themselves in a tank." * * * "It is supposed that 'caste' prejudices are such as to prevent native hospitals being properly built and supplied with requisites for the sick. But this has to be proved by giving natives a properly constructed and provided hospital. There are plenty of 'caste prejudices' in this country [England] against good hospital construction; but good hospital construction advances nevertheless."

Much more to the same effect wrote Miss Nightingale, amply supported by the fact of the case. Have these defects been remedied since that time? A few of the most glaring certainly have, and in the case of some of the largest civil hospitals and the chief 'station' hospitals a high degree of construction and management have been maintained, but there is no doubt that with regard to many of the larger and nearly all of the smaller hospitals, most of the above deficiencies still obtain. The ordinary native regimental hospital is the same as it was thirty years ago and the habits and customs pertaining thereto but slightly better. There is no doubt, however, that 'caste prejudices' have a good deal to do with the latter and have prevented the native—soldier and civilian alike—from enjoying many easily made improvements in regard to his surroundings. It is wonderful, all the same, how the nettle of caste, if firmly seized, ceases to sting, and how those who at one time constantly asserted that they would be ruined body and soul if they were not allowed their own way of doing things, have ultimately, if taken the proper way, been loudest in their praise of the new arrangements.

Hospital Sites.—As regards the site of a hospital, the elements which ought to determine its position are the following:—*

First, and before all others, purity of the atmosphere.

---

* Miss Nightingale. Notes on Hospitals, p. 29.

Second, the possibility of conveying the sick and maimed to it.

Third, accessibility for medical officers, and for the friends of the sick.

Fourth, convenient position for a medical school, if there be one.

Only the first need be considered here. On this subject a recent writer,* taking the Jamsetjee Jejeebhoy hospital as a type, "and by no means the worst one," of a large hospital in a large city, remarks: "The hospital is not crowded by surrounding buildings, and has a good margin of land about it. It stands, however, in the midst of a densely built and densely populated part of Bombay."

"Between it and the sea, in the direction of the prevailing west wind, lie $1\frac{3}{4}$ miles of land, part of which is marshy and part densely populated by the poorer classes; and the wind, blowing over the district from the Arabian Sea, loses a good deal of its purity. The action of the wind blowing over a town is not that of one solid plane object sliding over another. That part of the wind in contact with the houses on the ground eddies and rolls on its passage, taking up many impurities on its way. The vertical circulation that is set up by the sun's heat absorbed by the surface of the ground and by buildings, carries up foul air from alleys and gutters, and the more slowly the wind travels over such a district, the more of these impurities it will take up. Passing over houses and coming to an open space, the current of air descends until it meets with new obstructions."

"In this manner the hospital with its wards raised slightly above the ground level, is ventilated with air of considerably reduced purity, assuming the sea breeze to be the standard."

---

* Wallace, *op. cit.*, p. 214.

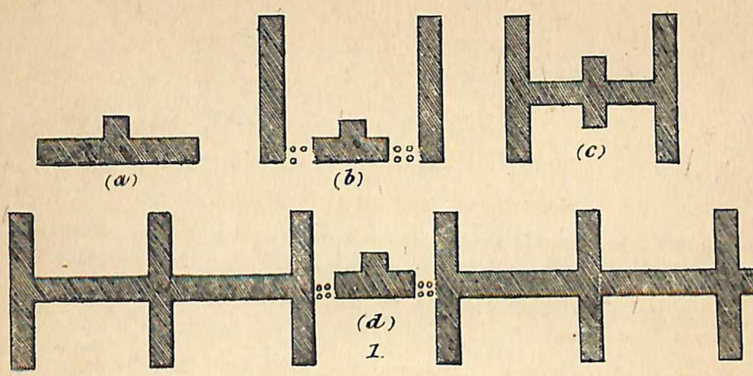
A hospital, then, requires not only a site fulfilling all the usual conditions, but one to which there is unlimited access of really pure air.

Hospital Designs.—Next, the design of the building has to be considered. All modern hospitals,* of any size, are constructed on the principle of separate blocks or *pavilions* joined together by a long passage or corridor. Each of these pavilions contains one or two wards (if two-storeyed), rarely more, and has belonging to it a complete set of rooms for the use of the medical officer, nurse, etc.; for cooking special dishes; a waiting-room for patients; a linen-room, etc. These are generally arranged so as to occupy the space on either side of the short passage leading from the main corridor to the ward. Then comes the ward itself, and finally, at the far end of the ward, the bath room and lavatory on one side, the latrines on the other, both these latter being more or less completely isolated or cut off from the general ward. This arrangement can easily be understood from the annexed plans. The pavilions may be placed side by side or in line, according as the hospital is large (over 100 beds) or small, and are planned to allow of free perflation by means of cross ventilation, abundant light and easy communication. The distance between the pavilions should be *at least* twice their height in a good situation: no hospital should be built in a bad situation. The details of size, number of wards, etc., cannot be considered here, but no ward should contain more than 20—30 beds, and there should be smaller wards of 4 beds in the pavilion for special cases requiring extra care, warmth or coolness, etc.

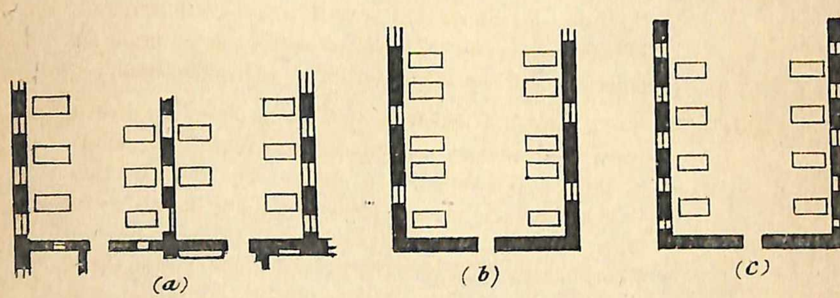
Ventilation.—The means of ventilation, the amount of air supply, cubic space and superficial area have next to be considered. This has already been done to a certain extent and the rules there given may be referred to.† One of the commonest errors in this country, as in the case of the hospital at Trimulgherry, before referred to, is to

* With few exceptions.

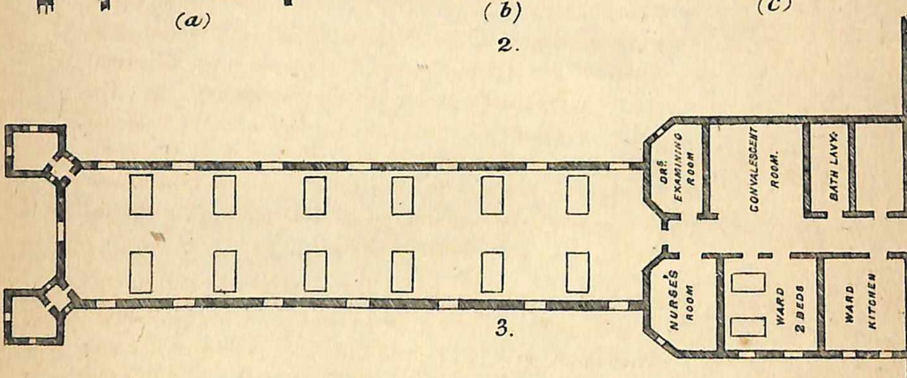
† *v.* Chap. I, pp. 23, 33.



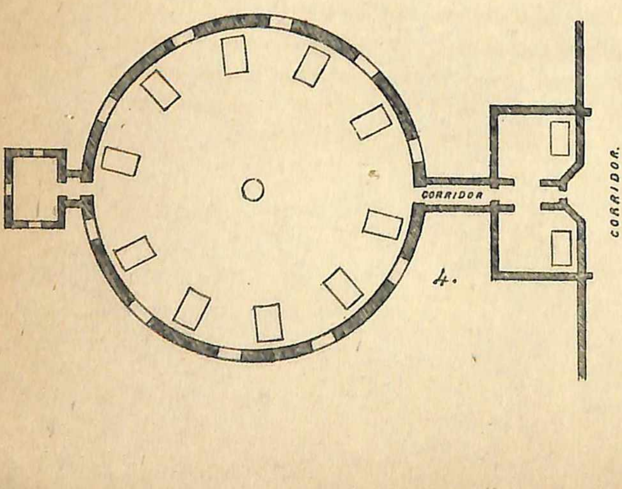
1.



2.



3.



4.

G. PACZENSKY LITH:

To face p. 256.

PLATE XIV.

HOSPITAL AND WARD PLANS.

Figure 1. Diagrams illustrating Designs for Hospitals on the 'Pavilion' System. In each figure there is a Central Administration Block with Single, Double, or Multiple Pavilions in connection therewith.

Figure 2. Plans of Wards, to shew various Arrangements of the Beds. In (*a*) there are double wards (as at Madras General Hospital) in (*b*) there are two beds between each window; in (*c*) the proper arrangement of beds is shown. (After Burdett.)

Figure 3. Plan of a Ward in a Modern Hospital arranged on the pavilion plan. Each pavilion contains one, two, or three such wards, according as it has one or more storeys. The latrine and bath room are seen projecting from the outer end of the ward, with cross ventilation between. Each ward possesses its own Examining Room, Nurse's Day Room, Ward for Special Cases, Kitchen for preparation of Special Food, etc., Convalescent Room for use of Convalescent Patients—a most important provision, Bath Room for use of Convalescents, etc., etc. The wards are connected with each other by means of long and airy 'corridors' or passages running throughout the whole length of the building, in which the air is kept fresh and warm (if necessary), thus affording an excellent place of exercise for those who are well enough to enjoy it.

Figure 4. Plan of Circular Ward as adopted in some Modern Hospitals. The advantages of this form over the ordinary oblong pavilion are by no means evident; though it is conceivable that in a very stagnant tropical climate the circular pattern might be cooler and more easily ventilated. In this latter case the central ventilating shaft (shewn in plan), might be carried well up above the roof and warmed by sun heat in the day time and by a small charcoal fire near its outlet at night.

build lofty wards and to fill them with beds so that each patient has about 25—30 sq. ft. of superficial area instead of at least 80—100 sq. ft. Such a mistake must be carefully avoided. For supplying fresh air, most modern hospitals are so arranged that the wards can be ventilated by simple perflation, during fine weather, and by artificial means with warm air, during cold or wet weather. No hospital in India is as yet supplied with pure, cool air, though it is highly desirable that they should all be. Instead of the weary, sleepless nights so trying to every one, but much more to the sick, to whom indeed it often means death, there would be the unspeakable blessing of cool, fresh air bringing with it the much-needed sleep and renewal of the bodily powers. It is earnestly to be hoped that this subject will shortly receive the attention it deserves and that once hospitals have been cheaply and effectively supplied with cool, pure air, the same benefit may be extended to dwelling houses, hotels and other habitations.* No method of natural ventilation is sufficient for Indian hospitals, save possibly for the cold season,

---

* Mr. Wallace, *op. cit.*, considers this subject carefully and has some pertinent remarks thereon. "It is unfortunate that in spite of the large sums that have been spent in India on the construction, furnishing and maintenance of hospitals, the subject of ventilation has been almost entirely neglected. If ample cubic space per patient, and plentiful communication with the outer air were sufficient, there is little to complain of, but if air for breathing may be regarded as a medicament which should be supplied of the best possible quality, to the patient, there is scarcely a hospital in the country that is not open to the charge of administering an inferior article." * * * "The quantity of air passing through the wards depends almost entirely upon the velocity of the wind, and when we follow up the question of air supply to single individuals, all idea of systematic ventilation is lost." * * * "The absence of data regarding the impurities of the atmosphere, and indeed of air analysis of any kind in India, is a most regretable circumstance, as it prevents any calculation as to the exact minimum quantity of air that should pass each patient *per* hour in the hospital. Even in Bombay where immense sums have been expended in sanitary work the Corporation refused to sanction the expenditure of Rs. 300 a month for some months in air analysis which would have been of the greatest value in furnishing a true and reliable basis for many of the works on which the health of the people depend." In his thoughtful work, Practical Observations on the Hygiene of the Army in India, Stewart Clark, M.R.C.S., late Inspector-General of Prisons, N.W.P., described in detail a proposed system of ventilation for hospitals, barracks, etc. It was tried in Agra jail (*v.* footnote, p. 29) but I have been unable to obtain any information on the subject beyond the

and it frequently happens that during monsoon time the whole building has to be closed for many hours on one or both sides, by reason of the violence of the wind and rain. In such a case, the heat and stuffiness become very trying *at once* and, owing to the darkness and absence of perflation, the mosquitoes swarm from every corner and worry the patients still further.

The actual form of the hospital in India should be that of a series of blocks or pavilions as before described, but the details of the design must vary very much according to the intended size, the money available, the local climate and many other conditions. Coolness of the building is of course important, but it must be remembered that coolness at night is more essential than coolness during the day, so that the walls must not be made too thick nor the eaves too low. Broad, shaded, verandahs* form useful and pleasant lounges, and the exposure of the hospital should be such that the direct rays of the sun fall principally on the ends and not on the sides of the pavilions. With a system of efficient artificial ventilation giving an abundant supply of

---

fact that it has fallen into disuse 'apparently because it did not prove a success.' It is to be feared that this is an example of a *laisser faire* policy adopted by a successor of the energetic inventor. It could be applied and worked much more easily than formerly, in large towns, by the use of a small gas engine or water motor. "The tunnel plan was tried some years ago at Agra and was not well thought of. But everything depends on the mode of making the tunnel." (Parkes-Notter, p. 522.) It must go deep enough and be absolutely impervious to ground air. Clark's method should be carefully examined and modified if necessary, by a practical Sanitary Engineer and then tried thoroughly at some large hospital or barracks. When the external atmosphere is warm and moist at the same time (the most trying condition of things in this country, especially for the sick and debilitated), some special method of cooling it would have to be invented, but for ordinary use, *khas-khas* screens or metal shafts covered with moistened cloth (*v.* p. 227) would be quite sufficient. The subject is worthy the attention of practical engineers, *i.e.*, *after* means and opportunity have been given by the authorities for the obtaining of data to go upon. Mr. Wallace's proposals (*op. cit.*, p. 219, *et seq.*) are of much the same nature as Stewart Clark's, or even simpler. The cost would be very small, not merely relatively to the advantages gained, but actually, and as compared with the system of steam-driven punkahs (the best of their kind in India) in the General Hospital, Madras, infinitely better for the patients.

* The verandahs should have openings in their highest parts for ventilation, and, if necessary, shafts projecting upwards from the openings. Double verandahs are a mistake and interfere seriously with ventilation.

cool air, the greater attention can be paid to securing a cool building; but in the ordinary Indian hospital, as in the bungalow, the small size and paucity of the windows, the deep and low verandahs mean the sacrifice of light and pure air in order to secure a slightly lower temperature. Of the two evils, slightly greater heat is far less injurious than impure air and the absence of sufficient light.

All hospitals in the plains should be entirely white* with the exception of the *chicks* (rattan blinds), windows and doors which should be green.† The floors must be made of some impermeable material, cement or concrete being the best.‡ Asphalte is fairly good§ and is cheaper. The impermeable wooden floors so much used in colder countries look well but are unnecessary in India, where coolness not warmth is the *desideratum*, and an Indian hospital should have as little wood about it as possible. The walls must be of impermeable‖ material also, either

---

* This important point is emphasised by Wallace, *op. cit.*, p. 195, *et seq.* With reference to roofs, he says, "A terrace roof, as generally constructed, offers very little advantage over the tiled roof. It is white at first, when new, but it soon becomes black with fungoid growths, and, being nearer the floor than the tiled roof, is often hotter. Being of greater mass, it cools more slowly at night. The temperature has been observed as high as 120° F. on the parapet of a terraced roof which had been blackened by age and fungoid growths." * * * "Whitewash will only adhere to a clean surface: if applied to a surface blackened by fungoid matter, the lime will scale off."

"An excellent limewash that will adhere to stone, iron or glass may be made by mixing 10 per cent. of any common vegetable oil with the lime while slaking. The lime to be weighed dry. If the oil does not saponify and incorporate with the lime, it must be boiled a little until the oil disappears. Castor oil must not be used. The oil forms with the lime an insoluble soap, which, when once dry, will not wash off with heavy rain. It must be strained and applied in the usual manner." A reduction of 26° in the temperature was obtained by means of a coating of this substance applied to the corrugated iron roof of the Bombay Tramways Company. It cost 11 annas *per* 1,000 square feet, labour and materials included.

† If exposed to direct sunlight, the outer sides should be painted white, so that the incoming air is not heated.

‡ Parkes, on the strength of a remark by Chevers, apparently, objects to cement as wearing into holes and being dusty; but good cement, well laid and of sufficient thickness, is certainly better than anything else for use in the tropics.

§ One disadvantage is that for some time after laying the asphalte, it blackens everything that comes in contact with it, such as the feet of the patients, and these in turn dirty all bedding, etc.

‖ *v.* p. 233. Certainly not permeable as proposed by various writers.

cement or polished chunam, or in special cases, glazed tiles set in cement. Probably the most effective wall would be white or coloured tiles in cement to a height of four feet from the floor all round the ward with cement or polished lime above that. Ordinary plaster, being absorptive of dirt and moisture, makes the worst wall; in this case, the plaster should be rubbed smooth and covered with several coats of oil paint. A good idea is to join the walls with the floor and ceiling by a concave moulding so as to obviate angles for dust and dirt to lodge in. The best ceiling is made by filling in the spaces between the beams with cement and painting the whole of a white colour with oil paint. If pictures are hung on the walls, picture wire must be used, not cord, and the frames must be quite simple. All pictures, etc., should be taken down once a month and dusted outside the ward.

It is impossible, in this manual, to go into the various details of hospital hygiene, but it must be remembered that no detail, however trivial apparently, is too small to be neglected. The occupants of the hospital are sick people fighting for life, as it were, and every thing should be so ordered and carried out as to give them all possible help in the struggle. Their beds, bedding, clothing and food, their hours of rising* and retiring to bed, their exercise and amusements, are all to be carefully planned and looked after, and it goes without saying that the practical sanitation of the whole place should be as perfect as skill and zeal can make it.

One important point remains to be noticed and that is the position, in general hospitals, of the wards which are

---

* A most injurious practice for the sick is confining them rigidly to certain hours for rising, sleeping, eating, etc. Regularity is of course essential both for patients and their attendants, but wherever necessary, permission to remain in bed, to smoke in bed, and any other little indulgence, should be freely given so as to avoid undue weariness, depression or irritation. The golden rule to 'do unto others as we would be done by' has special application here. The staffs of hospitals, from the medical officers to the sweepers, are so often overworked, however, that it is most difficult and requires the greatest self-denial, to invariably carry out this moral obligation.

to be occupied by natives. These latter, poorly clad and miserably nourished as a class, are very sensitive to anything like cold, and if placed in wards situated, say on a third storey, are sure to suffer during rainy or cold weather, *i.e.*, for more than seven months during the year. Whilst the wards should have plenty of fresh air, continually renewed, it is impossible, so long as direct perflation is the method of ventilation in use, to insure a sufficient supply of such fresh air during wet or cold weather, without the native sick being injuriously affected.* Finally, no hospital should have double wards, as it were, so that there are four beds in a straight line between each window : in such a case the ventilation is certain to be deficient.† There should be a double line of beds only, a low window being placed between each pair of beds, and no beds should be allowed at the ends of the ward. The best wards are frequently spoilt by overcrowding with 'extra' beds, a plan which is an injustice both to the patients already in occupation and the hospital staff, the latter being calculated for the authorised number of sick and quite insufficient for such additional work.

It is almost unnecessary to add that the admission of infectious cases such as cholera, small-pox, measles, etc., to the grounds and wards of a general hospital, as is done at Madras and probably elsewhere, is a direct violation of

---

* A good instance of this has occurred lately at Madras General Hospital. Two very stuffy and defective wards on the ground floor were turned into store rooms and the patients transferred to new wards in the top (third) storey of the building. During very hot weather the patients like these wards and do well, but whenever it is cold or chilly during rain, they begin to dislike them and that their dislike is well founded is shown by the fact that various diseases such as nephritis, bronchitis, asthma, rheumatism, etc., get worse or improve very slowly. The patients, of course, get the nurse or ward attendants to close all doors and windows on one or both sides, whenever they can persuade them to do so, so that ventilation speedily ceases and the other cases suffer. If a third storey must be constructed, it should be reserved for European patients only.

† This practice obtains at Madras General Hospital where, punkahs and all notwithstanding, the air, in still weather, stagnates about the arches in the centre of the wards (*v.* fig. 31, in Miss Nightingale's Notes on Hospitals). Otherwise the plan of this hospital is much better than those of others in India and approximates to the pavilion system. The same defect may be seen in the London Hospital at Whitechapel in London.

the simplest rules governing sanitary measures for the prevention of disease.

HOSPITALS FOR INFECTIOUS DISEASES.

Cholera and small-pox are the chief diseases which should be treated in separate hospitals in this country. Enteric fever ought probably to be treated in such hospitals, or at all events in special wards in general hospitals. In England, cases of typhus and scarlet fevers are sent to 'infectious' hospitals and cases of diphtheria should be sent also. There are many so-called hospitals for lepers in India, but these are really homes for incurables and as such do not fall to be specially considered here.

The principles which govern the construction and management of these hospitals are the same as for general hospitals, but there are some important practical differences due to the element of contagiousness and to the tendency to epidemic outbreaks.

In the first place, the site must be even more isolated and apart from other dwellings than that of an ordinary hospital, yet must be easily accessible for the speedy conveyance thither of the sick. The next question to be settled is whether the hospital is to be a permanent or a temporary one. This has been hotly debated in many countries, the true solution of the difficulty being evidently as follows: Large towns should each have a hospital of their own, smaller towns or the villages of a district should unite in having a common hospital, each town or village paying a *pro ratâ* share of the cost of up-keep. In both cases, as described below, the hospital should be a permanent one of small size, with a prepared site large enough to allow of considerable extension at short notice. Unfortunately, in this country, poverty of the people and the terrible rapidity with which cholera carries off its victims makes the latter plan unfeasible, at all events for the present, and all that can be done is to arrange for smaller towns having temporary hospitals, when necessary, constructed as afterwards described.

For large towns provision against outbreaks of infectious disease should be made thus. Having calculated the ordinary requirements of the town in the way of accommodation for cholera, small-pox, etc., and the probable requirements in cases of epidemic outbreaks, a suitable site is fixed upon, large enough for any possible extension of sick accommodation. This site is then prepared with reference to drainage, water supply, conservancy, etc., as if a large permanent hospital was about to be erected, and at a suitable spot, an administrative block for the use of the medical officers, nurses, ward attendants, etc., is built of most approved materials and design. Near this block one or two other small pavilions of one, or at the most two storeys, are erected for the reception of patients, these latter being isolated in separate wards according to sex and the disease they are suffering from. In addition a couple of small pavilions are built for the reception of 'doubtful'* cases, male and female. Thus the permanent hospital itself would consist of (*a*) an *administrative block*, arranged according to any desired plan; (*b*) *four small blocks* containing, say, four wards of six beds each, *viz.*, *two separate small-pox wards*, for male and female patients respectively, and *two separate cholera wards*; (*c*) *two small blocks*, each containing an '*observation*' ward of four beds; (*d*) a *laundry* for washing all clothes, bed-linen, etc., to which must be attached a *disinfecting chamber*† and a *small furnace* for destroying fouled dressings, cloths, etc.; (*e*) a *mortuary and post-mortem room*; (*f*) *stables and coach-houses*, including accommodation for one or more special ambulance waggons;‡ (*g*) *lines* for ward coolies, dhobies, sweepers, etc.

The water supply must be good and ample, preferably

---

* Most necessary in India, in order that patients suffering from violent diarrhœa may not be conveyed to cholera wards, as sometimes happens.

† *v.* Part III, Etiology and Prevention of Disease. The furnace might be of the nature of a small incinerator to be used for the destruction of all refuse matter, and placed in a special corner by itself.

‡ The hospital should be connected with the town by telephone to the 'central exchange' office or to the office of the M. O. H.

from a constant supply, and all arrangements for drainage, conservancy, etc., effective and on a liberal scale. The wards themselves should be large and well-ventilated, allowing the maximum obtainable of fresh air, cubic space and superficial area. Externally they should be whitened, and internally the walls, floors and ceilings must be perfectly smooth and impermeable. In addition, the doors, windows and other openings should be very carefully made so as to admit of complete closure and thorough disinfection at intervals.*

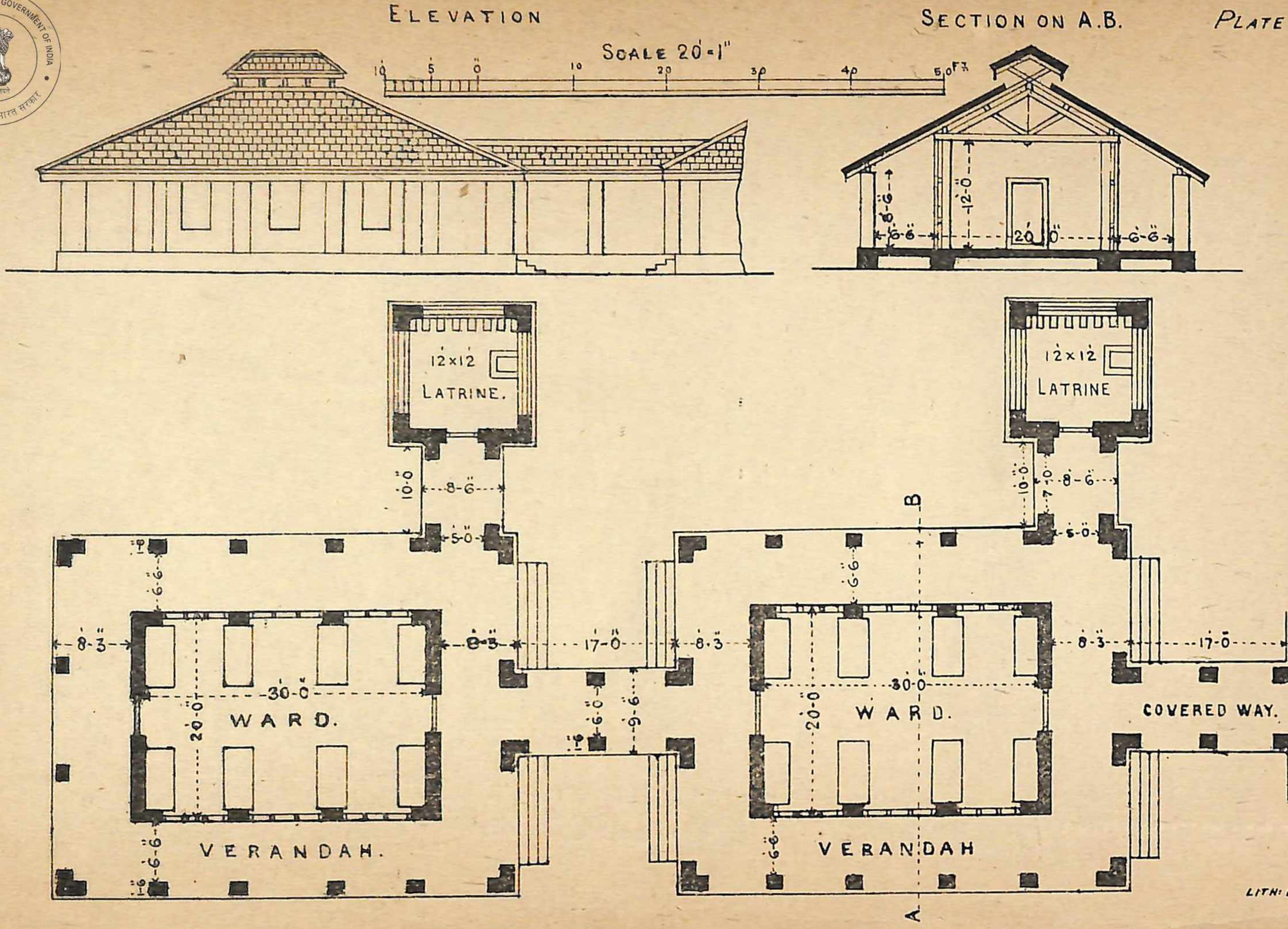
Having, then, made arrangements for treating the probable number of ordinary cases of small-pox and cholera, with observation wards for special cases and an administrative block large enough for emergencies, the next point claiming attention is the preparation of temporary buildings for the reception of numerous cases during a sudden outbreak. For such buildings the actual foundations alone need be ready prepared. The so-called 'contagious sheds' at the General Hospital, Madras, though not perfect, are a good example of the type of building required (*v.* description and plans). Each ward must, however, be completely detached save for a covered way, and no ward should contain more than six beds. The sheds are constructed of bamboo matting, which may be burnt after use, fitted on a wooden frame-work, and have ridge ventilation through their entire length in addition to windows between each bed. For convalescents there should be a dry, cool and pleasant place for exercise. The sullage water may conveniently be utilised for irrigating the compound† and so making it green and shady. Many other details require the most careful consideration, but for these, standard English works must be consulted and suitable modifications adopted. The patients, of course, should be admitted free of all payment and every inducement held out to encourage

---

* *v.* Part III.

† In such a case the quantity of water compared to the surface to be irrigated is so small that under-drainage is quite unnecessary, so long as the water continuously comes in contact with the roots of growing plants.

PLATE XV.



LITH: BY ROSS, BROS.

To face p. 264.

PLATE XV.

SHEDS FOR USE AS INFECTIOUS DISEASES HOSPITALS, ETC., IN THE TROPICS—SHOWN IN PLAN, IN SECTION, AND IN ELEVATION.

SPECIFICATION.—The wards to be 20′ wide, with verandah all round, about 8′ 3″ deep to edge:—they will be connected by covered ways 17′ long and 9′ 6″ wide. Each Ward to have a latrine 12′ square, connected to it by a short covered way.

The sides to be of bamboo matting, except where piers are required to support the roof trusses. There will be a window between each pair of beds, also of bamboo matting. The piers and other walls will be of brickwork plastered and lime washed (cement facing preferable). The roof to be of Mangalore (or Allahabad) tiles supported by teak or any other approved country wood. Ridge ventilators should be provided. The floor to consist of a concrete bed 5″ thick, well-rammed and consolidated, and laid with bricks set flat in mortar; the bricks to be plastered with 1 part of Portland cement to 2 of sifted sand. The floor to be slightly sloped outwards to facilitate washing. The matting should be made in pieces of convenient size, to allow of its partial renewal where necessary. It should be completely renewed at intervals, and the whole of the woodwork scrubbed and disinfected.

The superficial area allowed per head is 75′ square, and the air space 1125′ cubic.

them or their friends applying for their admission. One difficulty peculiar to the country is the constant separation of the sexes in different hospitals. If this be considered insuperable,* the male and female wards may be kept quite distinct in their own compounds, the administrative block being placed between.

JAILS AND ASYLUMS.

A very few words will suffice for this subject here. Of late years an enormous improvement has taken place in both classes of institution. Originally, the only consideration in either case was the construction of a building from which escape should be impossible, and as a consequence, no attention was paid to ventilation, cleanliness or the many other points essential to healthy living, so that diseases of all kinds carried off their helpless victims. Typhus fever, in particular, was so common that it received the name of 'jail fever.'† "At the present time, however" says a well known authority,‡ "the prisons of this country [England] are proved by the most rigid statistics to be far healthier than our homes, and so-called preventable disease of any kind is of such rare occurrence within their walls, that when any isolated cases do appear they at once give rise to surprise, and are sure to call for inquiry."

For many years Indian jails have been models of cleanliness and, to one who can use his eyes, a visit to any of the great central jails will be worth more than pages of writing. They are commonly arranged on the 'radiation' plan, in which the numerous blocks or pavilions of one or two storeys radiate from a common centre, the whole being

---

* That it is not really insuperable, witness the present plan of uniting the male and female general hospitals at Madras in one building.

† "My reader" wrote John Howard, the philanthropist, who devoted his life to ameliorating the conditions of life of prisoners, "will judge of the malignity of the air in jails, when I assure him that my clothes were, in my first journeys, so offensive, that in a post chaise I could not bear the windows drawn up, and was therefore often obliged to travel on horseback. The leaves of my memorandum book were often so tainted that I could not use it until after spreading it an hour or two before the fire."

‡ Dr. G. Wilson, Hand-book of Hygiene, 6th edition, p. 10.

surrounded with a high double wall. This plan, of course, is not so good as the true pavilion system described in the section on hospitals, but it is impossible or, at least, extremely costly to build pavilions for the housing of one or two thousand prisoners. Again, the high surrounding walls make the place hot and interfere with its ventilation; so that these defects, combined with the relative overcrowding, constitute an undoubted evil, which cannot, however, be easily remedied save by *artificial* ventilation with pure, cool air.

