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ORDINARY MEETING, MAY 16, 1881.

REV. R. THORNTON, D.D., VICE-PRESIDENT, IN THE CHAIR.

The minutes of the last meeting were read and confirmed, and the following elections were announced :—

LIFE MEMBER :—Rev. O. D. Miller, M.A., United States.

MEMBER :—Rev. J. P. Kempthorne, New Zealand.

ASSOCIATES :—C. Bryant, Esq., Cheshire ; Rev. W. C. Ley, M.A., Lutterworth ; Rev. M. W. Maclean, M.A., Canada ; Rev. J. W. Pratt, M.A., London ; F. J. Sowby, Esq., Gainsborough.

Also the presentation of the following Works for the Library :—

"Proceedings of the Royal Society."	*From the same.*
"Proceedings of the American Geographical Society."	*Ditto.*
"The Chain of Ages." By Rev. W. B. Galloway, M.A.	*Ditto.*
A Work by Professor Reinsch.	*Ditto.*

The following paper was then read by the Author :—

RAINFALL AND CLIMATE IN INDIA. By SIR JOSEPH FAYRER, K.C.S.I., M.D., F.R.S.

THE subject of this paper was suggested by one read here on the 7th March last by Mr. Bateman in which he dealt chiefly with the rainfall of our own islands : in the course of his remarks he pointed out its importance in reference to the production of food, and the regulation of our own climate, which, as regards its peculiarly variable character, and notwithstanding its attendant drawbacks, is one of a combination of causes "which contribute largely to the fertility of the soil, the perseverance, hardihood, and energy of the people, and to the enjoyment of life."

THE MAP.—The accompanying Map has been kindly prepared by the *Geographer at the India Office*, and is published by his permission : it is at once a map of the Physical Geography as well as of the Meteorology of India, coloured as regards the latter in accordance with the last published report of the Meteorological Department at Calcutta.

The author alluded to the meteorology of other countries, where the physical laws that regulate the production and distribution of rain are less subject to perturbation than in the northern latitude of our sea-girt islands, and referred to the benefit of a sufficient supply, and the evils that result from a deficiency of rain, as seen in some regions which are naturally almost rainless, or in others, which are in certain seasons the subject of drought.

In the discussion which followed, the remarks made in reference to the rainfall in other countries appeared to excite some interest; it therefore occurred to me that a brief account of this branch of meteorology in India—a country in which all are interested—might be acceptable as a supplement to Mr. Bateman's interesting paper, showing the results of excess or deficiency of rain, the operation of the meteorological laws that govern its distribution in tropical climates, and as affording opportunity for the further discussion of a subject which was far from being exhausted on that occasion.

As introductory to the meteorological question, let me say a few words on the geographical and physical features of that part of the world to which I am about to ask attention.

The physical peculiarities of a country have so much influence in determining the quantity, the distribution, and the periods of the rainfall, that it is expedient to take a brief general survey of them before considering details of the rainfall itself. It is necessary also to understand the conditions under which the atmospheric moisture originates, and the relations that the land and ocean bear to each other in respect of modifications of the air-currents and distribution of rain.

The subjects of climate and of meteorology are of great interest, and nowhere more so than in India; but, as even the most cursory glance at so comprehensive a matter would occupy more time than is allotted to a single communication, I must restrict my remarks chiefly to the rainfall, touching only incidentally on the climate and such other matters as may naturally be suggested by it.

A few words on the origin of rain. The gaseous envelope of nitrogen and oxygen by which our globe is surrounded, and which moves with it in its rotation and revolution, extends to a height or depth of forty to fifty miles in gradually decreasing density, where it may be considered, practically, to cease; though, doubtless, it extends further in an extremely attenuated form! This atmosphere is

permeated by another and no less important one of watery vapour, always present, though in varying quantities, according to circumstances of temperature, time, and place, derived from the ocean, the seas, lakes, pools, rivers, streams,—from the surface of the earth itself, and from all living things animal or vegetable. It is constantly rising and permeating the air up to the point where saturation is reached, or until it is condensed by cold, into the sensible form of dew, clouds, or rain. On the varying conditions under which evaporation, on the one hand, and condensation on the other, take place, the rainfall depends.

The ocean is the great source whence atmospheric moisture is derived; it is the great bourne to which it all returns. As the wise king said,—"All the rivers run into the sea, yet the sea is not full; unto the place from whence the rivers come, thither they return again."

The atmosphere is the great sponge that soaks up and holds the watery vapour, which, when condensed, falls into the ocean, or on to the earth, to fill the rivers, to sink into the ground, whence it rises again in springs, collects in wells, lakes, and pools, or runs off in streams and rivers, diffusing itself everywhere, ministering to the wants of nature, and supporting life and organisation; finally, to return to the ocean, again to rise in vapour, and repeat the endless circulation, without which life would be extinct, and the earth reduced to the condition of the moon, or of some effete worn-out world.

Water is always evaporating; expose a cup of it to the air and it will soon disappear,—all the sooner if the air be dry and warm. So will ice or snow, in regions where the cold may prevent it from melting, but not from evaporating; it is not lost, but assumes the impalpable form of vapour, and mingles with the air. This process is going on wherever there is water, but more especially from that part of the ocean which, lying near the equator, is subjected to the continued heat of the vertical solar rays. Here vaporisation is most active, and the warm air, saturated with moisture, rising in constant currents to higher regions, is replaced by colder and heavier currents rushing in from towards the poles; in turn to be heated, charged with moisture, ascend, and so keep up a constant circulation, making the equatorial rain-belt the great distillery of nature.

"The wind goeth towards the south, and turneth about unto the north; it whirleth about continually, and the wind returneth again according to its circuits." These perennial northern and southern currents, or trade winds, getting their

easterly direction from the earth's rotation, are always blowing towards the equator; whilst there is a regularity of climatic phenomena unknown beyond the tropics, where many and varied changes occur.

The northern hemisphere, containing much more land than the southern, is subject, on account of deflected ocean currents and "thermal" changes, resulting from the varying radiations of the land and sea, to greater perturbation of the conditions that determine the formation and distribution of aërial moisture, and other meteorological phenomena; and it is to one of the most remarkable of these, the monsoons of the Indian Ocean, that the climate and varying seasons of India owe much of their peculiar character.

Monsoons.

The great producers and distributors of rain in India, then, are the monsoons or periodic seasonal winds. The term is of Arabic origin, from "Mausim," a season, and is applied to the great air-current that blows for one half of the year northwards, carrying the moisture taken up from a vast extent of the Indian Ocean, extending from Africa to Malacca; whilst for the other half of the year it blows from the opposite direction. The north-east monsoon corresponds to the north-east trade, and would be constant were it not for the counteracting influences which disturb the atmospheric equilibrium. Monsoons are not peculiar to India, but occur in other regions where there are similar distributions of land and water. The Indian monsoons are caused in the following manner:—About the commencement of April, when the whole surface of the continent of India becomes hotter than the sea, the rarified air rises, and is replaced by the comparatively cooler currents drawn in from, and laden with moisture taken up by evaporation from, the Indian Ocean. This is the south-west monsoon, which, rising to higher regions, or, being intercepted by the mountain ranges, condenses its moisture in rain on the Western Ghâts and on the coast of Aracan. Following a north-eastern course, it gradually loses its influence and its rain, as it approaches the northern limits of the continent. About October the winds are variable; there is a reversal of the current, which begins to blow southwards for the most part as a dry wind, till on the Coromandel coast it brings moisture from the Bay of Bengal, which falls as rain on the coast of the Carnatic and on the Eastern Ghâts; whilst some parts of the South of India receive a certain amount of rain with each monsoon.

This winter or north-east monsoon, which on land has a northerly or north-westerly direction, returns again as a south-westerly current in the upper regions of the atmosphere, having been heated in the south. It is sometimes called the anti-monsoon, appears to be felt in the Himalayas, and, descending in the North-West Provinces and Punjaub, brings their winter rains.

The rainfall on the southern and western coasts is the heaviest; but there are many variations and peculiarities due to local conditions,—elevated regions receiving almost a deluge, whilst some lower areas are very dry. All the conditions favourable to the condensation and fall of rain exist in certain localities, whilst the converse obtains in others.

A few words on the geography and physical characters of the vast rainfall area we are about to consider. British India, the great central and southern promontory of Asia, situated between the eighth and thirty-fourth parallels of north latitude, and the sixty-sixth and ninety-fifth meridians of east longitude, includes also a portion of Afghanistan in the north-west, and part of the country on the eastern side of the Bay of Bengal, extending from Chittagong to Tenasserim as far south as the tenth parallel of north latitude. It has a coast-line extending for more than 4,000 miles. It is about 1,900 miles in length from Peshawur to Cape Comorin; and about the same distance in breadth from Sudya,—a frontier post in Assam,—to Kurrachee at the mouth of the Indus; it is 900 miles from Bombay to Point Palmyra in Orissa. The superficial area is above 1,500,000 miles,—equal to the whole of Europe, excluding Russia; three-fifths being under British rule, are, therefore, with the exception of certain districts, under the observation of the Meteorological Department of Government. The geographical boundaries are well defined, on the north by the Himalayas, a chain of stupendous mountains (the highest in the world), 150 miles in average breadth, running north-west and south-east in a crescentic manner, in a double range, which is traversed by great rivers (Ganges, Sampu, Indus) running east and west for 600 miles; the valleys reaching to a depth that places their bases at not more than 6,000 to 10,000 feet, whilst its mean height is from 16,000 to 20,000 feet above the sea level, Mount Everest and Kinchinjunga, the loftiest peaks, being over 29,000 and 28,000 feet high. This barrier, which separates and isolates India from Turkistan and Tibet, is crossed by passes 17,000 feet above the sea, nearly on a level with the line of eternal snow. On the north-west it is bounded by the edge of the plateau of Afghanistan and Beloochistan, rising to the Suliman and Hala mountain

