will survive, it may be, the British Empire itself, and with him will be remembered some others also, whom to single out might perhaps be invidious. But we may be sure of this, that among their names will be included the name of our distinguished guest of to-night. It is a common complaint that politicians have done nothing for science. In that I do not agree. They have done the best they could for it—they have let it alone; they have not corrupted it by their intrigues, nor vulgarized it by their squabbles; and they being what they are, and science being what it is, that is probably the best service they could have rendered it.

Lord Rayleigh proposed "The Health of the Chairman."

Prof. Stokes briefly responded, and the company, which numbered nearly two hundred, separated.

THE ELEVEN-YEAR PERIODICAL FLUCTUATION OF THE CARNATIC RAINFALL.

MORE than fourteen years ago, in the pages of NATURE, Mr. Norman Lockyer first drew attention to an apparent periodical variation of the rainfall registered at the Madras Observatory; which seemed to be such that it reached a maximum and a minimum alternately, at about the same epochs as the corresponding phases of the sunspot frequency. The idea, once started, was followed up by others, among whom perhaps the best known is Dr. (now Sir) W. W. Hunter, whose pamphlet on the subject, without laying claim to any originality as regards its subject-matter, attracted very general attention by the charm of its style, and also by its attempt to identify the periodical occurrence of famines in Southern India with the epochs of minimum rainfall shown by the Madras registers.

When, however, the data on which these speculations were based came to be critically examined, the general verdict of men of science was that the conclusions were "not proven." This was certainly my own opinion; and General R. Strachey, in a lecture delivered before the Royal Institution in 1877, and, at greater length, in a paper communicated to the Royal Society in May of the same year, showed that any attempt to educe a true cyclical variation from the recorded figures, ended in a negative result. Admitting that when the annual quantities were tabulated in eleven-year cycles, the means of the homologous terms seemed to indicate a period of maximum between the third and seventh years, and of a minimum between the eighth and second years, he found that, when the mean difference of the individual years from the supposed periodical means was compared with the mean difference of the former from the arithmetical mean of the whole series, the results differed but little.

It was further shown by myself that the supposed connexion between the periodicity of the Madras (Observatory) rainfall and that of famines in Southern India was by no means so intimate as might appear at first sight. The famines in question had occurred sometimes in one part of the peninsula, sometimes in another, by no means always in the country around Madras; but no other station in the peninsula (of those then available for the inquiry) showed even such an approach to a periodical variation of the rainfall as did the Madras Observatory.

At this stage matters have since remained, with the exception that, in 1879, an apparent periodical fluctuation of a very different character was brought to notice by Messrs. Hill and Archibald in the winter rainfall of Northern India. This, which has an interest of its own, I shall not further discuss at present.

In the course of a general investigation of the rainfall of India, the first part of which only has been as yet published ("Indian Meteorological Memoirs," vol. iii. part 1), I have lately had occasion to reconsider these old questions, and to re-examine them by the light of the accumulated data of the last twenty-two years. For convenience of discussion, I have divided India and Burmah into twenty-four rainfall provinces, one of which is the Carnatic.

This consists of the plain below the Eastern Ghâts, occupying the south-east of the peninsula, and extending from Cape Comorin to the mouths of the Kistna. Its area may be taken as 72,000 square miles. The town of Madras is situated nearly midway on the sea-coast of this province, and is a fairly representative station; but, in addition to the rainfall registers of the Madras Observatory, I have those of thirty-nine other stations, pretty equally distributed through the province; most of them extending back to 1864. The Carnatic is distinguished by one important peculiarity in the season of its chief rainfall. During the spring months, it receives a certain amount of rain, in common with the southern and eastern provinces of India generally; but while the heavy summer rains are falling in Central and Northern India, and also on the west coast of the peninsula, the Carnatic is but little affected by them. In its southern districts, indeed, the rainfall of June and July is less than that of May; and it is not until the rains are over in North-Western India, viz. in October and November, that this province receives the chief and heaviest rainfall of the year. Hence the vicissitudes of the rainfall of the summer months, which are all important in Central and Northern India, are relatively less important in the Carnatic, even if they affect that province in the same manner as Northern India—*and this is far from being always the case*—and as a final result the annual fluctuation of the Carnatic rainfall often differs widely from that of other provinces in the peninsula.

The mean annual rainfall of the Carnatic may be taken in round figures at 35 inches, which is about 7 inches less than the general average of the whole of India. The following table gives the annual variation from this average for the twenty-two years 1864–85, which results when the annual total fall of each individual station is compared with its local average, and the mean of all the differences taken for each year.