Lastly, it is important to remember, and most particularly so during an outbreak of contagious disease, that the occupants of a jail are prisoners and as such, are liable to be more or less depressed and careless of their lives: great care must therefore be exercised to make them as happy as may be under the circumstances and to let them see that their lives are accounted of the same value as those of other people.* In the case of high caste people, especially, the sudden change from freedom to prison life, affecting both their mental and bodily surroundings, has frequently a most depressing and even serious effect, and they require careful watching for a considerable period.

Two points there are in favour of prison hygiene, *viz.*, the amount of free labour available, and the fact that the occupants are *made* to be clean and to live perforce amidst hygienic surroundings.

With regard to Asylums for Lunatics the conditions are much the same and plenty of free labour is obtainable, the regular employment and exercise being a most valuable part of the treatment in many cases of insanity. Many insane persons, however, are so unspeakably filthy in their habits that extreme care is necessary to prevent them rendering themselves diseased or being the means of communicating disease to others.

---

* Of course without any of the foolish pampering of criminals which is becoming the fashion in the United States of America and elsewhere.

In countries not advanced in civilisation the treatment of the insane is marked by extreme cruelty, the result of ignorance, whilst in those highest in the scale everything is done to make their environment as pleasant as possible and to keep them in the best condition of body and mind.

BARRACKS.

More money has probably been wasted in India on this class of building than in any other country in the world, and with less satisfactory results. The barracks originally constructed for the accommodation of British soldiers were apparently modelled on native dwellings so far as light and ventilation were concerned and had the general appearance of an elongated gunpowder magazine. Following upon the condemnation of these rudimentary structures, huge blocks of one or two storeys each were erected, at enormous cost, in the chief military stations. In the work of Miss Nightingale alluded to before, she shows how radically defective these enormous structures were and are, and the same means of information being available to the designers and other officials concerned in their erection, it is to be regretted that they should have spent and been *allowed* to spend, such vast sums of money to so little purpose.

"Generally, very little attention appears to have been paid to independent ventilation as a cardinal point of barrack construction. Doors and windows have been trusted to; yet they are so placed that men are often exposed in bed to hurtful draughts, and if shut, the fresh air is also shut out. Sometimes there is no glass in the windows, and when these are shut there is darkness as well as foul air. *A knowledge of the proper application of sanitary appliances to buildings in India appears to be as yet in its infancy.*"* * * * "At Fort

* The italics are mine, and these words are as true now in almost every case as they were thirty years ago. Those to whom the designing and erection of public buildings are entrusted are too often guiltless of any real training in sanitary matters, and the honest ones confess it. Every fault regarding

William, the Dalhousie barracks which are said to be 'perfect,' have *six* rows of beds between the opposite windows, 216 beds by regulation in each room, and three floors of such rooms. While it is added, '900 men' (300 men per room) 'are generally accommodated in the barrack without inconvenient overcrowding.' What is *convenient* 'overcrowding'?"

So also, Stewart Clark* wrote—"Whatever the construction of the barracks may be, if the atmosphere be hot, still and sultry, and the apartments large, and occupied by what is at present considered the full complement of inmates, they can *never be healthy* if provided with no better ventilation than can be obtained through natural sources."†

It may be taken as an axiom then, though many who have not studied the subject practically are inclined to doubt it, that such buildings as are now in use as barracks for British troops throughout India *cannot* be properly ventilated except by artificial means, and that no amount of opening of doors and windows will compensate for the

---

the placing of doors and windows, etc., alluded to above is excellently illustrated in almost any barrack and military or civil hospital. Even where some well-informed and thoughtful man points out the shortcomings and defects he will be quietly ignored by some more potent individual who thinks sanitation "all fudge and nonsense."

* *op. cit.*

† "There can be but one opinion regarding the advantages, in a sanitary point of view, and, I believe, in regard to economy as well, of the location of troops or other large bodies of men in small parties in separate apartments. Some of the new, double-storied, one-company barracks, lately erected in India, are said to have cost upwards of 170,000 rupees each. Now, a very excellent, substantial house, containing four or five good rooms, each room affording ample accommodation for four men, could be erected for 8,000 rupees; six such houses could accommodate a company, including non commisioned officers; and four more similar houses on a slightly modified plan, for married men, would make a total of ten houses for each company, at say an average cost of 80,000 rupees, being less than one-half the sum which is said to have been expended on the immense piles of buildings alluded to, which will certainly have their turn of unhealthiness like their predecessors." [A true prophesy]. "When I speak of a house costing 8,000 rupees I mean one of a permanent description, built as substantially as the barracks in question." [This was thirty years ago; the cost of such a bungalow would be greater now, but so would the cost of the barracks]. Stewart Clark, *op. cit.*, p. 128.

want of this.* Elaborately-calculated inlets and outlets are all very well in a country like England where ventilation by circulation is constantly possible, but in India, as before stated, such is not the case, and the evils of deficient ventilation become many times accentuated in a barrack room where the useful cubic space† per man and the superficial area are generally far below the proper amount. In addition, it must be remembered that the barrack rooms are continuously occupied by a certain proportion of their inmates, night and day, a very different condition of things to the rooms of an ordinary house which are only inhabited continuously for a few hours.‡

* This defect is probably not so marked at places like Colaba and Fort St. George, which are constantly exposed to the sea-breeze; but in mofussil stations, where the choice for months lies between no ventilation or the free ingress of a burning wind laden with dust, varied with a chilling breeze laden with moisture, the want of systematic ventilation is evident to the most casual observer. Unfortunately, on this point also, there are, as usual, no reliable scientific observations available. "The standard barrack plan is, I think, rather a mistake, because *no one plan of barrack or bungalow is suited to every varying climate of India.* The climate demands modifications which have not been sufficiently considered, or at least authorised. *Barrack rooms should be so constructed as to admit of every man being partially screened from his neighbour.* Over-ventilation is a most fertile cause of chill, and chill is a most fertile cause of disease. Over-ventilation should be guarded against as much as under-ventilation. Ventilation in barracks is often excessive. If the doors and windows are open the men sleep in a draught, if shut they breathe foul air. There should be small windows above each bed, and so protected that while the most thorough current is secured above, draught on to the bed is impossible. In some few stations better bungalows for officers have been provided, but *much remains to be done under this head.*" Sir W. Moore, *op. cit.* The italics are mine. Regarding the remarks about 'over-ventilation,' it will be evident from what has been said in various parts of chapters I and V that the proper term is rather 'defective *methods* of ventilation.' So long as reliance is placed on purely natural means of ventilation and no proper attempt made to adopt some simple artificial method of regulating the amount and direction of the fresh air supply, so long will barracks and other Indian buildings be 'over-ventilated' at one moment and 'under-ventilated' at the next.

† *v.* p. 32.

‡ The subject of barrack construction and ventilation is briefly considered in its main points in Parkes-Notter, *op. cit.*, p. 517, *et seq.* "In India vast and extensive palaces have been reared in many stations, which testify at any rate to the anxiety of the Government to house their soldiers properly. Some of these great barracks, as at Allahabad, have not given satisfaction and have been found as hot or even hotter than the old barracks"—apparently from omitting to shadow all main walls with a verandah, and from insufficiency or omission of openings in the roofs and verandahs. The general principles of the proposed plans for barracks submitted by the Indian Sanitary Commission were undoubtedly good;—

There are many other points regarding the hygiene of barracks and barrack life, the consideration of which must be postponed till a future chapter.* It may be noted, however, that a soldier occupies an intermediate position, hygienically speaking, between ordinary civilians and the occupants of asylums and prisons, approaching most nearly to the condition of life of boys at a boarding school. He is to a certain extent looked after by the Government in whose charge he is with regard to his work, dwelling place and general surroundings: on the other hand he is free to move about, eat and drink, etc., where he pleases, within certain limits, so that although neither insane nor a criminal he is exposed to many risks of disease from which these latter classes, by their rigid confinement, are freed. Under these circumstances, the only effective rule, as in the case of school boys, is the rule of kindness and a good example, by which the soldier may be taught to respect himself and the uniform he should be proud to wear.

SCHOOLS.

The hygiene of schools has only begun to attract general attention in England and America of late years; in India the subject is still in its infancy. This is the more to be regretted when one considers what an extremely important influence such institutions have on the future men and women of a country, who in their turn will become the parents of the succeeding generation.

---

number of men under one roof to be 40—50 (half company barracks), except under exceptional circumstances [which should only refer to barracks in actual forts, etc.]; number of men in one room to be 16—20 and not to exceed 24; barracks to be two-storied in the plains and one or two-storied in the hills; single verandahs of 10—12 feet to surround these rooms; only 2 rows of beds in the dormitories, with beds 9 inches from the walls and a door or window for each two beds; closets and night urinals to be at extreme end of the verandah, leaving a space between them and the dormitory. 'Broadside on to the prevalent wind, and disposal *en échelon*, as now adopted in India, is obviously the proper plan' for arrangement of the buildings. But with all this the fact remains that many barracks do not comply with the above proposals, and that even when they do there are very many defective points in regard to construction and above all as concerns ventilation, which latter *cannot* be combined with coolness and freedom from injurious draughts so long as reliance is placed on natural means alone.

* *v.* Part IV.

Schools are divisible into two great classes, *viz.*: boarding schools, at which the scholars live, and day schools, to which the scholars go for so many hours daily, returning home at night. The subject of residential or boarding schools hardly concerns us here, for in India they are very limited in number and are principally Government institutions at which considerable attention is paid to the hygiene of the inmates.* Of more pressing importance is the condition of the scholars and their surroundings in the ordinary day schools and colleges scattered throughout the empire. It may be stated at once that by far the greater number of Indian schools are conducted in dwellings not originally intended to be used as such or else built entirely with a view to crowding as many persons as possible into a given space. Into the countless sanitary defects common to the large majority of these buildings it is impossible to go in detail here; all that can be attempted is to indicate some of the points to which special attention should be directed.

Ventilation.—As in other buildings, the first point requiring careful consideration is the ventilation. In the smallest native schools this problem is frequently solved by the teaching being done entirely in the verandah of the house wherein the master resides, and as the children taught are limited in number they probably each receive a fair allowance of air.† It is otherwise, however, when they are crowded into a small, hot building with no special provision for ventilation and the superficial area per head limited to the space actually occupied by each child. Remember that in children at their lessons there is a double reason for a plentiful supply of pure air; firstly, because they are young and their bodies are growing actively; secondly, because

* In these institutions there is generally a resident apothecary and a visiting medical officer. Upon the amount of personal interest taken and vigilance exercised by these officials depends chiefly the hygienic condition of the school and its inmates.

† Not necessarily pure, fresh air, however, for these schools are usually situated in crowded and dusty bazaars where the external ventilation is as bad as can be. Still, it is the same atmosphere as that in which their dwellings are situated, and can only be remedied by a general improvement in the bazaars themselves.

they are engaged in study, which means the expenditure of nervous energy and implies the necessity for clear-headedness. It is absolutely essential, then, that they be supplied with the proper amount of fresh air, cubic space and superficial area.* There is yet one other reason for abundant ventilation and that is the ease and rapidity with which the numerous contagious disorders of childhood,—measles, whooping-cough, diphtheria, etc.,—spread from one to the other. The testimony of all authorities on this subject amply confirms the above statement and, as a result, it has become customary, on the occurrence of an outbreak of contagious disease, to at once close even the best managed schools, till such time as the danger of infection shall have passed away.

Light.—The next important point is the amount and direction of the light supplied to the scholars.† If, from any reason, the amount of light is too small, the eyes, by constant straining to decipher words or figures, become seriously affected, and contrariwise, if the glare is too great, the vision will certainly be injured in time. The former is probably the more common evil in this country and systematic inquiry would doubtless demonstrate the fact that the rising generation of Indian students contains a very high percentage of myopic subjects. The light should fall on the left hand side of the pupils, entering through windows beginning from four to six feet from the ground, rising almost to the ceiling, and so protected with sunshades as to prevent the passage of direct sunlight.

When a child is very young and learning to read, it has to *spell out* each word, letter by letter, the labour of doing so being increased or diminished by the smallness or largeness of the type. For very young children the size known as *pica* type is the best: when they are older and begin to take in the words at a glance, their books may be printed in *small pica*, the type in which this book is printed.

---

* *v.* Chap. I, pp. 23, 33 and practical rules at the end of this section.
† *v.* Rules at the end of this section.

Desks and Seats.—The old-fashioned custom, which still obtains largely, of having rows of 'forms' or plain seats without backs for children to sit upon, and high desks in front for supporting their books, etc., is a distinctly injurious one and should be abandoned in every school. The spartan idea that a boy or girl should be made supremely uncomfortable when young is happily dying out and its place taken by the more rational and humane belief that they should be made healthy. When seats with backs to them first began to replace forms, it was thought sufficient if the backs were made almost, if not quite vertical. This is a grave mistake; the back of the seat should be so curved as to adapt it to the spinal column, and the seat itself should be ten inches wide at least and about the height of the child's knee. The desk should be sloping, not horizontal, and its edge about the height of the elbow. When used for reading the edge should be in vertical line with the edge of the seat; when required for writing it should be slightly pushed back. To obtain this movement a simple horizontal adjustment of either seat or desk is necessary. The best authorities are of opinion that each scholar should have a separate desk and seat according to stature and size. The following table* was prepared as a result of experiments made in this direction and may be taken as a guide. It shows that eight different sizes are required for a school where the pupils range from three to five feet four inches in height.

Height of Pupils.	Height of Table.	Height of Seat.	Height of back of Seat.
Feet.	Inches.	Inches.	Inches.
3·0 to 3·3	13·5	7·5	9·8
3·3 to 3·6	14·7	8·5	10·8
3·6 to 3·9	15·8	9·5	11·9
3·9 to 4·2	17·0	10·3	12·9
4·2 to 4 5	18·1	11·2	14·0
4·5 to 4·8	19·2	12·2	15·0
4·8 to 5·1	20·4	13·1	16·1
5·1 to 5·4	21·6	14·1	17·2

* By Dr. Guillaume, quoted by W. Blyth, Dict. of Hygiene, p. 512.

It is of great importance, then, that strict attention be paid to providing suitable seats for children, both for the sake of rendering them comfortable and thereby more fit for work, and to prevent injury being done to their spines before complete ossification has taken place.*

Of the many other matters in school hygiene for which constant and specially trained supervision is necessary, no further mention can be made here save to indicate the more important. (1) All schools should be inspected regularly by trained sanitary officers.† Routine inspections by ordinary medical officers already overburdened with work, are, with rare exceptions, useless. (2) The hours of work and play must be most carefully apportioned and strict adherence to these hours by the teacher insisted upon. (3) The latrine accommodation must be suitable, sufficient and inspected daily. (4) A suitable piece of land immediately adjoining the school should be set apart for the exclusive use of the children as a play-ground. (5) The children should be encouraged during recreation time to indulge in games and pastimes, and all solitary loafing prevented as much as possible.‡ On the other hand, if gymnastic exercises and other athletic sports are insisted upon, the greatest care must be taken that no child is made to unduly exert itself. The course should be occasionally, say once a month, watched by a medical officer. (6) The whole school should be medically inspected by a subordinate medical officer once a month with a view to the detection of disease, especially contagious skin diseases, ophthalmia, etc.

These points are not trivial and of small account: on the contrary, they are of the highest importance, and under

---

* "There is a general impression that deformities of the vertebral column, formerly rare, are now on the increase; this is most certainly due, in a measure, to ill-constructed seats." Dr. Blyth, *op. cit. supra*.

† Who may be officers of the Educational Department, if any can be found with the necessary aptitude and training. In addition there should be an annual inspection, at an unfixed period, by a capable medico-sanitary official.

‡ Note that the lower the social position of the pupils, the harder it is to induce them to take kindly to games and sports.

no circumstances are kindness and consideration better repaid or more worth expending than in the proper care of children. The good effected, as stated before, does not end with their schooldays but continues throughout their lives and makes them valuable citizens and the parents of healthy offspring. "The necessity for ensuring the best hygienic conditions in buildings for children, of whatever social class, is more than ever important now that the strain upon the child is so much greater than formerly, and consequently everything that may conduce to counteract this strain and pressure of education is indispensable, whether it concern the internal or external arrangements."*

The following excellent rules,† comprising the essentials for schools with regard to lighting and ventilation, are worthy of careful attention and consideration.

LIGHTING.

"1. Good lighting of school or class-rooms depends upon (1) sufficiency of light, (2) distribution and employment of the light to the best advantage.

2. As regards sufficiency, the general rule is that apertures for light should be about equal to $\frac{1}{5}$th of the floor area of the room to be lighted. A room 20 × 20 feet requires about 80 square feet of light. Another calculation is that there should be 200 square inches of light for each pupil, but something depends upon the situation and aspect of the building, and it is generally easy to see whether a room is sufficiently lighted or not.

3. As regards using the light, the thing to be kept in view is the avoidance of all strain or tension on the eyes of the children. Strain is caused

---

* S. and M., *op. cit.*, p. 702.

† Drawn up by Mr. T. B. Kirkham, Educational Inspector, Central Division, Bombay—and issued by the Department of Education for that presidency.

either by an excess or by a deficiency of light. Working in shadow and working in glare are equally injurious. The seats should be so arranged that the largest possible number of children may work in light *falling from the left side and as far as possible from above.* Side light from the right is next best, whilst light from behind is bad, because the body throws a shadow on the work. The worst light of all is that from the front falling on the faces of the children. This is most injurious, and should always be avoided. Where desks are used, the window sills should be higher than the desks, as light from below is confusing and fatiguing. The windows should be fitted with shutters to exclude the direct rays of the sun, when necessary. It may be added that in night schools the artificial light employed should be steady and not flickering. Colour-washed walls are preferable to whitewashed, which are apt to cause glare. French grey, light stone colour, or the light blue so easily procurable in these parts, distributes the light in the room much better than white.

VENTILATION.

4. Good ventilation, in like manner, resolves itself into (1) sufficiency of air or cubic space for the number of children to be accommodated, and (2) arrangements for changing the air as fast as it is used up.*

5. As regards sufficiency, sanitary authorities claim a space of 200 cubic feet or upwards for each pupil, but in India, where the doors and windows are habitually kept open, measurement of the floor-space is sufficient for all practical pur-

* *v.* Chap. I.

poses.* Assuming that the rooms are at least 10 or 12 feet high (14 feet is a better height), a minimum floor space of 10 square feet should be allowed for each child in attendance in a primary school, whilst 15 square feet and upwards should be allowed in secondary schools. For youths and big boys, 20 to 25 square feet per pupil is not too much.

6. With regard to the changing of the vitiated air, the thing to secure is *circulation without draughts*. The prevailing winds should be admitted and the impure air should be allowed to escape, whilst at the same time the breeze should not be allowed to play directly upon the bodies of the children.

7. From the above it will be apparent that the best windows for school and class-rooms, both for light and ventilation, are those which have deep window sills, say 4½ feet high, and which go up high towards the ceiling. With such windows the light falls from above, and the children are at the same time protected from

---

* The remarks here on ventilation, cubic space, etc., can only be considered to have reference to making the best of the existing state of things. A floor space of 10 square feet and a cubic space of 120 feet in a room twelve feet high is certainly too little. But little more than half of this will be 'useful' cubic space (*v.* pp. 32-3 and 269), and to give a sufficient amount of fresh air (2,600 cubic feet per hour) the air must be totally changed more than twenty times. During certain seasons of the year this may be possible without direct draught, but at other times when there is no wind, and ventilation by circulation is at a standstill, it is practically certain that in a room 20 × 20 × 12 (=4,800 cubic feet and 400 square feet), supposed, therefore, to accommodate about 40 children (at 10 square feet superficial area each), the necessary amount of fresh air, 104,000 cubic feet (at 2,600 cubic feet each), would not pass through the class-room, far less be utilised. A *larger* cubic space than in England is essential in a tropical climate, not a smaller, (*v.* p. 33). No plan can be really effective which does not make provision for the artificial supply of a *definite* amount of fresh air whenever thorough perflation is impossible, either from want of wind or from the trying nature of the wind. Carnelly, Haldane and Anderson in their well known series of practical experiments (*v.* Phil. Trans., 1887), have conclusively shown that even in Great Britain, where ventilation by circulation is in constant action, schools which are ventilated by mechanical means have much purer air than those ventilated naturally.

draughts. Small lattice window panes are objectionable. In ordinary cases, iron bars and wooden shutters on hinges answer best. Windows not protected by verandahs should have 'hoods,' so that they need not be closed for sun or rain. Perforated zinc has in many cases been found to prevent sufficient change of air and should only be adopted after careful trial. It need hardly be said that every class-room should have all its doors and windows thrown open, and be *thoroughly flushed with fresh air during every recess* and on every other available opportunity. In all new buildings, and wherever it can be introduced in old ones, ridge ventilation should be adopted."

8.* * * *

SHOPS, OFFICES, ETC.

The same defects as have been noticed in the case of schools, barracks, houses and other buildings will be found on inspection to exist in connection with shops, offices and public buildings of various sorts, *e.g.*, post offices, courts, theatres, etc.

Latrines.—One of the commonest and most serious is the want of proper latrine accommodation. It is not perhaps in this country an evil of such magnitude as in Great Britain and other European countries, on account of the general absence of a water-carriage system for the removal of excreta.† Still, it is essential that in any building wherein a large number of persons are employed there should be a sufficient amount of latrine accommodation afforded for all purposes, so as to avoid crowding, indecency and the creation of a nuisance. There must be separate latrines for both sexes, each containing a suffi-

* Has reference to the examination of the ventilation of a room. *v. ante*, pp. 42-3.

† Note, once more, that a badly managed water-closet, *i.e.*, one originally defective and allowed to fall into disrepair, is a literal death-trap.

cient number of partitioned closets, provided with dry earth, etc., well ventilated by perflation, cut off from the main building by cross-ventilation, and kept in a state of thorough cleanliness.*

Ventilation.—This likewise is often lamentably deficient, especially in mercantile offices and large Government offices occupied by the under clerks, and regular inspection of the same, accompanied with power to compel the application of remedies, is urgently required.† By far the worst, however, in this respect, as in others, are the Courts of Justice throughout India,‡ with but few exceptions. There is more need for unlimited fresh air in these buildings than in any others and yet the means of ventilation are frequently, to all intents and purposes, *nil !* "Owing to the noise that an Indian crowd *will* make in the corridors and outside of a court, the doors have frequently to be shut, in order that the business of the court may be heard. Crowds in any court usually contain a large unwashed element, and a court house soon acquires a kind of menagerie smell, familiar to all who frequent them, which seems to impregnate the walls and remain even when the building is empty."§ * * * "The administration of justice for many hours together, day after day, in a very foul atmosphere is not only bad for the highly educated and highly paid men who preside in the courts, but bad also for the work they do. It is impossible to work long in a badly ventilated court without suffering an amount of bodily and mental fatigue, which must militate against good work, and which is all the more to be deplored as it is quite unnecessary. Poisoning, by means of twice or thrice breathed air, is a slow process, involving slow

* If necessary, a *very small* deduction may be made from the pay of the *employées*, monthly or weekly, to ensure a sufficient staff of sweepers, etc.

† There is no doubt that ample fresh air, with coolness of the same, if merchants and others would only believe it, would enable them to get far better work from themselves, their assistants and their clerks.

‡ As in England also.

§ In fact the loathsome smell of organic matter that formerly characterised prisons and hospitals everywhere, and which is now almost abolished in civilised countries, save in the dwellings of the poorest classes.

deterioration which may continue for years, with intervals of change and recuperation, but the average intellectual vigour of any man in such circumstances must be a good deal under par."*

Cooling.—The usual methods for obtaining coolness in Indian buildings are to build walls of enormous thickness, to make the verandahs low and the windows as small as may be, and to use punkahs and *khas-khas tatties*. From what has been said in this and preceding chapters (I and III), it will be evident that these are very partial remedies and have serious drawbacks as a set-off. The only proper means is to *combine cooling with ventilation*, and that this will some day become general there is no doubt. Meanwhile, where bricks or country tiles are used as flooring, a good deal may be done by availing oneself of the cooling effect of evaporation, without the disadvantage of using an organic material such as *khas-khas*. The floor should be carefully swept early in the morning and thereafter water liberally poured on by a *bhisti* or other servant. With the doors or windows on the shady side kept open and punkahs swinging, the temperature may be materially lowered throughout the day, without the creation of the chilling draught from a *khas-khas* screen.†

Hours of Work.—It is principally the assistants in shops who suffer from effects of over-work. The general conditions under which they are obliged to pass their long day—a hot, stuffy shop, constant worry, continual standing, insufficient meal-times, etc.—all tend to undermine their

* Wallace, *op. cit.*, pp. 224-5. No better example could be given than the present Blacktown police court at Madras, relatively, a most expensive building. It is simply a dark, hot and excessively foul cellar as regards the lower storey, and but little better above. Doubtless any intelligent reader can supply examples for himself.

† This has been known for a long time to some, but is not nearly sufficiently taken advantage of. Suitable modifications of this plan might be adopted for houses, etc. By these means Wallace, (*op. cit.*, p. 190) obtained a reduction of 15° F., in the shade temperature between the verandah and office, and an increase of 31 per cent. of humidity at Cawnpore at 2 P.M. on a July day. Of course where the air already contains a high percentage of moisture, so great a reduction would be impossible.

health and render them liable to break down at any time. Eight hours, including one hour for meals, is the limit during which they should be called upon to serve, instead of which they are commonly made to stay from 8 A.M. till 6-30 or 7 P.M. They should also have seats provided for them and be allowed to use them when not serving. For lunch or dinner one hour is the shortest time allowable, whereas the heads of some establishments consider themselves indulgent if they give them a short half hour.

Housing.—This subject also demands attention by reason of the fact that proper houses for European shop assistants are not available to anything like the extent required. The humane owner of some large business, whereat many European assistants are employed, might well set a good example by building two sets of several small bungalows each, after the type of 'subalterns' quarters' at certain stations or 'bachelors' quarters' at some hotels, wherein the employées might reside, having common dining and recreation rooms, tennis courts, etc., and proper sleeping accommodation. The rent charged need be very little, if any, higher than that now paid by the assistants, whilst the gain to their health and consequent saving to the establishment would soon be demonstrated.*

Of many other buildings such as hotels, theatres, factories, etc., the defects in their construction and sanitation, and the proposed remedies, it is impossible to write here. In all cases the general principles are the same, and the intelligent sanitary officer will be able to detect the weak points and to advise as to the remedy required.

---

* This may have been done already, but I do not know of a case.

CHAPTER VI.

CLIMATE AND METEOROLOGY.

THE term climate, derived from the Greek word *Klima,* a slope, was formerly confined to astronomical or mathematical geography and had reference to the portion of the earth's surface included between two lines parallel to the equator and measured by the length of time during which the sun appears there during the summer solstice, *i.e.*, by the sun's inclination. The space between the equator and the pole was divided into half hour climates, in which the length of each day increased by half an hour. This unequal division of the hemisphere is now replaced by a division of the interval between the equator and the poles into ninety degrees, which constitute what are called degrees of latitude, and the word climate has received a more extended application.*

From the point of view of a sanitarian, the climate of a place may be defined as *the sum of the local atmospheric and physical conditions in their relationship to animal and vegetable life.* From climate, the expression 'weather' must be distinguished. By the former is meant the average condition of heat and cold, damp and dryness, and the like, characteristic of a place or country, in so far as they vary regularly with the succession of the seasons. The latter has reference to the apparently irregular, though not always minor atmospheric changes that take place from day to day.†

For our present purpose, it is necessary to study the climates of different places and their influence upon the health of the inhabitants ; the various climatic factors and

---

* *v.* Article, 'Climate,' by J. H. Bennet, Quain's Dict. Med., vol. I, p. 262.
† *v.* Blandford, Climates and Weather of India, p. 197.

their effects being considered, (1) individually, (2) collectively.* In addition to this which constitutes the science of Climatology, the means by which these climatic factors are estimated and expressed, in other words, the science of Meteorology,† must receive attention.

Climate as modified by the physical conditions of any place has been already partially considered‡, and the subject will be again referred to later. There remain, therefore, to be inquired into, as regards causation, significance, etc., the varying conditions of the atmosphere surrounding the earth, which exercise so important an influence on all organisms from the highest to the lowest.

THE ATMOSPHERE.

Before proceeding to examine in detail the various atmospheric conditions, a few words about the atmosphere itself are necessary. Of its composition sufficient has already been said.§ As regards the relationship of the atmosphere to the earth on which we live it may reasonably be compared to the mass of water superincumbent on animals living at the bottom of the sea, so that in like manner human beings may be said to live at the bottom of a "shoreless ocean of invisible fluid, to the surface of which they are powerless to rise." The atmospheric envelope probably extends more than two hundred miles from the earth's surface, but by reason of its compressibility nearly three-quarters of the total amount of air lies between sea-level and the tops of the highest mountains.‖ In addition, it is certain that an enormous amount

---

* The weather, of course, is of importance likewise, but more especially to sailors and engineers. To Sanitary Engineers, an intimate knowledge of the climates and weathers of India is most essential. The few facts already known and studied in this relation will be found in Blandford (*op. cit. supra*) and Wallace (*op. cit.*)

† The science of Meteorology serves two chief uses, *viz.*, (1) the obtaining of *data*, at daily or other fixed intervals from various meteorological stations whereby the probable weather may be foretold,—'Weather Forecasts', (2) the gradual accumulation of *data* relating to each station, upon which a knowledge of the climate of that particular place may be founded.

‡ *v.* p. 111. § *v.* Chap. I.

‖ *v.* Discussion in 'Realm of Nature,' H. R. Mill, p. 100.

of air is contained dissolved in the water surrounding the earth (hydrosphere), and is present also in the pores of the soil as ground air, the gases being present, however, in varying relative proportions.*

As regards the atmosphere itself, its composition is wonderfully constant, such constancy being partly due to the diffusion of gases,—the particles of which pass each other freely, without interfering, like crowds moving in different directions across a market place,—and partly to the gaseous interchange between animal and vegetable organisms.† The variations that are constantly occurring in the degrees of atmospheric humidity and pressure will be considered later.

Elements of Climate.—Understanding then, as far as may be, the nature of the atmospheric envelope and its composition, we are in a position to take up, one by one, the consideration of the various conditions or climatic elements of which the atmosphere is the agent or medium as it were.‡ These are (1) the Temperature (and Diathermancy); (2) the Humidity; (3) the Atmospheric Pressure (or Density); (4) the Circulation (or Movements) of the Air; (5) Light and Transparency; (6) Electrical States of the Atmosphere; (7) Atmospheric Dust. In this chapter each of these elements of climate will be considered with reference to the circumstances which produce or modify it, its relation to health and disease, the instruments and methods of observation which it requires, and its special manifestations in the climate of India.§

---

* *v.* pp. 66 and 118.

† *v.* Part II., Chap. VII., introductory remarks.

‡ These conditions, though conveniently considered as atmospheric, are not solely so, by any means, and are largely modified and influenced by the configuration of the land, nature of the soil, relative amounts of land and water, etc.

§ The science of meteorology is now so advanced and requires such accuracy in the methods of observation that it is impossible to do more than give an outline of its principles and practice in this manual. Those who wish to pursue the subject further or to undertake meteorological observations must carefully peruse the works of Blandford and other Indian meteorologists and pay strict attention to the instructions given therein.

TEMPERATURE.

Temperature* is one of the most important of the elements of climate, both directly of itself, and indirectly, since the radiant energy derived from the sun,† in its passage through the air to the earth's surface, is the original cause of all atmospheric changes. It is necessary to distinguish carefully between radiant or sun heat, and air or shade heat. At great altitudes, where the air is very pure and dry, the sun's rays have but a very slight warming effect on the air as they pass through it, but great power of directly heating the bodies of animals and other solid objects upon which they fall.‡ The gaseous particles, in other words, are able only very slightly to absorb the heat from the sun's rays and are therefore called *diathermic* or transcalent.

At lower levels, however, the air is full of water vapour and dust particles, and these, during the day time, absorb the radiant energy of the sun's rays and heat the surrounding air. In addition, the surface of the earth absorbs a considerable quantity of the solar radiant energy which it in turn radiates back to and thus warms the air. It is important to notice also that a considerable amount of heat is temporarily retained, as it were, near the earth's surface and helps to raise the temperature of the air. This was formerly believed to be due to the assumed fact that the water vapour was much less diathermic to the invisible heat rays radiated back from earth than to the direct luminous solar rays. It is now pretty certain that the

---

* "When a substance grows hot, it increases in energy, and is said to *rise in temperature*. The word *temperature* has not the same meaning as *heat*, but corresponds exactly to *hotness*. Temperature is a quality: heat is a quantity." Ramsay, Elementary Systematic Chemistry, p. 5. As a matter of fact, the term heat is often used to express the quality of hotness; the sense being evident from the context.

† The additional heat derived from the moon, stars and interior of the earth, is so small in amount that it may be disregarded here.