ranges, some of the peaks of the former reaching to a height of 11,000 feet; on the north-east, the heights of Assam, the Naga Hills, divide the drainage of the Brahmapootra from that of the Irawaddy. It is separated from Burmah and Siam by the Youmadong and other mountain chains, whilst its coasts have the Bay of Bengal on the east, and the Arabian Sea and Indian Ocean on the west and south, enclosing a table-land of from 1,500 to 3,000 feet above the sea level, between the Eastern and Western Ghâts; this table-land slopes gradually to the east, most of the rivers running to the Bay of Bengal. The mountains are separated into two distinct systems by a continuous low land extending from the Arabian Sea to the Bay of Bengal. This is washed by the streams of the Ganges and its tributaries on the east, by the Indus and its branches on the west. The western slope includes Scinde, the Punjaub, and part of Rajpootana; the eastern, which is divided from it by a water parting 900 feet above the sea level, contains the greater part of the North-west Provinces, Oude, and the lower provinces of Bengal. The north part of this lowland skirts the foot of the hills, and forms the damp region, called the Terai. The first or outer range of hills known as the Siwalik, and Salt Range, is about 2,000 feet high, whilst the valley separating these from the Himalayas is known as the Doon; the forest-clad base of the mountain range is known as the Bhabur. South of the lowlands of Hindostan is the triangular table-land of the Deccan, extending through 20° of latitude. The basins of the Indus and the Ganges are its base; its sides are the Eastern and Western Ghâts and the littorals of the Arabian Sea and Bay of Bengal, whilst the table-land seldom exceeds 2,000 to 3,000 feet high, and gradually slopes to the east. The Western Ghâts rise to 4,000 and 5,000 feet; Dodabetta, the southern peak in the Neilgherries, is 8,640 feet high. The Eastern Ghâts are not so high, and much less continuous than the Western. The whole of India forms two great watersheds; that of the Bay of Bengal on the east; that of the Arabian sea on the west. The former includes the whole of the peninsula east of the Aravulli Hills and Western Ghâts; the latter, the basin of the Indus, Nerbudda, Tapti, and the declivity of the Western Ghâts. The water, parting, runs nearly vertically from Cashmere to Cape Comorin. This vast country, which has nearly two hundred and fifty millions of inhabitants, of races more ethnically distinct, and more numerous than those of Europe, has, owing to the nature of its physical geography and the extent of its area, every kind of climate, from that of the Torrid to the

Arctic zone; possessing lofty mountains, elevated table-lands, alluvial valleys, desert tracts, and plains; noble rivers, extensive swamps, jungles, and magnificent forests; it has characters that invest it with peculiar interest for the meteorologist; for, as Mr. Blanford says, "it offers peculiar advantages for the study of meteorology, exhibiting at opposite seasons of the year an almost complete reversal of the wind system and of the meteorological conditions depending on it. Its almost complete isolation, in a meteorological point of view, from the rest of the Asiatic continent by the great mountain-chain along its northern border simplifies to a degree almost unknown elsewhere the conditions to be contrasted, by limiting them to those of the region itself and the seas around. India also presents in its different parts extreme modification of climate and geographical feature. In its hill stations it affords the means of gauging the condition of the atmosphere at permanent observatories up to a height of 8,000 feet. The periodical variations of temperature, vapour, tension, and pressure, both annual and diurnal, are strongly marked and regular; and these changes proceed so gradually that the concurrence and inter-dependence of these several phases can be traced out with precision." As regards climate, India may be divided into:—1. Himalayan, including Bhotan, Nepal, Gurhwal, Cashmere, and Cabul. 2. Hindostan, which extends along the foot of the Himalayan range, and includes the alluvial plains of the great rivers Ganges and Indus, with their numerous tributaries, as far south as the Vindyah mountains. 3. Southern India, or the Deccan, which consists of elevated table-lands, littoral plains intersected by numerous rivers, mountain ranges, and isolated hills. The Aravulli and Chittore hills, the Vindyah chain, rising to over 2,000 feet, covered with forest vegetation, with its off-set the Satpooras, traverse the continent connecting the Eastern and the Western Ghâts."

The rainfall varies according to latitude, elevation, and physical characters of the country, Northern India being less influenced than the Deccan by the south-west monsoon. The climates also vary; but in the plains of Hindoostan and the table-lands of the Deccan, the heat is intense, though often greatly modified by moisture. The effects of a dry or damp atmosphere at the same temperature, however, are very different. Dry air, in motion, at a temperature of 100°, is more tolerable than stagnant air loaded with moisture at 80°. The hot dry winds of Northern India are more endurable than the cooler but saturated atmosphere of Lower Bengal or parts of Southern India.

The *mean* temperature of a few well-known stations is as follows:—

Calcutta, 8 feet above sea level, is in May (hottest month) 89°; in January, 70°; but it ranges between 45° in the coldest and 92° in the hottest months.

Madras, sea level.—June (hottest), 88°; January, 76°. Range, 72° to 92°.

Bombay, sea level.—May (hottest), 86°; January, 74°. Range, moderate.

Peshawur, 1,056 feet above sea level.—June and July (hottest), 91°; January, 52°. Range, great.

Punjab, 900 feet above sea level.—June (hottest), 89°; January, 54°. Range, from frost to intense heat—110° and more.

Bangalore, 3,000 feet above sea level.—May (hottest), 81°; January, 69°. Range, moderate.

Poonah, 1,089 feet above sea level.—May (hottest), 85°; January, 70°.

Belgaum, 2,200 feet above sea level.—April (hottest), 81°; May, 78°; June, 75°. December (coldest), 70°.

The coldest months are December and January; the hottest, April, May, and June.

There are fluctuations in temperature owing to hot, dry winds, sea and mountain breezes, great river basins, the presence of forests, tracts of jungle and vegetation, arid treeless rainless deserts, which give local peculiarities of climate; but it may be said, generally, that there are three distinct seasons in India—the hot, the rainy, and the cold,—which vary in duration and times of setting in; but approximately the cold season extends from November to March, the hot from March to June or July, and the rainy season from that to October or November, these seasons being greatly influenced by the monsoons. The south-west monsoon commences with storms of thunder and wind, which are soon followed by the bursting of the rain on the Malabar coast, in May, but reaches regions further north later in the year. Its force and influence, indeed, are well-nigh spent ere it passes the twenty-fifth parallel of north latitude. The Carnatic and Coromandel coasts, being sheltered by the Western Ghâts, are exempt, when the west coast is deluged with rain.

About Delhi and in the north-west the rains begin towards the end of June, and fall in diminished quantity. In the Punjab, near the hills, the rainfall again increases; but in the Southern Punjab, and in the Great Desert regions, there is very little rain,—in some parts none. There are belts or tracts of country commencing, in Sind and the north-west, almost

rainless, or with a rainfall as low as two inches; whilst the highest fall is at Cherra Poonjee, in the Khasia hills, on the north-east frontier, where 600 inches fall in the year. Next to this, the Western Ghauts have the greatest rainfall; at Mahabuleshwar 253 to 300 inches, and on the Tenasserim coast 180 inches fall yearly. The provinces in the North-east receive rain in rather a different manner; the wind which brings the rains to that part of the continent blows from the south-west, over the Bay of Bengal, till, meeting the mountains, it is deflected. The prevailing wind, therefore, in this region is south-easterly, and from this quarter Bengal and the Gangetic valley receive their rain; when it reaches the mountains in the north-west, it is compelled to part with more of its moisture.

Near the sea, where the land is low and the temperature high, very little rain falls; at Kurrachee it was, in 1879, 1·92 inch. In inland districts, as at Peshawur, in 1879, only 5·84 inches fell; whilst the rainfall in Calcutta averages 63; in Madras, 48·50; in Bombay, 74; in Delhi, 27·5; in Meerut, 27; in Lahore, 21; in Mooltan, 7; in Benares, 37; in Bellary, 18; in Bangalore, 35; in Poonah, 27; in Belgaum, 49; in Kamptee, 22; in Akyab, 198. The amount of humidity in the air also varies greatly. Flat hot plains, like Scinde, where there is little or no rain, have an atmosphere almost saturated, and on some of the lower mountain ranges, in Bengal, and in many districts near the coast in Southern India, the air is very damp. But the elevated table-lands of the Deccan and Central India, and the hot sandy plains of North-west India, have a dry air during the months of May and June, which blows like a furnace blast, heated and desiccated by the burning country over which it has passed!

The north-east monsoon commences gradually in October, and is attended with dry weather throughout the Peninsula generally, except on the Coromandel coast, where it brings rain from the Bay of Bengal, between October and December, after which it is dry until March, when it gives place to variable winds, which last till about June, when the heat is great and the tendency is then from the south. About the end of May the south-west monsoon again sets in, bringing a few showers, known as the lesser rains, before the regular rains set in. In the hill stations of Darjeeling, Mussoorie, Nainee-tal, Murree, Simla, and generally in the elevated provinces of the lower ranges of the Himalayas, also at Ootacamund, Conoor, Wellington, Mahabuleshwar, in the Neilgherries, and Ghauts—stations at elevations of 5,000 to 7,000 feet—the climate is genial, the rainfall moderate, it

is healthy in summer, and almost as bracing in winter as Europe. These are favourite health resorts, and may, perhaps, become the sites of future colonisation, for it seems probable that there the European will thrive and continue to reproduce his race, which it is said would cease to exist in the plains after the third generation.

The following extracts from Mr. J. Talboy Wheeler's "Rare and Curious Narratives of Old Travellers in India in the Sixteenth and Seventeenth Centuries," published in Calcutta in the year 1864, gives a quaint and graphic account of the Monsoons as observed in those days, by Purchas and Van Linschoten.

The former, who visited India somewhere about 267 years ago, says:—

"THE mightie Riuers of *Indus* and *Ganges*, paying their fine to the *Lord of waters*, the Ocean, almost vnder the very Tropick of *Cancer*, do (as it were) betwixt their watery armes, present into that their *Mother's* bosome, this large *Chersonesus;* A Countrey full of Kingdomes, riches, people, and (our dewest taske) *superstitious costomes.* As Italy is diuided by the *Appennine*, and bounded by the Alpes, so is this by the Hills which they call *Gate*,* which goe from East to West (but not directly) and quite thorow to the *Cape Comori*, which not only haue entred league with many In-lets of the Sea, to diuide the soyle into many Signiories and Kingdomes, but with the Ayre and Natures higher officers, to dispence with the ordinary orders, and established Statutes of Nature, at the same time, vnder the same eleuation of the Sun, diuiding to Summer and Winter, their seasons and possessions. For where as cold is banished out of these Countries (except on the tops of some Hills) and altogether prohibited to approach so neere the Court and presence of the Sun; and therefore their Winter and Summer is not reckoned by heate and cold, but by the fairnesse and foulnesse of weather, which in those parts divided the yeere by equall proportions; at the same time, when on the West part of this *Peninsula*, between that ridge of Mountaines and the Sea, it is after their appellation Summer, which is from September till April, in which time it is alwayes cleere skie, without once or very little raining; on the other side the hills, which they call the coast of Choromandell, it is their Winter; euery day and night yeelding abundance of raines, besides those terrible thunders which both begin and end their Winter. And from April till September in a contrary vicissitude; on the Westerne parte is Winter, and on the Easterne, Summer; insomuch that in little more than twentie leagues iourney in some place, as where they crosse the Hills to Saint *Thomas*, on the one side of the Hill you ascend with a faire Summer, on the other you descend attendant with a stormy Winter. The likes, saith *Linschoten*, hapneth at the *Cape Rosalgate*, in Arabia, and in many other places of the East.