Annual mean rainfall variation of the Carnatic rainfall.

	Inches.		Inches.
1864 ...	− 5·0	1875 ...	− 5·2
1865 ...	− 5·0	1876 ...	−13·2
1866 ...	− 4·0	1877 ...	+ 8·3
1867 ...	− 9·4	1878 ...	0
1868 ...	− 4·6	1879 ...	+ 2·3
1869 ...	− 0·3	1880 ...	+ 7·0
1870 ...	+ 1·8	1881 ...	− 2·1
1871 ...	+ 5·5	1882 ...	+ 4·4
1872 ...	+11·5	1883 ...	+ 5·2
1873 ...	0·1	1884 ...	+11·6
1874 ...	+ 7·3	1885 ...	− 1·1

During the first thirteen years (with the exception of 1873) the fluctuation, here shown, is remarkably distinct and regular. The rainfall reached a minimum in 1867, then rose steadily to a maximum in 1872, and after a drop in 1873, and partial recovery in the following year, fell rapidly to a second minimum in 1876. From 1877 to 1881 it oscillated considerably, but thereafter rose again steadily to a second maximum in 1884, dropping again in 1885 to something below the average. Thus we have, apparently, two complete cycles in the twenty-two years; the first remarkably regular, the second less so, but with the periodical fluctuation still dominant.

In order to ascertain with somewhat greater precision the probable character of this periodical fluctuation in an eleven-year cycle, the coefficients of the first two periodical terms of the harmonic formula have been computed, taking 1864 as the initial epoch. These coefficients are—

$$u' = 5 \cdot 340 \text{ inches.} \qquad u'' = 2 \cdot 873 \text{ inches.}$$
$$U' = 206^\circ\ 29' \qquad U'' = 247^\circ\ 15'$$

and the values of the eleven annual phases of the cycle thus found are—

			Inches.
1864	and	1875	− 5·1
1865	,,	1876	− 6·7
1866	,,	1877	− 4·4
1867	,,	1878	− 1·5
1868	,,	1879	− 0·6
1869	,,	1880	− 0·7
1870	,,	1881	+ 0·8
1871	,,	1882	+ 4·4
1872	,,	1883	+ 7·3
1873	,,	1884	+ 5·9
1874	,,	1885	+ 0·5

Taking the differences of these values from the recorded rainfall of each of the twenty-two years, the mean deviation of the latter in any one year from its periodical value is found to be—

$$\pm\ 3 \cdot 5 \text{ inches,}$$

which is only one-fourth of the range of the periodical variation as above determined; and the probable error ϵ, of the periodical value, as found by the formula—

$$\epsilon = 0 \cdot 6745 \sqrt{\frac{\Sigma\,(v^2)}{n(n-1)}},$$

is ± 0·70 inch.

On the other hand, the mean deviation of a single year from the general average is

$$\pm\ 5 \cdot 2 \text{ inches,}$$

and the probable error of that average ± 0·94 inch.

What, then, is the numerical probability of the cyclical variation, thus determined, being a true periodical fluctuation, representing a regularly recurrent phenomenon? As a general problem this cannot be solved, because we do not know all the variations to which the rainfall may conceivably be subject. But we can compare the relative probability of this particular variation being the result of a periodic law, and of its being a mere fortuitous series of variations from a constant average. That it is the most probable variation, having the assumed period of eleven years (with the exception of such as might be computed from a larger number of periodic terms), is assured by the method of its computation, which is based on that of least squares; and one may assume that this relative probability for a single year is represented by the inverse ratio of the probable errors of the two means above determined, viz.—

$$\frac{0 \cdot 94}{0 \cdot 70}.$$

This ratio of probability increases in geometrical progression, as the number of years during which it is found to hold good increases in arithmetical progression[1]; and, for twenty-two years, becomes—

$$\left(\frac{0 \cdot 94}{0 \cdot 70}\right)^{22} = 655 : 1.$$

This ratio, although by no means amounting to demonstration of the exact validity of this particular cycle, affords at least a very high probability that the apparent undecennial fluctuation is no chance phenomenon.

Apart from the approximate identity of its period, the oscillation of the rainfall, thus disclosed, is very different in character from that of the sunspot curve. The periodical minima of both rainfall cycles preceded those of the corresponding sunspot cycles by two years; the actual year of minimum rainfall coincided with that of sunspot minimum in the first cycle, and preceded it by two years in the second. The periodical maximum of the first cycle followed the sunspot maximum by two years, that of the second cycle coincided with the corresponding phase of sunspots, which, in this case, was retarded by two years. The actual rainfall maximum occurred two years later than the sunspot maximum in the first cycle, and one year later in the second.