‡ At Leh, in Northern India, 11,500 feet above sea-level, Dr. Cayley raised water to the boiling point by exposing it in a blackened bottle (placed inside another bottle to protect it from cooling by the wind) to the direct rays of the sun (*cf.* black-bulb vacuum thermometer, p. 298).

chief absorbents of radiated heat are condensed vapour and the dust particles of the atmosphere. Hence on clear evenings, when the amount of condensed moisture in the atmosphere is small, the temperature falls rapidly after sunset and *vice versâ*. The suspended dust probably plays an important part in the diurnal heating of the lower atmosphere which gives rise to the hot winds of April and May.*

There is then to be distinguished, practically, the influence produced by the direct heat of the sun (sun heat) and that produced by the warming of the air (shade heat) through absorption of heat by the water vapour and dust particles in the atmosphere. The shade heat, itself, is partly derived from radiant solar energy directly and partly from heat radiated back from the earth's surface by land and water. Of these two,—sun heat and shade heat,—the shade heat or temperature of the *air* at any place is by far the more important and must be further considered.

Shade Heat.—The temperature at any place depends primarily on the *quantity of solar heat absorbed and radiated back* by the earth's surface and by the amount of moisture and dust particles present in the atmosphere. Certain circumstances modify this quantity ; of which the principal are :—*latitude ; elevation ; quantitative relation of land and water ; character of the surface ; existence of currents, either of air or of water ;* and *rainfall.*

Between the tropics the sun is always vertical somewhere ; and nowhere do the solar rays strike the surface at noon with any considerable degree of obliquity.† In the Low Latitudes of the torrid zone, therefore, the greatest quantity of solar heat is received, and the lower the latitude, (if other things be equal), the higher will be the mean temperature. Owing to disturbing causes, however, the fall in temperature as the latitude increases is not regular.

---

* *v.* Blandford.

† *v.* Explanation and diagram, Realm of Nature, p. 82.

Elevation Above Sea-Level reduces temperature. The air being chiefly heated, not by the solar rays which pass through it but by radiation from land or water, the strata nearest to the general surface must be the warmest and heat will diminish in proportion to height. A hill or range of hills, therefore, will be cooler than the plain from which they rise. Again, the greater the elevation, the less the mass of heat-absorbing matter and the more rapid its radiation into space. At the greater heights, also, there will probably be less atmospheric moisture and dust to absorb and radiate the heat proceeding both from the sun and by radiation from the earth. The fall in temperature due to elevation is chiefly due, however, to *dynamical cooling*, as it is called. Heated air currents as they rise are naturally subjected to decreasing pressure and consequently (by Boyle's law) expand considerably. The act of expansion, being work done against gravity, causes the consumption of heat with a consequent fall in the temperature = 1° F. for every 180 feet of ascent when the air is unsaturated. Conversely, cold air carried downwards from a great height towards the earth's surface, is continually subjected to an increasing pressure and its volume diminished. The work so done on the air by gravity is changed into heat, whereby the temperature of the air is raised 1° F. for every 180 feet of descent.*

The Relative Amounts of Land and Water influence temperature to a powerful degree ; the more the latter preponderates the lower will be the mean temperature and the more equable the climate. Land absorbs, and therefore radiates, heat more readily than water. Its specific heat, also, being very much lower than that of water, its tem-

* Practically, however, the decrease of temperature, is found to be 1° F. for every 270 feet of ascent. "Thus, whatever the temperature may be at sea-level, there is a certain height where the air has an average temperature of 32° F., no matter how much sun heat passes through ; and snow which falls above that height does not melt. This limit is termed the *snow line*. It is sea level in the extreme arctic regions, about 5,000 feet at latitude 62° in Norway, about 9,000 feet in latitude 46° in Switzerland, and above 16,000 feet at the equator." H. R. Mill, *op. cit.*

perature rises higher in a given time of exposure to solar heat; so that while a thermometer placed on the ground in a hot country may rise to 160° F., (or even to 237° F. if protected from air currents), the surface temperature of water rarely exceeds 80°—90° F.*; and the air immediately above it will be cooler still by from two to five degrees. Heating during the day and cooling during the night being, then, more rapid processes in the case of land than in that of water *the diurnal and annual ranges of temperature will be less in insular and coast positions than in the interior of continents.*†

The nature of the Soil and its effects upon temperature have been already considered.‡ Some soils absorb heat and give it out more abundantly than others. Bare surfaces will heat the air more, and more quickly than those clothed with vegetation. Evaporation from water or from wet surfaces, like marshes or the banks of tidal streams, cools the air. The shelter of hills or high rocks, may lower the temperature of certain spots by diminishing the duration of exposure to the solar rays or by keeping off a chilling wind.§

Currents, aerial or oceanic, are well known to modify temperature. The hot land-wind, the cool sea-breeze, the

---

* *Enclosed* tropical seas have the highest temperature of any water surfaces in the world. In the Red Sea readings of from 90°-100° F. have been reported, but the hot surface water in the tropical zone is merely a film covering a vast depth of cold water.

† *v. post.* under Climates.

‡ *v.* Chap. III.

§ The local influence on the temperature exercised by land and water respectively, is often very noticeable early in the night in India. When marching along a road in hot weather and approaching a large tank or other sheet of water the air feels much colder for some minutes before arrival at the water and continues so till it is left behind. Again, when approaching one of those bare, rocky hills, so common in central and southern India, the temperature of the air is considerably raised, so that the feeling is like that of entering an oven. In the one case the solar heat has been absorbed slowly and is being slowly radiated back at night, in the other, the large quantity of heat absorbed during the day is being rapidly radiated back to the air. In addition, in the latter case, the large mass from which heat is radiating must be taken into consideration, and in the former, the cooling effect on the air due to the evaporation going on from the water surface.

trade-winds blowing from polar towards equatorial regions, are familiar instances of the former; the gulf-stream of the latter. Winds may act indirectly also upon temperature, by bringing up clouds which either fall in rain or absorb heat, solar and terrestrial.

In tropical countries Rain has a marked influence in lowering the temperature, partly on account of the circumstance that since it falls from higher and cooler regions it is actually at a lower temperature than the air at the earth's surface, and partly because of the cooling due to subsequent evaporation. It should, however, be noted that the increased dampness of the air after a shower largely neutralizes the benefits of the lowered temperature.

In considering the effects produced on the human organism by alterations of temperature, there require to be noticed; (1) the effect of a *sudden change* from a low to a high temperature and *vice versâ*; (2) the effect of a *gradual lowering* of the temperature; and (3) the effect of a *gradual raising* of the temperature.

Effects of sudden changes in temperature.—These are apt to be most trying and may indeed have a fatal effect on persons who are in any way debilitated or sick already. There are two occasions in Indian life when this danger is especially prominent, *viz.*, at the setting in of the 'rains' after a lengthy period of hot, dry weather, and on going up to a hill station at an elevation of 5,000—8,000 feet.* In either case there is great risk of sudden congestion of the visceral organs. In a healthy person the free action of the skin, which is his safeguard in a high temperature, is checked, but its place is taken by greatly increased renal secretion and, in some cases, by diarrhœa for several days in addition. On the other hand, persons newly arrived in the tropics from colder climates run a great risk also, unless very careful. If their skin acts freely and they do not expose themselves too much to the sun there is not much fear of harm; but if at all careless, so that their

* A journey of 3—5 hours duration only by pony *tonga dâk*.

perspiration receives a 'check' as it is called, the probability is a violent attack of congestion of the liver or worse. In either case, a healthy person will be perfectly safe if reasonable precautions are taken as to food, its quantity and quality, clothing, exposure to the sun or to chilling winds, etc., etc. For those in any way out of health or weakened by long residence in a tropical climate, the greatest care is necessary, and their change to a lower or higher temperature should be as gradual as possible.*

Effects of Cold.—To healthy adults a low temperature is certainly not detrimental and is probably beneficial. Humid cold, where the air contains a high percentage of moisture, is very trying and, if the temperature is very low, may be fatal. If, however, the air is very dry, a most extraordinary degree of cold (as of heat) can be borne, such as −70° F. or 102° below freezing point. Prolonged exposure to great cold means complete physiological contraction of the arterioles and capillaries, with consequent interference with the circulation of the blood, resulting in death commencing at the extremities, *i.e.*, in the most distant and dependent parts. In addition, from the same reason probably, either extreme drowsiness with diminished sensibility comes on or, in some cases, delirium; death occurring from coma, rarely from syncope or asphyxia.

Effects of Heat.—A slight rise of the bodily temperature (from 0°·5 to 1° F.) is one effect of a heightened atmospheric temperature and is observed, temporarily, in transition from a temperate to a hot climate. Taking the normal temperature of the body in England at 98°·30 F. it was found to be 98°·66 within the tropics, and 99°·02 at the equator, the thermometer standing at 84°. There seems to be a slight but regular increase of bodily, proportional to rise of aerial, temperature, each degree of the latter corresponding to 0°·05 of the former. This increase is observ-

* For further information on this important subject, *v.* Chevers, Diseases of India, p. 9, *et seq.* and references therein given.

able in new arrivals at the tropics; it is not quite certain whether it is permanent or not. It occurs even when external and internal heat, on the one hand, and radiation from the body, evaporation from skin and lungs, and movement of air, on the other, maintain their normal correlation, and is not to be regarded as pathological. When, however, excessive humidity interferes with free evaporation, the temperature of the body rises and may increase to a dangerous extent. In the well-known experiments* in which the effects of exposure to a heated atmosphere in ovens were tried it was found that a temperature of 260° F. could be borne without injury or serious discomfort and with a rise of but 2°·5 degrees of bodily heat, provided the air was dry and free evaporation from the skin and lungs possible; but that in a moist atmosphere the temperature increased by 8°. The effects of intertropical heat, then, in raising the temperature of the blood are partly constant and partly dependent upon atmospheric humidity.

The function of Respiration is less actively performed in a hot than in a temperate climate. The number of respirations is diminished, and about 20 *per cent.* less carbon and water are eliminated by the lungs. Not only is less air by 18 *per cent.* respired in a given time but that which is taken into the lungs, being rarified by heat, contains less oxygen in a given volume than in cooler places. Thus it is estimated that 9 *per cent.* less oxygen is inspired at 80° F. than at 32°. The respiratory capacity, however, of the lungs is increased so that they contain more air but less blood and therefore weigh less in hot than in cold climates.

The action of the Heart is diminished under the influence of a hot climate.—Digestive power is accommodated to the altered conditions of the system; it is less powerful and there is less appetite, because there is less demand for food.—The activity of the sudorific and sebaceous glands

* By Blagden and Fordyce.

of the Skin is much increased; the papillæ of the former becoming often obstructed and inflamed, giving rise to the condition of *lichen tropicus* or 'prickly heat.' A change sometimes takes place in the pigmentary layer, after protracted residence, producing the yellowish tinge supposed to be characteristic of 'Anglo-Indians.'—Owing to increased action of the skin the quantity of Urine is diminished; and also that of excreted sodium chloride. Less food yields less urea.—Some European residents complain of want of energy and other results of a depressed condition of the Nervous System; but there is strong reason to believe, and abundant illustration by example, that as much and as good work, bodily or mental, can be done in this country as in Europe; and that the want of definite employment and the habits of indolence and self-indulgence which that want engenders are more to blame than climate for lack of energy and wasted lives.

Effects of the Direct Heat of the Sun.—The study of this subject is of importance on account of the relationship between it and insolation or sunstroke, so-called.* In moderation, sunshine is of the greatest use and "though its intimate chemical and physiological effects on the human economy may be as yet unknown to us, we recognise its healthful influence in promoting all changes, in quickening capillary circulation, in stimulating gland secretion, and fostering growth and development."† In excess, however, the heating action of the sun's rays has a powerful deteriorating influence on the human body, giving rise, ultimately, to a pale, anæmic appearance with corresponding languor and debility.‡

From what has been said at the commencement of this

---

* Formerly erroneously designated heat-apoplexy.

† S. and M. *op. cit.*, p. 189. Advantage is taken of this vivifying and heating power, by the use of so-called 'air' or 'sun' baths in certain parts of Europe, where the patients under treatment expose the naked body for a certain period daily to the direct rays of the sun, the head being duly protected.

‡ How far this is due to heat pure and simple, as distinguished from heat *plus* rarified and moist air, is not yet definitely settled.

chapter as to the great heating power of the direct rays of the sun upon solid bodies, it can easily be imagined how careful it behoves those exposed to such influence to be. The extent to which the body temperature in general and that of the head, neck, spine and skin in particular are raised has not been satisfactorily determined, though it is well known that great risk is run by those whose skin does not act freely or who do not protect the head and spine sufficiently. Again, it has been found impossible as yet to separate the part played by the sun's heat in the production of heat-stroke, from the usual concomitants of rarefied or impure air, excessive humidity, etc. It is certain that young, active and healthy persons do not easily get attacked whilst on the other hand three things strongly predispose, *viz.*, debility, fatigue and dissipation. Amongst British soldiers drunkenness was formerly the chief predisposing cause.

It is well worthy of note that cases of heat-stroke in mid-ocean or at great elevation are extremely rare, notwithstanding the great power of the sun's rays, and this fact certainly strengthens the view that humid or impure (but not rarefied) air or some other atmospheric condition, plays an important part in bringing about an attack of heat-stroke. One notable difference there is, common to mid-ocean and great altitudes, as compared with other places, and that is the entire absence, or presence only in very small amount, of ground surface from which heat is continually being radiated back rapidly.* Lastly, the glare and intense

* I believe how, in opposition to first impressions, that the risk of heat stroke to a healthy person living above an altitude of 5,000 feet is extremely small, and that it is only when much fatigued or when from any other cause there is a temporary accumulation of effete products in the system, that there is danger. Of course, a sensible European will always wear a *solah topee* or at least a *terai hat* when obliged to be much in the sun, for though the risk may be small the results of heat stroke are most serious. Yet one sees people, ladies especially, driving about day after day in the sun with no real protection, save perhaps their abundant hair and, it may be, a parasol held over them by their syce, without any harm accruing; a thing they would not dare to attempt in the plains. This does not prove that sun hats are unnecessary; only that the risk is much less than at lower altitudes.

light reflected from all surrounding objects, and especially from the ground bathed in Indian sunshine, are perhaps not less trying to the unacclimatised visitor to India, than the heat which they accompany.*

A great deal has been written on this subject, but as usual in India, careful experiments are urgently wanted and would do more to settle the matter than volumes of writing.†

Thermometers.—As temperature, for meteorological purposes, is always observed by means of these instruments, it is necessary to understand the principle of their construc-

---

* Blandford, *op. cit.*, p. 4.

† For further information the works of Parkes—Moore—Chevers—Fayrer, etc., may be consulted. Chevers gives reference to many important memoirs.

Fayrer (*v.* article 'Sunstroke,' Quain's Dict. Med., p. 1558) recognises three chief forms of Heat-stroke, *viz.*, (1) the *Syncopal* form or heat-exhaustion following on great fatigue, over-exertion or depression from any cause, during exposure to a high temperature: complete recovery common. This form is frequently seen amongst soldiers during a long fatiguing march in the tropics. (2) The *Asphyxial* form, sunstroke proper or the real *coup-de-soleil*, following exposure, particularly of the head and spine, to the direct rays of the sun. The symptoms are those of sudden and violent injury to the nerve-centres; death resulting from rapid failure of the respiration and circulation. Recovery is complete—tedious—or imperfect, ending in serious impairment of health or intellect—or the result may be fatal. (3) *Hyperpyrexial* form or thermic fever, an intense state of fever,—the result of the influence of heat on the nerve-centres, and through them on the vaso-motor nerves, and of the heating of the body generally, by the direct action of either artificial or solar heat, —may occur, quite independently of the immediate operation of the sun's rays. It comes on as frequently at night or in the shade, as in the day or in the sunshine, especially in persons who are exhausted by fatigue, overcrowding, depression from any cause, such as dissipation, want of rest, present or recent illness, and notably when the atmosphere is impure from overcrowding. The temperature of the body rises to 110° F., or higher. Recovery is often incomplete; or is followed by permanent impairment of health, and generally by intolerance of heat and exposure to the sun.—Chevers (*op. cit.*) gives a quaint list of the predisposing causes to heat-stroke, saying in conclusion, 'Numerous as the constitutional causes of heat stroke are, all Indian experience combines to show that Drunkenness is the chief.' Again, 'Long residence in the tropics does not strengthen our brains against heat-stroke, but no one is more secure against its attacks than an experienced, prudent Englishman, still young and with a well-preserved brain.' * * * 'Can one harden oneself against tropical heat? The impression which my experience has left is distinctly in the negative.'—The dark-skinned races are certainly less liable to sunstroke than the fair-skinned, especially negroes, but it is quite a mistake to suppose that Hindus and Mohammedans are not subject to this complaint. 'To a temperature of the air rising above a certain standard, all succumb; and the natives of India suffer like others, and die in numbers every year from *loo-marna* or hot-wind-stroke.' (Fayrer).

To face p. 295.

PLATE XVI.

METEOROLOGICAL INSTRUMENTS.

Figure 1. Shade Maximum Thermometer (Phillips'). *v.* also pl. xviii.

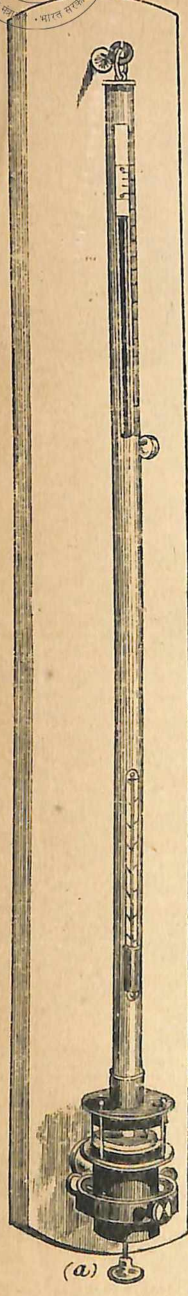
Figure 2. Shade Minimum Thermometer (Rutherford's). *v.* also pl. xviii.

Figure 3. (*a*) Standard Barometer (Fortin's Principle), showing the various parts of the same. (*b*) and (*c*) Part of the Scale—magnified. AB. The fixed scale of the barometer; CD. The moveable Vernier scale. (*v.* pp. 348-51).

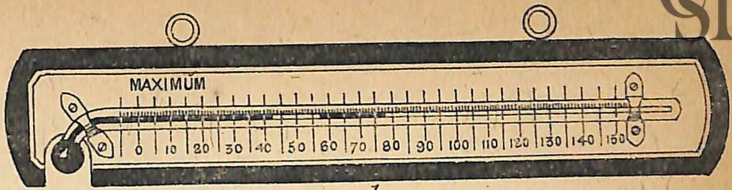
Figure 4. Section of Cistern of a Barometer constructed on Fortin's Principle, showing the column of mercury in direct continuity with the mercury in the cistern, the bottom of the latter being made of Leather and its capacity regulated by means of the Moveable Screw below. The Ivory Stud is seen in the upper part of the cistern. (*v.* pp. 348-49).

Figure 5. (*a*) Rain-Gauge, showing Outer Cylinder, Funnel and Receiver. (*b*) Graduated Measuring Jar.

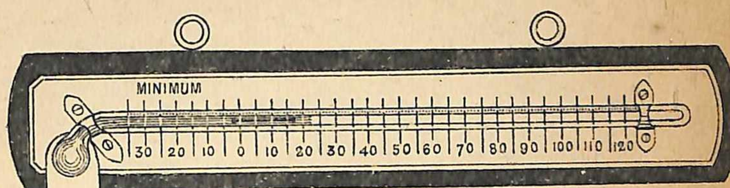
Figure 6. Lower portion of Wet-Bulb Thermometer, showing the Bulb covered with Muslin, from which depends the Cotton Wick dipping into a Vessel containing Water (not shown—*v.* plate xviii.).



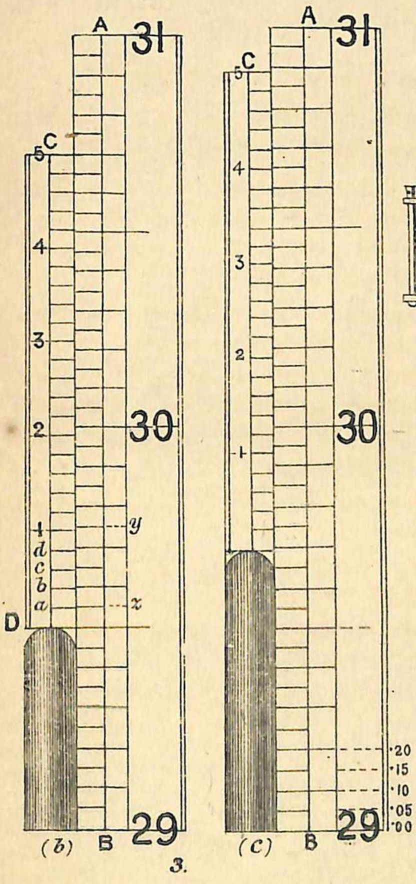
(a)



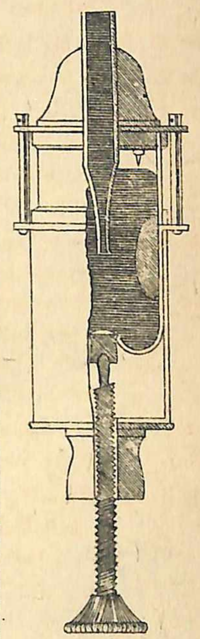
1.



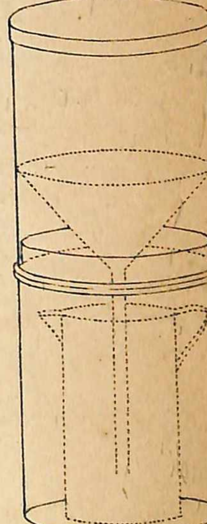
2



(b) 3. (c)

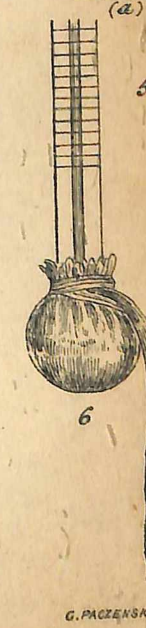


4



(a)

5 (b)



6

C. PACZENSKY LITH:

tion and the different varieties in use. Most of them are used for ascertaining aërial or solar temperatures under varying conditions, but there are others for use below the surface of the ground, or in water, etc.

A thermometer consists essentially of a closed glass tube partially filled with mercury, alcohol or other fluid; the measurement of temperature depending on the difference of expansion between the glass tube and the contained liquid.* Mercury is most commonly used because of its low specific heat, great conducting power, ready expansion when heated, low melting-point and high boiling-point. In a mercurial thermometer the tube has a very fine bore and is expanded at the lower end into a cylindrical or globular bulb. Whilst filled with boiling mercury it is sealed, so that afterwards, by the contraction of the mercury, there is a vacuum in the hollow upper part of the stem.

It is graduated by immersing it in melting ice and marking on the stem the upper level of the contracted mercury, and thereafter suspending it in the vapour of water boiling at the ordinary atmospheric pressure† and marking on the stem the upper limit of expansion. The space between these two marks can then be graduated as desired.‡

Only two methods of graduation are now in common use, *viz.*, the Centigrade and Fahrenheit.§ The former is the more scientific and will ultimately become the only recognised scale.|| By this system, the lowest mark—freezing-

* Air thermometers are theoretically the most perfect, but are not adapted for meteorological work.

† *i.e.*, 29·905 inches or 760 millimetres. A difference of 1 inch in the atmospheric pressure either way, as indicated by the barometer, means about 1·7° F. difference in the temperature at which water boils; below or above 212° F. according as the pressure is lessened or increased.

‡ For further details *v.* any text book on Physics, or article 'Thermometer,' Encycl. Britt., 9th ed.

§ The Reamur scale is also used in Germany and Russia: *v.* Special Works.

|| The Fahrenheit scale is still likely to be used for many years amongst English speaking nations, for ordinary meteorological purposes.

point—is 0° and the highest—boiling-point—is 100°, the intermediate space being divided into 100 equal spaces each of which is called 1 degree. In the Fahrenheit scale, the freezing point is marked 32° and the boiling-point 212°, the intervening space being divided into 180 degrees.

Varieties of Thermometer.—Five thermometers are in ordinary use in meteorological stations for determining the temperature, *viz.*—the ordinary thermometer, two maximum and two minimum thermometers. The temperatures observed by these are (1) the *shade temperature,* or temperature of the air at any given time; (2) the *maximum* and (3) the *minimum temperature of the air* during each twenty-four hours; (4) the *maximum temperature of solar radiation*; (5) the *minimum temperature of terrestrial radiation.* From the readings of (1), (2) and (3) is obtained the *mean temperature of the air* during each day of twenty-four hours.

The Temperature in the Shade, as stated above, is observed by means of three thermometers. The *dry-bulb thermometer* of the dry and wet-bulb hygrometer is used for ordinary purposes and consists of a simple mercurial thermometer graduated from − 20° F. to 130° F. By consulting it, with certain precautions, described below, the temperature of the air at any particular time can be ascertained. In this country it is usually read thrice a day at meteorological stations, *viz.*, at 8 A.M., 10 A.M. and 4 P.M.

To register the Maximum Temperature of the Air attained during twenty-four hours a *maximum thermometer* is used, either Phillips' or Negretti and Zambra's. In the former, the index is formed by a small portion of the mercurial column separated from the remainder of the mercury by a minute air bubble. So long as the temperature rises and the mercury expands, the index is pushed along the tube, but when it falls, the index does not fall back but remains at its furthest point and thus, by its distal extremity, indicates the highest temperature reached. In Negretti and Zambra's maximum thermometer the tube is bent near the bulb and a minute obstruction* introduced. When the temperature rises, the mercury forces its way past this obstruction, but when it falls, the molecular attraction of the mercury does not suffice to allow the column to pass the obstruction and therefore the full length of the column remains in the tube, its distal extremity, as in the former case, indicating the highest temperature reached. Both patterns are reset by taking the thermometer off its hooks and lowering the bulb gently: sometimes, a gentle shake or swing is necessary. Both are hung a little off the horizontal, the bulb end being the lower.

For registering the Minimum Temperature of the Air the thermometer known as *Rutherford's Minimum* is almost universally used. It is an alcoholic thermometer, the spirit being coloured pink for convenience, and contains a glass index in the hollow of the stem. When the temperature rises the expanding alcohol flows past the index, but when it falls, the contracting alcohol, by capillary attraction, carries back the index with it. The upper end of the index being always flush with the extremity of the receding column, ultimately marks the lowest temperature reached by the column, and even if the alcohol again expands from a rise in the temperature, remains in its position.

Great care is necessary, in order to get results of any value, to see that the Exposure of the thermometers is the best that can be obtained. For this purpose it is essential that, whilst the direct rays of the sun do not fall upon the instruments nor upon the ground immediately beneath, there should be no obstruction to the free play of the air around them. Such conditions are not usually obtainable in a house or its verandahs, which have thick walls and other disadvantages; accordingly, a thatched shed of the pattern indicated in the plate has been generally adopted throughout India and thereby more uniform and trustworthy readings obtained.

To determine the heating power of the sun's rays, *i.e.*, the

* A thread of glass fixed by heating or simply a constriction in the tube.

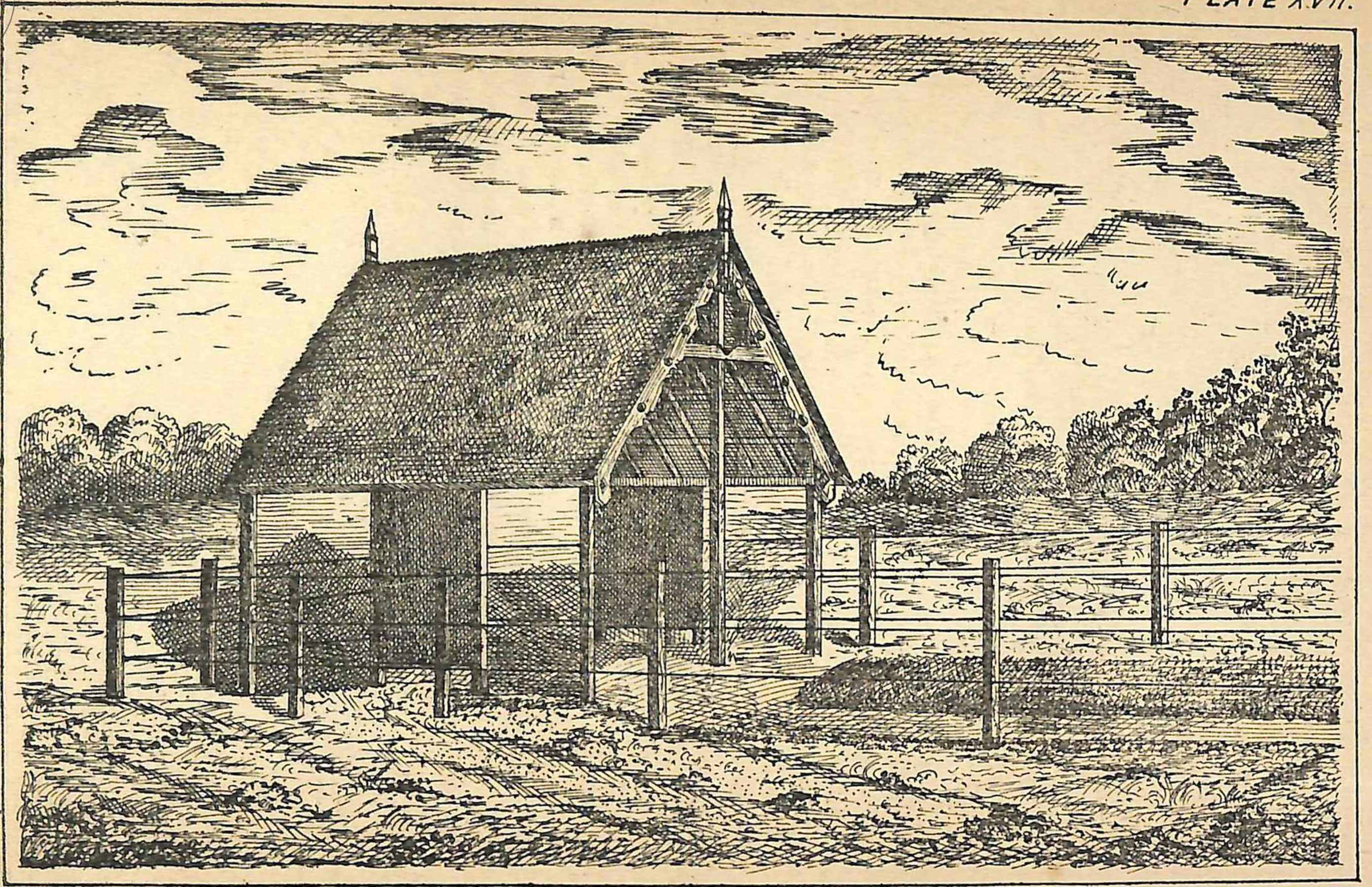
amount of Solar Radiation, appears at first sight a very simple matter but in reality it is not so, owing to several causes. An ordinary bright mercurial bulb acts as a spherical mirror and reflects instead of absorbing the heat rays. In addition, the bulb is cooled by wind, rain, etc. The *solar radiation thermometer* most generally used is therefore made by coating the bulb and part of the stem of an ordinary maximum mercurial thermometer with lamp black and enclosing it in a glass vacuum jacket as shown in the illustration. Even then the wind, etc., cools the outer jacket and this in turn interchanges heat by radiation with the inner bulb, so that the arrangement is not perfect. The highest reading is usually recorded as the 'maximum solar heat *in vacuo*,' whilst the excess of this temperature over that recorded by the maximum shade thermometer is considered to represent, approximately, the greatest amount of solar radiation which has occurred during the day. This thermometer is placed, of course, in direct sunshine and on a wooden stand at different heights according to different opinions, four feet being the regulation height in India.

To estimate Terrestrial Radiation a *minimum thermometer* of the same pattern as that previously described, or Cassella's modification of the same, is employed. It is placed on wooden trestles just clear of the ground, since the effect of terrestrial radiation is most marked where the disturbing influence of wind is least felt. When snow is lying on the ground it should be placed on it directly. Scott recommends laying a large, black board on the ground and placing the thermometer in a small groove cut in its surface to prevent rolling. In India, where the presence of grass cannot be insured, a pad is placed under the bulb. The difference in reading between this minimum thermometer and the minimum air thermometer is considered to express the amount of terrestrial radiation. It is not a perfect method by any means, but none better has been devised.

It is also becoming customary now to keep a record of

VIEW OF THERMOMETER SHED.

PLATE XVII.



LITH: BY ROSS, BROS.

To face p. 298.

PLATE XVII.

THERMOMETER SHED AND ENCLOSURE FOR USE IN INDIA.