* He alludes to the Western Ghauts.

"Their Winter also is more fierce then ours, every man prouiding against the same, as if he had a voyage of so many moneths to passe by Sea, their ships are brought into harbour, their houses can scarce harbour the Inhabitants against the violent stormes, which choake the Riuers with Sand, and make the Seas vnnauigable. I leaue the causes of these things to the further scanning of Philosophers; the effects and affects thereof are strange. The Sea roareth with a dreadfull noyse: the Windes blow with a certaine course from thence: the people haue a Melancholike season, which they passe away with play. In the Summer the Wind bloweth from the Land, beginning at Midnight, and continuing till Noone, neuer blowing aboue ten leagues into the Sea, and presently after one of the clock vntill midnight, the contrary winde bloweth, keeping their set-times, whereby they make the Land temperate, the heat otherwise would bee vnmeasurable."

Van Linschoten, who visited Southern India in 1583 or thereabouts, says:—

"The Summer beginneth in September and continueth till the last of April, and is alwaies cleare skie and faire weather, without once or very little raining: Then all the ships are rigged and made ready to sayle for all places; as also the Kings Armie to keepe the Coast, and to convoy Merchants, and the East windes beginne to blowe from off the Land into the Seas, whereby they are called *Terreinhos*, that is to say, the *Land windes*. They blowe very pleasantly and cooly, although at the first, by hanging of the weather they are very dangerous, and cause many great diseases, which doe commonly fall in *India*, by the changing of the time. These winds blowe alwaies in Summer, beginning at midnight, and continue till noone, but they never blowe above ten miles into the Sea, from off the coast, and presently after one of clocke, until midnight the West winde bloweth, which commeth out of the Sea into the Land and is called *Virason*. These winds are so sure and certain at their times, as though men held them in their hands, where they make the Land very temperate, otherwise the heate would be unmeasurable.

"It is likewise a strange thing that when it is Winter upon the coast of *India*, that is from *Diu* to the Cape *de Comorin*, on the other side of the Cape *de Comorin*, on the coast called *Choramandel* it is clean contrary, so that there it is Summer, and yet they lie all under one height or degrees, and there is but seventy miles by land betweene both coasts, and in some places but twenty miles, which is more, as men travel overland from *Cochin* to Saint *Thomas* (which lieth on the same coast of *Choromandel*), and comming by the Hill of *Ballagatte*, where men must pass over to go from the one coast to the other: on the one side of the Hill to the top thereof it is pleasant clear sunne shining weather, and going down on the other side there is raine, winde, thunder and lightning, as if the world should end and be consumed; which is to be understood, that it changeth from the one side to the other, as the time falleth out, so that on one side of the Hills it is Winter, and on the other side Summer; and it is not only so in that place and Countrie, but

also at Ormus, the coast of *Arabia Felix* by the Cape of *Rosatgatte*, where the ships lie, it is very still, cleare, and pleasant water, and faire Summer time; and turning about the Cape on the other side, it is raine and wind with great stormes and tempests, which with the times of the yeere doe likewise change on the other side, and so it is many other places on the Orientall Countries."

Having given some account of the monsoons, which are the great rain-carriers, and of the physical characters of the country which so largely influence its distribution, I now proceed to describe some facts relating to the rainfall, and the effects thereby produced.

It is only within the last ten or twelve years that the comprehensive system of meteorological observation now carried on has been in operation, but it promises to yield valuable results; and one can hardly over-estimate the importance of such researches towards a thorough comprehension of the laws that regulate atmospheric pressure, vapour tension, and the supply of rain, when we consider their bearings on the causes of scarcity and famines which from time to time affect large tracts of country, and sweep away millions of lives.

The annual meteorological reports of India abound in careful, comprehensive, and scientific work, and in information that must ultimately be productive of valuable results to the people of India.

A glance at a hyetographical map of India shows that there are areas of rainfall of various degrees of irregular form and extent, corresponding to the latitude, physical characters of country, and proximity to sea or hills. Let me briefly describe them.

In the north-west corner of India there are arid regions, which have a rainfall of less than 15 inches; in many parts of it, indeed, it is much less; whilst the desert tract of the Thur is to a great extent rainless. This area includes Sind, part of the Punjaub, and Rajputana. Then there is a zone with an annual fall of between 15 and 30 inches, surrounding the arid region on the north and east in a belt of 100 to 200 miles wide, which includes Delhi and Agra. This is the northern dry zone. The upper parts of the valley of the Ganges, Central India, and the eastern coast of the Madras Presidency, have a fall of between 30 and 60 inches.

There is a southern dry zone, which extends from Nassick to Cape Comorin, at a distance between the two seas. The deltas of the Mahanuddi and Ganges, and the lower part of the Gangetic Valley, have a fall of between 60 and 75 inches. There are two belts of excessive rainfall,—one extending

along the Aracan coast, from the mouth of the Irawaddy up the valley of the Brahmapootra. The other, on the west coast of India, from Cape Comorin to the Tapti—from the seashore to the summit of the Ghauts! It is in these regions that the most remarkable falls occur, for the reason that they are placed in the direct course of the south-west monsoon, catching its first impact at heights where vapour is most readily condensed into rain. Mr. Bateman told us that at 2,000 feet the greatest condensation takes place in our islands; it is at a greater elevation in India, and the most striking illustration is found at Cherra Poonjee, in the Khasia hills, where, at 4,000 feet above the sea, 600 inches of rain fall in half the year. Here the locality is on the edge of an abrupt mountain ridge and plateau, situated about 200 miles from the Bay of Bengal, the intervening country being flat alluvium, covered with rivers and swamps. Over this the south-west monsoon blows, laden with moisture from the ocean, which is increased by absorption from the wet country over which it passes. On the plateau of Cherra Poonjee the first condensation takes place, and the fall is so great that in a few weeks the plains of the Sylhet district, lying at the foot of the hills, are converted into a sea; whilst a few miles inland, and at little greater elevation, the fall is reduced to less than one-half. I spent my first year in India at this station, and the 610 inches I registered on that occasion gave me an interest in rainfall that I have never lost.

At Mahabuleshwar, in the Western Ghauts, the conditions are somewhat similar, but there the fall is less, amounting only to about 300 inches. In these instances, we have all the conditions favourable to the production of rain in the highest degree, but these excessive rainfalls in certain elevated regions are quite local, and no more represent the average rainfall of all India than does the dryness of the desert tracts in the north-west; or the heavy fall on the hills on the west coast of Britain, in Cumberland or Scotland, the average rainfall of Great Britain. There is, however, an analogy between India and Britain in this respect, much as they differ otherwise in the nature of the distribution of rain, that the heavy falls at Cherra Poonjee and Mahabuleshwar are paralleled by the heavy falls on the slope of Ben Lomond, Glengyle, or the Cumberland hills; while the heavy rainfall on our western coasts—the result of the warm moist air coming from the Atlantic and Gulf Stream—resembles the south-west monsoon, which deposits its heavy rain on the Western Ghauts and on the coast of Aracan—proximity to the Equator and high temperature in the latter cases making the effects so much more striking.

The average annual rainfall in Equatorial regions is, I believe, about ninety-five inches; in the temperate regions thirty-five inches, that for the whole of Tropical India is considerably less; while for Hindostan it would be reduced to a lower figure, if we include in the average the almost rainless Thur desert; but, if the rainfalls of the Himalayan be included, the average would, no doubt, be considerably raised. The problems presented by the rainfall are of a comparatively simple character in Southern India and Bengal, where the influence of the monsoon is prominently felt; but in the northern regions of Hindostan, where the influence of mountains, river basins, and the desert come into operation, there must of necessity be perturbation of the direction of the air currents and of the amount of rain. Further observations will, no doubt, in time throw much light on these points.

For the purpose of estimating the general results of rainfall, Mr. Blanford divides India into rainfall provinces, each of which may be represented by a general average, without any disregard of the normal variation of distribution, and be taken as the average rainfall of all the stations included in it; except that when particular stations, such as Cherra Poonjee in Khasia, Mount Abu in Rajputana, Matheran, Mahabuleshwar, and Baura Fort on the Western Ghauts, &c., have a fall very greatly in excess of the majority of the stations, a fall which must be considered as purely local, only a half or third value is assigned in summing up in the general average.

The following table, taken from Blanford's Meteorological Report for 1879, gives the result of this estimate as regards certain localities. The areas of the several provinces have been measured on one of the Surveyor-General's maps:—

	Rainfall Provinces.	Area Square Miles.	Number of Stations.	Mean Rainfall, 1878.
				Inches.
1.	Punjaub Plains	118,000	29	21·66
2.	N.W. Provinces and Oudh...	82,000	42	37·35
3.	Rajputana.....	67,000	18	24·36
4.	Central India States	89,000	21	42·00
5.	Behar	30,000	8	42·31
6.	Western Bengal	38,000	6	51·24
7.	Lower Bengal	54,000	21	67·52
8.	Assam and Cachar	52,000	13	98·18
9.	Orissa and Northern Circars.	27,000	13	45·92
10.	South Central Provinces.....	61,000	14	49·22
11.	Berar and Kandesh	43,000	11	30·08
12.	Guzerat.....	54,500	9	35·98
13.	Sind and Cutch	66,500	10	9·24
14.	North Dakhan.....	48,000	14	28·68
15.	Konkhan and Ghauts	16,000	10	118·77
16.	Malabar and Ghauts	18,000	8	113·95
17.	Mysore and South Hyderabad	84,000	10	27·01
18.	Carnatic	72,000	29	33·34
19.	Arakan	11,000	4	171·05
20.	Pegu	32,500	6	74·91
21.	Tenasserim	10,500	4	170·73
	Total.....	1,074,000		

Certain areas are yet imperfectly represented by rain-gauge stations, such are the Thur desert (about 65,000 square miles) in Northern Hyderabad, Jaipur, Singbhoom, and South Rewah, which, taken together, form about one-sixth of the whole. Omitting these from consideration, it appears that, on a rough approximation, there was, in 1878, a rainfall equal to 4·9 inches in excess of the average, over the whole of India and its dependencies, omitting seas and islands. This shows that, although the general character of the seasons is pretty constant, yet that there are annual fluctuations which perhaps recur in cycles and are more remarkable in some districts than in others; years of deficiency being conducive to imperfect irrigation of the land, which results in scarcity,—sometimes in famine.