Hence, as far as the evidence of two cycles goes, the minimum of the rainfall tends to precede the minimum of the sunspots, the maximum of the former to follow that of the latter; and it is noteworthy, as I shall afterwards show, that the droughts which, during the last century, have visited with more or less intensity certain portions of the Indian peninsula, have, on an average, preceded years of sunspot minimum by about one year.

In the other provinces of tropical India, an eleven-year cycle is hardly, if at all, to be detected; a conclusion fully in accord with that which I drew, in 1877, from an examination of the rainfall registers of Bangalore, Mysore, Bombay, Nagpur, &c. The more pronounced phases of the Carnatic cycle are indeed reproduced as a rule, more or less distinctly, as seasons of high or low rainfall respectively, in most parts of the peninsula; but some of the intermediate years are characterized by vicissitudes as great, and even greater than these, destroying the appearance of anything like regular fluctuation.

The Carnatic minimum of 1867, which was the culmination of five years' (1864–68) deficient rainfall, was represented also in Mysore and Bellary, in Malabar and the Deccan; but, in the last two of these provinces, 1866 had a still lower rainfall: and in Berar and Khandesh, while the deficiency of 1866 was (relatively to the average) greater than in any of the more southern provinces, that of 1867 was above the average. In the Konkan again, there was no very great deficiency before 1871, and this was shared more or less by the whole of the peninsula, excepting only the Carnatic and Malabar, which had an excess of 16 and 13 per cent. respectively.

The Carnatic maximum of 1872 was reproduced in Orissa and the Northern Circars—that is to say, in all the eastern provinces of the peninsula—and also in Berar and Khandesh; but in other parts of the peninsula the rainfall of this year differed but little from the average. 1874, however, was a year of excessive rainfall in all the western and southern provinces of the peninsula.

The great drought of 1876 (the second Carnatic minimum) extended with even greater intensity to Mysore, Bellary, Hyderabad, and the Deccan districts of Bombay, and affected more or less the whole of the peninsula, and, in addition, a great part of extra-tropical India. But in the Konkan and Malabar the deficiency was only 18 per cent. of an average fall. In the Konkan the deficiency of the following year was much greater; and in the northern provinces of Bombay, as well as in the greater part of North-Western India, the summer rainfall of 1877 failed almost completely; whereas in the Carnatic the rainfall of that year was remarkably copious.

[1] The probability of throwing any given series of numbers of a single die, in any prescribed order, repeatedly for n throws, is obviously the same as that of throwing a single given number n times in succession, viz. $\left(\frac{1}{6}\right)^n$; and the probability of throwing, in like manner, one out of a given series of dyads or triads, the dyads or triads varying in any prescribed order is $\left(\frac{2}{6}\right)^n$ or $\left(\frac{3}{6}\right)^n$. *The relative probability of the dyad to the triad series is* $\left(\frac{2}{3}\right)^n$; and generally the relative probability of a phenomenon, the law of variation of which is unknown, varying n times in succession, between limits $\pm p$ and $\pm (p + 2)$ respectively, is—

$$\left(\frac{p}{p + x}\right)^n.$$

Similar reasoning holds good when p and $p + x$ are the measures of the *mean* variation; and also when, as in the case before us, they represent the probable errors of alternative averages. Finally, the relative improbability of the more limited range, as a chance result—in other words, the probability *of the limitation being the result of a regulating cause*—*is expressed* by the inverse ratio.

The following year, 1878, was one of remarkably copious rainfall in nearly all parts of the peninsula, with the exception of the Carnatic, where the rainfall did not exceed the average. In Hyderabad it was greater than that of any other year since regular registers have been kept; and, on the general average of the peninsula (excluding the Carnatic), it is approached only by that of 1874 and 1882.

Finally, the Carnatic maximum of 1884 coincided with a small excess in Hyderabad and with a larger excess in the north-west of the peninsula (the Central Provinces, Berar, Khandesh, the Konkan, and Guzerat); but this was due to independent conditions. In Mysore, Bellary, Malabar, the Deccan, the Northern Circars, and Orissa, the rainfall of the year was more or less deficient, especially in Mysore, where the fall was only three-fourths of the average.

It may, then, be considered as demonstrated that the apparently periodical variation of the Carnatic rainfall is by no means representative of a similar variation in that of Southern India generally; and I might here conclude the discussion, were it not that the independent evidence of a certain apparent regularity in the recurrence of droughts and dearths seems to require a few words of notice.