The frame work is generally made of teakwood, and the roof consists of a foundation of bamboo matting with a substantial thatching of straw, not less than six inches thick. The side screens, which are intended to shield the thermometers from morning and evening oblique sunshine, reflected sunshine and rain, should be similar to the roof, but not so thickly thatched. Of course, unless the sheds are properly set up, and the roofs well covered with straw, the thermometrical observations will be affected by solar influences. A clear space of about nine inches should be left below each side screen to admit air. A nice open position, at least fifty feet from any wall or obstruction, should be selected for the erection of the shed, and it should be carefully set up, the ends pointing north and south. The shed is painted green and enclosed by posts and fencing; the latter being telegraph wire, iron bars, or barb fencing. The cost of a complete thermometer shed made of teakwood according to the Madras pattern is about Rs. 120, and it lasts for upwards of twenty years, only requiring re-thatching about once a year. The ground surface of the shed is generally of red gravel, or in some places white sand. There is a path round the southern grass plot on which the radiation thermometers and rain gauge are exposed, as shewn in plate xviii. (*v*. Administration Report of the Meteorological Reporter to the Government of Madras, 1885-86).

To face p. 299.

PLATE XVIII.

GROUND PLAN AND SIDE VIEW OF THERMOMETER SHED AND ENCLOSURE.

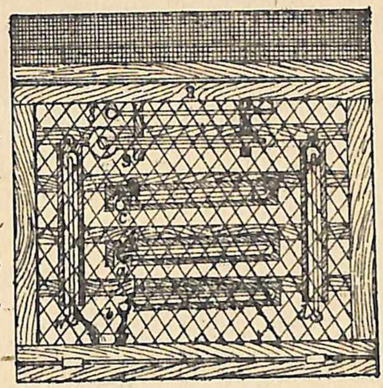
THERMOMETER CAGE.

The cage is carefully fixed to the centre pole of the thermometer shed, at a height of about three feet eight inches, so that the bulbs of the dry and wet thermometers are four feet from the ground. The substitution of these cages in place of the open boards has proved advantageous in securing the safety of the instruments. Each cage is made secure by a lock and key.

THERMOMETER CAGE. PLATE XVIII.

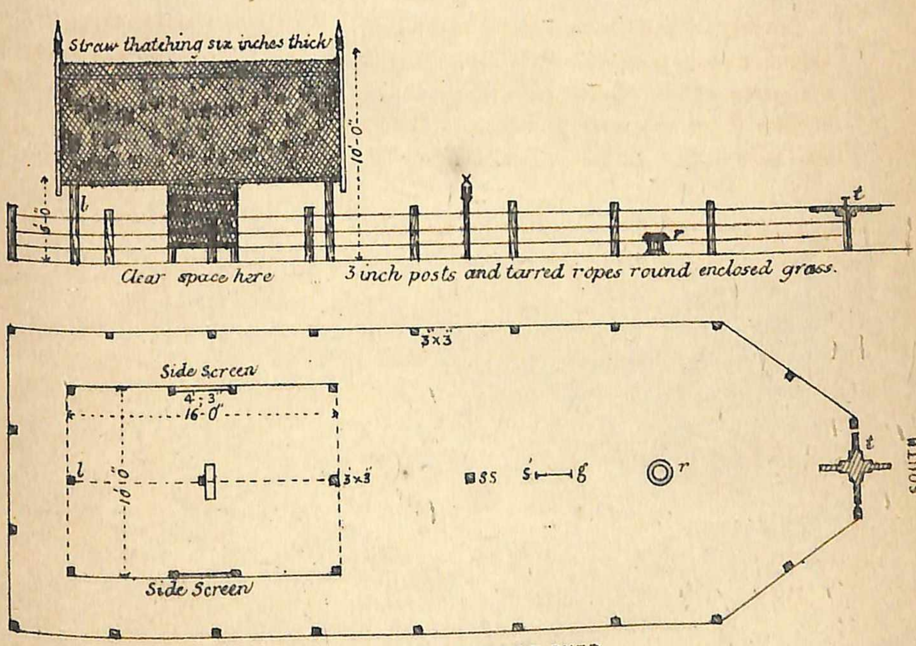
SHOWING ARRANGEMENT OF INSTRUMENTS

Dry bulb thermometer d
Wet bulb do w
Maximum dry bulb c
Minimum dry bulb a
Minimum wet bulb b
Rain gauge r



Sun maximum thermometer s.
Grass minimum g.
Turnstile t.
Lamp shelf 4' from ground l.
Radiation thermometer stands ss s'-g

The instruments to face due North and to be in a line with the centre of the two side screens.



PLAN & SIDE VIEW OF THERMOMETER SHED

LITH: BY ROSS, BROS.

the number of hours of Bright Sunshine *per diem,* and for this purpose an instrument known as a *sunshine recorder* is used. Of these instruments there are two classes, on the principle of the burning glass and photographic camera respectively The former type is specially suited to this country. It consists simply of a spherical glass lens beneath which a card ruled into divisions marking hours is placed in a curved holder. When the sun shines brightly, the rays are focussed on the paper, in which an interrupted series of linear marks is thus produced by burning, their total length indicating the duration of sunshine. It is worthy of note that the *intensity* of the burning is found to vary, being often greatest during the short periods of brilliant sunshine on cloudy days.

Having, then, at our command, these five thermometers, *viz.*, the ordinary dry-bulb thermometer, the shade maximum and minimum thermometers, the maximum solar radiation and minimum terrestrial radiation thermometers, with, in addition, a sunshine recorder, and supposing that each and all have their suitable exposure, as before described, we are in a position to investigate the temperature, etc., at any time and at any place fixed upon.

As a result of such observations it has been found that certain changes in temperature are *periodic* and others are *non-periodic.* The periodic or regular changes are sometimes termed *fluctuations* and the non-periodic or irregular changes *undulations.*

Fluctuations depend upon the earth's diurnal and annual motions, that is, on the alternations of day and night and of the seasons. The Diurnal fluctuation is greater on land than on water, inland than on the coast, in elevated places than at sea-level. On land, therefore, it is least on the shores of inter-tropical islands, as Ceylon and Singapore. The hottest time of the 24 hours is generally about 2 P.M., the coldest just before sunrise, the rise or fall of temperature between these extremes being nearly uniform. This applies to land stations; the maximum and minimum taking place also in the duration and rapidity of the rise and fall. Its magnitude is greatest in the most northerly* and in the driest places, and least in the most southerly and wettest places. Thus at Leh a difference of 103° between the lowest and highest temperatures has been recorded in one year, whilst in Southern India the annual range is only about 30° — 40°.†

In connection with this subject, however, it must be carefully noted that comparisons between the temperature ranges of different places have absolutely no value unless the instruments have all been carefully compared with standard ones and have the same exposure, as nearly as may be, in every case. On account of want of care in this respect much laborious work has been uselessly undertaken and necessarily discarded, and many wild and unfounded statements have been made.

As regards the Annual Periodic Variations in temperature, the "popular division of the year into a cold season, a hot season, and the 'rains,' holds good in the greater part of India, and fairly represents the more obvious phases of the climate."‡ The accompanying table brings out the above points for the chief stations of India and Lower Burmah.

Sudden and Irregular Changes of Temperature are not so marked in India as in other countries and when they do occur are temporary in nature and due to a sudden heavy fall of rain or, on the coast, to the setting in of a cool sea breeze in place of the hot land wind. They are generally a great relief and eagerly looked for. In Northern India, however, more frequent and irregular changes do occur suddenly, and as such changes have an important bearing

---

* *i.e.*, places where there is the greatest difference between the longest and shortest day.

† Such is the uniformity of climate on the south-west coast of Ceylon, that the extreme range of temperature in the course of the year is only about as great as that experienced within 24 hours at Simla and little more than half that of a single day at Jacobabad.

‡ *v.* Blandford, *op. cit.*, p. 15.

on the production of chill, the subject is worthy of careful study.*

In this country the Intensity of the Sunshine is greater than in higher latitudes and the excess of temperature (solar radiation) registered by the maximum black bulb thermometer *in vacuo* as compared with the maximum shade thermometer is about 50°—70° F. as a rule. It is not however this excess *per se* which is so important hygienically, but the fact that the shade temperature is already high, *e.g.*, in Southern India the excess may be only about 58° F., but the shade temperature is much higher than in England and the risk of sunstroke correspondingly greater. At hill stations the excess is generally large, 70°—80° F., but the lowness of the shade temperature lessens the risk of insolation, provided the head and upper part of the spine are protected.† The actual number of hours of sunshine is also greater than in such a country as England, particularly in Northern India where the average appears to be about 9 hours *per diem*‡ as compared with about 4 hours in England.

MEAN AND EXTREME TEMPERATURES AND RANGES AT FIFTY-ONE STATIONS, CHIEFLY HILL STATIONS AND MILITARY CANTONMENTS.§ (Deg. Fahr.)

Stations.	Elevation in feet.	Mean Temperature of			Mean Highest Reading.	Mean Lowest Reading.	Annual Range.	Rise January to May.	Change May to July.
		Year.	Hottest Month.	Coolest Month.					
Kurrachee . .	49	77	87	65	107	45	62	20	− 1
Quetta . . .	5,501	58	77	40	99	15	84	26	+ 11
Jacobabad . .	186	78	96	57	118	32	86	34	+ 3
Mooltan . . .	420	76	94	54	114	34	80	35	+ 3
D. I. Khan . .	573	74	93	52	117	31	86	35	+ 4
Leh	11,503	40	62	18	90	−4	94	29	+ 15
Peshawar . .	1,110	70	89	50	115	29	86	30	+ 9

* *v. ibid.*, *op. cit.*, pp. 10—12. † *v. ante*, p.

‡ The actual average daily duration of bright sunshine in many parts of India is uncertain as yet, but is probably less than might be imagined in the absence of accurate observations.

§ After Blandford.

MEAN AND EXTREME TEMPERATURES AND RANGES AT FIFTY-ONE STATIONS, CHIEFLY HILL STATIONS AND MILITARY CANTONMENTS. (Deg. Fahr.)—*cont.*

Stations.	Elevation in feet.	Mean Temperature of			Mean Highest Reading.	Mean Lowest Reading.	Annual Range.	Rise January to May.	Change May to July.
		Year.	Hottest Month.	Coolest Month.					
Rawalpindi .	1,652	69	89	49	114	29	85	32	+ 6
Murree . . .	6,344	56	71	39	93	24	69	26	+ 3
Sialkot . . .	829	73	91	52	117	34	83	33	+ 2
Lahore . . .	732	75	93	54	117	34	83	34	+ 1
Simla . . .	7,012	55	67	41	88	25	63	23	0
Delhi	718	77	93	59	116	40	76	30	— 2
Meerut . . .	737	76	92	57	112	37	75	32	— 3
Agra	555	79	95	60	116	40	76	34	— 7
Deesa. . . .	465	80	92	67	112	40	72	25	— 9
Abu	3,945	68	79	58	96	39	57	21	— 9
Neemuch . .	1,639	75	88	62	111	39	72	26	— 9
Ajmere . . .	1,611	74	89	58	112	34	78	31	— 7
Lucknow . .	369	78	92	61	114	38	76	31	— 6
Allahabad . .	307	78	92	61	116	40	76	31	— 7
Patna. . . .	183	78	89	61	110	42	68	28	— 4
Darjiling . .	7,421	51	61	40	72	25	47	14	+ 7
Hazaribagh. .	2,007	74	85	61	106	43	63	24	— 7
Berhampore .	66	78	85	65	109	46	63	20	— 2
Calcutta . . .	21	78	85	65	102	48	54	20	— 2
Dacca . . .	22	78	83	66	100	48	52	17	0
Chittagong . .	87	77	82	67	94	48	46	15	— 1
Sibsagar. . .	333	73	84	59	99	42	57	19	+ 6
Cuttack . . .	80	81	89	70	110	51	59	17	— 6
Saugor . . .	1,769	76	89	63	110	42	68	26	— 11
Jubbulpore . .	1,341	75	90	61	111	36	75	28	— 11
Pachmarhi . .	3,511	69	83	56	100	35	65	25	— 12
Nagpur . . .	1,025	79	93	67	115	46	69	24	— 14
Poona . . .	1,849	78	86	72	106	44	62	13	— 10
Bombay . . .	37	80	85	74	95	61	34	11	— 4
Belgaum . .	2,550	74	81	71	102	51	51	8	— 9
Sholapur . .	1,590	79	89	70	110	47	63	17	— 10
Secunderabad .	1,787	78	89	69	109	48	61	19	— 12
Bellary . . .	1,455	80	89	73	108	54	54	15	— 7
Bangalore . .	2,981	73	80	67	98	51	47	12	— 7
Wellington . .	6,200	61	66	55	80	37	43	11	— 3
Madras . . .	22	82	88	76	108	60	48	11	— 1
Trichinopoly .	275	82	88	76	106	60	46	12	— 3
Cochin . . .	11	80	84	79	95	67	28	3	— 5
Madura . . .	448	82	86	77	105	62	43	9	— 2
Galle	48	80	82	78	89	70	19	4	— 2
Rangoon. . .	41	79	84	75	104	58	46	8	— 5
Moulmein . .	94	78	83	75	99	58	41	7	— 5
Thyet Myo . .	134	79	87	68	108	45	63	17	— 5
Tounghoo . .	181	78	85	70	104	51	53	13	— 5

HUMIDITY.

Under this heading there falls to be considered the Water Vapour present in the atmosphere, and thereafter the various manifestations of the same in the form of Dew and Hoar Frost, Fog, Mist and Cloud, Rain, Snow and Hail.

Water vapour is a most important constituent of the atmosphere owing specially to the fact that it is near the temperature at which it becomes liquid or solid and is nearly always in the presence of liquid water; so that temperature changes greatly affect the amount of vapour present.*

Wherever we have a surface of water or, what amounts to the same thing, a moist surface of any kind, evaporation is going on from it unless the air is saturated with vapour. The amount of vapour required to produce saturation depends simply on the temperature, a rise of temperature corresponding with an increase and a fall with a decrease of the amount required. Now, since the vapour in the atmosphere may be measured, just as the atmosphere as a whole is, by the *pressure* it exerts, so we may say that for any temperature there is a certain limiting vapour pressure which cannot be exceeded. If the pressure is below this then evaporation will be going on and will continue till this limiting pressure is reached. The vapour, when it reaches this limiting pressure, is said to be *saturated*. Suppose, then, we have a quantity of saturated vapour in presence of water at a given temperature: if the temperature rises, evaporation will recommence because the vapour, though saturated for the lower, is not saturated for the higher temperature. On the other hand, if the temperature falls, the amount of vapour is in excess of that required

* "Let us suppose for a moment that the atmosphere consisted of water vapour only and that the hydrosphere covered the earth uniformly with a liquid layer. The amount of this atmosphere, and consequently its pressure, would depend upon the temperature. Evaporation takes place from cold water, or even ice, but *at every temperature when the vapour exerts a certain definite pressure upon the liquid, evaporation is stopped, and the vapour is said to be saturated at that temperature.*" H. R. Mill, *op. cit.*

for saturation at this lower temperature, and some of it, accordingly, must be re-condensed into water.

As a matter of fact, the air temperature is continually changing and consequently the amount of water vapour is continually changing also. Sometimes, however, the air is completely saturated for a time, or exerts sufficient pressure to put a stop to the process of evaporation.

When water vapour at 32° F. exerts a pressure of 0·18 inches of mercury the air is saturated, but at 50° F. it must exert twice the pressure, 0·36 inches, and at 70° F. double the pressure at 50° F., 0·73 inches, which is another way of stating that air at a temperature say of 70° F. can hold twice the amount of water vapour held by saturated air at 50° F. but only half the amount held by saturated air at 90° F. It is thus evident, as may be seen also by consulting a table of the weight of vapour, that the amount of vapour which can be rendered insensible increases with the temperature, but not regularly; comparatively more is taken up at high temperatures. Thus at 67° F., 7·22 grains are supported in a cubic foot of air; at 72° F., 8·47 grains, or 1·25 grains more; at 77° F., 9·92 grains, or 1·45 grains more than at 72° F. Therefore, if two currents of air of unequal temperatures, but saturated with moisture, meet in equal volume, the temperature will be the mean of the two, nearly, but the amount of vapour which will be kept invisible is less than the mean and some vapour therefore necessarily falls as fog or rain. Thus one saturated current being at 67° F. and the other at 77° F. the resultant temperature will be 72° F. nearly, but the amount of invisible vapour will not be the mean, *viz.*, 8·57 grains per cubic foot, but 8·47 grains per cubic foot; an amount equal to 0·10 grains per cubic foot will therefore be deposited, and will become visible as cloud. Should this condensed vapour meet with air not saturated, it will be re-absorbed, partially or wholly according to the capacity of the latter.

The total amount of water vapour which is contained at any time in a given volume of air and expressed in the pressure it exerts in inches of mercury or in grains of moisture per cubic foot of atmosphere, is termed the Absolute Humidity. For our purpose, however, this is not nearly so important as the estimation of the percentage of moisture present relative to the total possible amount which the air at any particular temperature might contain if saturated. In other words, it is the percentage of saturation which is so important. It is called the Relative Humidity and is expressed as so much *per cent.*, 100 being saturation.* When, therefore, the relative humidity is low the atmosphere feels dry and evaporation proceeds readily from moist surfaces such as the human skin; when, on the other hand, the relative humidity is high or approximates to saturation, evaporation proceeds very slowly and the air is said to be 'damp.' In such a case a very slight fall in temperature leads to saturation and consequent condensation of moisture. These properties of water vapour are of the highest importance and furnish an explanation, partial or complete, of many atmospheric phenomena such as evaporation, the formation of fog, cloud, rain, etc. Two points remain to be noticed. Firstly, that vapour in contact with its own liquid always tends to become saturated, but the saturation will not necessarily extend far from the surface of the liquid, if the vapour be mingled with air which retards its movement.† Hence at sea the humidity of the air is always high or near saturation. Secondly, on account of the low temperature at great elevations, water vapour, although its density is only half that of the air, is almost entirely confined to the lower regions of the atmosphere. Still, as a general rule, the air becomes *relatively* more humid as we ascend, for water vapour is always *tending* to ascend through the atmosphere,—tending towards a distribution which it can never attain,—as explained above, so that, as will afterwards be seen, at hill

* The relative humidity bears a distinct relation to the temperature at the time of observation; the absolute humidity refers only to the amount of water vapour present, independent of temperature.

† *v.* Blandford, Meteorologist's *Vade Mecum*, sec. 12, p. 108.

stations even during fine dry weather, the relative humidity is always much higher than on the plains below.

During evaporation or condensation important Thermal Changes take place. "The change of a pound of water into a pound of vapour requires the same expenditure of energy whether it takes place in a kettle boiling on a fire, or over the surface of a freezing pond."* Thus when the temperature of the air resting over the surface of a tank or moist ground is raised, evaporation commences, and heat being used up in the process, the air is cooled and continues to be cooled till the temperature of saturation is reached. In practice, owing to the fact that the partially saturated air is removed by wind, the process of evaporation generally continues at varying degrees of rapidity, throughout the day. Conversely, when air saturated with vapour is cooling by radiation, the vapour as it condenses gives out heat and so lessens the rate by lowering the temperature. In both cases the effect is to *retard the rate of the temperature changes*, and thus influence in a striking manner the local climate.

The Rate of Evaporation from a given surface varies with the temperature of the air, the state of the wind, the amount of moisture already present in the atmosphere, the nature of the surface itself and its exposure to solar action. The greater the heat the freer the evaporation, other things being equal; but the latter increases more rapidly than in proportion to the rise of temperature, because heat acts not only by promoting vaporization but also by augmenting the capacity of the air for humidity.† Wind favors evaporation by replacing air more or less nearly saturated by drier air, unless the current is itself moister than the air which it removes. The less the moisture already present above the evaporating surface the more rapid is evaporation: the process becoming gradually slower as saturation is approached. The shade afforded by trees, hills, buildings, etc., diminishes evaporation; and

* Mill, *op. cit.*, p. 108.

† *v.* p. 306.

finally, a moist soil yields more vapour in a given time than an equal area of water.

Humidity in Relation to Health.—There is no doubt that the varying degrees of atmospheric humidity exercise upon the human body a very powerful influence; but such influence is so greatly modified by and so closely dependent upon other variable climatic factors such as temperature, pressure, winds, etc., that it is quite impossible to ascertain and define accurately the part played by humidity alone.

One very important point has before been alluded to and that is the fact that the moisture of the atmosphere acts as the *great regulator of the distribution of warmth* over the earth's surface, partly by retaining or obstructing the heat radiated back from the earth* and partly by the thermal changes consequent on the processes of evaporation and condensation. There is strong reason to believe that it is not so much the water vapour itself as the dust and moisture particles which absorb the heat radiated from the earth's surface, but in any case the effect produced is well-marked.

In places then where the air is more or less constantly damp the variations in temperature are generally gradual and the climate is said to be equable. As will be afterwards seen, this is characteristic of *island* climates, *i.e.*, climates of places situated on or near the sea, and while it suits the constitution of some people is apt to prove very trying and depressing to others. It is believed that when the air contains a large amount of moisture the excretion of carbonic acid from the lungs is increased, and *vice versâ*.

If the absolute humidity is low the respiratory functions are especially affected, and the amount of expectoration much diminished.

When the relative humidity is low and the temperature

---

* "The aqueous vapour [or condensed vapour and dust particles] takes up the [heat] motion, and becomes thereby heated, thus wrapping the earth like a warm garment, and protecting its surface from the deadly chill which it would otherwise sustain." Tyndall.

high, when, in other words, the air is warm and dry, as ordinarily understood, the process of evaporation from the skin is continually going on and the body temperature is maintained at safe limits. If the air is cold and dry the loss of moisture takes place principally from the lungs. Such air has frequently a most exhilarating effect and is especially valuable in the treatment of many pulmonary complaints and in the debility, when not extreme, following long residence in moist, tropical climates. Epidemics of small-pox and plague are generally checked by a very dry atmosphere.

In India the greatest danger to health is incurred when the temperature is high and there is at the same time a high relative humidity: and this for a two-fold reason. In the first place the process of evaporation from the skin is not active and when the air, as frequently happens, is very still, the surface of the skin and the clothes become saturated with moisture. In such a case the relief naturally afforded to the organism by the loss of heat consequent on evaporation is almost entirely wanting and the body temperature may rise to such a height as to endanger life.* In the second place a person whose body and clothing are bathed in perspiration may be suddenly exposed to a breeze, whereby rapid evaporation, followed by cooling of the body surface, causes sudden congestion of the internal organs and a serious 'chill' is received, resulting in pleurisy, rheumatism, hepatitis, dysentery, etc. The liability to suffer from chill varies much in different persons, as also the organ affected, but the abdominal viscera being most commonly congested, diarrhœa, dysentery, and hepatic abscess are very frequent affections in warm moist climates about the beginning and end of the 'rains.'

The general effect of long continued warmth and moisture of the air on European constitutions is the production of a feeling of languor which may amount to complete disinclination to mental or bodily exertion. The appetite is

* *v. ante*, p. 291.

lessened, but the tissue changes being markedly lessened also, the amount of subcutaneous fat is often increased. Certain diseases, such as malaria and cholera, find a particularly congenial home when to the ordinary conditions, such as excess of organic matter in the soil, etc., continued atmospheric warmth and moisture are added.

When the air is cold and moist there is a tendency to rheumatic and catarrhal affections, and great precautions are necessary in the direction of always wearing woollen clothing next the skin. Under such circumstances the kidneys become specially active whilst the loss of moisture through the skin is reduced to a very small amount.

It is not possible to lay down any definite rule regarding the degree of relative humidity most conducive to health, on account of its close relation to other climatic factors: it is generally stated to be between 70 and 80 *per cent.*, but the statement is of little value *per se*.

Estimation of Humidity.—The absolute or relative humidity can easily be calculated when the temperature and dew-point are known. The amount of aqueous vapour which air can retain without depositing it as dew or rain, varies, as we have seen, with temperature; and the Dew-Point at any time is *that temperature at which the quantity of vapour then present would be sufficient for saturation, so that any further depression would be attended with deposition of dew.* It is ascertained either *directly* by Regnault's or Daniell's Hygrometers,* or *indirectly* by the Wet and Dry Bulb Hygrometer, sometimes called the Pyschrometer of August.

Regnault's hygrometer consists of a glass tube, closed below by a cap of thin and highly polished silver, 1·8 inch in depth and 0·8 inch in diameter, a very sensitive thermometer passing through a cork in the upper orifice of the tube and descending nearly to the bottom of the cap.

---

* Other Hygrometers are Dines' (direct) and the Hair Hygrometer of Saussure (indirect). For their description *v.* any text-book of Meteorology, S. and M's Hygiene, etc.

From the same depth rises a thin glass tube, also passing through the cork: while an opening in the upper part of the instrument communicates with an aspirator. When an observation is to be taken, ether is poured into the tube until it is about half full and atmospheric air is drawn through the ether by means of the aspirator and the fine glass tube. As the air bubbles through the ether the temperature of the latter and of the silver cap in contact with it falls until the dew-point is reached, that is, until the air outside the cap is cooled to such a degree that it can no longer retain its moisture, which is deposited as a dew upon the silver. The immersed thermometer indicates the temperature at which this occurs, and it should be read at the instant of the clouding of the silver. Three or four observations are generally necessary to accurate determination, which may be thus made to 0°·1. The temperature of the air must be simultaneously noted.

Daniell's hygrometer is more portable and convenient than Regnault's, but the indicating thermometer is so small that determinations cannot be made nearer than to 0°·5. There is difficulty also in catching the precise instant at which the dew appears. The instrument consists of two spherical glass bulbs about 1¼ inch in diameter, communicating by a glass tube bent at right angles. One of these is black, the other transparent. A small mercurial thermometer with pyriform bulb is enclosed in that limb of the tube which communicates with the former, the bulb descending to the centre of the black sphere. Sufficient ether to fill this about three-fourths has been originally introduced, the air excluded as completely as possible by boiling, and the whole hermetically sealed. The other sphere is covered with muslin and the whole supported by a stand on which is fixed a second delicate thermometer indicating the air temperature. To take an observation the ether is first collected into the black sphere and the temperature of the air noted. Ether is then dropped upon the muslin. As it evaporates, the cold produced condenses the ether vapour which fills the transparent sphere and the connecting tube, and so compels evaporation and consequent cooling in the black sphere. The mercury in the enclosed thermometer falls and, when it reaches the dew-point, a ring of condensed vapour appears on the black sphere at the level of the surface of the ether within. As the ether recovers its original temperature the ring gradually disappears. At the moment of its disappearance the indication of the enclosed thermometer gives another approximation to the dew-point, and the mean of the two observations is sufficiently near the truth for ordinary purposes.

These instruments, as above stated, give the dew-point directly, whilst the Wet and Dry Bulb Hygrometer, by a comparison of its indications, gives the same indirectly. This instrument consists of two similar thermometers, set at least one foot apart in a frame fixed four feet from the ground, with the precautions before described.* One gives the air-temperature in the ordinary way; the other the "temperature of evaporation." The bulb of the latter is covered with muslin which is kept constantly moist by means of cotton thread connecting it with a small reservoir of rain or distilled water fixed on the stand. The cotton should be perfectly free from grease which might interfere with its transmission of water to the bulb. As the moisture evaporates the bulb cools and the mercury falls;† and the less the humidity present in the air the more rapid is the evaporation and the greater the depression of the mercury. When the air is nearly saturated evaporation is very slow and the indication of the wet bulb thermometer is little lower than that of the dry bulb; at saturation they coincide

* *v.* p. 297.

† "In computing the dew-point from the depression of the wet bulb, it is assumed that the air around the bulb gives up heat sufficient to evaporate the additional quantity of water requisite to saturate it; and that, this atmosphere being constantly renewed, the wet bulb is kept at the temperature to which it is thus depressed". (Blandford). From which it follows that the air round the wet bulb must at all times circulate gently: the stagnant air of a room is therefore unsuitable, that of the thermometer shed (p. 297) generally fulfilling the requisite conditions best.

and their common indication is the dew-point. When the temperature is very low, as when it is freezing, evaporation still proceeds; but very slowly, because the capacity for moisture is low. The differences are then minute and observations require special care and precautions. Unless the air is saturated, the indication of the wet bulb thermometer will always be below that of the dry bulb and above the dew-point.

Having observed the difference between the indications of the two thermometers the dew-point may be calculated either by Apjohn's* or August's formula or by Glaisher's tables. Into the theory and practice of these methods for estimating humidity it is not necessary nor desirable to go here. In practice the humidity is, for all ordinary meteorological purposes, obtained from tables which shew the humidity corresponding to any given depression of the wet bulb, for all temperatures of the wet bulb. In India, Blandford's tables are most convenient.

---

* This formula gives, not the dew-point itself, but the *Tension* of aqueous vapour of the dew-point in terms of the tension at the temperature of evaporation. The corresponding temperatures are obtained from a table, which expresses the tension or elastic force of vapour at various temperatures in inches or fractions of an inch of mercury. If a glass tube, closed at one end, whose inner surface has been moistened with water, be filled with mercury and inverted with its open end immersed in a vessel containing mercury, the level in the tube will be lower than in the ordinary barometer; because the upper part of the tube, instead of being a vacuum, is filled with aqueous vapour, whose tension or elastic force depresses the mercury and is measured by the amount of depression. So long as water is present above the mercury, to supply vapour, the tension is constant, however the space may be increased by raising the tube in the vessel, (provided the open end remain immersed); and if the tube be depressed, contracting the space above, some vapour will be re-converted to water and the tension will be the same, temperature and pressure being unchanged. The amount of depression of the mercurial column corresponding to every ordinary degree of temperature has been ascertained and tabulated. It must be added that if air were present, along with the aqueous vapour, the relation of tension to temperature would be unaltered: the only difference between the two cases being that *in vacuo* the space is saturated very rapidly with vapour, while more time is necessary if air be present.

Blandford prefers August's formula to Apjohn's, as being based on more accurate determinations of the elastic force of aqueous vapour and as simplifying calculation by adopting 29·7 as a mean barometrical pressure. The error involved in this assumption is unimportant except at hill-stations, where corrections must be applied. In comparing meteorological observations it is necessary to ascertain and bear in mind the formula which has been used.

The Absolute humidity or total amount of aqueous vapour present in the air at any given time is expressed in grains per cubic foot and may be estimated (1) experimentally, by drawing a measured amount of the air through a drying tube and ascertaining the resulting increase in weight, (2) by determining the dew-point, directly or indirectly, and thereafter consulting a table giving the quantity of moisture which saturated air contains at different temperatures.

Atmospheric Humidity in India.—One of the chief peculiarities of Indian climates as a whole is their variability with respect to humidity, and not only so, but when the humidity is at its maximum at certain parts of the country, the air in other parts is at its driest. Examples of this will be given afterwards.

With respect to the Diurnal Variation in humidity, the latter* may almost be said to vary inversely as the temperature, so that the air is dampest in the early morning before sunrise, becomes drier as the temperature increases, the maxima of temperature and dryness corresponding, and finally becomes damper again towards evening as the temperature falls.

The Annual Variations in humidity are very curious and interesting and undoubtedly play a most important part in regard to outbreaks of disease, more especially malaria and dysentery. It must not be forgotten that when the relative humidity begins to rise rapidly, other conditions, such as marked alteration in the level of the ground water, are generally brought about, and accordingly it is extremely difficult to make out whether the increased humidity is a true disease-producing factor or merely a danger signal as it were.

The rainy season from June to September is also the dampest for nearly all parts of India, the percentage of humidity averaging about 75—85; at certain stations, like

---

* It is *relative* humidity only which is here referred to.

Darjeeling and Mercara, it may be as high as 95—99 or even saturation for July and August. At a few stations in the north, the winter is the dampest season, July being the driest month, as mentioned below.

The driest time of the year varies very much in different parts of India, *e.g.*, on the coasts of Bengal and Orissa, November or December are the driest months, in the interior of Bengal and Assam it is April, May in the Punjab and Upper Sind, June at Quetta, Peshawar and Leh. When it is driest on the east coast of Ceylon and the Carnatic, the humidity on the west coast and in the north is at its maximum.

The Geographical Distribution of humidity in different parts of India is stated by Blandford to vary according as moist or dry winds are most prevalent. The part played by winds in thus influencing the degree of humidity is most important and will be afterwards referred to.

MEAN ANNUAL HUMIDITY OF THE SEVERAL PROVINCES OF INDIA.*

Provinces.	Rel. Hum.	Provinces.	Rel. Hum.
Ladak	49	Orissa	76
N. W. Himalaya (lower ranges)	62	Central Provinces (southern)	59
Nepal Valley	72	Berar and Khandesh	53
Sikkim Himalaya	84	Konkan and Surat	72
Baluchistan	50	Deccan	55
Sind† and Cutch	50	Hyderabad and Bellary	54
Punjaub Plains	55	Northern Circars and Godavery	71
Rajputana	48	Carnatic	67
Guzerat†	47	Mysore	66
Central India Plateau	50	Malabar and Coorg	79
Nerbudda Valley	55	Ceylon	80
N. W. Provinces and Oudh	59	Arakan	80
Behar	65	Pegu	77
Bengal	80	Tenasserim	80
Assam	80	Bay Islands	81
Chutia Nagpur	57		

With reference to the foregoing table it must be noted that different parts of one and the same province or even district may shew considerable differences owing to local peculiarities.