In our own favoured land, where, with all its uncertainties of a variable climate, we have happily little or no experience of the desolation caused by a deficiency of rain, we can hardly understand what is implied by a failure of the rains in India. A charming and talented writer* in India has recently drawn

* P. Robinson.

a most graphic picture of it in the following words: "We in the West can hardly understand what it means that 'rain has fallen in India,' and it may seem, at first sight —so wide is the world, and so far apart the interests of races—a strange thing that a fall of rain should be magnified by such language as is often used. And yet in a year of threatened famine it is not easy to find in history a greater blessing than the sudden relief of a shower. Those who best know the land so sorely athirst,—who remember the dreary, leafless months, when, scathed by hot winds, the country side lies bare and brown under a sky of relentless blue, and who have had experience, too, of that first day of gathering clouds, when the face of Nature betokens a welcome to the coming rain; when almost in a single night the heat-cracked plains clothe themselves with grass, the fainting trees are lit up with the brightness of young leaves, and the world awakens on the morrow to a surprise of fertility,—these can best picture to themselves the true spectacle of the change that transfigures the face of India, when the clouds burst upon the empty fields. During the months of July, August, September, and October, which in other and more kindly seasons are rich with springing vegetation, and glad with the grace of standing corn, India lay, in 1877, wasting under a remorseless sun a great length of deadly days, while the ploughs stood idle under the old peepul tree in the centre of the village, and the men gathered gloomily about the headman's house; and sadly along the dusty highways went the tinkling feet of the women sent forth to the shrine by the river to supplicate the Goddess of Rain; day by day the peasant doled out for the present meal the precious store put by for sowing of his fields for the next year's harvest; day by day the women going to the well found their ropes yet another inch too short for the bucket to drop into the shrinking water. The cattle, long ago turned loose to find their food where they could, had given up the vain search in the fields, and lingered about the villages sniffing at the empty troughs, and lowing impatiently for the evening meal of bitter leaves which the lads were beating down from the trees in the jungle. And then there came over many a sad village a day when the bucket brought up no water from the well, when the grain-bag was empty and the cattle dead. Famine, stealthy and pitiless, prowled from village to village.

"Along the raised pathways between the empty fields the sad processions of mourners filed all day, bearing to the river-side the bodies of the dead. Yet the sun still flamed ruthless in the sky. The villages gradually emptied of men; some

had perished, while the rest had fled from their homes. To stay and hope was to die. At last came this rain. It did not bring food, but it brought the assurances of future harvests, and set the poor souls to work and to hope. Even food would grow cheaper, and be more freely obtained as those precious drops pattered; for the rain came at the right time. Just when further hope seemed useless; when, from the Indus, all along the Ganges valley to the Bay, from Oude, 'the garden of India,' and the principalities of the Rajput and Maharattah; from the wild fastnesses of Sind to the palm-fringed shores of the Eastern coast—the danger of a second year of drought was gathering force. Just when it seemed inevitable that half India must be involved in the disasters of Madras, the rain-clouds hurried up in a night, and the peninsula awoke from despair."

And after a most eloquent and touching account of the sufferings during July, August, and September, when the natural rain was withheld, he goes on to say:—

"So the days wore on to October. The sowing of seed for next year's food now seemed hopeless, and another year of famine inevitable; but the people did not repine. They waited patiently and pathetically, closing in round the famine-works and doing their day's labour for a day's food, enduring the 'evil times' without hope but without murmur. Indeed, hope looked like folly. The news came from every side that crops had failed. The horizon of disaster seemed expanding every day. Even the stout heart of the English official began to fail him, and he spoke dismally of the future. The sky was still unflecked with clouds, and a great multitude was dying at his gates. Then, suddenly at last, when it seemed almost too late, nature relented. A shadow of clouds had grown up on the horizon, the great rain-wind blew, driving a tempest of dust before it, whirling the dead leaves from the trees, and signalling that help was coming. The birds could be seen gathering in the sky, and the cattle turned their heads to the wind, for they could scent the approaching showers. There would be a strange gloom while the dust-storm was passing, and the people would throng, gazing at the clouds, or waiting for the rain that they knew was close behind. The streets would be filled with men and women, and all hands would be idle, and all tongues silent, and then, lo! the rain.

"First, great sullen drops, pattering one by one, and then, as if it could not come down fast enough or thick enough, the torrent descended. Not a mocking shower, but a glorious life-saving deluge, brimming the tanks to overflowing, and sending the dead weeds swirling down the nullahs. In

instant response the earth broke out into life. From forest and hill the familiar cries of Nature were again heard, the crane trumpeting to his mate as he stalks among the waving sedges, the cry of curlew and plover wheeling above the meres, the clamour of wild fowl settling upon the waters, the barking of the fox from the nullahs. The antelopes found out their old haunts, and from the villages the hyena and jackal skulked away to ravine and cave. Men and women came straggling back to their villages; ploughs were dragged afield; and, where a week ago was hopelessness and desolation, the only sounds of living things, the cries of beasts and birds over the corpses, there awoke a glad renewal of busy peasant life."

Something has been said and written on the influence of the solar spots on the cyclical changes that involve recurrence of dry seasons, and consequent scarcity or even famine, but no very definite conclusions have been reached in regard to their value as causal agencies. Mr. Blanford, however, says that he considers the evidence in favour of the general fact that the solar heat increases and decreases *pari passu* with the spots in the photosphere, is at least much stronger than any that has been brought forward in favour of the opposite view, but the numerical value of the variations has yet to be ascertained.

The relation of the sun spots to rainfall is yet a *quæstio vexata.*

The following are the Rainfalls of some of the principal Stations in India for 1879, compared with the average yearly falls :—

Stations.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Total.	Average.
Calcutta	.....	0·28	.....	.....	3·07	7·52	12·21	12·54	6·22	2·41	.....	0·42	44·67	62·95
Dacca	.....	0·75	0·06	0·51	4·42	14·37	20·51	13·71	13·28	6·29	.....	0·90	74·80	73·29
Chittagong..	0·36	.....	0·11	0·07	4·28	36·58	25·98	12·84	7·37	6·71	.....	1·01	95·31	103·36
Sibsagar	1·60	0·62	1·55	7·51	21·01	17·28	19·18	16·40	16·63	3·93	.....	0·38	106·14	94·45
Silchar	.....	0·51	5·48	4·73	16·26	32·49	17·75	22·82	10·22	2·83	.....	0·41	113·50	117·40
Cuttack	.....	0·07	1·15	.....	8·52	3·57	12·23	18·96	9·44	4·89	0·25	1·54	60·62	55·89
Hazaribagh .	.....	0·60	.....	.....	1·47	7·42	13·09	12·17	7·07	2·53	.....	.....	44·35	48·33
Patna	.....	1·37	.....	.....	0·02	5·23	9·78	12·87	8·93	6·53	.....	.....	44·73	40·26
Darjeeling...	.....	0·47	.....	1·51	13·36	27·67	53·53	40·68	19·84	3·63	.....	0·23	160·92	120·17
Allahabad ...	.....	0·07	0·02	.....	.....	9·26	6·01	9·58	13·95	3·46	.....	.....	42·35	38·45
Lucknow ...	0·17	0·02	.....	.....	0·05	3·70	18·12	8·47	5·67	1·96	.....	0·16	38·32	39·52
Meerut	0·56	1·32	0·75	0·30	0·05	1·87	12·49	13·81	3·10	0·40	.....	0·92	35·57	27·44
Delhi	.....	0·21	1·03	0·05	.....	6·79	15·28	8·99	2·29	0·09	.....	1·22	35·95	27·49
Agra	0·66	0·11	0·15	0·03	.....	3·02	7·93	10·62	6·60	0·28	.....	0·20	29·60	25·77
Jhansi	0·40	.....	.....	.....	.....	2·90	16·76	17·10	9·17	0·91	.....	.....	47·24	35·08
Agmere	.....	0·89	0·27	0·02	0·13	6·56	0·38	16·71	2·03	0·10	.....	0·51	27·60	22·90
Saugor	.....	0·85	.....	.....	0·75	4·93	11·88	13·81	3·23	3·88	.....	.....	39·33	46·90
Jubbulpore .	.....	0·73	.....	.....	0·06	3·60	10·84	17·45	8·67	3·92	.....	.....	50·27	52·24
Mooltan	.....	.....	1·73	.....	.....	1·32	0·81	1·03	.....	.....	.....	.....	4·89	7·41
Lahore	.....	0·01	1·32	.....	0·01	5·48	1·13	7·49	3·12	0·17	.....	0·45	19·18	21·38
Peshawur ...	.....	0·46	2·73	0·24	0·14	0·05	0·47	0·97	0·16	.....	0·10	0·52	5·84	14·66
Ranikhet ...	0·23	1·55	3·32	0·53	0·20	9·65	21·78	13·30	2·01	2·40	.....	1·22	56·19	48·56
Chakrata ...	0·36	1·56	5·65	0·70	0·22	12·37	15·91	27·62	6·41	0·75	.....	0·81	72·36	61·07
Indore.....	.....	0·61	.....	.....	2·29	6·16	3·45	7·79	14·67	3·29	.....	.....	38·26	36·30
Deesa	.....	0·86	.....	.....	.....	5·42	9·42	15·12	1·59	0·01	.....	.....	32·42	24·13
Kurrachee ...	.....	.....	1·00	.....	.....	0·04	.....	0·87	0·01	.....	.....	.....	1·92	7·37
Bombay	.....	.....	0·03	.....	5·23	16·56	11·21	22·36	5·61	0·40	.....	.....	61·40	74·06
Belgaum.....	.....	0·05	.....	0·64	5·35	13·40	8·66	17·13	1·40	3·81	4·40	0·07	54·91	48·15
Nagpur	.....	0·63	.....	.....	5·92	13·46	8·48	13·50	6·54	3·65	.....	.....	52·18	43·71
Bellary*.....	.....	0·39	.....	0·59	3·03	1·50	7·34	2·98	3·54	3·03	0·86	0·02	23·28	17·57
Bangalore*...	0·33	1·38	3·19	0·26	6·58	2·93	7·20	3·56	4·76	8·35	2·13	.....	40·67	35·46
Madras*	1·30	.....	1·50	.....	4·43	2·10	4·30	6·61	0·54	18·23	10·91	4·33	54·25	48·56
Rangoon.....	0·04	.....	.....	4·57	12·17	15·12	19·14	20·25	18·66	8·48	15·26	.....	113·69	101·10
Akyab.....	.....	.....	.....	.....	10·82	54·02	60·10	58·83	24·29	16·02	.....	3·16	227·24	197·98

* The fall at these three Stations in September, October, November, and December, shows the effect of the north-east monsoon as a wet wind.