At page 21 of the Report of the Indian Famine Commissioners is given a list of all the serious droughts, and consequent seasons of dearth, that have affected India during the last century. Selecting those that have chiefly affected some part of the peninsula, we have the following:—

Droughts.	Intervals.
1782	
1791	9 years.
1802	11 ,,
1806	4 ,,
1812	6 ,,
1823	11 ,,
1832	9 ,,
1844	12 ,,
1853	9 ,,
1865	11 ,,
1876	11 ,,

Omitting that of 1806, which divided the ordinary interval into two, the mean interval is 10·36 years, and the deviation from this mean in no case amounts to two years. According to Wolf's table, the years of minimum sunspots and their intervals were:—

Sunspot Minima.	Intervals.
1784	
1798	14 years.
1810	12 ,,
1823	13 ,,
1833	10 ,,
1843	10 ,,
1856	13 ,,
1867	11 ,,
1878	11 ,,

the mean interval being 11·18 years. The coincidence of these mean intervals is hardly so close as might be anticipated were there any real physical interdependence between recurrent phases of the sun's condition, and the recurrence of the droughts. And a comparison of the dates in detail brings to light further discrepancies. Thus the years of drought vary in their relations to the nearest years of minimum sunspots as follows:—

One, midway between two sunspots minima; seven years distant from each;
One, four years earlier;
One, three years earlier;
Three, two years earlier;
One, one year earlier;
One, coincident;
One, one year later;
One, two years later;
One, four years later.

Omitting the first (that of 1791), which occurred four years after a year of maximum sunspots, and midway between two minima, in an unusually prolonged cycle, the years of drought, on a general average, anticipated the sunspot minima by somewhat less than a year, instead of following the minima, as might have been expected on the hypothesis of the former standing to the quiescent condition of the sun in the relation of effect to cause.

I should not, however, hastily conclude from these facts that there is no relation between the recurrence of drought in Southern India, and the periodical variation of the solar photosphere; but merely that the interdependence of the two classes of phenomena, if real, is far from being simple and direct, and also that other and, as far as we know, non-periodic causes, concur largely in producing drought. If we accept the conclusions, drawn in the first part of this note, as to the highly probable periodicity of the Carnatic rainfall, one must admit that there is, in that province, a recurrent tendency to drought at eleven-year intervals, though it does not always culminate in drought of disastrous intensity; and this epoch anticipates by about two years that of the sunspot minimum. This tendency is evidently much weaker in other parts of the peninsula; and in Northern India there is some indication of a tendency to the recurrence of drought about the time of maximum sunspots, as in 1803, 1837, 1838, and 1860—all years of disastrous drought in Northern India; and the experience of late years has demonstrated that these droughts generally extend to the northern provinces of the peninsula.

HENRY F. BLANFORD.

NOTES.

WE print elsewhere a report of the speeches delivered by Mr. Goschen and by some members of the influential deputation who waited upon him last Thursday to press the claims of University Colleges. The deputation had certainly no reason to complain of the manner in which they were received. Mr. Goschen, speaking as Chancellor of the Exchequer, was of course obliged to adopt a cautious tone; but it was plain enough that those who addressed him represented a cause with which he had strong personal sympathy. His promise that the Government would give the matter "its most serious attention," means, we may hope, that the principle of State aid for University Colleges has been practically accepted.

ON Monday the foundation-stone of the Imperial Institute was laid by the Queen. No representative of science, as such, was invited to be present at the ceremony, and NATURE did not receive a Press ticket. Evidently science is to have little to do with the New Institute.

THE Prussian Society for the Promotion of Industry has recently offered a prize of about £150 for the most exhaustive critical comparison of all kinds of existing bronze, tombac, and brass alloys, used or recommended for machinery, giving their chief properties with regard to resistance, ductility, friction at different temperatures, malleability, electrical conductivity, behaviour with acids, hydrogen and carbon sulphides, chlorine, and other strongly corrosive substances met with in practice. The same Society also offers a gold medal and £250 for the best work on light and heat radiation of burning gases. The time limit in the former case is the end of 1887; in the latter, the end of 1888.

The National Association for the Promotion of Technical Education has now been formed. A meeting of persons interested in the movement was held on the 1st inst. at the rooms of the Society of Arts, Adelphi. Lord Hartington presided, and among those present were Lord Rosebery, Mr. John Morley, Sir Lyon Playfair, Sir John Lubbock, and representatives from Colleges, technical schools, trade-unions, School Boards, national Societies, and Chambers of Commerce.