Thus, at the Alipore Observatory near Calcutta the average of February and March is 69, but in the *more closely-built* suburb of Chowringhee only 66; a difference of 5 *per cent.*

DEW.

When on a clear night heat is rapidly radiated from the earth's surface and the temperature falls below the satu-

* After Blandford. † Exclusive of the coast.

ration point of the water vapour present, moisture is condensed upon all exposed objects in the form of small drops or, in some cases, minute ice crystals. In the former case it is called Dew, in the latter case it is called Hoar Frost. It was formerly supposed that the moisture found in the morning on objects exposed to the night air was simply derived from the water vapour in the air. It is now known, however, that this is not the case, but that a large amount of the condensed moisture found is derived from water vapour which is exhaled from the earth, blades of grass, etc.*

Whatever favours the process of cooling by radiation favours also the abundant formation of dew, *e.g.*, absence of clouds or other form of condensed water vapour, absence of trees, buildings or any other obstructions. Movement of air is unfavourable because it removes partially cooled particles before they have been sufficiently chilled to deposit. Good conductors such as metallic bodies do not generally exhibit dew, because they receive continuous and rapid supplies of heat from the earth. Foliage and fibrous structures like clothing being good radiators and bad conductors receive the most copious deposit† ; to which a moist atmosphere and a still and cloudless night are most conducive. But, as stated above, the question is not simply one of the condensation of moisture from air cooled below its dew-point. The exact nature of the processes

---

* It is impossible here to go into the complex question of dew-formation. The subject has lately received a large amount of attention from Mr. Aitken (whose papers will mostly be found in the Proc. and Trans. R. S. Ed.) the Hon. R. Russell and others. The latter has published an interesting pamphlet, *Observations on Dew and Frost*, Standford, and his conclusions are given in detail in Nature for 29th December, 1892. The latest observations appear to be those of Herr Wollny, *v.* Nature for 23rd February 1893, who concludes that 'Dew depends partly on evaporation from the ground, partly on transpiration. It is at present doubtful [?] whether precipitates from the air share in it or not. A cloudy sky weakens the cooling process without stopping it wholly. * * * The more moisture there is in the ground the more water is evaporated from the ground and the plants * * *'.

† According to Herr Wollny, however, the excess of moisture found on 'organic' bodies as distinguished from 'inorganic', is simply due to their greater power of hygroscopic absorption.

involved in the deposition of dew is not yet fully understood.*

Hoar frost is simply dew frozen after deposition. It is commonly well seen during the colder months of the year in certain parts of Upper India and in the more sheltered positions at hill stations situated at an altitude of about 7,000—8,000 feet or more.

HAZE.

In India, particularly in Northern India, the sky is rarely very clear, nor the blue colour very intense; such pallor of the sky being apparently due to a haze arising either from thin diffused cloud-matter at a high level or else to the dust which is daily carried up by the convection currents in the heated atmosphere. In other words, it is sometimes a pure dust haze, at others it is made up of moisture condensed on dust particles. This will be again referred to under atmospheric dust, and is only now alluded to, in order to point out its possible connection with reference to the formation of mist, cloud, rain, etc.

MIST AND FOG.

As a matter of fact fog, mist and cloud, rain, snow and hail, may all be looked upon as examples of the same phenomenon occurring under varying conditions, this phenomenon in itself being simply the condensation of water vapour in the atmosphere as a natural occurrence. The most important discovery in this connection of late years was that of Mr. Aitken,† who showed that water almost never condenses except on a solid particle. He proved this by showing that, if moist air be kept perfectly free from dust, the temperature can be lowered much below the dew-point without condensation occurring; but that as soon as dust is admitted to the air condensation at once takes place, each dust particle forming a nucleus upon which the moisture condenses. In all cases, therefore, of condensa-

* Carefully conducted experiments on this subject, in India, would well repay the trouble taken.

† v. Nature for 1881—85—88 and 90 and references given therein.

tion of atmospheric moisture, whether in the form of mist, fog, rain or cloud, etc., the presence of dust particles is essential to the commencement of the process.

Fog and Mist are to a large extent interchangeable terms and are often applied indiscriminately to the same phenomenon.* In both cases they are caused by a sudden cooling below the dew-point of masses of moisture-laden air. Where the dust particles are very numerous and the temperature suddenly lowered, each particle will only receive a relatively small coating of moisture. And it may happen that owing to the absence of wind, the minute globules thus formed remain suspended for a very long time in the air. Such fogs, of which the nuclei are minute particles of carbon derived from the smoke of coal fires, are unfortunately only too common in the great cities in England and elsewhere, more particularly London, and may last continuously for 8 or 9 days. In colour they vary from pale yellow up to dark brown,—'black fog' so called,—and may so obstruct the sunlight as to necessitate the continued use of artificial illuminants in the houses and streets for days together.

Mists are comparatively uncommon in the plains of India save along the course of large rivers or over marshy land during the cold weather. They are soon dispersed by the increase in temperature after sunrise.

CLOUD.

Clouds, which are simply mist at high altitudes, are continually forming, dissolving, and re-forming according to varying temperatures of different masses of air. The

* By Blandford, the meteorological sign (*m*) is reserved for the haziness of the sky above alluded to, whilst the term fog (*f*) is used for the visible masses of condensed vapour that are seen over damp places in the evening or early morning. "Fog differs from mist in not wetting solid objects with which it comes in contact." Mill, *op. cit.*, p. 114. 'A dry fog may thus result from cold causing condensation on a very large number of dust-particles which are radiating heat rather freely, and a damp mist from partial condensation from supersaturated air on a comparatively small number of dust-particles not radiating freely owing to a clouded sky. * * A dry fog is the work of cold radiating particles, a wet mist is the work of cold air mixing with warm.' Russell, *op. cit.*

various shapes and appearances of clouds have been the subject of observation from unknown ages, by those to whom weather changes are naturally of extreme importance. "To an experienced eye" says Blandford "the forms and movements of the clouds and the general aspect of the sky are eloquent of impending weather, but save seamen, and among intelligent and observant nations, farmers and herdsmen, there are but few who have learned their language and can rightly interpret it, while such knowledge as these possess is for the most part empirical and little capable of being harmonised with the facts and translated into the language of physical science. Among meteorological observers of the ordinary class, it is certainly rare; it cannot be learned from books and unlike the art of managing and reading a thermometer or barometer, cannot be imparted in a few easy lessons."

For a long time, the simple classification proposed by Howard has been in use. According to this classification clouds are divided into four principal forms. (1) *Cirrus.* (2) *Cumulus.* (3) *Stratus.* (4) *Nimbus.*

Cirrus cloud is that which is commonly seen floating far above other clouds, and which is made up of streaks or fibres of clouds parallel or divergent or forming a fleecy brush or network. Under various conditions these cirri have the appearance of horses' tails, of the teeth of a comb, fine wisps of cotton-wool, etc. They are the highest clouds because the lightest, and reflect the sun's rays after sunset long after lower strata of cloud are dark. They have been known to retain their form unchanged for two days while a strong breeze was blowing lower down, showing that they are raised out of the reach of ordinary atmospheric disturbances. They probably consist of frozen water.

The term Cumulus is applied to those large, billowy cloud masses which so commonly surround the horizon during fine weather, the base or under surface being more or less flattened, the upper surface rounded. After the sun has risen the atmospheric strata in contact with the earth become heated; so that, their specific gravity being diminished and their capacity for vapour increased, they rise, carrying up with them in solution the vapour which they had absorbed during the night and early morning. Reaching colder regions of the air, the vapour of the ascending current is condensed to cloud which, descending slowly, meets the ascending current and condenses, partially or wholly, its moisture. Thus a mass of cloud continually increasing in size is formed. Were the supply of vapour for condensation equal from all sides the cumulus would be spherical in form; but, as the under surface is in contact with air not fully saturated and, therefore, not yielding condensed vapour, the shape is hemi-spherical or conical as has been described. The cumulus is formed only by day, then only the conditions necessary for its development being fulfilled. It disappears late at night; because at that time the upper atmospheric strata have increased in temperature and vapour-absorbing power, while the lower layers are cooler and cease to supply an ascending vapour-bearing current.

The Stratus is a widely-extended, continuous, horizontal sheet of cloud, often forming at sunset, when the air is calm; the atmospheric strata near the earth becoming cooled below the dew-point, and depositing dew on the surface and cloud above. It increases by growth at its upper surface as the higher layers cool. The mists or fog-banks which rise from valleys, lakes, etc., during night and early morning, and which are dispersed by the rising sun, belong to this class of cloud.

The Nimbus, or cumulo-cirro-stratus as it is sometimes called, is the typical 'storm-cloud' and consists of a dark grey or black sheet of stratus cloud, above which the cirrus* is spread, while it presents a mass of cumulus laterally. From its under surface rain is usually falling.

It is evident to any observer that these four forms are

* Called 'false' cirrus in contradistinction to the true cirrus of great altitude.

the chief types of cloud shapes and that there are several fairly common forms which are intermediate or a compound of two primary forms, *e.g.*, Roll-Cumulus, Cirro-Cumulus, Cumulo-Stratus, Cirro-Stratus. But it must be observed that such terms are by no means exact and bear no relation to the altitude of the particular cloud alluded to. It appears probable, moreover, that the forms assumed by cloud masses are largely dependent on temperature and also that certain forms are more or less characteristic respectively of dry or wet weather. As a result of many years observation and experience a scheme applicable to all parts of the world has been proposed by Messrs. Abercromby* and Hildebrandsson, which will "probably be the basis of the future classification of clouds, and which recognises the very important distinction between such as are characteristic of fine, and such as betoken or accompany rainy weather."

The following is the proposed classification :—

MESSRS. HILDEBRANDSSON AND ABERCROMBY'S PROPOSED SCHEME OF CLOUD CLASSIFICATION.

a. *Discrete tending to rounded forms (principally in dry weather).*	β. *Extended and sheet-like forms (rainy weather).*
A. Highest clouds, mean height 30,000 feet.	
1. Fibre cloud [*Cirrus* or mare's tails].	2. Thin cloud veil [*Cirro-stratus*].
B. Medium elevation 13,000 to 20,000 feet.	
3. Small globular cloudlets, shining white like silk, 20,000 feet [*Cirro-cumulus*, mackerel sky].	5. Thicker ash-coloured or bluish-gray sheet, 17,000 feet [*Strato-cirrus*].
4. Larger globular, like white wool, 13,000 feet [*Cumulo-cirrus*].	
C. Lower clouds, 5000 to 7000 feet.	
6. Great rounded masses or rolls of gray cloud [*Strato-cumulus*].	7. Ragged sheets of gray cloud from which rain commonly falls [*Nimbus*].

* For an interesting account of cloud forms and formation *v. Weather*, by the Hon. R. Abercromby, International Scientific Series, and other writings of the same author.

D. Clouds in ascending air currents.

8. Heap cloud [*Cumulus*]. Summits at 6000 feet; bases at 4500 feet.
9. Storm (thunder) clouds [*Cumulo-nimbus*]. Summits 10,000 to 16,000 feet; bases 4500 feet.

E. 10. Elevated fogs. Below 3500 feet [*Stratus*].

Estimation of Cloud.—A perfectly clear sky is regarded as 0, whilst one completely overcast is regarded as 10.* To estimate the degree of cloudiness, the observer looks midway between the zenith and horizon and turns slowly round, comparing the clear parts of the sky with the clouded. The usual times for observation are the same as for temperature and pressure. To observe both the shape and movements of clouds due allowance must be made for perspective. The velocity of movement of a cloud can sometimes be measured, under favourable circumstances, by noting the time taken by its shadow to traverse a space of country, of which the distance is accurately known.

In all these observations care and practice are necessary if useful results are to be obtained.

Cloud in India.—It appears extremely probable that the elevations given in the foregoing table, made from European observation and measurements, would have to be considerably raised in this country.† Careful observation, by the unaided eye, of the clouds as seen from the neighbourhood of Ootacamund,—where the view extends from the summit of the western *ghâts* (8,000 feet) to the Mysore plateau and the plains of the Coimbatore district,—have strengthened the writer's belief in the approximate accuracy of the foregoing classification, with the above reservation as to the relatively greater elevation in the tropics of the various cloud forms therein given.

As to the lessons to be learnt from clouds it is impossible to write much here. The higher clouds act as 'floats' indicating the direction of the air currents in the elevated region of the atmosphere. This speed may be very great, and according to one observer the average rate of movement

---

* This may, of course, be expressed as a percentage, 100 being a completely overcast sky.

† Blandford.

of cirrus cloud is 40 miles an hour* or about three times as fast as the surface winds. The study of cloud movements will ultimately, no doubt, prove both interesting and instructive, but at present nothing is known bearing specially on the subject of hygiene†.

In India during cloudy weather the days are relatively cool and the nights hot, the clouds acting as heat-curtains preventing access of solar heat during the day time and checking the loss of heat by radiation from the earth's surface at night. Cloudy days and clear nights are therefore the pleasantest in the tropics and the opposite conditions correspondingly unpleasant. When the air is very moist at night and the sky completely overcast, with absence of rain, the most trying weather conditions are experienced.

July is the cloudiest month throughout the greater portion of India, *i.e.*, at the height of the rainy season, and August is almost as cloudy. The exceptions are Upper Sind, the Punjâb, and Baluchistan where the cloudiest months are February and March.‡ The season of clearest skies or greatest serenity varies more than the foregoing according to locality, being as early as October in the Punjâb and as late as February at Bellary and Dharwar. Further south than that the monthly mean is never very low. The mean cloud proportion is below 5 throughout India save in Assam and Sikkim, the Carnatic, Ceylon, and the southern parts of Pegu and Tenasserim. In different months and at different places it may range from 0·5 to 9·5 or even 10 at stations like Mercara.

RAIN.

The exact conditions relating to the formation of rain are as yet imperfectly understood, but speaking generally, when a mass of vapour-laden air is cooled below its dew-

* Which is not astonishing when one considers "how small is the retarding friction at great heights in the atmosphere." Blandford.

† "When a cyclone is forming in the bay [of Bengal], cirrus cloud from the S. W. is often seen passing over Bengal before there is any other distinct indication of its existence." *ibid.*

‡ *cf.* humidity.

point, the air being at the same time comparatively free from dust particles, a large amount of vapour will be condensed and each dust nucleus will become the starting point of a rain drop. Rain may thus fall from a cloudless sky, but as a rule it comes from clouds. It is supposed that the upper part of a cloud is freer from dust than the lower part; hence relatively large drops are formed in the upper part which, as they fall, absorb the smaller ones beneath, till ultimately they become large rain drops that fall towards the earth's surface at a rate which increases with their increasing size.

Upon the altitude of the rain-forming cloud and upon the temperature and degree of saturation of the atmospheric strata near the earth's surface depends the question of the originally condensed moisture ultimately falling as rain upon the earth. If the cloud is floating very high and between it and the earth is a mass of warm and relatively dry air, the condensed moisture will tend to evaporate and may be carried upwards again to become once more condensed: if, on the other hand, the cloud has formed at a low level and there is comparatively cool and moist air between it and the earth, instead of disappearing into vapour, the drops will become larger and will ultimately reach the earth as a heavy shower of rain.

The conditions for an abundant fall of rain are most perfectly fulfilled when a warm, vapour-laden sea breeze blows against a lofty range of hills and is forced to rise. Owing to the dynamical cooling of the air which thus results* a great and rapid condensation of vapour takes place and sheets of cloud are formed from which an enormous quantity of rain falls. The steeper the slope the greater the precipitation. As the wind continues its journey over the mountain tops and descends on the other side the air begins to grow warmer† and any moisture it

---

* *v. ante*, p. 287. The cooling is not to any large extent due to the 'chilling effect' of the mountain mass as is so often asserted.

† *v. ibid.*

contains is evaporated, so that the clouds disappear and the wind sweeps over the low country with a relatively low humidity and becomes a drying wind, causing increased evaporation of moisture from water and land surfaces and from objects in general such as clothing, vegetation, buildings, etc.

Cherra Punji in the Khasi hills, long renowned as having the highest recorded rainfall in the world, is a remarkable illustration of the combination of these favouring conditions. "The Khasi hills rise abruptly from the *Jhils* of Sylhet, which being but a few feet above sea level, and receiving the copious drainage of the hills that surround Cachar and Sylhet, present, during the rainy season, a broad sheet of water, from which emerge a few villages built on mounds and the low ridges locally termed *tilas*. Over this low inundated tract sweeps the south-west monsoon from the Bay of Bengal; and, meeting the Khas hills, is abruptly driven up to a height of 4,000 feet, before it resumes its course towards Upper Assam and the Eastern Himálaya. * * * Cherra Punji is surrounded, or nearly so, by vertically ascending currents of saturated air; the dynamic cooling of which is the cause of the enormous precipitation which has made this place famous."*

Effect of Rainfall upon Health.—The amount of the rainfall at any place, which itself depends chiefly on the local physical conditions and upon temperature and winds, has a very important influence upon health, this influence being (1) general and (2) individual.

In a country like India the influence of rainfall upon the General Health and well being of the community is very marked and of extreme importance. The failure of the crops and consequent famine resulting from a deficient rainfall is too well known to need any further explanation. On the other hand, an excessive fall of rain occur-

---

* Blandford.

ring suddenly, may cause great damage and widespread distress; or again, a large annual fall, coupled with peculiar local conditions, may bring about a water-logged condition of the ground, from which may result a large and serious increase in malarial and other diseases. Yet again, except in the largest towns, a deficient rainfall for one or two seasons not only leads to famine from a scarcity of food grains, but also increases the prevalence of special diseases from the drinking of filthy and polluted water, and many other less noticeable evils.

The influence of rain upon the Health of Individuals is more temporary and consists chiefly in the danger of chill to those who are exposed to a wetting when clad in miserable cotton cloths and who have neither knowledge nor means to avert the effects of such chilling. At any large hospital such influence is easily recognisable, and as surely as heavy rain has fallen, with its usual accompaniment of a cold wind, so surely does the number of cases of pleurisy, pneumonia, rheumatism, dysentery, bronchitis, etc., suddenly undergo a distinct increase. The relationship between rainfall and cholera is often very marked. If cholera is prevalent, slight showers of rain generally increase the amount of the disease, whilst heavy rain will almost certainly put an end to the outbreak, probably owing to the thorough cleansing of the ground surface and subsoil. The seasonal prevalence of certain diseases in India and their correlation with other factors, such as insufficient or unsuitable clothing, food, habitation, etc., is a subject well worthy of far more systematic study than has yet been given to it.

Estimation of Rainfall.—The total amount of rain falling at any one time in a place is estimated by means of a Rain Gauge. Of these instruments there are various forms, the simplest being that of a bottle into which is inserted a metal funnel. For meteorological purposes, however, greater accuracy is required and an instrument constructed as follows is used. (*v.* illustration). It consists of an outer cylinder of such a height that its mouth is exactly one foot above ground level whilst the base is slightly buried in the ground to fix it and prevent its being blown over or upset. Inside this cylinder is a metal funnel which fits accurately, and underneath the funnel is placed a receiver, generally a glass vessel* with a lip to facilitate pouring, and into which the tube of the funnel passes. In addition, there is a graduated glass vessel into which the water is carefully poured from the receiver when a measurement is to be made. "The measuring jar is divided proportionately to the area of the gauge, the diameter of which should always be an exact dimension, 5·00 inches or 8·00 inches, as it is then easy, if the original measuring jar is broken, to obtain a new one precisely adapted to the funnel. It is thus graduated. Take a 5-inch guage; if the diameter be 5 inches the area is 19·64 inches, therefore a rainfall of an inch, *i.e.*, 1 inch deep over the whole of a certain place or district, would in this rain gauge deposit 19·64 cubic inches, or 4958 grains of water. It is found in practice most convenient to make the jar hold ½ an inch. Therefore 2479 grains are poured in and the jar is marked with a line representing 0·50 or ½ inch; sub-divisions are similarly marked and so finally the jar has fifty divisions, one for each 0·01 inch and is figured at ·10, ·20, ·30, ·40, and ·50."†

Float gauges were formerly in common use but are now almost entirely abandoned on account of their radical defects in working. A good many gauges of the old Madras pattern are still in use. In these the diameter is about 4·7 inches so that 1 inch of rain is equal to 10 ounces of water and can be measured with an ordinary ounce glass. The gauge in ordinary use throughout India at the present time has a diameter of 5 inches. It should be placed on level ground, at least as many feet from trees, buildings, etc.,

---

* Or metal can with a lip. The graduated measuring jar must *never* be used in place of the receiver.

† G. J. Symons, F. R. S. Each one-hundredth of an inch is generally called a *cent.*, so that a fall of 0·5 inches would be 50 cents.

as these are high. Old gauges should not be abandoned until at least two years after the new ones intended to replace them have been established; in order that the two sets of results may be satisfactorily compared. When very heavy rain falls it should be measured as soon as the fall has ceased. In the case of snow $\frac{1}{12}$th of the average depth is counted as rain.* Hail is allowed to melt in the cylinder and the resulting water measured as rain. The water condensing from dew and fog is measured, when measurable, as rain,† though its immediate source is really very different according to recent researches.‡

Rainfall in India.—By means of the rain-gauge the Rainfall of any place can be accurately measured. From the returns thus made available, a knowledge of the rainfall throughout the Indian Empire has been obtained.

The total amount of rain that annually falls in India is very unevenly distributed, particularly in Northern India,§ where it ranges from Cherra Punji in the Khasi hills on the east with an average annual fall of 500—600 inches to Jacobabad in the west with an annual average of 4·50 inches. In Southern India the relative positions are, roughly speaking, reversed so that the west coast receives a far larger quantity of rain than the east coast. A glance at the accompanying plate will show this point clearly. Another fact of immense economic importance is that it is just at those places in which the rainfall is relatively scanty that it is also precarious, whilst in the rainiest parts the fall is most regular. To this rule, however, there are

* This is a rough method and not to be recommended except in cases of necessity. Another way is to melt the snow in the gauge by adding a measured quantity of warm water and subtracting this latter from the total quantity; the residue being entered as rain. It is best to try both plans. (Symons.)

† *E.g.* The total quantity of dew collected in England by Colonel Badgley in one year, by means of 'grass plates', was 1·6147 inches, the amount being measured with great accuracy. *v.* Nature, Vol. XLIII., p. 311. Of the whole annual precipitation at Munich dew gave 3·23 *per cent.* (Wollny).

‡ *v.* p. 317.

§ *Cf.* also what has been said before regarding humidity and cloudiness.

exceptions, *e.g*, at parts of the Central Provinces south of the Satpura range, with an average rainfall not exceeding 50 inches, drought is almost unknown, whilst the North-West Provinces, with an average of 86 inches, have been visited not less than seven times during the present century with disastrous droughts.

Another point of great importance to sanitary engineers and others, to which attention has previously been drawn,* is the extraordinary difference there may be in the amount of rain received by two places situated comparatively near to one another. This is especially well seen in places which, though not distant from each other, vary in their geographical relation to neighbouring hills. An example of such a difference, given by Blandford, is the case of Baura Fort and Gokak. The former, situated on the crest of the Western Ghâts, has an average fall of 251 inches, the latter, at a lower level and sixty-five miles to the east, has an average of 22 inches. Enormous falls of rain sometimes take place in a few hours, amounting to 20—40 inches in twenty-four hours, and, curiously enough, these deluges may occur in places where the one fall of rain is more than three times the *average total* for the year!

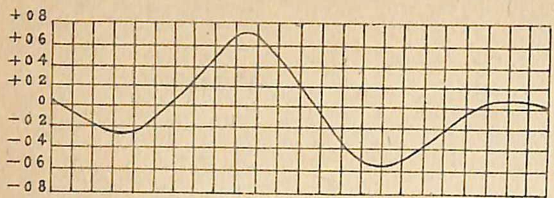
The Average Annual Rainfall of the whole of India, exclusive of the mountain barrier (including Assam and Cachar) and Burmah, has been computed at 42 inches, but this enormous amount is very unevenly distributed, as the table from Blandford, given on the next page, will show.

The ordinary Seasonal Distribution of the rainfall in India may be roughly described in a few lines. In the spring there are slight showers at comparatively frequent intervals in Assam, Cachar and Lower Bengal, and in Southern India also three or four inches generally fall during the months of April and May—the so-called 'mango showers.' With the advent of the south-west monsoon the regular rainfall begins and continues from June to October.

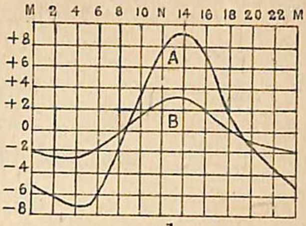
---

* *v*. pp. 48-9.

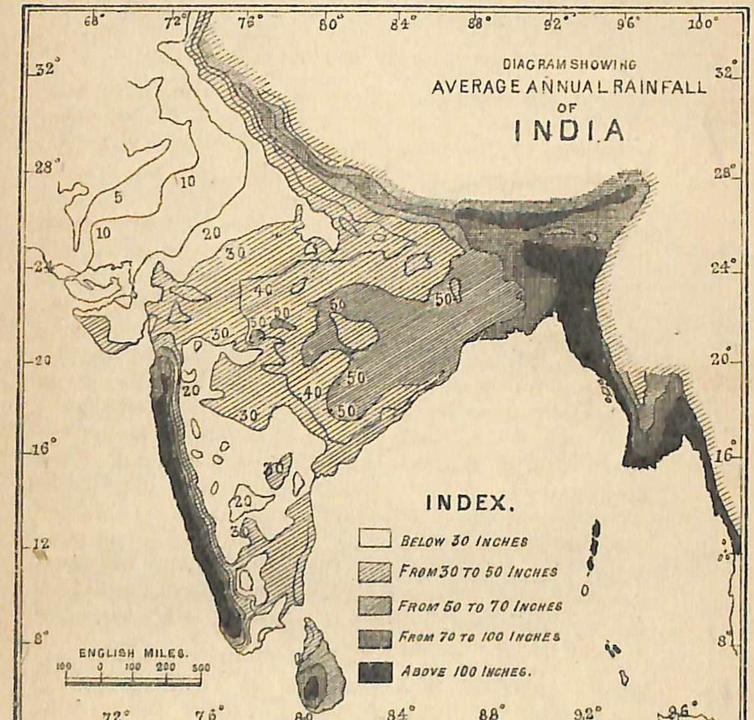
Plate XIX.



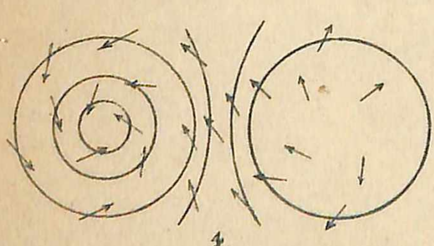
2



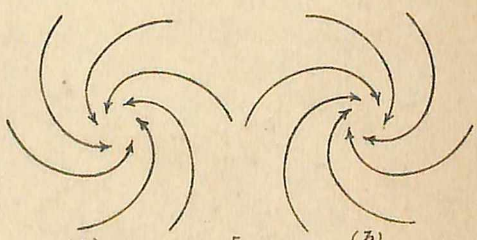
1.



3



4.



(a) 5. (b)

C. PACZENSKY LITH:

To face p. 330.

PLATE XIX.

RAINFALL, Etc. [After Blandford.]

Figure 1. To illustrate Diurnal Variation (*Fluctuation*) of the Temperature in India. Average Diurnal Curves, A. for March, B. for July, in Calcutta (*v*. p. 301).

Figure 2. To illustrate Diurnal Variation (*Fluctuation*) of the Atmospheric Pressure in India. Average Diurnal Curve for April, in Calcutta (*v*. p. 358).

Figure 3. Diagram of the Average Annual Rainfall of India.

Figure 4. Diagram of Cyclone and Anti-cyclone. "Let the right hand circle be supposed to represent a region where the barometer is highest, and the left hand circle that where it is lowest, the intermediate lines indicating a number of isobars of intermediate gradations of pressure. Then the winds that blow outwards from the region of high barometer, if in the northern hemisphere, instead of blowing directly outwards like the spokes of a wheel, all take an increasingly oblique course to the right of the radial direction, as shown by the arrows, and those that blow in towards the region of low barometer all blow obliquely to the right of that course which leads directly to the centre. The result is that the former describe a series of spirals curving round the seat of high barometer in the same direction as the movement of the clock hands; the latter, a series of spirals circulating round the seat of low barometer against the direction of the clock. The latter represents the movements of the winds in a cyclone" [in the northern hemisphere]. "When, as in the case of the monsoons" [*v*. pl. xx.], "neither the seat of highest barometer nor that of lowest barometer is a circle or any other regular figure, the course of the winds is not in such regular spirals" as those shown in figures 4 and 5.

Figure 5. Diagram showing the Spiral Course of the Winds in a Cyclone, (a) in the Northern Hemisphere, *e.g.*, in the North of the Bay of Bengal, (b) in the same latitude in the Southern Hemisphere.

AVERAGE ANNUAL RAINFALL OF THE PROVINCES OF INDIA AND BURMAH.

Rainfall Provinces.	Area in Square Miles.	Number of Stations.	Average Rainfall.	Local Variation.
			Inches	Inches.
Punjab Plains . . .	120,000	29	22	6 to 36
N. W. Provinces and Oudh . .	83,500	45	36	25 ,, 50
Rajputana (Eastern only) . .	67,000	19	28	14 ,, 63†
Central India States* . .	91,000	21	42	32 ,, 55
Behar	30,000	14	43	39 ,, 48
Western Bengal, Chutia Nagpur, etc.	38,000	10	49	43 ,, 61
Lower Bengal . . .	54,000	29	66	54 ,, 112
Assam and Cachar . . .	61,000	17	94	69 ,, 475†
Orissa and Northern Circars. .	27,000	16	47	31 ,, 70
Central Provinces, South . .	61,000	19	51	43 ,, 79†
Berar and Khandesh . . .	43,000	11	35	21 ,, 69†
Guzerat	54,500	14	33	18 ,, 47
Sind and Cutch . . .	68,000	10	9	4 ,, 19
North Deccan . . .	48,000	14	29	18 ,, 49
Konkan and Ghats . . .	16,000	13	141	74 ,, 261†
Malabar and Ghats . . .	18,000	8	114	74 ,, 132
Hyderabad	74,000	19	32	23 ,, 43
Mysore and Bellary . . .	58,000	17	29	18 ,, 36
Carnatic	72,000	40	36	20 ,, 62†
Arakan	11,000	6	156	105 ,, 214
Pegu	32,500	7	73	46 ,, 123
Tenasserim	10,500	4	171	142 ,, 196

This is the 'rainy season' for the whole of India save the south-east which only receives occasional showers. Later, when "north-east winds are beginning to blow in the north-west of the Bay, and both the incipient north-east monsoon and the residue of the southerly current are drawn towards the Carnatic and the southern half of the Bay," the heavy rain begins to fall in these latter places and continues to do so as long as the so-called north-east monsoon lasts. There is thus no time of the year when rain does not fall in some part of India.

There are many other points of extreme interest in connection with the rainfall of India, for details of which

* Including Jhansi, Saugor and Damoh, and the Nerbudda valley.

† In these cases one or more hill stations have a much higher rainfall than any at the lower levels.

Average Monthly Rainfall of Eighty Stations in India, Ceylon, and Burmah.