I have taken from the meteorological report for 1878 the rainfall in a number of stations in illustration of the influence of season and the monsoons in different regions of India; 1878 seems to have been an exceptional year, with peculiar variations from the ordinary conditions, for, whilst unusually dry in some, it was unusually wet in other districts. The general result was an average rainfall for the whole country registered, 4·9 inches in excess of previous years.

The following averages of a number of previous years are instructive. In Calcutta, for example, 65·80 inches fell, the greatest falls being in the months of,—June, 11·78; July, 12·77; Aug., 13·96; Sept., 10·15.

In Chittagong, the greatest falls were in,—June, 21·35; July, 21·93; Aug., 21·71; Sept., 14·05. The whole rainfall was 103·7.

In Bombay, the whole rainfall was 74·20. The greatest was in,—June, 20·95; July, 24·27; Aug., 15·21; Sept., 10·71.

In Kurrachee the fall was 7·61. The greatest being in,—July, 2·97; Aug., 2·10; Sept., 0·81; Dec., 0·22; Jan., 0·67; Feb., 0·26.

In Mangalore, on the west coast, in the full intensity of the south-west monsoon, the fall was 134 inches. The greatest falls were in:—June, 40·09; July, 37·68; Aug., 23·14; Sept., 11·70; Oct., 8·55.

In Madras, 48·15 fell. The greatest falls were in,—Oct., 10·73; Nov., 13·0; Dec., 4·99; Jan., 0·65, showing the influence of the wet north-east monsoon.

In Tinnevelly, the fall was 28·16 in the whole year, greatest in,—Oct. 6·25; Nov., 9·86; Dec., 2·63; Jan., 1·55.

In Southern India at several stations, as, for example, Coimbatore, Bangalore, and others, both monsoons are felt, and a certain amount of rain is due to each.

Irrigation.

Though a great part of the continent of India is amply supplied with rain, there are extensive regions where the normal quantity is so small that it is insufficient to produce the crops that are necessary for the support of the population, and where, without the aid of artificial irrigation, the land would be sterile. This irrigation is effected by reservoirs, canals, and wells. In regions where the yearly rainfall is less than 15 inches irrigation is always necessary; such are the arid zone in the north-west, including most part of the Punjab, the great desert tracts of the north-west, and in that known

as the southern arid region, occupying the central portion of India from Nassick to Cape Comorin!

In regions having a rainfall of between 30 and 60 inches, such as the upper part of the valley of the Ganges and the eastern coast of the Madras Presidency, irrigation is often needed, and great distress has been caused by the want of it. Where the rainfall is between 60 and 75 inches, as in the deltas of the Mahanuddi and lower part of the Gangetic valley, irrigation is looked on as a luxury—often useful, but not necessary, except in exceptional years. There are two belts of excessive rainfall—the coast of Aracan, extending from the Irrawaddy to the valley of the Brahmapootra; and the west coast of India; where the need for irrigation never exists. In those wet belts, where a superabundance of rain falls, embankments are necessary to preserve the crops and villages from destructive floods; whilst the maintenance of the river embankments in Lower Bengal is an important part of the duties of the Irrigation Department; for the cultivation of the land is entirely dependent on their efficiency. This, however, is the result of the land lying below the flood level of the river rather than the excessive rainfall. There are upwards of 2,000 miles of such embankments in Bengal, under the charge of the Irrigation Department, kept up by the State. Mr. Bateman alluded to artificial irrigation in Ceylon and India, and to the great works that had been constructed in past ages for the purpose, many of which had fallen into disrepair and disuse; and he mentioned the canals that have been constructed by the British Government with the view of irrigating those tracts where the natural rain supply is deficient during the whole year, or where it is so partial that it fails to supply the needs of cultivation, and he contrasted the condition of a country so situated with our own more favoured islands, where drought is infrequent.

The Government of India has given much attention, of late years, to artificial irrigation for those districts that are most in need of it, and many gigantic works have been completed, whilst others are in course of construction for this purpose; some are altogether new, others are the reconstruction on former lines of old works of the Hindoo and Mahomedan periods, and the importance they must have attached to irrigation is manifested in the canals, anicuts or dams of rivers and reservoirs, many in ruins, left by them. It would be impossible for me now to give a detailed description of the irrigation works, ancient or modern, in use in India. I can merely give a general sketch of the great canal system actually in existence, supported and carried on by Government.

About sixty years ago the British Government seriously

took up the subject of irrigation by canals or other great works; since then, the work has been steadily going on, and with it the names of Cautly, Cotton, Fife, Baker, and others, are honourably associated; nearly the whole of the peninsula is now provided in those regions where water is needed, and a vast area of land, that would otherwise be sterile, is brought under cultivation. The works, consisting of canals of various sizes, dams or anicuts, lakes and tanks, extend from Himalaya to Comorin, and, to effect this, great rivers, such as the Ganges, Indus, Jumna, Sone, Sutlej, Ravi, Mahanuddi, Godavery, Kistna, Cavery, Colerun, Tunga-Badra, and Tapti, have been laid under contribution, with many other lesser streams, for the formation of artificial lakes and reservoirs; whilst several others are in project. An idea of the magnitude of the work may be derived from the length in miles of the canals that form the canal system in India.

The total length in Bengal, Madras, and Bombay, amounts to 4,900 miles; but this does not include the Tanjore system, which is 700, the inundation canals of the Punjâb, 1,550, or the canals of Sind, 5,600 miles. Thus there are 12,750 miles of lesser or greater canals, whilst the total length of the distributing canals is unknown. In Northern India alone, however, it amounts to 8,300 miles. The area now irrigated amounts to 1,900,000 acres in Madras and Bombay, 300,000 in Behar and Orissa, 1,450,000 acres in N.W. Provinces, 1,350,000 in Punjâb, and 1,250,000 in Sind; in all, 6,310,000,—nearly six and a half millions of acres. The area irrigable by canals is yet considerably greater than even this large total, so that the system is capable of extension. The capital outlay by the State on this canal system may be set down at twenty and a quarter millions sterling, on which the net returns yield an interest of six per cent. Sir R. Temple says: *—"Apart from the direct receipts from these canals, many indirect benefits accrue. These benefits are represented by the security afforded to agriculture, the assurance provided for the people against the extremities of drought and famine, the protection of the land revenue, the instruction of the husbandmen by the example of the superior husbandry established, and the introduction of superior products. The value of the canals during the recent famines has been inestimable. Without irrigation, these calamities, great as they are, would have been infinitely greater. The value of the produce which the canals saved in order to feed a famishing people, equalled the capital outlay on their construction."

* "India in 1880."

Another point of view from which meteorology is most important in its bearings on the material prosperity of India is the effect which it exercises over the sanitary condition of the people. There can be little doubt that public health is greatly affected by the rainfall, and that fluctuations or extraordinary departures from the normal state are attended by fluctuations in the standard of public health. The diffusion and activity of epidemics are probably influenced by it. It would be saying too much, perhaps, to assert that the fluctuations in the death-rate are altogether due to variations in the rainfall, but that they are to a great extent influenced by it seems to be proved by what obtains all over India.

The following* appears to have been ascertained in relation of climate to epidemics :—

1. If epidemic cholera be about, its intensity will be increased by continued dryness, evaporation, and high temperature. If cholera exists under this form, heavy rain will greatly diminish it, or wash it away.

2. Dryness, heat, and rapid evaporation reduce the intensity of fevers. Rain following, greatly increases their intensity. But the effect is not what can be called immediate. The rain must accumulate and the ground be soaked; as soon as drying up begins, fever augments until the evaporation reaches a certain intensity, when it declines. It is not so much the great amount of rain as the soaking and saturation that does the mischief. In some places fever declines very much when the country is completely flooded, but increases in intensity when the rain ceases, and drying up begins.

3. Small-pox in India does not appear to be related to rainfall. It augments with increase of heat, and so continues till colder weather arrives, irrespective of the amount of rain.

4. Rain with cold and high temperature range appears to augment the liability to bowel diseases, but not to a very great degree.

There is yet one point to which I would refer, though I can only do so very briefly; it is the influence of the rainfall on the growth of forests, and their effects on climate. There is reason for believing that some of the desert plains of India were at one time covered with trees, and that when they were so the climate was less rigorous in its extreme heat than it now is. When we think that the desert regions in the north-west were at one period the seat of early Hindoo civilization and population, it is obvious that the physical conditions of the country must have been very different to what they are now, and it seems probable that the change is due to destruc-

* Dr. Sutherland.

tion of trees. The cultivation of forests, therefore, is a matter of the greatest importance, for, not only do they temper the climate by the moisture they exhale, but they tend to cause rain where there would be none.

The subject of rainfall is one that involves so much, and that suggests or leads to so many collateral inquiries, that it is difficult in discussing it to draw the line where one would stop; but I feel that I must do so here, for I have exhausted the time at my disposal in giving what, after all, is but a mere sketch. I trust, however, that it may have conveyed some useful information on a subject that is fraught with interest to 250,000,000 of our fellow-subjects.

The CHAIRMAN.—I have to return our thanks to Sir Joseph Fayrer for his very interesting and useful paper. It is now open for any present to make remarks upon the subject.