Stations.	Elevation in Feet.	Rainfall in Inches.												
		Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Kurrachee	49	0·6	0·3	0·2	0·2	0·1	0·2	3·1	1·8	0·9	0·1	0·1	0·2	7·8
Hyderabad	66	0·2	0·1	0·1	0·2	0·1	0·4	2·8	3·2	0·8	...	0·1	...	8·0
Quetta	5,501	1·6	1·9	2·4	1·3	0·5	0·1	0·8	0·6	0·2	0·1	...	0·4	9·9
Jacobabad	186	0·2	0·2	0·3	0·2	0·1	0·1	1·4	1·4	0·3	...	0·1	0·1	4·4
Mooltan	420	0·4	0·3	0·5	0·3	0·5	0·4	2·2	1·3	0·8	0·1	0·1	0·3	7·2
D. I. Khan	573	0·4	0·7	0·9	0·8	0·4	0·6	1·8	1·6	0·6	0·1	0·1	0·3	8·3
Leh	11,503	0·2	0·2	0·2	0·1	0·1	0·2	0·5	0·4	0·2	0·5	...	0·1	2·7
Peshawar	1,110	1·6	1·2	1·8	2·0	0·7	0·3	1·7	2·0	0·8	0·2	0·6	0·6	13·5
Rawalpindi	1,652	2·4	2·0	1·9	2·3	1·6	1·7	7·4	7·3	3·2	0·6	0·9	1·1	32·4
Murree	6,344	2·8	3·4	3·7	4·3	3·8	2·4	11·0	14·0	6·1	2·2	1·7	1·2	56·6
Sialkot	829	1·4	1·8	1·9	1·6	1·2	3·2	11·6	9·1	3·2	0·6	0·4	0·8	36·8
Lahore	732	0·7	1·1	1·1	0·6	0·9	1·8	7·4	4·6	2·4	0·6	0·2	0·5	21·9
Umballa	902	1·4	1·5	1·1	0·6	1·0	4·0	11·6	8·6	4·1	0·6	0·2	0·7	35·4
Simla	6,953	2·8	2·7	3·0	2·8	4·7	7·9	19·3	18·1	6·0	1·4	0·3	1·1	70·1
Delhi	718	1·0	0·5	0·7	0·4	0·7	3·4	8·5	6·9	4·5	0·5	0·1	0·4	27·6
Roorkee	887	2·0	1·4	1·0	0·4	1·2	5·1	12·5	12·3	5·1	0·6	0·2	0·4	42·2
Meerut	737	1·0	0·7	0·7	0·4	0·8	3·6	9·2	7·2	4·0	0·5	0·1	0·3	28·5
Agra	555	0·5	0·3	0·2	0·2	0·7	2·9	9·8	6·7	4·3	0·4	...	0·2	26·2
Deesa	465	0·1	0·2	0·1	0·1	0·2	2·2	9·8	8·5	3·3	0·8	0·1	...	25·5
Abu	3,945	0·2	0·4	0·1	...	1·0	5·1	22·2	22·5	9·1	2·1	0·2	0·2	63·1
Jodhpur	1,274	0·3	0·2	...	0·1	0·6	1·3	3·6	5·2	2·3	0·2	0·1	0·1	14·0
Neemuch	1,639	0·1	0·2	0·1	0·1	0·5	3·9	11·2	10·4	5·5	1·0	...	0·2	33·2
Indore	1,822	0·4	0·3	...	0·1	0·6	6·8	10·4	7·8	8·1	1·2	0·2	0·2	36·1

Ajmere	1,611	0·2	0·3	0·4	0·1	0·7	2·5	6·9	7·3	3·4	0·3	0·1	0·3	22·5
Jhansi	855	0·5	0·2	0·4	0·1	0·3	4·0	13·6	10·5	5·2	0·8	...	0·2	35·8
Lucknow	369	0·8	0·3	0·3	0·1	0·9	5·0	10·8	10·4	7·1	1·4	...	0·5	37·6
Allahabad	307	0·8	0·4	0·4	0·2	0·3	4·6	11·9	9·6	6·7	2·3	0·2	0·2	37·6
Benaras	267	0·7	0·5	0·4	0·2	0·5	5·0	12·8	10·7	6·5	2·1	0·1	0·1	39·6
Gorakhpur	256	0·7	0·5	0·4	0·3	1·5	7·7	13·3	11·8	8·8	3·0	0·2	0·1	48·3
Patna	179	0·7	0·5	0·3	0·3	1·6	7·1	11·0	10·1	7·9	2·9	0·2	0·2	42·8
Darjiling	6,912	0·7	1·2	2·4	3·7	7·1	24·1	30·5	26·0	17·8	6·4	0·2	0·2	120·3
Jalpaiguri	270	0·4	0·4	1·7	3·7	11·2	28·6	26·3	25·9	24·3	5·5	0·1	0·1	128·2
Hazaribagh	2,010	0·4	0·8	0·7	0·4	1·6	8·3	12·6	12·7	8·0	3·4	0·3	0·2	49·4
Bhagulpore	159	0·5	0·7	0·4	0·8	2·5	8·3	11·2	10·7	7·8	4·1	0·2	0·1	47·3
Berhampore	66	0·4	1·0	1·0	1·9	4·8	9·7	10·3	10·8	9·8	5·3	0·3	0·1	55·4
Calcutta	18	0·4	1·0	1·3	2·3	5·6	11·8	13·0	13·9	10·0	5·4	0·6	0·3	65·5
Dacca	15	0·3	1·1	2·5	5·8	9·2	13·8	12·8	12·4	10·2	5·2	0·7	0·2	73·7
Chittagong	87	0·4	1·2	1·9	4·6	9·2	23·8	22·2	20·5	14·1	5·7	1·6	0·6	105·8
Silchar	87	0·6	2·6	7·9	13·0	15·7	19·1	20·6	18·2	14·2	6·4	1·0	0·7	120·0
Charrapunji	4,455	0·6	2·6	9·0	29·6	50·0	110·0	120·5	78·9	57·1	13·6	1·8	0·3	474·0
Gauhati	370	0·6	0·9	2·5	5·8	10·1	12·9	12·7	11·2	8·1	3·1	0·6	0·3	68·8
Sibsagar	333	1·1	2·2	4·4	9·9	11·1	14·1	15·6	16·0	11·7	5·2	1·3	0·6	93·1
Cuttack	80	0·4	0·6	1·1	1·5	3·2	10·7	12·6	11·2	9·8	5·8	1·0	0·5	58·4
Samblapur	451	0·6	0·6	0·7	0·5	1·6	13·0	17·7	15·2	8·7	2·4	0·3	0·4	61·7
Saugor	1,769	0·6	0·5	0·2	0·2	0·6	6·3	16·8	11·2	7·3	1·3	0·4	0·7	46·1
Jubbulpore	1,351	0·6	0·5	0·5	0·2	0·5	8·5	18·6	13·8	8·2	1·5	0·4	0·3	53·6
Pachmarhi	3,504	0·5	0·3	0·4	0·3	0·6	10·8	28·8	18·2	15·1	1·9	0·4	0·7	78·0
Nagpur	1,025	0·6	0·4	0·6	0·5	0·8	8·8	13·3	8·9	7·8	2·3	0·4	0·5	44·9
Amraoti	1,213	0·5	0·2	0·3	0·2	0·6	6·9	8·8	7·0	5·3	1·6	0·2	0·6	32·2
Dhulia	1,000	0·3	0·1	...	...	0·4	4·8	4·8	4·0	4·6	2·0	0·5	0·4	21·9
Poona	1,819	0·2	...	0·2	0·6	1·6	5·6	6·6	4·1	4·3	4·1	0·8	0·2	28·3
Bombay	37	0·1	...	...	...	0·5	20·8	24·7	15·1	10·8	1·8	0·5	0·1	74·4
Matheran	2,200	0·1	...	...	...	0·8	35·7	84·4	50·7	31·0	5·3	0·6	0·1	208·7
Mahableshwar	4,540	0·4	0·1	0·4	0·9	1·4	47·3	102·1	68·6	32·9	5·8	1·1	0·4	261·4
Karwar	44	0·2	...	0·1	0·3	2·9	34·5	37·7	21·7	12·0	5·2	1·7	0·2	116·5
Belgaum	2,550	0·1	...	0·5	2·0	2·8	9·3	15·2	9·0	3·7	4·7	1·2	0·3	48·8

Average Monthly Rainfall of Eighty Stations in India, Ceylon, and Burmah—Contd.

Stations.	Elevation in Feet.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
		Rainfall in Inches.												
Jalna . .	...	0·1	...	0·1	0·1	0·8	7·2	6·8	5·3	7·5	3·4	0·8	1·4	33·5
Sholapur . .	1,819	...	0·1	0·3	0·7	1·2	4·6	4·3	6·0	7·5	3·7	0·7	0·4	29·5
Secunderabad .	1,787	0·3	0·2	0·7	0·7	1·4	3·7	6·0	5·7	5·2	3·3	0·8	0·3	28·3
Bellary . .	1,455	0·1	...	0·6	0·8	1·8	1·8	1·3	2·3	3·7	3·9	1·0	0·3	17·6
Bangalore . .	2,981	0·2	0·1	0·6	1·3	5·0	3·2	4·0	5·9	6·3	6·4	1·9	0·7	35·6
Wellington . .	6,200	0·8	0·3	2·0	2·9	4·1	3·6	3·2	4·0	4·7	9·8	8·5	4·1	48·0
Bimlipatam. .	30	0·3	0·5	0·2	0·2	2·0	3·2	3·6	4·4	6·3	8·1	2·5	1·3	32·6
Masulipatam .	10	0·3	0·1	0·3	0·1	1·7	4·4	5·6	6·0	6·5	8·8	4·0	0·7	38·5
Rajamundry .	68	0·2	0·3	0·3	0·9	3·3	4·5	7·2	6·6	7·1	6·5	1·7	0·2	38·8
Cuddapah . .	477	0·1	...	0·2	0·3	1·6	2·6	3·5	5·1	5·8	5·3	3·1	0·7	28·3
Madras* . .	22	0·9	0·3	0·4	0·6	2·1	2·1	3·9	4·6	4·8	10·5	13·5	5·3	49·0
Trichinopoly .	275	1·0	0·5	0·7	1·8	3·8	1·3	2·2	4·4	5·3	7·8	5·2	3·1	37·1
Cuddalore . .	20	1·0	0·3	0·4	0·9	1·5	1·4	2·3	5·1	4·7	8·1	14·1	5·7	45·5
Madura . .	448	0·7	0·4	0·6	2·0	2·8	1·6	1·7	4·7	4·5	8·7	5·1	2·2	35·0
Mangalore . .	52	0·2	0·1	0·1	2·0	8·1	37·8	37·9	23·1	11·3	8·0	1·9	0·5	131·0
Cochin . .	11	0·9	0·7	2·1	4·4	12·7	30·7	22·7	12·4	9·4	12·1	5·1	1·9	115·1
Trincomalee .	175	6·2	2·4	1·3	1·6	2·2	1·9	2·2	4·2	4·6	8·9	13·1	13·2	61·8
Colombo . .	40	3·0	1·7	5·5	8·8	13·2	8·2	5·5	4·5	4·9	12·9	12·7	6·4	87·3
Galle . .	48	4·4	3·3	4·7	8·7	11·6	8·2	5·7	5·3	7·6	13·0	11·5	6·7	90·7
Rangoon . .	41	0·2	0·1	0·1	1·8	10·9	18·4	21·3	18·6	16·0	8·1	3·4	0·1	99·0
Moulmein . .	94	...	0·1	0·1	3·0	19·7	38·4	43·9	43·0	30·3	8·4	1·5	0·1	188·5
Thyet Myo. .	134	...	...	0·1	0·7	5·3	7·9	8·0	8·5	7·8	4·9	2·3	...	45·5
Tounghoo . .	169	...	0·2	...	1·5	6·6	13·4	17·5	18·1	11·8	7·4	1·4	0·2	78·1
Akyab . .	15	0·1	0·2	0·5	1·6	12·2	51·6	51·0	38·6	23·0	12·4	3·9	0·6	195·7

* Average for 80 years. C. Michie Smith.

special works must be consulted.* Attention must be directed, however, to the peculiar character of tropical rainfall as illustrated in India, *viz.*, its 'heaviness,' whereby the average fall of each rainy day at some stations is between 0·6 and 0·7 of an inch as compared with about 0·1 in climates like Great Britain. "In consequence," says Blandford, "of this character of Indian, in common with tropical rainfall generally, it is less penetrating in proportion to its quantity than in countries where much of it falls in a state of fine division, allowing time for its absorption by the ground. Instead of feeding perennial springs, and nourishing an absorbent cushion of green herbage, the greater part flows off the surface and fills the dry beds of drains and watercourses with temporary torrents. In uncultivated tracts, where jungle fires have destroyed the withered grass and bushy undergrowth, and have laid bare the soil and hardened its surface, this action is greatly enhanced; and while all perennial water supplies which depend on the absorbed rain are either greatly reduced or altogether suppressed, a rainfall which, if husbanded by nature and art, would suffice for the agricultural and domestic requirements of the population, is thrown into the nullahs and rivers, and not only is wasted and lost for any useful purpose, but by producing floods, becomes an agent of destruction. Under any circumstances, the character of the rainfall is hardly compatible with its economical storage and expenditure in any high degree: much more, therefore, than in temperate regions, is it incumbent on us to safeguard such provident arrangements as nature has furnished for the purpose."

SNOW AND HAIL.

When water vapour in the atmosphere becomes condensed at a temperature below freezing point it forms spicules of ice which may ultimately reach the earth as snow. The original ice-spicules combine to form snow

---

* Blandford, *opera cit.;* also, Indian Meteorological Memoirs, vol. III. "The Rainfall of India," and various other meteorological papers.

crystals, usually six-rayed, and these crystals becoming felted together form snow-flakes. Snow never falls save on the hills in Northern India. The snow-line is about 14,000 feet but snow may fall in abundance at a lower level, *e.g.*, Simla, 7,048 feet. In such a case, however, it soon melts, whilst above the snow-line there is always snow. In colour snow is really bluish, but as ordinarily seen appears white owing to the reflection and refraction of light by the myriads of crystals. Under great pressure it may become compacted into solid ice. One foot of freshly-fallen snow is said to be about equivalent to one inch of rain, a very rough approximation.

Hail is a term applied to two different phenomena. True hailstones consist of pieces of ice which may vary in size from minute pellets up to large masses weighing several pounds. A section of such a hailstone generally shews alternate layers of clear ice and compacted snow.* It is said by some to be formed by a soft hailstone, as described below, which originally comes from a great height, falling into a rain cloud from which it receives a coating of water, and is thereafter carried back by an ascending air current into higher regions where the water becomes frozen into clear ice: this process of alternate ascent and descent being repeated several times till finally the stones fall to the earth's surface as a shower of hail. In the tropics, there are sometimes terrific hailstorms, the stones being of sufficient size to inflict great injury.† Hailstorms are commoner at hill stations than on the plains, but are not so destructive as a rule, the usual size of the hailstones being that of small marbles.‡

The other form of hail is known as soft hail, and looks like small snow balls about the size of a pea. Its origin is

* *v.* illustration in *Nature*, 27th July 1893, p. 294.

† *E.g.*, Murree was this year (1893) visited on the 28th May by a storm of this nature. The hailstones were described as being the size of racquet balls, or about 1 inch in diameter, and are said to have rebounded from the ground to a height of several feet. Much damage was done to property. There are many worse storms than this on record. *v.* also Blandford's Ind. Met. *Vade Mecum*, p. 232, *et seq.*

‡ *v.* Blandford.

uncertain but it appears to be formed by the "larger ice particles in a deep ice cloud overtaking and adhering to the smaller ones."* It sometimes falls on the hills in India ; never on the plains. It is common in climates like that of Great Britain during cold dry weather in winter, whilst true hail falls there only in summer.†

Influence of Snow and Hail upon Health.—The only point of any importance in this relation is the part played by snow in cold climates. Loosely compacted snow, as when newly-fallen, contains in its meshes a very large amount of air : the snowy covering thus acts as an excellent non-conductor of heat, by which radiation from the ground at night is obstructed and the earth prevented from freezing. Such an action is of extreme value in preventing the destruction of the young crops of wheat, etc., which are sown just before the winter season in Great Britain.‡ In very cold climates, such as in parts of North America, advantage is frequently taken of such a protective covering by persons who are overtaken by a storm. With their hands they scoop out a hollow in the snow big enough for them to lie in and, having covered themselves with snow, are thus able to avert otherwise certain death from cold.

Estimation of Snow and Hail.—Already described under Rain, in the previous section.

Snow and Hail in India.—Any further details than those given above would be foreign to the scope of this book and must be sought for in special works.

ATMOSPHERIC PRESSURE.

It is necessary at the outset to distinguish carefully between the *pressure* and *weight* of the atmosphere, the former being that with which alone we are here concerned. It is only when the air is at perfect rest and undergoing

* Mill, *op. cit.* *Cf.* formation of rain-drops, p. 325.

† The term 'Sleet' is applied to a mixture of snow and rain. It is unknown in the tropics.

‡ There are few more striking sights than the carpet of tender green shoots which is seen to cover a field after the melting of snow, the earth being bare and free from vegetation before the fall of the snow.

no change of temperature that the pressure and weight are equal, and this is a condition never completely fulfilled; so that it may be said truly that we "know nothing accurately of the weight of the atmosphere, but only that it cannot be very different from the average pressure."* In reality the atmosphere is continually in motion, upwards or downwards, and undergoing contraction or expansion, whence it follows that the height of the barometric column, as explained afterwards, though "always a measure of the pressure of the air acting on it, is no longer an exact measure of its weight."†

The following explanation may help the student to understand clearly the meaning of the term pressure as used in hydrostatics generally. Take a book measuring 6″ × 5″ and place it flat on the table. On the top of the book let a weight of 60lbs. be placed and evenly distributed over the cover. Then across any page of the book there will be equal and opposite forces acting, which tend to bring the two parts of the book on either side of the page closer together. We may express any one of these forces either as a force simply, *viz.*, 60lbs., or as a force per unit area of the page, *viz.*, 2lbs. per square inch. The former denotes the total thrust across the page, the latter denotes the pressure. *Pressure*, then, is the *thrust per unit area.*

Now take the case of heavy fluids at rest. They exert a force or thrust across any surface with which they are in contact and this thrust is always perpendicular to the surface. Suppose a plane area, of a square inches, immersed horizontally in a heavy fluid at rest. The fluid will exert a force of, say, P lbs. across either face of this area. Over the area, then, or at any point in the area the pressure is $\frac{P}{a}$ lbs. per square inch. Now, the following propositions hold in the case of heavy fluids of uniform density, at rest.

(i) That the pressure is the same at all points in the same horizontal plane.

(ii) That the pressure increases uniformly with increase of depth below the free surface.

That air is a heavy fluid was first proved by Otto Guericke. The same is true of gases generally. Consider, then, a mass of gas contained in a closed vessel. Strictly speaking, the pressures at different points not in the same horizontal plane are not equal. If, however, the dimensions of the vessel are not very large, this difference will be very small and can be neglected. The pressure at all points will thus be equal and its value is called the *pressure of the gas.* This pressure is due, not to the weight of the gas, but to the *mass and motion of its molecules.* The molecules of a gas are constantly moving about with very large velocities on the average. If the gas is confined in a box, the molecules will be continually impinging on and rebounding from the sides. It is the blows thus given to the sides that cause the pressure.

In the year 1643, Torricelli, a pupil of Galileo, proved

* Blandford.

† *Ibid.*

by a simple experiment that the atmosphere exerts a certain pressure upon all objects. He knew from experience that if he took a tube open at both ends and, having plunged the lower end into a trough containing mercury, poured mercury into the upper end, the mercury would, by its own weight, run out through the lower end as fast as he poured it into the upper end. So he took a glass tube about 33 inches long and closed at the top, and, having filled it with mercury, he inverted it and plunged the lower end into the mercury in the trough. As a result he found that the mercury within the tube sank slowly till it stood almost exactly 30 inches above the level of the mercury in the trough and then ceased to fall.

From what has been said above it is evident that in such an experiment every point at the surface of the mercury must be at the same pressure, the only difference being that the mercury in the trough, but outside the tube, is subject to the pressure of the atmosphere, whilst that immediately under the tube is subject to the pressure exerted by the column of mercury within the tube, but not to the pressure of the atmosphere. Thus it is clear that the pressure exerted by the atmosphere on a given area is equal to the pressure* of about 30 inches of mercury, or 14·75 pounds *per* square inch.

Another way of proving the existence of this pressure is to take such a tube and, having exhausted it of air as completely as possible, to invert it as before in a basin of mercury. The fluid will at once enter the tube from below and continue to rise till it stands at about 30 inches above the level of the mercury in the basin, or in other words, until the pressures exerted by the atmosphere and by the fluid in the tube have been equalised. The actual height of the column of liquid which is 'supported' by the atmospheric pressure depends mainly upon the specific gravity of the liquid of which the column is composed. Therefore, if water is used instead of mercury the column

* or *weight*, for in this case they are the same.

of liquid will be about 34 feet instead of 30 inches. The principle of the common pump is simply the partial exhaustion by suction of the air in a closed tube, the lower end of which is inverted in water, so that on the pressure of the atmosphere being removed, the water rushes up the tube and is discharged.

Soon after Torricelli had made his discovery and furnished the explanation, a practical demonstration of the correctness of his theory was given by Pascal and his brother-in-law Perrier. The former argued that if Torricelli's explanation was the true one, then the column of mercury would stand at a lower level if the experiment was repeated at the top of a mountain, owing to the diminution in the depth of the atmospheric strata above the mercury and consequent lessening of the pressure. Accordingly, Perrier ascended a mountain about 3,500 feet high and, having repeated the experiment, ascertained that the column stood at about 26 instead of 30 inches, at that elevation. Since that time the pressure of the air has been constantly measured by means of an instrument constructed on this principle, which has received the name of barometer, and which may also be used, with certain precautions described afterwards, to measure the height of any place above sea level.

It was discovered by Dalton that a space filled with any gas or vapour is as a vacuum to any other gas or vapour. There is thus surrounding the globe an atmosphere of nitrogen, which exerts its own pressure upon the earth's surface, an atmosphere of oxygen, which exerts about one quarter of the pressure exerted by the former, an atmosphere of carbonic acid, small in amount and exerting but a slight pressure and, finally, an atmosphere of water vapour; all of which together make up the total atmospheric pressure. Of these, the water vapour is the most variable at any one part of the atmosphere, is that which differs most at different parts and, consequently, is that which is most influential in producing changes of pressure.

It was formerly assumed, and acted upon in reducing barometric observations, that the "pressure or tension of the water vapour in the air could be deducted from the total pressure and that the balance would be the pressure of dry air." This, however, has been shown to be a mistake. Hence, owing to the distribution of temperature, whereby the upper atmospheric strata are practically always cooler than those below, and to the fact that the water vapour by its friction communicates its pressure to the dry air with which it is intermingled, "although the separation of the pressures may indicate the proportions in which air and vapour contribute to the total pressure around the cistern of the barometer, the distinction has only a local meaning, and does not apply to the great mass of the superincumbent atmosphere."*

Attention has already been drawn to the fact that owing to its compressibility about one-half of the atmosphere lies between the earth's surface and a height of 15,500 feet, so that at the latter height the barometer stands at about 15 inches. At double this height, 37,000 feet,† the mercury would stand at 7 inches, and so on, till at 21 miles the mercury would stand at 0·5 inch. If Boyle's law‡ held good indefinitely, the atmosphere would have no definite limit. "It has however been proved that this law does not hold for gases of very small density, which behave like very light liquids and have a definite surface, so that the atmosphere has an upper limit beyond which the particles of gas do not stray.§

Changes in atmospheric pressure are mainly due to the effects of heat, but they are also brought about, especially indirectly, by the agency of water vapour. The great

---

* Blandford. *v.* Ind. Met. *vade mecum*, pp. 108—10 for fuller explanation.

† Reached by Mr. Glaisher in his memorable balloon ascent from Wolverhampton in England, 5th September, 1862. At a height of over 29,000 feet, Mr. Glaisher noted a reading of 9·75 inches, and became unconscious soon afterwards. His partner, Mr. Coxwell, believed that he saw the mercury standing at 7 inches, before the descent began.

‡ *The density of any gas is proportional to the pressure it supports.*

§ Mill, *op. cit.*, p. 101.

annual variations of pressure are easily traceable to the effect of the position of the sun's maximum heating effect varying with the season, but the causes of the minor and more local variations are less easy to trace. The important depressions which, in the tropics, give rise to cyclones are probably due, primarily, to excessive local heating of the air by the sun in a region well supplied with moisture. The effect of this is to produce an upward flow of air and, as has already been explained, this air cools as it ascends and part of the moisture condenses as rain. But, when the moisture condenses, heat is liberated which prevents the air cooling to the extent it would otherwise do, and so the upward current, instead of ceasing as it would do in dry air, continues and, if the supply of moisture is sufficient, becomes intensified, the barometric depression is increased, and a violent cyclone may be formed.

When we come to study the effects produced upon the human organism by changes in pressure, it is found that the subject has to be considered under three aspects, analogous to those under which temperature changes in their relation to health have been already discussed,* *viz.*, (1) the effect of a *sudden change* from a relatively low degree to a high degree of pressure and *vice versâ*; (2) the effect of a *gradual lessening* of the pressure; and (3) the effect of a *gradual raising* of the pressure.

Effects of rapid changes in pressure.—The human body, as is well known, is marvellously adaptable to changed conditions, provided that the changes are made at a reasonably slow rate. Conversely, when one or more important conditions to its vitality are suddenly and materially altered there is great risk of a shock fatal to the organism being sustained. Now the extreme variations in atmospheric pressure which take place at or near sea level amount to but a few inches rise or fall of the barometric column, such rise or fall occurring only within limits consistent with perfect health. But there are three chief occasions

---

* *v.* p. 289.

when human beings are liable to be subjected to sudden and violent alterations in pressure, *viz.*, in balloon ascents, in working under water in closed pneumatic chambers or *caissons*, and when working as divers at the bottom of the sea, either naked or clothed in a special dress or 'diving bell' communicating with the air by means of tubes. In balloon ascents, as noted before,* the pressure may be very rapidly lessened by as much as ten to twenty inches, and such lessening produces very serious and even fatal effects upon those who are exposed to it. In the case of men working in pneumatic tubes a wonderful increase of pressure can be borne with safety, *when gradual*, but if the pressure in the caissons be too rapidly increased or decreased, most serious symptoms, ending in some cases in sudden death, are set up. The explanations of these fatal results, so far as known, will be given under the next two headings.

Effects of Increased Pressure.—It is obvious that miners and others working at a great depth below the surface of the ground, carry on their labour under a constant increase of pressure, but it has not been proved that such amount of increase has any appreciable effect on their health. If anything, it probably increases their muscular power which, however, is apt to be seriously interfered with indirectly by adverse conditions of foul air, dampness, etc.

In pneumatic tubes the pressure generally varies between 2·5 and 4·5 atmospheres, which is, of course, largely in excess of any pressure occurring naturally.† When the men are subjected to a gradual increase and decrease of

* *v. f. note*, p. 341. In the ascent made by Messrs. Crocé-Spinelli, Sivel and Tissandier on 15th April, 1875, the balloon rose in two hours to about 26,000 feet and remained at 26,000—28,000 feet for two hours more. At the end of this period the two former were found suffocated with their mouths full of blood, and the sole survivor, M. Tissandier, became insensible.

† The pressure may be largely increased as a result of an accident in a coal mine, on board ship, etc., and many men may be confined in a small space. In one such instance, the air in a confined space in a coal mine was under sufficient pressure to drive a man out of the opening made by the relief party and kill him. The other men who had been shut up with him had suffered no serious inconvenience during their enforced captivity of several days, without food of any kind.

pressure on entering or leaving the tube no ill effects are observable. It is specially important that the return to a normal from a greatly increased pressure be slowly made; it should occupy twenty minutes to half-an-hour or longer. Divers also work under greatly increased pressures, and in their case there is the additional pressure due to water, which may amount to as much as 6 atmospheres. They are apt to suffer from pricking pains, hæmorrhages, tinnitus and deafness, etc., and in serious cases become paralysed, owing to extravasation of blood between the spinal cord and its membranes.

Therapeutically, compressed air has been tried in the form of 'compressed air baths' for various pulmonary complaints,* the apparatus consisting of a strong, circular chamber made of metal in which, after the patient is seated, the pressure can be raised to the desired extent by pumping in air. A pressure equivalent to an additional 0·4 to 0·6 atmosphere above the normal is generally employed. Besides minor symptoms, the following effects are produced upon the respiratory system. The frequency of the respirations falls to about twelve per minute, whilst the pulmonary capacity and the amplitude of the respirations are increased. An extra quantity of oxygen is inhaled and the excretion of urea and carbonic acid is increased. It is further stated that if the patient is suffering from any pulmonary complaint attended with difficulty of breathing, there is marked improvement in the ease and quality of the respirations, particularly in the case of emphysema. Of course, in these cases the pressure is increased and lessened very gradually, about twenty minutes being allowed for each change. The chief physiological effect of increasing the pressure appears to be that the blood is driven inwards, so to speak, whereby the superficial parts become relatively bloodless whilst the internal organs are congested to a degree corresponding to the excess of the external pressure above the normal.

* v. Paper by Dr. C. Theodore Williams in B. M. J., 15th April, 1885.

Effects of Lessened Pressure.—The exact nature of the effects produced by a gradual lessening of the atmospheric pressure has been much disputed and so, for the purpose of settling the matter as far as possible, Mr. Whymper, the well known alpine climber undertook, about the year 1880, an arduous journey to the mountainous interior of Ecuador, in S. America, in order to see 'whether human life can be sustained at great altitudes above the level of the sea in such a manner as will permit of the accomplishment of useful work,' as opposed to the mere possibility of existence for a short time.*

The three points investigated were as follows :—(1) At what pressure were any unusual effects noticeable ; (2) What was the precise nature of these effects ; and (3) Was it possible to become habituated to these effects ? At a pressure of 16·500 inches (16,664 feet) the three explorers were quite incapacitated for work and found themselves 'preoccupied by the paramount necessity for obtaining air.' Special stress is laid on the fact that such incapacity for work was neither due to exhaustion nor to deficiency of bodily strength, nor to weakness from want of food, but was caused by the whole attention being taken up in efforts to get enough air. The attack was very sudden, the chief symptoms being laboured and gasping respiration, intense head-ache and an 'indescribable feeling of illness' throughout the whole body : in addition, there was feverishness and a marked acceleration of the pulse. The attack gradually passed off. Mr. Whymper concludes that his party became *somewhat habituated* to low pressures, as evidenced by an improved rate of speed during the later journeys.† He finds, however, that the

* "The most opposite statements and opinions have been advanced concerning this matter. The extremes range from saying that fatal results may occur, and have occurred, from some obscure cause, at comparatively moderate elevations, down to that no effects whatever have been experienced at the greatest heights which have been attained." *Travels Amongst the Great Andes of The Equator*, Whymper. The original work is full of interest and should be read by all concerned with this important question.

† It is noteworthy that an extra member of the party, who was with

rate of progress is materially affected at a pressure of 21 inches (9,850 feet), a fact which must affect 'all calculations which may be made on the basis of higher pressures either in respect to the marching of troops, transport of animals, the labour of the navvy, or any other description of muscular exertion.'

He divides the effects produced into two classes :—(1) *transitory*, and (2) *permanent*. Under the former head come increased pulse-rate, increased body temperature, and pressure on the blood vessels [rise in blood pressure?] : under the latter, increase in frequency and altered character of the respirations, loss of appetite and loss of muscular power. The Temporary symptoms he ascribes very reasonably to the expansion of gaseous matter within the body, the result of diminished external pressure, these symptoms dying away on the establishment of equilibrium between the internal and external pressure.* From the Permanent effects, the direct result, no doubt, of the rarefaction of the air, there is no escape. At a pressure of 14·750 inches (19,600 feet) it is possible to sustain life while at rest, by breathing through the wide-opened mouth, but any attempt at movement, entailing a further demand for air, makes it almost impossible to breathe at all.

At lower elevations, such as 3,000—8,000 feet, between which extremes most Indian hill stations are situated, various temporary effects are noticeable;† but in the healthy these soon pass off and great exertion can be undergone

---

them during their first attack and who had lived for many years in Ecaudor, did not suffer at all. He did not ascend, however, above 17,000 feet. None of the party suffered at any time from the so-called *mal-de-montagnes* or mountain sickness, complained of by many travellers, and upon which great stress has been laid by some. For an account of the symptoms and other details of this supposed malady, and references to Indian literature on the subject, *v.* Hirsch, *Handbook of Geog. and Hist. Path.*, Vol. II., p. 503, *et. seq.*

* In the case of aeronauts the lessening of the pressure is so *rapid* that violent hæmorrhage, with suffocation, is apt to supervene and cause a fatal result.

† The most prominent is, naturally, 'want of breath' on first arrival. In some cases there is disorder of the cerebral circulation with giddiness, deficient accommodation, etc.

with pleasure and safety. Persons suffering from advanced heart disease* or from a liability to hæmorrhage from any of the mucous surfaces should on no account be permitted to ascend above 3,000 feet; for such, a sea voyage or a change to a colder climate is in every way more suitable.

The subject of the effects produced by lessened atmospheric pressure upon healthy and sick persons is by no means thoroughly elucidated as yet,† but it is of immense importance, both on account of the great elevation of some of the Indian sanitaria and because of the chance of future military operations on the N.-W. frontier being carried on at still greater altitudes.

Barometers.—As mentioned before, the instrument invariably used for measuring the atmospheric pressure at meteorological stations is known as the Barometer. There are two chief classes of barometer, the *mercurial* and *non-mercurial*, the former being much the more important. Every mercurial barometer is essentially a modification or adaptation of the tube and basin of mercury used by Torricelli in his famous experiment. In some cases a U-shaped tube is used, in which one leg is only about $\frac{1}{8}$ as long as the other and open at the end. There is, of course, a 'Torricellian vacuum' between the upper level of the mercury and the closed end of the long limb, the space so left containing nothing but a little vapour of mercury. As the pressure rises the mercury is depressed in the short limb and raised in the long limb, and *vice versâ*. Two readings must always be taken, *viz.*, the height of the mer-

* A case occurred not long ago at a hill station about 8,000 feet above sea level, in which a lady, newly arrived, suffered from almost continuous fainting fits on the smallest exertion, such as walking across a room, and was only kept alive by the constant administration of cardiac and other stimulants.