Mr. J. F. BATEMAN, F.R.S.—I am happy to think that a paper of mine should have suggested so valuable and interesting a communication as that which we have just had from Sir Joseph Fayrer. There can be no question that the registration of meteorological facts all over the world is of great service; but the object of my paper was the particular one of confining the observations made on this subject to the British Islands, with a view to showing that it was necessary to take all the circumstances into consideration with the practical object of providing for the floods which occasionally deluge the country, and making a fair estimate of the quantity of rain which might be collected from a given area. I desired to show that it was not, as has been falsely assumed by many meteorologists, the mere elevation of the country which increased the quantity of rain, and I showed that the heads of all valleys and the first land (if the hills are only of a certain height where they are swept over by the south-west wind, which brings the largest quantity of aqueous vapour) received most rain, while as the south-west wind proceeds gradually to the east there is a lessening quantity of rainfall. I am happy to see that the observations of Sir Joseph Fayrer have corroborated this statement. But in the districts he has spoken of the difference in the rainfall is so large that little practical result can be obtained from the observations except that it is found that there is a very large rainfall in the mountains to the west, while in some of the districts beyond there is next to none, the difference being as between a rainfall of less than 2 inches and the enormous amount of 600 inches, so that about 300 times as much rain falls in one district as is registered in another upon the average of years, there being certain months during which no rain falls, while there are other months in which as much as 50 or 60 inches of rain are occasionally registered. In the tables which Sir Joseph Fayrer has given, which are exceedingly interesting, there are registers of rainfall, showing that in some places no rain whatever has fallen in the months of January, February, March, and

April, while in May, June, July, August, and September, the rainfall has amounted to 60 inches and upwards. The provision that has to be made under these circumstances is, therefore, of two kinds. They have first to provide for the construction of roads, railways, and other works, so as to pass the floods which arise from the prodigious quantity of rain which falls at certain seasons of the year, and they have also to provide works of irrigation in those parts where the rainfall of the wet season can be utilised for purposes of cultivation, or any other use to which it can be applied for the benefit of mankind ; and in these cases they have to base their calculations on the length of the drought which may be expected, and the period during which they must maintain a sufficient supply of water by artificial means. They must, of course, consider the capacity of the reservoirs they have to construct for the purpose of collecting and storing the rainfall which is obtained in such abundance during the rainy months. These are practical questions which can only be deduced from such observations as those which Sir Joseph Fayrer has brought before us. Therefore, quite apart from the interest the subject intrinsically possesses, they are of the greatest interest and importance to mankind in reference to their arrangements for works of improvement, or the mechanical operations by which man is able either to control the floods, or to impound the water falling in the wet seasons for use in the dry seasons. There are so many interesting points in connexion with the subject of meteorology, quite apart from those relating to the practical objects to which I have referred, that it is a matter in which I can well understand a great many people will feel an interest. Whether we shall ever find out and apply the laws which govern the fall of rain, so as to convert them into an exact science, I doubt ; but at all events a great number of observations, extending over a large area of the earth, must prove of the greatest possible benefit in enabling us to form opinions as to the quantity of rain which has produced, in flat districts, deltas like those in Egypt and Lower India. The difference in the fall of rain is so great, and the purposes to which the rainfall is applicable are so varied, that we cannot help thinking the distribution of water must necessarily call forth the intellect and the energies which God has bestowed upon us for the purpose of enabling us to make use of the great advantages which He has conferred upon us for applying the surplus rainfall of one district to counterbalance the deficiency of another. In this respect the observations of Sir Joseph Fayrer must be of the greatest advantage, quite apart from the practical results which it was the object of my paper to direct attention to. (Hear, hear.) I may mention one circumstance that has also been alluded to by Sir Joseph Fayrer, namely, that evaporation is constantly going on, and I have known as much as five inches of snow disappear during an east wind, although there was no thaw and the weather was freezing the whole time; the effect of the dry east wind prevailing over the whole country being to produce this result. This fact shows that evaporation depends not so much on the temperature as it does on the dryness and capacity of the air to absorb moisture. Thus in the

tropics, through which I have passed, I have found that the atmosphere has been so saturated with moisture that at night, when the temperature has become reduced and condensation has taken place, the deck of the steam vessel would be absolutely wet, as if recently washed, owing to the deposition of dew or moisture upon the surface. (Applause.)

Dep.-Surgeon-General N. CHEVERS, C.I.E.—I was for a long time a near neighbour of Sir Joseph Fayrer's in India. I have been at Chittagong, where we had about 160 inches of rainfall in the year. It is pleasant to remember that, the very first, I believe, of the numerous illustrations of natural science in every part of India by which Sir Joseph Fayrer has enriched our literature, was a contribution to the meteorology of Burmah, in which he undertook the very difficult task of obtaining for a specified time, the hourly temperature, the rainfall, and the barometrical readings of that district. He and Mr. J. Bedford were the only men who were the actual pioneers in this work. Then followed what was certainly a violent measure on the part of the Government, and I am afraid that Sir Joseph Fayrer and Mr. Bedford are to be charged with bringing it down upon us. The Government sent us a most terrific paper, upon which already hard-worked men were expected to register the dry and wet bulb and barometrical readings, and the direction of the wind, six times a day, to observe also during the night what were the prevailing winds ; and, at the end of the 24 hours, to register the rainfall. I am now speaking of two and thirty years ago, and some of the results were very curious. For instance, some barometrical readings, which Mr. Bedford told me had been sent to him, were of a very wonderful and surprising character ; upon his inquiring whether they could possibly be true readings, the observer wrote back to him, saying, "You are employed in registering atmospheric phenomena ; this is an atmospheric *phenomenon*, and you must register it." There was one phenomenon for which I can vouch. A surgeon who was very much overworked, made the duty over to the sub-assistant surgeon, who, I am afraid, made it over to a native doctor, who observed that a certain wind blew "due east-west" for a whole week. (Laughter.) This was registered in one of the documents, and there may have been well nigh as little accuracy in some of the other conjectural registers. It was my duty, as secretary to the Medical Board, to make over the whole mass of these records to one of the brothers Slagenthweit, who afterwards died in India, who, I believe, was unable to publish them ; still, many of them were true and accurate documents, very carefully compiled by such men as Sir Joseph Fayrer and Mr. Bedford ; and, if they could be recovered now, they would give some very curious and interesting information. This was all before the time of Mr. Blanford. There was one point which interested me very much in Sir Joseph Fayrer's paper, and that was the allusion made to the effects of tree vegetation on the rainfall. I remember one or two spots which were wide wastes of sand swept bare by the mighty river the Brahmapootra, and which were left entirely without the appearance of vegetation for several months in the year ; but we

took certain pieces of this land, enclosed them, irrigated and cultivated them, and before five or six years were over, those sands were tolerably productive gardens. There has always been a great want of wood in India, and fire-wood is very expensive. There was a great sacrifice of wood caused by the introduction of railways. There was an extreme, almost a rabid, anxiety to get wood for sleepers, and large forests were cut down and carted away for the purpose. When I first went to India, thirty-three years ago, no person had any need to be what is called weatherwise. The seasons were then almost as regular in India as day and night are in England. You know perfectly well in Calcutta that on the 20th or 21st of June the rains would set in, and so on with regard to the rest of the climatic changes. Everything was fixed; but of late years, and especially since heavy cyclones have been frequent in southern India, there has been a difference: whether this is a mere coincidence or stands in the relation of cause and effect I am unable to say. At any rate, the climate of Calcutta is beginning, as to the rainy season, to be in some years most uncertain. In olden times, from the 20th of June until September, we had heavy rains every day, generally until about five or six o'clock in the afternoon, which was our driving time, and then we could get out and take a little exercise. The rainfall amounted to some 60 or 70 inches in the course of the year; but, of late years, you have sometimes almost a month in the rainy season without any rain whatever. The rainy season was a comparatively cool one, because the sun was kept off by the clouds. Now, that shelter is to a great extent withdrawn, and the sun comes down upon you with most intense heat. Coincidently with this it is to be noticed that Calcutta, which is not a very ancient place, dating from about 1680, used to have in its vicinity beautiful forest trees, such as the tamarind, the peepul, and a great variety of others. It was, in old times, thought a great virtue to plant avenues of trees under which the troops and wayfarers could pass, and you see them still remaining on some of the old roads from Burhampoor, and between Calcutta and Barrackpore. It was the almost sacred duty of the Zemindar to have mango groves planted, which supplied the people with a food that is, perhaps, second only in value to rice in some of the districts, especially in Behar. Since the cyclones and the construction of the railways, the great trees of Calcutta have almost entirely disappeared; and I cannot help thinking there is more than a mere coincidence between the disappearance of these trees and the great irregularity of the seasons in the Calcutta district, so that now one must be exceedingly weatherwise to predict what sort of a day one is likely to have. The great thing for scientific men to do is to endeavour to equalise the fall of rain in some of those unhappy countries where it is so uncertainly distributed. I believe that trees are beginning to be more plentiful in Scinde than they were. The objects to aim at are, first of all irrigation, then of course growth of the crops, and then the planting of forest trees.

Mr. W. GRIFFITH, Barrister-at-Law.—The subject is one of so much interest that I am sure a paper upon it from any member of the Victoria

Institute must be worthy of attention, more especially one from a gentleman of such authority in the scientific and medical world as Sir Joseph Fayrer. Those who know the high position he has occupied in India, the great services he has rendered, and the opportunities of observation he has had, must admit that a more trustworthy and competent witness could not appear upon the scene. He has given us a great deal of very valuable information as to the effect of the rainfall not only on the famines of India, but also the health of the people,—on such diseases as cholera, fever, and other matters connected with Asia. I was glad to hear what he said with regard to the forests, which may in time to come be of so much importance in that country. He has told us that the rain is produced by the monsoons breaking on the mountain ranges during certain months in the year. I remember some years since reading in Alison a statement that during six months of the year the rainfall of India was designed by Providence to produce fertility in that country, while during the other six the melting snows swelled the rivers and produced a similar effect. I would, with all respect, ask Sir Joseph Fayrer whether this is a fact. Of course, I merely quote the statement on the authority of that eminent historian; but the authority of a witness who has lived so long in India would be valuable, as tending to enlighten us upon that point, because some seem to think we can have no exact science on the question of rainfall. The interesting map exhibited illustrates with considerable accuracy, the results of Sir Joseph Fayrer's observations, showing that in Scinde the rainfall does not exceed 10 inches, while in various parts of the country it is over 100 inches. In a country with such au opportunity for the Government to exercise its powers to remedy the want of water, and to produce fertility among the arid districts, any postponement of irrigation works is to be deprecated. Of course, India is so extensive a theme that those only who have the best acquaintance with its history and its present condition can dilate upon these subjects to our satisfaction. It is very interesting to consider the history of the past military achievements of England in that part of the world, and the results of our statesmanship in consolidating that mighty empire, and to remember the great results achieved by a few British merchants. One cannot but contemplate with some satisfaction the benefits of our rule in that country; there is no doubt that we have been the means of producing peace and improving the administration of justice, and it is satisfactory to find that we are doing much to promote the prosperity of the natives; that we are considering the education of the people, and the means of averting any of the calamities that are likely to befall them, while we are promoting the productiveness of the soil by those great works of irrigation to which Sir Joseph Fayrer has referred. I was surprised to hear that those works had been extended to thousands of miles of canals. It is also to be remarked, and it is perhaps an argument why these works should be demanded of and carried out by us, that we are the landlords of the country, and that

whatever benefits we may produce must benefit ourselves by increasing the rent. This, of course, is a mere utilitarian argument. It is important that we should bind the natives to ourselves by anything that will tend to make them more satisfied. In times past they have had the opportunity of witnessing our military rule, and they may have had cause to admire our administration of justice; and I think we ought to consider it a hopeful sign that they are now to have the opportunity of finding that we are doing all we can in other ways to promote their welfare, and to increase their prosperity. I am glad we have had such men as Sir Joseph Fayrer out there, and I trust there will be many more who will go and do as he has done, and produce the same amount of benefit to that important country.