† A most elaborate series of experiments upon himself and other human beings and upon the lower animals, was carried out by the late Paul Bert, the distinguished French scientist. An account of these is given in his book *La Pression Barometrique*, a summary of which will be found under appendix J. in Mr. Whymper's book. He strongly recommended the carrying of oxygen for inhalation when at great heights. Hitherto its bulkiness has prevented this being done, but it is quite possible that it may some day be rendered easily portable in large quantity.

cury in both limbs. This form is known as the Siphon barometer and resembles the mercury manometers used in physiological experiments to measure blood pressure, etc. It is a good form of barometer, and is especially adapted for use in mountain ascents. Owing, however, to the necessity for a double reading it has been almost completely replaced by the instrument next to be described. When a siphon barometer has to be moved, the upper end is gently lowered so that the mercury in the long limb rises to the top and that in the short limb passes beyond the bend into the long limb. In this way air is prevented from passing up so long as the instrument is carried in the proper position.

The standard barometer on Fortin's principle is that now in general use in India. It consists essentially of a glass tube, about 34 inches in length, closed at the top and filled with pure mercury (spec. grav. 13·594). The lower end of the tube is open and dips into a cup containing mercury, the cistern. The tube is placed exactly vertical, so that the mercury stands at a height between 27 and 31 inches above the mercury in the cistern, according to the changes in the atmospheric pressure from time to time; the instrument being at or near sea level. The space above the mercury is a 'Torricellian vacuum' as in all ordinary barometers.

It is said above that the total length of the column is *measured** from the upper level of the mercury in the cistern and as, during changes in the mercury level in the tube, mercury must enter or leave the cistern it is obvious that the level of the mercury in the cistern undergoes changes related to those in the column. This may be compensated for (1) by a so-called 'capacity correction'; (2) by a pliable cistern base; (3) by a contracted scale; or (4) by dispensing with the use of a cistern altogether and employing a siphon barometer as previously described. Of these the second method is the most important for our purpose and is that invented by Fortin. By the use of a cistern, of which the bottom is formed of a bag of leather or of a

* N. B. not *read*. *v.* p. 351, line 9.

solid, but movable, piston the cistern level is adjusted to a *constant point* which is the zero of the scale (Pl. xvi.) This constant point or zero of the scale is generally a pointed ivory stud, its tip being known as the *fiducial point.* To 'set' the barometer, before taking a reading, the level of the mercury in the cistern is adjusted by means of the thumb screw at the base till the fiducial point and its reflection in the mercury *exactly meet.*

The tube is mounted in a brass* case suspended vertically from a hook at the top of a mahogany board, whilst at the lower end of this board is a socket or ring with clamping screws to steady the barometer during the time a reading is being taken. To the front of the case a thermometer is attached.

The scale is engraved with great accuracy on the case, in inches and divisions of an inch, and attached to the case at its upper part is a movable dividing scale, controlled by a rack and pinion, and called, after its inventor, the *Vernier.* The principle of the Vernier scale is as follows. Each inch on the fixed scale engraved on the case is divided into tenths (0·1) and half-tenths or twentieths (0·05), and the Vernier scale is so divided that 25 of its divisions are equal to 24 of the smallest divisions on the larger scale. In other words, each vernier division is $\frac{24}{25}$ of these latter, *i.e.,* it is $\frac{1}{25}$ smaller. Now $\frac{1}{25}$ of $\frac{1}{20} = \frac{1}{500}$ or 0·002 inch and this is the value of each of the smaller divisions on the vernier scale. For convenience sake, however, there are engraved upon it at proper intervals, larger divisions corresponding to $\frac{1}{100}$ or 0·01 inch. Thus the fixed scale and the vernier are usually graduated as follows :—

Every long line	cut on the barometer	a tenth	(0·100)	of an inch
,, short ,,	scale corresponds to	,, five hundredth	(0·050)	,,
Every long line	cut on the vernier	,, one hundredth	(0·010)	,,
,, short ,,	scale corresponds to	,, two thousandth	(0·002)	,,

* "Brass is considered the best material, because its coefficient of expansion by heat is well known; and this is very important, as the tables for correcting barometer readings for temperature, founded upon the coefficients of expansion of mercury, glass, and brass, always give identical results with such barometers, although the nature of the alloy forming the cases may not in all instances be exactly similar." *Official Instructions in the use of Meteorological Instruments,* Scott.

By such an arrangement the barometer can be read accurately to 0·002 of an inch.

In reading the vernier the two primary essentials are that the barometer shall hang vertically and be placed in a good light. The milled head of the pinion is turned till the *lower* edges* of the vernier are exactly on a level with the convex top of the column of mercury, so that the front edge of the vernier, the *middle* and *uppermost* point of the column and the back edge of the vernier are on the line of sight.† The eye of the observer must also be exactly on a level with the top of the mercury column, otherwise the reading will be incorrect. If, when this has been done, the lowest line on the vernier exactly corresponds with one of the divisions on the fixed scale, the last line of the vernier will correspond also with another division, but none of the other divisions will so correspond, and the reading is made direct from the fixed scale and may be, *e.g.*, 29, 29·6 or 29·65 inches. If, on the other hand, *e.g.*, the eighteenth division on the vernier is the first to correspond exactly with a division on the fixed scale, then the fixed scale is read to tenths and five hundredths of an inch, say 29·650, and to this is added 0·002 × 18 = 0·036 inch‡; the actual reading of the barometer being thus 29·650 + 0·036 = 29·686 inches. It is thus evident that as the vernier divisions are followed upwards, 0·002 inch is lost for every vernier division as compared with the divisions on the fixed scale, till the fractional excess of the mercury column above 29·650 inches has been lost;

* In some barometers the 25 divisions on the vernier correspond to 26 of the smaller divisions on the fixed scale, instead of 24, so that each vernier division is $\frac{1}{25}$ *larger* than the others. In this case the vernier is read downwards instead of upwards, from its own zero.

† If the vernier edge is brought too low, instead of being tangential to the column of mercury, it will correspond with a chord of the curve made by the convex surface of the mercury. The reading is much facilitated by a piece of white paper placed behind the tube so as to reflect the light, and at night by a candle held at the side, for as short a time as possible.

‡ *i.e.*, if the long lines on the vernier scale are disregarded. If these, each of which is equal to 0·01 inch, are counted, it will be found that there are 3 below the division containing the eighteenth short line. Add therefore, 0·01 × 3 = 0·03 to the reading on the scale, and then 0·002 × 3 = 0·006, *i.e.*, altogether, 29·650 + 0·030 + 0·006 = 29·686.

when the marks on the two scales must correspond. The above will be easily understood by a reference to the diagrams in plate xix. or, better still, by practising the reading of a barometer itself, if access can be had to one.

In making use of the barometer it is necessary (1) to set the instrument; (2) to read it; and (3) to apply certain corrections to the observed readings.

To set the barometer, (*a*) read the attached thermometer; (*b*) adjust the mercury in the cistern,* so that the fiducial point and its reflection exactly meet, forming a double cone; and (*c*) set the vernier. It is then read, the setting and reading being done as quickly as possible, to avoid heating of the instrument by proximity of the observer.

Before the records of any barometer can be accepted as trustworthy it is necessary to ascertain that the proper corrections have been applied. Some of these corrections have reference to the special instrument employed, whilst others are applicable to all instruments used under the same conditions. The corrections of the former class are three in number, *viz.*, (1) for *Index Error*, (2) for *Capacity*, and (3) for *Capillarity*. As before explained, in barometers constructed on Fortin's principle, the mercury in the cistern is adjusted at each observation to the *neutral point*, so that there is no 'capacity correction' to be applied to the reading.† So also for siphon barometers there is no capacity correction, a double reading being taken instead; neither is there any correction for capillarity, if both legs of the siphon have the same diameter.‡

In a Fortin's barometer the 'index correction,' resulting from error in graduation, and the 'capillarity correction,' arising from the capillary action of the glass tube upon the mercury, are constant and are usually combined. The com-

* The barometer being kept exactly vertical by means of the clamping screws mentioned on p. 349. It is well to tap the tube gently before setting the vernier, and at least three different settings should be made for each reading.

† *v.* p. 348. ‡ *v.* p. 347.

bined correction may be positive or negative, but is usually negative.* These errors are ascertained by comparison with a standard barometer at Kew, Calcutta, etc.; the engraved scale being also compared with a standard scale.

The corrections applicable to the readings of all instruments are (*a*) for *Temperature*, (*b*) for *Altitude* above sea level. To a certain extent, a barometer acts like a thermometer, the mercurial column expanding (rising) or contracting (falling) with every rise or fall of the temperature. It is necessary, accordingly, to allow for this in comparing different barometric observations, and the difficulty is got over by applying to all readings a 'temperature correction,' whereby the reading is stated as if taken at a temperature of 32° F. That is to say, we subtract the increase in height of the mercurial column due to the difference between a reading taken at 32° F. and the observed temperature, say, 87° F. The correction is usually made by reference to special tables, but it can easily be applied from a formula. The necessity for applying a 'correction for altitude' is obvious from what has previously been said,† and, roughly speaking, the barometer reading falls about 0·001 inch for every foot above sea level.‡ All readings, then, taken at any station not more than 2,000 feet above sea level, are reduced to the value they would have at sea level and are so expressed. At places situated at a higher level than between 2,000 and 3,000 feet, and many Indian hill-stations are so situated, the pressure is that of a "stratum of the atmosphere, in which the relations of pressure are, at certain times, demonstrably different from those on the plains below. The reduced pressures of these stations are, therefore, not comparable with those observed on the plains."§

* The correction for index error may be positive or negative: the correction for capillarity is necessarily positive.

† *i.e.*, of course, when 'weather observations' are being made, in contradistinction to the calculation of the elevation by means of the fall in the mercury level.

‡ For the first 300 feet, when the air has a mean temperature of 90° F.; and by a greater amount for all lower temperatures. *v. post.* pp. 354-7.

§ Blanford. For further details as to the methods of applying these corrections, the works of Blandford and others must be consulted.

The only important non-mercurial form of barometer, and one which is extremely portable and very sensitive, is the Aneroid. This instrument consists essentially of a small, hermetically-sealed metallic box, exhausted of air as completely as possible, so that when the pressure of the atmosphere rises the top of the box is forced inwards, and when it falls the top is pushed outwards by means of a spring acting in opposition to the vacuum chamber. The changes in shape of the vacuum chamber are communicated by mechanism to a hand which indicates the increase or decrease in pressure on a graduated dial. These instruments do not, of course, indicate pressure absolutely and so have to be graduated experimentally. They are usually compensated for temperature by a special arrangement, and do not, therefore, require a temperature correction. Readings of the mercurial barometer, if compared with them, must first be reduced to 32° F. As a matter of fact, however, there is usually an error of some sort in the readings of an aneroid, and the instrument should be compared from time to time with a standard barometer.*

As with temperature, so with pressure, there are certain changes which are regular or *periodic* and others which are irregular or *non-periodic*, the former being known as *fluctuations*, and the latter as *undulations*. Thus, there is a diurnal fluctuation of the barometer in India, of a remarkably regular character. It is described later and is illustrated in plate XIX. There are also monthly and annual fluctuations. These periodic pressure changes bear a distinct relation to the temperature fluctuations before described.† The causes of the non-periodic changes are sometimes very easy and sometimes very difficult to trace. They are of extreme importance in connection with weather forecasts but do not specially concern us here.

---

* For further information on the great precautions necessary to obtain anything like reliable readings from aneroid barometers under greatly varying pressures, *v. How to use the Aneroid Barometer*, by E. Whymper.

† *v.* pp. 299, 300.

Barometric *charts* are much used in connection with weather reports. In these charts places with the same pressure* are connected by lines indicating equal pressure and termed *isobars.* As a rule, the isobars show differences of 0·1 inch in the pressure. The space enclosed within an isobar of lowest pressure is termed a *barometric depression* or *minimum,* and that surrounded by an isobar of highest pressure is named a barometric *elevation* or *maximum.* The rate at which the pressure falls between any two places is termed the *barometric gradient,* and is usually expressed by the distance in which the pressure falls 0·1 inch.† In Indian charts, however, as will be afterwards explained, very slight variations in barometric readings are so important that isobars are given for differences of 0·05 inch. Its value in any case is easily ascertained by measuring to scale on a weather chart the number of miles between, *e.g.,* an isobar of 29·95 and 29·85, or any others where the difference is 0·1 or 0·05 inch. Where the distance is small and the isobars relatively near one another, the gradient is said to be *steep* and *vice versâ.* Isobars are therefore strictly comparable to the contour lines used by surveyors and others to indicate points of equal altitude, the contour lines being closely placed or distant according as the gradient of the intervening ground is steep or the reverse. Examples of barometric charts illustrating the above points will be found in plate xx.

The Calculation of Heights by Means of the Barometer.—Pressure diminishes as we ascend above sea-level because the quantity of air above us becomes less; but not uniformly, because the atmosphere is less dense in proportion to elevation. The greater the height above the sea the greater must be the number of feet to be ascended in order to produce a given depression of the mercurial column. These facts are illustrated by the following table, which affords a rough method of measuring heights. The differ-

---

* *i.e.,* after the local barometer reading has been corrected and reduced to sea level.

† Sometimes, by the decrease in pressure per 100 miles.

ence between reduced readings before and after ascent gives the depression; and the number of feet corresponding is corrected for temperature by multiplying it by $1 + \frac{t + t' - 64}{900}$, t and t' being the temperatures of the points left and reached.

TABLE FOR ROUGH MEASUREMENT OF HEIGHTS.

Depression of Mercury in Inches.		Ascent in feet.
From	To	
31	30	857
30	29	886
29	28	918
28	27	951
27	26	986
26	25	1,025
25	24	1,068
24	23	1,113
23	22	1,161
22	21	1,216
21	20	1,276
20	19	1,341
19	18	1,413

As this method assumes that temperature and pressure remain constant at each point during the ascent, it is obviously unsuited to cases where accurate measurement is required. For this purpose precisely simultaneous readings of two good barometers, at the two points the difference between whose heights above sea level is to be ascertained, are desirable. If this is impracticable the barometer should be carefully compared before starting and after return with that in the nearest Meteorological Station, and the regular observations made at the latter compared with the traveller's. Besides noting the attached thermometer for reduction, the indications of an accurate thermometer freely exposed in the shade are to be recorded.* If the places are only a few miles asunder, two or three readings are generally sufficient; if the interval be considerable, half-monthly means should be compared. From these data and the Table following differences in height can be calculated with almost absolute accuracy.

TABLE FOR CALCULATING HEIGHTS.

Barometer reduced.	Height in Feet.	Difference.	Barometer reduced.	Height in Feet.	Difference.	Barometer reduced.	Height in Feet.	Difference.
22·0	9,347	124	25·0	5,863	109	28·0	2,774	97
22·1	9,223	123	25·1	5,754	108	28·1	2,677	97
22·2	9,100	122	25·2	5,646	108	28·2	2,580	96
22·3	8,978	122	25·3	5,538	108	28·3	2,484	96
22·4	8,856	122	25·4	5,430	107	28·4	2,388	96
22·5	8,734	120	25·5	5,323	106	28·5	2,292	96
22·6	8,614	120	25·6	5,217	106	28·6	2,196	95
22·7	8,494	120	25·7	5,111	106	28·7	2,101	95
22·8	8,374	119	25·8	5,005	106	28·8	2,006	94
22·9	8,255	119	25·9	4,899	105	28·9	1,912	94
23·0	8,136	118	26·0	4,794	105	29·0	1,818	94
23·1	8,018	118	26·1	4,689	104	29·1	1,724	94
23·2	7,900	117	26·2	4,585	104	29·2	1,630	93
23·3	7,783	117	26·3	4,481	103	29·3	1,537	93
23·4	7,666	116	26·4	4,378	103	29·4	1,444	92
23·5	7,550	116	26·5	4,275	103	29·5	1,352	92
23·6	7,434	115	26·6	4,172	102	29·6	1,260	92
23·7	7,319	115	26·7	4,070	102	29·7	1,168	92
23·8	7,204	114	26·8	3,968	102	29·8	1,076	91
23·9	7,090	114	26·9	3,866	101	29·9	985	91
24·0	6,976	113	27·0	3,765	101	30·0	894	91
24·1	6,863	113	27·1	3,664	100	30·1	803	90
24·2	6,750	113	27·2	3,564	100	30·2	713	90
24·3	6,637	112	27·3	3,464	100	30·3	623	90
24·4	6,525	112	27·4	3,364	99	30·4	533	90
24·5	6,413	111	27·5	3,265	99	30·5	443	89
24·6	6,302	110	27·6	3,166	98	30·6	354	89
24·7	6,192	110	27·7	3,068	98	30·7	265	89
24·8	6,082	110	27·8	2,970	98	30·8	176	88
24·9	5,972	109	27·9	2,872	98	30·9	88	88

* In practice this temperature is best got by swinging a thermometer rapidly round at the end of a string 2 or 3 feet long till it reaches a steady temperature. The thermometer used has a glass ring at one end to allow of its being attached to a string and is known as a *thermomètre à fronde* or 'sling' thermometer, and the temperature so obtained, after a few swings of the instrument, is very nearly accurate.

The following example (taken, with the table, from Mr. Pogson's *Meteorological Reduction Tables*) will explain the method of procedure. The barometer indications having been reduced to 32°, the difference between the corresponding heights, as found in the table, is corrected for temperature; the correction factor being the sum of the shade temperatures at the two places and 900, divided by 1,000, which is multiplied into the tabular difference between the heights. Thus, at Yercaud on the 27th March 1869, Captain Edgcome, R.E., took three observations, at 9-30 A.M., 12-30 P.M., and 4-30 P.M. The reduced readings and corresponding temperatures in shade were—

25·42	25·41	25·33
74°·00	76°·50	77°·00

The means were 25·387 and 75°·8. By applying suitable corrections to the observations made at Salem on the same day the reduced mean barometer reading for the same hours was found to be 28·987 and the corresponding temperature 97°·1 F. We have therefore for comparison—

	Barometer.	Thermometer.
Yercaud	25·387	75°·8
Salem	28·987	97°·1

The corresponding heights as found from the Table are 5,444 and 1,830 feet* giving a difference of 3,614. The sum of the temperatures, *plus* 900, is 1072·9; giving, when divided by 1,000, a correction 1·0729. This multiplied by 3,614 is 3,877 feet, the height of Yercaud above Salem.

Atmospheric Pressure Changes in India.—In the same way as the mean daily temperature is obtained from the readings of thermometers with a certain correction applied, the Mean Daily Pressure of the Atmosphere is deduced from the recorded barometric readings at 8 A.M., 10 A.M., and 4 P.M., and the application of certain corrections.

* In the Table 25·3 corresponds to 5,538, from which is subtracted 0·87 of 108, the number found in the "difference" column. 87 × 1·08 = 93·96; which, taken from 5,538 leaves 5,444·14. So 28·9 gives 1,912 — 0·94 × 87 = 1,912 — 81·78 = 1,830·22.

This method is not applicable except at stations where the average value of the readings has been already ascertained for several years: in other cases the true mean daily pressure can only be found by dividing the sum of the hourly readings by 24. The Mean Monthly or Half-Monthly Pressure and the Mean Annual Pressure are obtained in the same way as the corresponding temperature means.* As the interest of barometric observations, except at great altitudes, is chiefly confined to weather forecasts and the physics of the atmosphere it is not necessary to discuss their significance in detail here. One marked peculiarity in this country is the *smallness of the variations* in the readings except under very exceptional conditions. The Diurnal fluctuation is remarkably regular and is as follows: From 4 A.M. till 9-30 A.M. the pressure rises to its maximum; falls till about 4-30 P.M.; rises again till 10 P.M.; and, finally, falls till 3 or 4 A.M. The whole change only amounts to about 0·1 inch, and bears no relation to the prevailing weather. Its importance arises from the fact that the changes or undulations due to alteration in the weather are in themselves of very small amount in India and mistakes will arise unless the diurnal fluctuation is discounted. The Annual fluctuations of the pressure in different parts of India only amount to about 0·1 inch to 0·6 inch, proceeding upward from Ceylon to the Punjab.†

From what has been said above, and previously, it follows that until the 'average value' of any place has been fairly well ascertained, a single reading of the barometer will not give any trustworthy information regarding the weather. In other words, the elevation at which the cistern of the barometer hangs must be known to within a foot or two, the daily and seasonal fluctuations allowed for, as also the daily change in temperature, which may amount to between 30° and 40° F. and affects the barometer reading to a corresponding degree. In addition, of course, the

---

* *v.* p. 301.

† *v.* Table of average monthly readings at various stations. Blandford, *op. cit,* Appendix I.

necessary index and capillarity or other corrections peculiar to the instrument must also be applied. Supposing that all such data are available and have been made use of, a fall of *e.g.*, 0·3 inch below the average of the time and place is strongly indicative of very disturbed weather and it is only in violent cyclones and in the vicinity of the storm's centre that this amount is very greatly exceeded. In the centre of such a storm the pressure may rapidly fall 2 inches below the average of the place and time of year.*

Of much greater value than the information afforded by a single reading at one time and place, is that now made available by means of telegraphic weather reports from various parts of India. By this latter means a very correct idea of the existing pressure conditions over the Indian Empire at any time can be obtained. "Primarily," says Blandford, "it is some difference in the pressures of different parts of the country and the surrounding seas that determines the course of the winds, and it is the character of the winds as damp or dry that determines that of the weather. The place where the pressure is least, or in other words, where the barometer stands lowest, is usually termed a *barometric depression* or *minimum*,† and the immediate neighbourhood of this depression is the place where rain is most likely, and where it falls most abundantly. The last statement is, indeed, not to be taken without some qualification, but the exceptions are readily recognisable: as a general rule, the maxim holds good."

CIRCULATION OF THE ATMOSPHERE—WIND.

It would be beyond the scope and object of this work to discuss in any detail the causes and nature of the various movements of the atmosphere classified under the generic name of wind. Only the merest outline of the subject can be given here: for fuller information, the student must consult special works.‡

---

* Blandford. † *v.* p. 354, and p. 363.

‡ Mill, *op. cit.*; *Elementary Meteorology*, R. H. Scott; Blandford *opera cit.*; *Popular Treatise on the Winds*, W. Ferrel; *etc.*, *etc.*

As before mentioned, variations in the atmospheric pressure depend primarily on temperature changes and, to a lesser degree, on the amount of water vapour present at any given time, whilst the pressure variations themselves are the immediate cause of the movements of the air known as winds. Winds have been classified as (1) Permanent Winds, (2) Periodical Winds, and (3) the Variable Winds of high latitudes. It is those of the second class, the so-called periodical winds, which chiefly concern us here.

The general circulation of the atmosphere is brought about as follows: In the intertropical region, extending from about lat. 20° N. to lat. 20° S., and especially over the region of the equator, the air is constantly being strongly heated by solar radiation* and, as a consequence, the pressure is diminished and the heated air rises.† At the polar regions, on the other hand, the air receives but little heat from solar radiation whilst a large amount of heat is radiated into space during the long dark winter period. Here, consequently, the air becomes chilled and

---

* *v* p. 286.

† "If we imagine a column of air confined in a chimney, *extending above the limit of the atmosphere*, and, therefore, only able to expand in a vertical direction, and if we apply heat from below, the total weight will be unchanged, as no air can escape from the chimney laterally; while at any section taken above the base, a greater amount of air will be above that level when the column is heated than when it is at its ordinary temperature, and the pressure at such upper section will be increased. We can prove that this action really goes on in the atmosphere by the following comparison of the monthly mean readings at different levels in winter and summer:

Place.	Elevation, Feet.	Pressure. January, Inches.	Pressure. July, Inches.	Difference, Inches.
Geneva	1,335	28·66	28·66	0·00
Great St. Bernard ...	8,174	22·11	22·39	0·28
Col. St. Théodule ...	10,899	19·77	20·16	0·39

This shows that while at the lowest of these stations the pressure was the same in January as in July, the increase from the former to the latter month was augmented with the altitude of the station, and at the level of 11,000 feet was as much as 0·39 inches, nearly $\frac{1}{50}$ of its total amount." Thus, "the atmosphere will stand highest over the equatorial regions, as the district where the air is most expanded by the action of heat, *etc.*, and accordingly the pressure in the upper levels in low latitudes will be greater than at an equal elevation above the earth's surface in high latitudes." Scott, *op. cit.*

denser, and descends towards the surface. As a result of the heating and expansion of the air at low latitudes, near the equator, the pressure at the upper level of the atmosphere is relatively high and, conversely, at high latitudes the pressure of the upper levels is relatively low. Now, the atmospheric pressure is constantly *tending* to attain an equilibrium. Consequently, the heated upper strata of air from the equatorial region are set in motion towards the poles, blowing spirally as a W.S.W. wind in the northern hemisphere and as a W.N.W. wind in the southern hemisphere, whilst the cooler and denser air from the polar regions tends to be driven towards the equator as a N.E. wind in the northern hemisphere, and a S.E. wind in the southern hemisphere.

The above may be called the theoretical circulation of the atmosphere. From observation it has been ascertained that the upper currents descend to the surface of the earth at about lat. 20°—30° N. and S., the result being an increased pressure and the production of a region of calm* at these latitudes in both hemispheres—the calms of Cancer and Capricorn. From the regions of these calms, the Trade-Winds, as they are called on account of their steadiness of direction, blow towards the equator. Their primary courses are southward in the northern hemisphere and northward in the southern; but as they reach in succession parts of the earth's surface which rotate eastwardly with greater velocity than that with which they, moving eastward at the rate of circumpolar rotation only, are travelling, they are, as it were, left behind by the intertropical surface, with the apparent effect of making them north-easterly in the northern and south-easterly in the southern hemisphere. Near the equator is the zone of calm, of varying degrees of width according to the season, termed in former days the *Doldrums*, and much dreaded by sailors on account of the absence of wind and resulting loss of time and probable ill-health of the crew.

* With exceptions where the conditions are disturbed by local heating of the earth's surface.

Thus there is a central or equatorial region of calm towards which the N.E. and S.E. trade winds blow, whilst beyond these latter come the tropical belts of high pressure, the calms of Cancer and Capricorn, as before explained. "The tropical regions swept by the equator-seeking (trade) winds are windy, hot, cloudless, but the scene of great evaporation from the hot sea surface. The narrow equatorial belt of low pressure into which the equator-seeking winds blow from north and south is also a region of calm. The air as it ascends here expands, cools, and the enormous supply of vapour swept in from the tropics, condenses into the heaviest cloud, and falls as deluges of never-ceasing rain. The heat liberated by the condensation of so much vapour strengthens the equatorial up-draught. The equatorial belt of low pressure always lies nearly under the vertical sun, consequently in the northern summer it swings to the north, and in the southern summer it swings to the south, displacing the belts of tropical high pressure northward and southward alternately. For reasons which cannot be explained here, this displacement is comparatively slight, extending over only five or six degrees of latitude. All parts of the earth's surface that the equatorial rain-belt traverses in its annual movement experience a rainy season as it lies over them, and a dry season all the rest of the year, when swept by the equator-seeking winds. Near the equator, where the narrow rain-belt crosses a tract of the earth both in its northward and in its southward swing, there are two wet and two dry seasons in the year. The theoretical circulation of the air and its resulting climates are affected by two causes, unequal heating of the air by land and sea surfaces, and the deflection of the prevailing winds by plateau edges and mountain ranges. Consequently, regular zones of surface winds and climates are found only in great expanses of ocean, and do not appear in narrow seas or on land."*

Cyclones have already been alluded to in connection

* Mill, *op. cit.*

with the subject of atmospheric pressure. The term was formerly used to denote a particular kind of storm of great violence occurring chiefly within the tropics. At the present time, however, it is applied to denote the system of winds round a barometric depression—a *cyclonic system*—the reverse condition, the system of winds round a barometric maximum, being termed an *anticyclonic system.* The term, which literally means a circle, is rather misleading for it is now known that the wind blows in *converging spirals* towards the region of low pressure, its strength depending on the steepness or the reverse of the pressure gradient.* In the northern hemisphere the direction of the spirals is opposite to that of the hands of a watch, in the southern hemisphere the direction is the same. In spite of the fact that the air is rushing towards the centre of the cyclone, the latter remains the point of lowest pressure, and thus it is evident that the air must rise in the centre and flow out above, so that above the cyclone, there is an anticyclone of high pressure with outward flowing winds. In an anticyclonic system the conditions of things is exactly reversed, both as to the direction of the wind and the relations of pressure. From the upper regions of the atmosphere air moves in and sinks downward to supply the place of that passing out as surface winds, so that the pressure above the barometric maximum of the anticyclone is relatively lower than the pressure in the neighbouring upper regions of the atmosphere. In an anticyclone the winds are usually light and variable and the weather frequently pleasant.

Of other winds, the so-called south-west and north-east monsoons, land and sea breezes, etc., the consideration must be left till the section on wind observations in India.

Effect of Wind upon Health.—The influence upon health exercised by winds is a dual one and is divisible into (1) Its general influence upon a community; and (2) Its influence upon individual human beings.

---

* v. p. 354.

Under the former heading comes the General Action of the wind whereby the air in a town or other place is prevented from stagnating, the polluted air being replaced by pure air. In other words, the 'external ventilation' of any place is chiefly carried on by this means, aided, of course, by circulation, etc., as before described.* With regard to the relationship between wind and the increase or decrease of certain diseases, there is little doubt that under varying circumstances the latter may be diffused by this agency or, in some cases, may be dissipated. Many diseases, such as malaria, cholera, small-pox, plague, influenza, etc., are stated to have been so spread, but the tendency of modern investigation is to show that the statements are wanting in accuracy and that the intercourse of human beings, impure water, food and clothing, etc., are the real channels of infection.† There are strong reasons, however, for believing that in regard to two diseases, *viz.*, malaria and influenza, the movements of the air may play an important part in their diffusion.‡ On the other hand, there is no doubt that many diseases, *e.g.*, typhus fever and small-pox, are favoured in their spread by a stagnant condition of the air, whilst the epidemic may be held completely in check by free ventilation aided by the action of a strong wind bringing abundance of pure air to the infected spot.§

The effects of exposure to the wind in any Individual Case depend chiefly upon its velocity, temperature, and

---

* *v.* pp. 18-9. † *v.* Part III. Ætiology of Disease.

‡ The action of wind in directly spreading malaria is certainly very much smaller and less frequent than formerly supposed. It is only where people live near very malarious jungles or swamps, over which the wind blows frequently towards their habitations, that there are any solid grounds for believing in this method of infection. The old idea that the malarial poison could be carried for hundreds of miles by wind is certainly a mistake. In any case it is extremely difficlut to eliminate all the other possible means of communication of the disease.

§ "So convinced were the ancient Greeks of the beneficial influence of wind to combat disease, that at Girgenti (Agrigentum), in Sicily, the traveller is shown the artificial opening which Empedocles made in the rock to admit the Tramontana, or north wind, and thus to dispel the malaria arising from the plain below the city." S. & M., *op. cit.*, pp. 196-7. Curiously enough there is said to be a distinct increase in the number of cases of malarial fever in Sicily and S. Italy during the prevalence of the humidity. As a rule, the most important effect produced by its action upon the body is cooling. In a cold or temperate climate where people of necessity wear thick and abundant clothing there is little risk of any dangerous degree of *sudden* cooling of the body surface, *i.e.*, 'chill': if from poverty or other reason the body is insufficiently protected in such a climate, the person so exposed will probably suffer from some acute inflammatory condition, such as pleurisy, bronchitis, rheumatic fever, etc. In India the same thing may happen, especially during rainy weather, to those who are lightly clad or who sleep in a direct draught of cold damp wind. But the real and ever present danger throughout the tropics is that of sudden and violent chilling owing to the constant free action of the skin combined with the evaporation set up by the wind, whereby intense congestion of the abdominal viscera is rapidly brought about. This matter has already been alluded to* and it is difficult to exaggerate its importance. At all times of the year it is necessary to be on one's guard against the risk of chill, and most of all after exercise or at night time during the season when a cold, moist wind may begin to blow after some hours of still, sultry weather.†

It is questionable whether the custom of taking exercise before sunrise, on the plains of India, is a good one. Prior to the increase in temperature, which occurs very soon after the sun has risen, the air is usually very stagnant and without doubt is frequently laden with malarious or mephitic exhalations. Formerly this custom prevailed to

---

African desert wind or sirocco. This wind, however, is a warm and moist one when it arrives on the N. shore of the Mediterranean and it is probable that the rise in temperature and increased humidity resulting from its prevalence are the essential factors in increasing the amount of malaria. *v.* Hirsch, *op. cit.*, Vol. I., and references given therein.

* *v.* pp. 310 and 327.