Col. J. A. GRANT, C.B., C.S.I., F.R.S.—As the hour is getting late, I should have preferred to hear Sir Joseph Fayrer's reply to saying anything myself; but I may allude to the equatorial region of Africa, in which I was with Captain Speke, where we had only 49 inches of rain. The altitude of the country is 4,000 to 5,000 feet, and as one goes northward to 5° north latitude and 2,000 feet altitude, the country is more of a desert, and resembles parts of Ceylon in there being a small rainfall. In the region of 3° south latitude, where the rains reach both the Congo and the Nile, the fall of rain may be 60 inches. But, as I have said, I only wish to hear my old friend Sir Joseph Fayrer's reply; I have been delighted to hear such an admirable paper.

General MACLAGAN, R.E.—Sir Joseph Fayrer has described the great inequalities of water distribution in India. India suffers sometimes from excess of rainfall, causing destructive floods, and sometimes from deficit, causing much distress from scarcity of water. And these two things may happen at the same time in different parts of the country,—a country not only of great magitude, but of which the physical features and conditions vary as much as the different countries of Europe, and in some respects much more. A great problem in India, where it may be said there is ordinarily an abundant supply of water upon the whole, is how to make the most of this most valuable gift, and to prevent or diminish the injury it causes. Works have to be constructed in India for both objects, at one place for removal of excess water, or protection against it, at another for catching and economising every drop. Of the irrigation canals that have been referred to, some flow continuously throughout the year, the quantity of water admitted being to a certain extent under regulation. Others, more simple works, known as *inundation canals*, fill only when the rivers rise from the melting of the snows, and then from the periodical rains in the hills. Reference has been made to the effects of clearing forests in India. There has been, we know, extensive clearance in some parts, in past years, before the British occupation of the country. It is on record that wild animals used to be hunted in great forests, where now there is not a tree. And there can be little doubt that these clearances have affected the climate. But it can scarcely be said that the supply of the railway requirements in

our own time has helped to increase the injurious clearance of forests in India. The requirements are of two kinds, timber for sleepers and buildings, and small wood for fuel. The *deodar* timber, which in Northern India is the wood chiefly used for sleepers, as it is not liable to the attack of white ants (other woods have to be protected by creosoting, &c.), has been chiefly supplied from native hill states. It is true that under native management there was much wasteful and indiscriminate felling of the timber, the rulers looking only to immediate gain, regardless of the future. The British Government has taken a lease of some of the principal hill forests of deodah and other pines, and in the hands of the Forest Department the felling is under careful and systematic management, due care being taken for reproduction of timber trees and increase, in certain places, of forest area. The provision of fuel, and the management of the jungle tracts in the plains, from which fuel supplies are obtained, are likewise under careful regulation; and extensive fuel plantations in selected places provide for continuous supply and reproduction. The untrustworthiness of the meteorological registers, to which allusion has been made, was due to imperfect arrangements, imperfectly qualified agency, and imperfect means of compiling and examining the results. Matters are differently managed now, and a competent meteorological department has been organised. Many have heard the old story of the native official at a rural station (who, among other duties, had charge of the meteorological instruments), making things ready, on one occasion, for the expected visit of the Commissioner of the Division, who would be sure to ask to see the meteorological instruments. They could all be examined and read except the rain-gauge. The Commissioner might be disappointed if it had nothing to show, so a jug of water was poured in that he might find something to observe in the rain-gauge too! We may fully trust that, under Mr. Blanford, meteorological records will be obtained of great value and importance to India.

Surgeon-General Gordon, M.D., C.B.—I have been a good deal in India, and can endorse almost everything that has been stated by Sir Joseph Fayrer, especially with regard to the important bearing which meteorology has upon certain kinds of disease. Sir Joseph Fayrer has alluded to the prevalence of particular kinds of disease, according to the particular atmospheric conditions of the country. In so far as those atmospheric conditions at particular periods, or at the same period of the year, are very variable in different parts of the large continent of India, so do we find the phenomena of disease vary in a similar manner. That is to say, the disease which prevails in one part of India, and at one period of the year, differs in many respects in its phenomena from a similar disease prevailing in another part of India. I noticed that it was represented by Sir Joseph Fayrer that there are certain epidemics which have a natural relation to meteorological conditions, while there are others with regard to which similar conditions do not seem to be established,

With regard to those that are connected with meteorological conditions, such as cholera, we can almost trace the advance of cholera from one part of India—namely, from Lower Bengal upwards, according to the advance of the season—year by year, almost with unerring certainty. The cholera, beginning in Lower Bengal, especially in Calcutta, about the month of February, advances steadily upwards along the banks of the Ganges to Burhampoor, Dinapore, Benares, Cawnpore, Meerut, and so on to Peshawur, reaching the latter place about the latter part of autumn. It then frequently advances north and west, even in the winter season. But there is another respect in which the meteorological condition of India has a very important bearing, and that is with regard to the question of vegetation. We know that according to the peculiarities, climatic and otherwise, of particular localities, the vegetation varies, inasmuch as the influence of the climate of India upon vegetation, particularly upon plants, roots, bulbs, and other things imported from England, is very remarkably seen. When we see this, I think we must make allowance for the influence exerted by the climate of India on the health of Europeans who have gone to reside in that country. It is a very common saying in England, and especially amongst those whose personal knowledge of the conditions to which they refer is limited, that the mortality amongst our people is, in the majority of cases, attributable to faults on the part of the people themselves ; it is due, they say, to too much eating or too much drinking. I am always glad when an opportunity occurs, such as the present, to try and show that such views are not correct. I have seen as much of European,—that is, British,—life in India as most people, and although, of course, there is a good deal of mortality and sickness due to excesses there, just as there is here in England, still, the great difference in the rates of sickness and mortality there over the rates prevailing in Britain is to be accounted for by something else than mere excess ; and that something else is, I believe, to be found in those grave conditions, climatic and local, which we have not the means in the instruments at our disposal of identifying, and which affect vegetation in the way I have alluded to. (Hear, hear.) In order to make my meaning more clear, I may say that flowering plants – those, for instance, that have been introduced into India from England—completely change their characteristics ; that is to say, many of them so completely deteriorate in a year, or a couple of years, as not to be recognisable. Plants that are exceedingly productive in England in regard to seed, fail in that respect in India. Flowers and plants flowering or budding in spring do not bud or flower very often in some parts of India until the autumn, while in other parts they flower twice a year. Some trees, as, for instance, the ornamental trees that have been introduced from England, completely change their appearance and become unrecognisable ; and not only does this apply to trees taken from England, but also to those that have been introduced from Australia. I remember a gentleman from Australia going about with some of the officers in one part of India, and asking what a particular tree was. " Bless my heart," he said, " surely you

know that that is the *Acacia dealbata?*" The reply was, "It is so completely different in appearance from what the tree is in its native country that I really do not know it." When I take these things into account, as well as other facts resulting from the climate in regard to vegetation, I think it puts us in a better position to understand how people from this country should be similarly affected by the climate in India. Therefore, I hope the few remarks I have made will have some effect in leading my hearers to the belief that when our soldiers and officers come home pallid and ill from India, their sickness has been brought about by something more than mere excess. As long as we are able to maintain India, which I hope will be for many generations, this is a point to which I think we ought to look. The more we consider the great influence which the climate has upon organic nature generally, and the more we apply the observations that are thereby presented to us to our own case, the better we shall be able to consider this subject in its more rational and scientific aspect.

Surgeon-Major PARK, R.A.—I should like to ask one question. I have not served in India myself, but I have seen a great deal of the British soldier, and his wife and children, and I should like to know whether there are any observations with regard to the effect of rainfall on the health and mortality of the soldier. From a personal experience of many parts of the world, excepting India, I feel strongly that he is a greatly belied man, and if such a Society as this can, by its publications, let the public have the views of such men as Dr. Gordon and Sir Joseph Fayrer as to the effects of the Indian climate on the soldier and his family, I think it will have a good effect. This may appear to be going somewhat wide of the subject of the paper, but I think the matter is one well worthy the attention of the English people. There is another point on which I should like to put a question to those who have served in India, and that is in reference to the common remark that three generations exhaust the vitality of the British residents in Lower Bengal. I wish to know whether there is any authentic record showing that this is the fact or the reverse?

Dr. CHEVERS.—That proposition has been considered by all the medical men in India, not merely as to Lower Bengal, but throughout the country, except, perhaps, Simla and the high lands and hill sanitaria, which are modern places of European residence, scarcely occupied as such for more than fifty or sixty years, so that in their case there has not been room for observation. But with regard to other places which have been in a great measure inhabited by soldiers and their descendants, and where the invalids used to be allowed to retire and make themselves comfortable, it has nowhere been discovered by any medical man that there have been any genuine descendants, of unmixed blood, of any European family of the fourth generation; that is, assuming there has been no return to Europe for education and improvement of health. If an instance could have been cited I am sure one or another of our active inquirers would have certainly brought it forward.

The CHAIRMAN.—In calling upon Sir Joseph Fayrer to make any comments upon what has been said, I would remark that the climatic conditions of life in India are interesting as affording us some means of judging what the condition of man might have been in past times in our own island. We may also learn therefrom facts which will enable us to draw valuable conclusions upon some geological questions. I will now call upon Sir Joseph Fayrer.

Sir JOSEPH FAYRER.—The first thing I have to say is that I thank those who have been good enough to speak so kindly of my paper. They have not raised any controversial question, so that really there is not much to reply to, and I need only refer to one or two observations that have been made. You, sir, have invited me to make some comments on what has been said, and first of all I would remind the meeting that this paper is essentially one on the rainfall of India. I included something about the climate, as it was necessary to do so: indeed I could hardly have avoided it in dealing with such a subject; but I did not include the whole scope of the science of meteorology. If I had attempted that—though the subject is one that is far beyond my powers—I should have occupied your attention, not for an hour only, but for many hours and many days. This will explain why I did not speak of the melting of the snows filling the rivers, and so on; and also why I did not go into such questions—about which I know very little—as the meteorology of Central Africa, though I should have liked to have heard more upon that subject from Colonel Grant. I will, however, notice one or two points that have been mentioned. Mr. Bateman spoke about the necessity for an equal distribution of water, and pointed out that heavy falls of rain take place in certain seasons and in certain localities, whilst it is dry in others. This, however, is not the case to such an extent in our own country as it is in India; and I endeavoured in my paper to point out the great efforts that have been made, not only in the present day, but in past times, by those who preceded us in India, who were as much alive as ourselves to the necessity of supplying the wants of the country by irrigation, by digging wells, and by constructing reservoirs and canals. Of course there were great difficulties even then. In a country like the Deccan, or Southern India, which is a high tableland, sloping gently to the east, with the rivers running from west to east across the continent, there is plenty of water, but it is not available because the rivers cut such deep channels that they are beyond reach. Consequently, it is necessary to make great reservoirs by damming the water, and to cut the communicating canals for its distribution, of which I have spoken. This is a subject, the engineering aspect of which I know little; it is one on which General Maclagan could thoroughly enlighten you. Dr. Chevers gave you an amusing statement of my early initiation into meteorology. I may say that I might well have my attention attracted to the subject, considering that I spent my first year in a station where 600 inches of rain fell in six months, sometimes 30 or 40 inches in a day, filling the rain gauge so fast

that one had to look at it frequently to see that it did not run over; where the atmosphere was saturated with moisture and the heaviest thunder shower you have ever known in England, lasting only a few minutes, is there continued for days and nights without ceasing, sending down torrents of water that wash away every loose portion of earth on the plateau, and fall in great and magnificent cascades down to the plains below, which are very soon converted into a sea. Under such circumstances, it is not to be wondered at that one should have given some attention to the study of this subject. I was enthusiastic in those days. Going to Burmah, it seemed to me necessary that I should know something of meteorology. I therefore kept registers, and day by day for months I used to note the barometer, the thermometer, and the rainfall; and once every hour of the 24, *on term days*, which was by no means an easy task, as one felt very sleepy towards two or three o'clock in the morning. I am afraid, however, that those observations did not lead to much, unless they contributed something in the shape of an inducement to others to undertake the same kind of duty. I am happy to think that at the present time there is no department in India the working of which is more thoroughly organised than that of the Meteorological Department, under my old friend Mr. Blanford. In reading my paper I omitted certain paragraphs, because I thought I should have wearied you had I read them all; otherwise you would have noticed that I alluded to the value of Mr. Blanford's reports, which one can hardly extol too much, not only for the ability and science they display, as well as the perseverance and patience with which they have been worked out, but also for their prospective value, for I am quite satisfied they will yield excellent results in time to come; so that, whatever may have been the case in the past, we may for the future look forward with great satisfaction towards the culture of that branch of science in India. Dr. Chevers spoke on the important subject of the destruction of the forests and the use of wood on the railways. I have no doubt whatever that at the inception of the railway system in India much damage was done in this way, and I am afraid that some is done even now. The wood—not the forest trees so much as the smaller trees and the brushwood—used to be cut down to supply fuel for the lines of railway; but I believe that this is not the case now. As to railway sleepers, I do not think the forests we are concerned in are much indebted to them for their destruction, as the timber for this purpose comes chiefly from the great forests of that magnificent region where I have spent many happy months—the forest district at the foot of the Himalayas, where those magnificent trees, the sāl and the sissu grow. These are the valuable trees, especially the sāl, from which the sleepers I believe are made. Another speaker alluded to the importance of the effects produced by the melting of the snows upon the rivers. It is quite true that after the winter, when the great heat falls on the hill-sides and melts the snows, the rivers come down in floods, which no doubt help considerably towards the irrigation of the country, and even render a special arrangement of inunda-

tion canals necessary. Colonel Grant spoke of the comparative smallness of the rainfall in Central Africa at certain elevations, which would seem to involve the necessity of a large rainfall, because in the equatorial regions, as I have already said, we have the great distillery of rain. But if you go into the centre of India, in the tropical regions within 15 degrees of the line, over 12 you find it to be very dry. These are the arid regions. You have the damp, moist wind, the monsoon, blowing from the equatorial regions, the reversal of the north-east trade, that would be blowing the other way, but for the distribution of land and water which disturbs the atmospheric equilibrium. These monsoons, on their first impact on the ghâts which fringe the west coast of India, rising to a height of 3,000 or 4,000 feet—the height at which condensation most rapidly takes place,—have the water squeezed out, and it falls in the shape of rain; while in the centre of the peninsula you have a dry table-land almost under the shadow of the mountains that are squeezing out the rain. Old travellers noticed the phenomenon, but were unable to explain it. We understand how it is that those western ghâts condense the water out of the clouds and allow the air to pass dry over the other side. In that portion of the country south of Madras the atmosphere is comparatively dry, simply because the whole of the moisture has been squeezed out by the mountains it has passed over; one can readily understand how it may be that the portion of equatorial Africa referred to should be dry for similar reasons. I am not sufficiently acquainted with the physical geography of that part of the world to go beyond this; but imagine the explanation may be something like that which I have given. Colonel Grant's exploration of that part of the world has been so large that I feel sorry he did not give us more information on the subject. General Maclagan was very kind in his comments on my paper. Indeed, I felt some hesitation in reading it in his presence, for he knows more about the country than I do. He spoke of the distribution of rain. It is not that there is want of water, but difficulty in its distribution. We hear of terrible famines in India and the destruction of millions of lives, and we are led to suppose that this is occasioned by want of food. It is only a want of food in the famine districts. There is plenty of food produced in the country to supply the whole population if one could only distribute it. It is also important to remember that the country we are talking of, though it does not look very large on the map, is really equal in size to the whole of Europe, with the exception of Russia, and by this I mean the United Kingdom, France, Spain, Germany, Austria, Hungary, Italy, Sweden, Norway, Denmark, Greece, European Turkey, and more. Of course, the conditions are very varied in different portions of the country. As to the distribution of water, of which there is abundance at one season of the year and very little at another, while in some regions none at all, or scarcely any, it is made more or less available by irrigation; and it is owing to the particular department charged with this, of which General Maclagan is so distinguished a member, that the country is so well supplied with water, and will by-and-by be still

better supplied than now. It is the officers of his service that have done so much to bring about the supply he has advocated. Dr. Gordon spoke on a very important subject, and as he did so it seemed to me how extensive was the question I had introduced; I had contemplated only the rainfall, but I see now how many other things it leads to. My old friend and brother officer, Dr. Park, has also introduced a question of great interest, though hardly germane to the subject of the paper—the health of Europeans and their families in India. I merely touched on it because I thought it right not to pass it over altogether, for how could one deal with so large a subject, or do more than just touch upon it in the brief space at my disposal? The question of the continuance of the European race in India is a very important one, and as it has been discussed, I may say that my experience is the same as that of Dr. Chevers, and that I have never heard of an instance of the fourth generation of pure Europeans living in India. I have seen the third generation; and I think, if anything were wanted to make one satisfied that the fourth could not thrive, it would be a sight of the third. I have nothing to add, except to thank you for the kind way in which you have listened to me.

The meeting was then adjourned.

ADDENDUM.

REMARKS ON RAINFALL AND FLOODS IN INDIA.

By W. P. Andrew, Esq.

In India the 'rains commence about the middle of June, and continue with little intermission until the end of September.

The rainfall varies greatly in the North-West Provinces and Guzerat. It ranges from 15 to 30 inches, most of it falling in three months.

In the Khasia Hills, 600 inches of rain have been measured in the year There is also the season of inundations from the melting of the snow in the mountains causing the rivers to overflow their banks.

The rivers of India vary much, according to the season of the year, at one time being small streams, at another resembling mighty seas: as, for instance, the Indus. In the summer months the melting of the winter snows swells the volume of its waters; then the pent-up torrents, warmed into new life by an almost tropical sun, dash down from the everlasting glaciers of the Himalayas, and, mingling with their parent stream, roll in one turbid mass through the narrow gorges of its upper courses. Bursting

its bonds at Kalabag, the waters spread like a sea over the surrounding country, until at Dera Ismail Khan the eye can with difficulty discern the farther shore. In the winter all this is changed; nowhere does the current exceed three miles an hour; while the breadth, often less than a furlong, permits of pontoon bridges being thrown from bank to bank at more spots than one.

The Indus is the longest river of India, being 1,800 miles in length, and, after receiving the other rivers of the Punjab, debouches by many mouths into the Arabian Sea. The Ganges, the next in magnitude, is 1,500 miles in length, having its turbid volume swollen at Allahabad by the blue waters of the Jumna, and falls into the Bay of Bengal. The Ganges, like the Indus and the smaller rivers of India, is liable to enormous expansion during the season of inundation.

The Sutlej and other rivers of the Punjab are not only liable to overflow their banks, but are continually trying to change the channels in which they are flowing, either seeking their ancient beds or making new ones for their tortuous and impetuous floods.

Messrs. Brassey & Co., when building the Sutlej Bridge for the Delhi Railway in 1869, required to add some twenty additional spans of 102 feet each to provide for the alteration in the river's course, which appeared to be imminent.

The Mulleer Viaduct in Scinde was 1,800 feet long, in twenty-one spans of 80 feet each, built on stone piers, each pier consisting of two upright pillars, sufficient only for a single line. The foundations were of three kinds: the foundations of the two piers first built, Nos. 3 and 4, being in cofferdams, and sufficiently large for a pier to carry the double line; Nos. 1, 2, 5, 6, 7, and 8 are built in brick wells, and the others were intended to be the same; but, the foundations not being sufficiently good, piles were driven in the wells, and the interstices filled in with concrete, the piers being built on this.

Two rivers meet the Mulleer above the viaduct,—the Dumb about half a mile above, and the Sookham, quite close to the bridge. The sources of these streams are widely separated, and it would appear, on the morning when the viaduct was carried away, that the streams were discharging themselves at different levels, causing great turbulence in the water passing under the viaduct.

At daybreak, on the morning of the disaster, there was little or no water visible in the bed of the river, and at eight a.m. it had almost reached rail level. At nine a.m. the bridge was carried away. The water came down in a succession of bores,—the largest of which, bringing down with it the ruins of a village about a mile and a half up the river, came down with immense force, rising above the level of the rails, and carrying away eleven spans of girders, with their piers, as if they had been straws. Some of the girders were found within a few feet of the bridge; but two of them were at least half a mile down the stream. Each span, with rails, &c., would weigh about 60 tons.

The Agent to the Oude and Rohilcund Railway Company pointed out that "in 1870 and 1871 the floods were so excessive and so entirely unforeseen, that the estimates submitted and the project prepared had to be reconsidered and altogether superseded; the bank had to be raised, and the designs of bridges to be revised, increasing largely the waterway.

These floods fortunately occurred before the works were much advanced. This, however, has not been the case in other places. Disasters have accordingly occurred, and much damage has been inflicted on several railway bridges. Now that more is known, more will be done to avert mischief; but, after taking every precaution, there will always be considerable difficulty where shifting streams have to be encountered, and where foundations have to be laid in the soil subject to a scour of 50 or 60 feet in depth.