† Young and healthy new-comers to the tropics are very apt to make light of this subject, whilst even their elders, who should know better sometimes laugh at the 'fuss' made about chill. It is the duty of all medical officers to explain carefully to the rash and thoughtless how great and real the danger is, yet how easily it can be averted by a little care and a few simple and by no means irksome precautions. *v. post.* Part II., Clothing.

a much larger extent than at the present time and numerous sudden and seemingly inexplicable cases of cholera, dysentery, fever, etc., occurred. Any old Anglo-Indian resident can recall many such instances, which are now, apparently, much rarer than in former years. Amongst natives it is still the general custom to rise very early and go outside to answer the calls of nature, clean the teeth, etc., and there is little doubt that many cases of diarrhœa, hepatic congestion, etc., result from their practice of going out before sunrise, clad in the scantiest of clothing, and exposing themselves to the risk of chill and the respiration of air laden with impurities. As soon as the sun rises the air is set in movement, both in a horizontal and upward direction, and then is the time for exercise, ablution, etc.

In certain parts of India, notably in Sindh and Cutch, a very fatal form of hot wind—the *simoom*—is apt to arise in the hot weather. During its continuance men and other animals are killed, apparently with great suddenness. Its origin and the manner in which it causes death are still quite uncertain, but it must not be confounded with the dust storms which are so common in Northern India. Careful investigation of the exact nature and effects of this phenomenon, more especially with regard to the statements as to its occurrence, etc., made by camel drivers and others, is much required.

The Estimation of Wind.—There are three main points to be noted in wind observations, *viz.*, (1) its *Direction*; (2) its *Velocity*; and (3) its *Pressure.*

To observe the Direction an instrument termed a *wind-vane* is used, which is simply a balanced lever, with one end broad, the other narrow. The latter points towards the direction from which the wind blows, *e.g.*, in a S.-W. wind it points towards the south-west. On the vane rod immediately below the vane is a fixed cross-bar, the extremities of which indicate the four cardinal points. The direction of the wind is judged by comparing the vane pointer with these fixed points. Great care is necessary in erecting a wind vane, otherwise its indications will certainly be rendered useless by the action of purely local currents of air. It should be fixed on the highest accessible point of a building or other structure, in as open a space as possible, and the cardinal points set by compass.* The indicator should be examined occasionally to see that its movements are perfectly free. Sixteen of the thirty-two points of the compass will be enough to note and register. They are registered by numbers, N. being 0 or 32 and S. 16, the odd ones being omitted. In ordinary Meteorological Stations observations are made at 8 A.M., 10 A.M. and 4 P.M.

The Mean Direction is generally calculated by adding together the number representing the points noted and dividing by the number of observations. If no two points observed differ by more than 16—in other words, if all the points, projected on a circle, are in the same semi-circle—this method may be used. Otherwise, the points observed should be represented on the circumference of a circle by marks in positions corresponding to the observations; when the eye can determine which part of the circle would gravitate lowest if the marks were weights, and this part indicates the mean direction. As, however, the varying velocity of the wind is not taken into consideration in the observations the determination of the mean direction is of little practical utility. In addition, the direction, as indicated by the wind vane, is much influenced by local conditions, *e.g.*, presence or absence of trees, the contour of the ground, etc.

To estimate the Velocity of a wind various forms of *anemometer* are used, the best known of these being Robinson's anemometer. It consists of a revolving vane with four crossed arms carrying four hemispherical cups of

* To the true, not magnetic, north. The declination of the compass is very small in any part of India, not exceeding 2°, and magnetic north is east of true north. This variation, small as it is, must not be disregarded, otherwise there will be a serious error in the average of a large number of observations. Blandford.

thin sheet copper. In the larger instruments the vane revolves with one-third of the velocity of the wind, but in every case the instrument, whether small or large, requires correction for friction, etc., and must be carefully compared with a standard anemometer. The revolving vane communicates its movement to a train of toothed wheels which, in turn, indicate the distance travelled on a dial. They usually register up to 1,000 miles. To read the anemometer it is necessary to subtract the previous reading from the total, and then, if the difference so obtained is divided by the number of hours or minutes since the last reading, the result will be the average rate per hour. To this reading the necessary correction must, of course, be applied. The small *air-meter* of Casella has already been referred to*; its principle is much the same, only it is a more delicate instrument and is used for recording the rate of movement through ventilatory openings, etc.

If there is no anemometer, a useful record of the approximate wind velocity may be kept for any place by the use of the so-called Beaufort scale, as here given, in much the same way as the amount of cloud is noted.

		Approximate velocity. Miles per hour.
Calm	0	... 0 to 5
Light Wind ...	1	... 6 „ 15
Moderate	2	... 16 „ 25
Fresh	3	... 26 „ 36
Strong	4	... 37 „ 52
Heavy	5	... 53 „ 80
Violent (hurricane)	6	... 80 and upward.

For recording the Pressure exercised by wind, numerous *pressure gauges* have been invented. One of the oldest and simplest, and one which has been lately recommended for general adoption, is essentially the same in appearance as a swinging sign-board, *viz.*, a plate or sheet of metal suspended vertically on bearings from a horizontal fixed

* *v.* p. 42.

bar, so that when the wind blows against its surface it swings backward; the angle which it thus makes indicating the amount of pressure, as originally determined by experiment. It is attached to a large vane which keeps it always facing the wind. Another form is that known as Osler's wind gauge, the essential part of which is also a metal plate behind which there are springs whose elasticity serves to measure the force of the wind. None of the instruments yet invented is free from error and it is further found that instruments varying in size or construction do not agree in their records. Another very important point is this, that during gales of wind when the estimation of the pressure is of the greatest importance, there are *sudden and great variations* in the pressure exerted both as regards its amount and direction. For example, a structure which is evidently stronger than a neighbouring one may be blown down, whilst the weaker one is left uninjured.

Besides the direction, velocity and pressure of the wind, the observer should note the times at which it begins and subsides, or suddenly changes its course; the direction of the changes; the point from which it blows steadily after alterations or fluctuations; the existence of currents in the upper regions of the atmosphere (shown by cloud-movements)*; the times when hot or cold winds set in and the points from which they blow; the connexion of weather—cloudy, rainy or fine—with the quarter from which the wind is blowing, or has been blowing for some time previously.

In daily weather reports the points usually given with regard to the wind are (1) The Mean Direction and (2) The Velocity in 24 hours. The actual discussion of wind observations is a complicated matter and cannot be further alluded to here. It should be noted that anemometers merely record the horizontal motion of the air and take no account of the important upward and downward motions due to convection, etc. Probably the most satisfactory method of recording the wind observations of any station

* v. p. 323.

is by a *wind-rose* which consists of a table or diagram constructed to shew the percentage proportion of the number of wind observations from sixteen points of the compass and sometimes also, the varying force of the wind. In other cases a table is given showing the Mean Monthly Resultant Wind Direction and Velocity. The *wind-resultant* is compounded of direction and velocity and gives the position which a body, freely moving under the influence of wind alone, would occupy after a given time. It is obviously most important for sanitary purposes; being capable, for instance of determining whether malaria or other material poison has been borne by the wind from one place to another. It requires, however, frequent observations and complicated calculations and is, unfortunately, rarely attainable.

Observations on the Wind in India.—The chief characteristic of the winds in this country is their prevailing lightness, though at times, of course, they may blow with tremendous violence during a cyclone or other storm. Owing, also, to the very various climatic conditions which are found between the limits of the Empire, almost every kind of wind may be encountered, such as very hot or very cold winds, very dry or very damp winds, special winds giving rise to dust storms, the peculiar wind known as the simoom, etc., etc., and not only so, but in certain localities when the annual ranges of temperature and humidity are very great, almost every variety of wind may be experienced in the course of twelve months. In a country like England, people naturally lay great stress on the direction from which a wind is blowing, *e.g.*, the east wind is practically always a cold wind, the south wind a warm wind, and so on, but in this country much more stress is laid upon the fact as to whether a wind is a land wind or a sea breeze, a wet wind or a dry wind, and the reason is obvious enough, for a wind in traversing the peninsula may keep the same direction approximately but completely change its character, whilst a sea breeze is always a cool wind whatever direction it blows from.

As with temperature, pressure, and humidity, so with the wind, there is a regular Diurnal Variation in its velocity, which at certain seasons is completely masked or obscured, but occurs at other seasons for days together. It follows very closely the daily temperature fluctuation, so that the air is stillest just before sunrise, after which a light breeze springs up and continues to increase till about 2 P.M., again declining towards evening *pari passu* with the temperature.

At places situated near the sea, this daily wind is most frequently a sea breeze, but not always so; it may simply be that the prevalent wind at that particular season increases in force as above described, but its direction, though slightly modified temporarily, may be seawards or, in fact, from any point of the compass. Sometimes a land wind at night alternates with the sea breeze during the day, the changes in direction occurring after well-marked morning and evening periods of calm. This is commonly the case during the intervals between the strong winds of the summer and winter monsoons, the alteration in direction being brought about, roughly speaking, by the relatively more rapid absorption and radiation of heat by the land surface as compared with the water.*

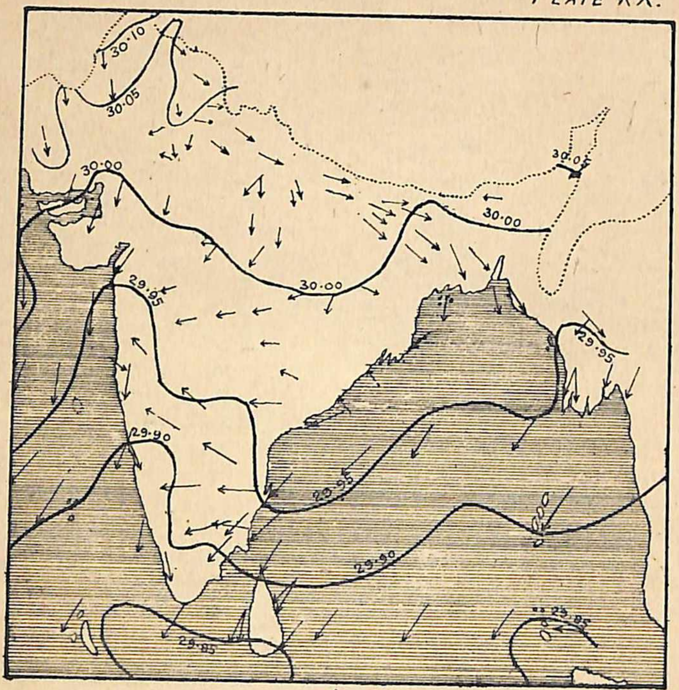
Two winds, common to mountainous countries, are met with in the Himálaya and other parts of India, and as they bear an important relation to health, they deserve mention. These are respectively the 'down-valley' and 'up-valley' winds. The former blows with great force where the valleys widen out into the plains and begins suddenly in the early morning after the period of calm. In the same way the up-valley wind blows strongly upwards, especially in the narrow mountain passes, during the afternoon hours, subsiding at sunset. As these winds blow with great regularity at certain seasons, the traveller, whether camping or marching, should be on his guard against receiving a chill when sleeping or when lightly clad.

* For explanations and diagrams illustrating this and other wind phenomena, *v. Met. Vade Mecum*, Part II., and Mill, *op. cit.*, p. 128, etc.

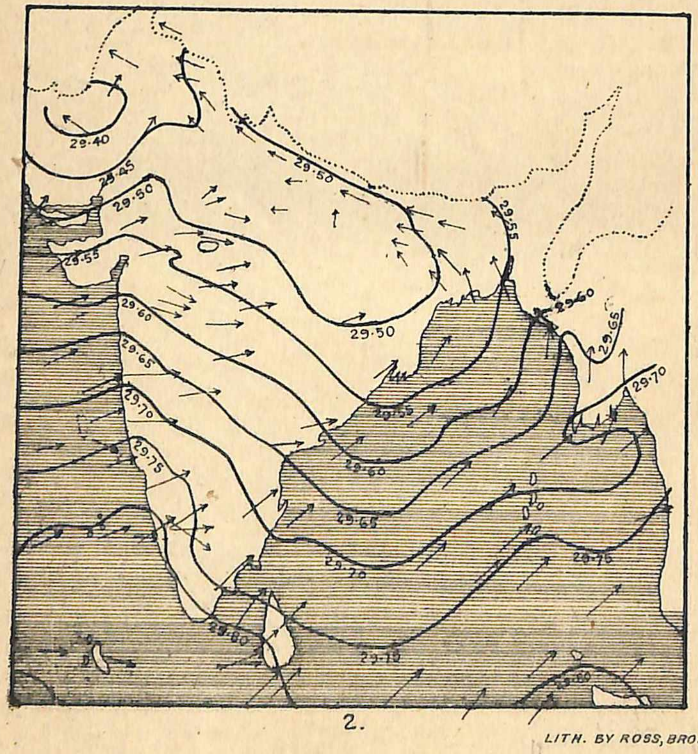
The Annual Variation in the direction of the winds in India is so marked a feature that the two *monsoons* are popularly known as the South-West monsoon and the North-East monsoon. But, as pointed out by Blandford and others, these names are inaccurate and misleading for many places, so that the terms Winter and Summer monsoons are to be preferred. Into the cause of these great changes in the atmospheric circulation, so far as known, it is impossible to go here and only the merest outline of the subject can be given. If a series of charts showing the average monthly distribution of atmospheric pressure over the Indian peninsula and neighbouring seas be examined, it will be found that in the month of January (*v.* pl. xx.) the pressure is lowest at two principal regions, *viz.*, to the south of Ceylon and near Sumatra, whilst it gradually increases northwards till it reaches its maximum in the extreme north-west of India. In the month of July (*v.* pl. xx.), on the other hand, this condition of things is exactly reversed, so that the barometric minimum is found in the region of Upper Sindh, and the maximum near Ceylon and Sumatra. In general terms, this shifting of the pressure which goes on from January to July and July to January, is brought about by changes in temperature, the seat of highest pressure being the place where the temperature is relatively lowest and *vice versâ.*

During March and April the weather over the Arabian Sea is generally fine; in the Bay of Bengal it is uncertain, and dangerous cyclones sometimes form. In May, south-west winds begin to blow in the Bay of Bengal, and later, west to south-west-winds blow from the Arabian Sea on to the west coast of India. The former sweep over the S. of India and Ceylon up the Bay and become divided into two main currents of which the larger part passes over Burmah and Assam to the eastern Himálaya, whilst the remainder curves first to the south in Bengal and then recurves along the face of the Himálaya, becoming an easterly wind up the Gangetic plain. The latter, *i.e.*, the westerly and

PLATE XX.



1.



2.

LITH. BY ROSS, BROS.

To face p. 372.

PLATE XX.

BAROMETRIC AND WIND CHARTS—INDIA. (AFTER BLANDFORD).

To illustrate the various points alluded to on p. 354, and to show the Annual Variations in the Wind Direction due to the Gradual Shifting of the Centres of Highest and Lowest Barometric Pressure respectively.

Figure 1. Average for the month of January.

Figure 2. Average for the month of July.

south-westerly winds from the Arabian Sea, blow right across the peninsula as far north as the Satpura range in Central India. Both currents bring with them deluges of rain which fall chiefly on the west coast of India, the west coast of Burmah, and the eastern Himálaya and Assam.* In the North-West of India the winds are at this time variable and uncertain, as is also the case in the region of country between the westerly current reaching as high as the Satpura hills and the easterly current sweeping up the Gangetic plain. During the summer monsoon the lower half of the east coast of India, the Carnatic, receives but a small portion of its annual rainfall, for the south-westerly current up the Bay of Bengal passes it by almost entirely, whilst the wind which reaches it overland has parted with most, if not all, of its excess of moisture on the other side of the peninsula.

In October and November, however, as the centre of low pressure is gradually moving south, it lies over the Bay, opposite the coast of Madras, and it is then that the north-easterly wind begins to blow strongly and ushers in the winter monsoon. During the months of October, November, and December Madras receives about 30 inches of its annual rainfall of 49·02 inches. In the southerly portion of the Bay the north-east wind continues to blow till the end of February and then, becoming more unsteady, gradually veers to the east and sou' sou'-east—the 'long shore wind' of April and May—till its place is taken by the advancing south-westerly current of the summer monsoon. In other parts of India, during the so-called 'cold weather,' the winds are very light and in many places there is calm for days together.

It is thus evident that the terms south-west and north-east are inaccurate for a large part of India. In addition, it must be carefully noted that the winds of the monsoons are not nearly so constant in their force and direction as is commonly assumed, and finally, that the summer mon-

* *v. ante*, Rainfall, p. 329, *et. seq.*

soon is essentially *the* monsoon, whilst the winter monsoon affects only a very small portion of the Indian peninsula in any marked degree.

The following table is instructive as showing clearly the gradual change in direction and velocity of the wind throughout the year.*

MEAN MONTHLY RESULTANT WIND DIRECTION AND VELOCITY.
MADRAS—MEANS OF 23 YEARS.

Months.	Miles.	Points.
January ...	130	N. E.
February ...	95	East.
March ...	135	S. E.
April ...	169	S. E. by S.
May ...	164	S. by E.
June ...	133	S. W. by S.
July ...	131	S. W.
August ...	101	S. W. by S.
September ...	84	S. W. by S.
October ...	44	N. N. E.
November ...	120	N. N. E.
December ...	154	N. N. E.

LIGHT.

Though a climatic factor of great and undoubted importance, Light does not usually receive special notice in meteorological observations and records save in the form of sunshine or direct sunlight. It can only be briefly considered here in its immediate relation to health generally and to health in India in particular.

Light in relation to health.—Reference has before been made to the important influence exercised by sunlight, both diffused and direct, upon living organisms.† A most

* Compiled from table given on p. 394 of *Results of the Meteor. Observations at the Government Observatory, Madras, from 1869—1890*, edited by C. Michie Smith, B.Sc. F. R. S. E., an invaluable work for all interested in the Meteorology of India.

† *v.* p. 292.

notable point and one pregnant with suggestion to the hygienist is the fact that whilst to the higher classes of organisms, such as human beings, flowering plants, etc., abundance of light is essential to health, the lower organisms, such as many of the invertebrate animals, cryptogamic plants, etc., can carry on a healthy existence in the entire absence of direct sunlight, and, finally, the lowest classes, including specially, various forms of animal and vegetable parasites, are able to dispense altogether with light during their brief cycle of existence.* The above is not to be taken as invariably true, for there are many marked exceptions; but it is found that where an organism or class of organisms originally living in strong light, is compelled, through change of environment, to exist for successive generations in almost complete darkness, it undergoes marked structural alterations of a degenerative nature. Many animals, of course, are more or less nocturnal in their habits and others pass a great deal of their time underground, but in most of these cases the deprivation of light is not so extreme as the superficial observer might imagine.

The most marked effect of absence or deficiency of light upon human beings and plants is 'etiolation.' If some rice, sown on a moistened flannel cloth, or upon earth, is kept in a dark place, it will be found that it will germinate but that the stalks and leaves will be of a pale yellow colour instead of green, and that it will not ripen. The same experiment is often performed in nature and may be demonstrated by turning over a heavy stone under which grass is growing. The portions of the grass which have been freely exposed to the light will be quite green, whilst those to which light has not had access will be pale and etiolated. "Without light there is no fructification, and, indeed, few plants can flower without direct sunshine. Under the influence of light plants absorb carbonic acid from the air, the carbon is fixed, and the oxygen is exhaled, a process of nutrition which ceases in the dark.

* *v.* Part III.

According to Carpenter, Henfrey, Ellis, Garreau, and others, plants also respire continuously night and day, producing small quantities of carbonic acid, formed by the combination of oxygen with their superfluous carbon, a process of combustion which continues in the dark. Thus we see why in high latitudes, where the days are long and even extend into months when the sun never sets, there is almost a quite uninterrupted progress and that is why growth in those countries is so rapid, and why plants will fructify more rapidly there than in the hotter but shorter days of the south."* Sunlight, then, is of extreme importance to mankind both as furnishing the plants whereon we subsist with the power of assimilation and as maintaining the purity of the atmosphere.†

Amongst the human race the evil effects of living and working in deficient light are sometimes obvious enough, but as a rule, in such cases, there are many other contributing factors to ill-health, and it is extremely difficult to assign to each its proper share. Especially should it be noted that pure air and abundance of light are almost always found together and the marvellous effects produced upon children removed to the country from the foul air and narrow streets of large cities, though partly attributable to improved diet, are undoubtedly due in a measure to the beneficent action of light and sunshine.

Many people are extremely sensitive to alterations in the amount of sunlight, especially those who go from the sunny climates of S. Europe and the East to dwell in Great Britain. The lowered temperature and the frequent rain do not depress them nearly so much as the long, gloomy winter months and the constant fogs‡ in the great cities.

On the other hand, too frequent exposure to intense sunlight may produce serious injury, especially upon the extremely sensitive retinal membrane of the eye. Most of the ill effects due to exposure to the sun have already been

---

* G. T. Symons, F.R.S., quoted by Dr. Sykes, *Public Health Problems*, p. 30.
† *v.* p. 284 and *f. note.* ‡ *v.* p. 319.

stated to be due to excessive heating of the body, but in the case of the eye, the injury is caused by the constant stimulation of the retina by the light rays, whereby the stock of retinal pigment is exhausted more quickly than it can be renewed, and this is specially the case in men fatigued or weakened in any manner by disease. Sometimes, as a result of this overstimulation* by day, the condition known as 'night-blindness' is set up. When this occurs, the eyes must be carefully protected during the day time by neutral-tinted spectacles or other means, and, if nothing better is available, the right and left eyes should be covered with a bandage during the daytime on alternate days.

Light in relation to health in India.—There are one or two points calling for special notice under this heading. To a new-comer from northern latitudes one of the most striking things on arrival is the intensity and constancy of the sunlight, and conversely, on first entering an Indian house, more especially if it is one belonging to a native of this country, he wonders at the sudden change from the brilliant sunshine outside to the comparative obscurity within. Where coolness is made entirely dependent upon the exclusion of direct sunlight, a state of semi-darkness follows of necessity, as also defective ventilation.† From the injurious custom of shutting themselves up for many hours daily in a much darkened house arose a good deal of that pallor ‡ that was formerly so characteristic of Anglo-Indians, and especially of the women and children; though doubtless the excessive heat contributed, and still contributes, an important share in its production. Of late years things are much improved in this respect owing to the improved habits of Anglo-Indians in the taking of exercise,

* "It has been estimated that the light emitted by the sun and falling on the page of such a book as this is about 60,000 times greater than that of a good wax candle placed at a distance of 1 yard from it, and about as much greater than the light of the moon at the full." H. Power, F.R.C.S. The only artificial light of sufficient intensity to cause serious injury to the eye is the naked arc electric light.

† v. p. 226. ‡ Strictly analogous to the 'etiolation' of plants.

in not completely shutting up the house, save in the hottest weather, and so on, but the evil can never be fully remedied till the designing, construction, and ventilation of houses in the tropics receive the careful consideration which the importance of the subject merits.

With regard to the mass of the people in India, the only class which appears to suffer much from the evil of deficient light,—in addition to deficient ventilation, bodily exercise and mental recreation,—is that of the wives of high-caste Hindus and of Mahommedans, who spend the greater portion of their lives in the seclusion of the womens' quarters or zenana and who, if they do take 'carriage exercise' (*sic*), do so with the blinds drawn or closed and darkened glass windows. The poorer classes, especially, pass their life to a large extent in the open air and it is probable that the death rate of the children would be even higher than it is were it not that conditions unfavourable to vitality are partially compensated for by free exposure to light.

When there is a possibility of long continued exposure to the 'glare' of sunlight* reflected from a white surface, more especially snow, great precautions should be taken to protect the eyes as before mentioned.† Medical officers and others who may be compelled to drive in open carriages during the day time in the hot weather may save themselves from headache and, possibly, permanent injury to the eyes by wearing neutral-tinted 'goggle' spectacles which exclude excess of light, heat and dust, and give a most delightful sense of coolness to the eyes.

ATMOSPHERIC ELECTRICITY.

Comparatively little is known with regard to atmospheric electricity in India or elsewhere and the whole subject is one that requires far more systematic observation than has yet been attempted. The general conclusion arrived at many years ago by Lord Kelvin and others is

---

* *v.* pp. 293-4.

† *v.* p. 377. For an account of 'snow-blindness,' by Dr. H. Cayley, *v. I.M.G.*, 1868.

that in fine weather the potential of the air relatively to the earth is positive but that in stormy weather it is often negative. In India this conclusion requires modification in one important respect, for observations made in Madras* have shown that in fine weather with a dry west wind the normal state of affairs is that the potential of the air becomes negative as soon as the surface of the ground gets heated—say between 9 and 10 A.M. This is almost certainly due to the dust in the air.

Observations upon atmospheric electricity are most easily made with one of Sir William Thomson's (Lord Kelvin's) portable electrometers.

The relation between health and atmospheric electricity is probably close and important, but too little is at present known to make a discussion of the subject here of any value.

ATMOSPHERIC DUST.

There are three chief sources of the dust† with which the atmosphere surrounding this earth is laden, *viz.*, (1) Meteorites; (2) Volcanoes; and (3) The general wear and tear of the Earth's Surface due to natural causes and human operations.

Meteors, or 'falling stars' as they are erroneously called, consist of masses of solid matter of varying size, which seem to be scattered in incalculable numbers through

---

* *v. Atmospheric Electricity*, by C. Michie Smith, B.Sc., Phil. Mag., Nov., 1885, and references therein given to other papers.

† To illustrate how extremely light are these minute dust particles, which are found by experiment to take several days to settle, even in perfectly still air, the following example from Mill, *op. cit.*, p. 109, will suffice. "When a cube of stone 1 inch in the side is falling, its mass drags it down, and the friction of the air on its six square inches of surface, resists the fall. If the cube were cut into ten slices $\frac{1}{10}$ of an inch thick, each of these into ten bars, and each of these into ten cubes $\frac{1}{10}$ of an inch in the side, there would result 1000 little cubes drawn down by the same force as had acted on the one; but the atmosphere would now have sixty square inches of surface to act on. If each of these little cubes were cut into 1000 the downward attraction of the earth on the whole million would be the same as for the one-inch cube, but the air-break would be applied to no less than 600 square inches of surface, so that their fall must be very slow indeed. The average dust-motes of the air are much smaller than these, hence it is not surprising that even the stillest air [in nature] is never free from dust." *v.*, also, *The Floating Matter of the Air*, by Tyndall.

space.* When they enter this earth's atmosphere they do so with an enormous velocity and, the energy of motion being converted by the friction of the air into heat, they are very rapidly heated, the larger ones becoming visible for a few seconds as so-called falling stars. Thereafter they are dissolved into fine dust which, owing to its extreme lightness, is capable of long periods of suspension in the atmosphere.

During volcanic eruptions an immense amount of fine dust and ash are carried up into the atmosphere by the explosive force of the steam emitted. For example, in the great eruption at Krakatoa, a small island in the Eastern Archipelago, on the 27th August, 1883, the column of dust and vapour was estimated to be 20 miles in height, and the dust was carried to all parts of the earth, giving rise to beautifully-coloured sunsets and various other phenomena.

Allusion has already been made† to the third source of atmospheric dust, to which the various occupations and industries of the human race contribute no inconsiderable amount. Amongst the immediate sources of dust under this heading come first the constant wearing down of the earth's surface by the action of rain, frost, wind, and other agents of denudation, and the solid particles of sodium chloride and other salts derived from sea spray ; secondly, the enormous number of minute animal and vegetable organisms, dead and living, which are constantly passing into the air, as also, the pollen from forest trees and smaller plants ; and thirdly, the very varied dust given off from the combustion of coal, wood, and other fuels, from mills and factories of all kinds, and indeed from any place which human beings inhabit. Mr. Aitken, whose researches are referred to later, has found, when examining into the amount of dust in the air of an open space in the country, that it is easily possible to detect the existence of a house or houses invisible to the observer by a change in the direc-

* It has been estimated that about 20,000,000 meteorites reach the earth daily.

† *v.* p. 6, *et seq.*

tion of the wind, whereby the latter, instead of reaching the observer after blowing over uninhabited country, is caused to blow over a small village or other inhabited place. An immediate rise in the number of dust particles is the result.

Having proved by experiment that moisture always condenses upon a solid nucleus, which is generally a dust particle, Mr. Aitken took advantage of this discovery to invent an apparatus by means of which the number of dust particles in any sample of air might be ascertained. This Dust-Counter cannot be described in detail here, but the principle of its construction and use is as follows:

An *inverted* flask of known capacity is filled with dust-free air obtained by drawing air into it through a cotton wool filter.* Into this flask is admitted a measured amount of the air to be examined, say 2 c.c. Inside the inverted flask at a certain distance from its inverted bottom is a small counter† with a silvered surface. By a simple device the air in the flask is kept almost completely saturated, so that by a sudden reduction of the pressure—by means of a stroke of a small air-pump attached—the moisture is condensed upon the dust particles within the flask. All the minute droplets thus formed in the air between the bottom of the flask and the upper surface of the counter, say 1 c.c., fall upon the latter, whose surface is divided into measured squares. By counting the number of droplets on a certain number of these squares, through the aid of a hand lens, the total number of dust particles contained in the air above the counter, *i.e.*, in 1 c.c., is found, and from that is calculated the total number in the flask, *i.e.*, in the 2 c.c. of dusty air originally admitted. From this result a simple calculation will give the number present in a cubic foot or any other desired amount of the original air. Since the invention of this apparatus Mr. Aitken has designed a more portable one which he has named the Pocket Dust-Counter. Careful observations in India with this instrument, if

* Of the same nature as those used in bacteriological work, *v.* Part III.

† Analogous to those used for counting bacterial colonies, or the corpuscles of the blood.

sufficiently numerous and combined with simultaneous meteorological records, would doubtless yield very interesting results.

The number of dust particles in the air has been found to vary enormously both at different places and at the same locality under varying conditions. Thus, in illustration of the former statement, the number has been found to vary from 0 dust mote in 1 c.c. of air on the top of Ben Nevis, the highest hill in Great Britain, to 210,000 in 1 c.c. in the air of the city of Paris. In illustration of the latter statement, a reference to Mr. Aitken's researches and tables shows that the air in Dumfries, a town in Scotland, contained 11,000 particles per 1 c.c. at 10 A.M. one day, whilst next morning at 10 A.M., there were but 325 per 1 c.c. For these variations there are very numerous reasons, such as the strength and direction of the wind, presence or absence of rain, etc. A summary of the conclusions arrived at by the above observer is herewith given, but the whole subject is still far from being completely elucidated.

1st. The earth's atmosphere is greatly polluted with dust produced by human agency.

2nd. This dust is carried to considerable elevations by the hot air rising over cities, by the hot and moist air arising from sun-heated areas of the earth's surface, and by winds driving the dusty air up the slopes of hills.

3rd. The transparency of the air depends on the number of dust particles in it, and also on its humidity. The less the dust the more transparent is the air, and the dryer the air the more transparent it is. There is no evidence that humidity alone—that is, water in its gaseous condition, and apart from dust—has any effect on the transparency.

4th. The dust particles in the atmosphere may have vapour condensed on them even though the air itself is not saturated.

5th. The amount of vapour condensed on the dust in unsaturated air depends on the 'relative humidity' and also on the 'absolute humidity' of the air. The higher the humidity and the higher the vapour tension, the greater is the amount of moisture held by the dust particles when the air is not saturated.

6th. Haze is generally produced by dust, and if the air be dry, the vapour has but little effect,—and the density of the haze depends chiefly on the number of particles present.

7th. None of the tests made of the Mediterranean sea air show it to be very free from dust.

8th. The amount of dust in the atmosphere of pure country districts varies with the velocity and direction of the wind; fall of wind being generally accompanied by an increase in dust. Winds blowing from populous districts generally bring dusty air.

9th. The observations are still too few to afford satisfactory evidence of the relation between the amount of the dust in the atmosphere and climate.*

It should be noted that these observations have reference solely to the quantity of dust present and take no account of its quality. In its relationship to health both aspects of this question are of importance. For example, instances have been given in the first chapter† where in the one case it is more especially the *quantity* of dust inhaled which is injurious, whilst in another it is the *quality*, though of course the quantity and quality are more

* Mr. Aitken's papers have already been referred to, *v. f. note** on p. 318. The large Dust-Counter will be found figured and described in Trans. R.S.E., Vol. XXXV., 1888; the Portable Dust-Counter in Proc. R.S.E., Vol. XVI., 1889; and the paper here referred to, in Proc. R.S.E., Vol. XVII., 1889-90.

† *v.* pp. 6-7.

or less correlated.* It is, roughly speaking, the inorganic dust particles which are harmful only when present in great quantity, whilst a very small amount of organic particles if consisting of pathogenic organisms may give rise to serious disease. This may be called the *individual* relation of dust to the health of human beings. The tendency of the researches above referred to is to show that it exercises a most important *general* influence upon health, by the intimate relation that exists between the amount of atmospheric dust and the temperature of the air, its humidity, transparency, electrical condition, etc., etc. There is no doubt that future investigation in India will demonstrate most important relationships existing between the health of communities according as they live in crowded and dusty cities, less dusty villages, or in the purer air of the hill sanitaria, and that the relationship will prove to be both an individual and a general one.

CLIMATOLOGY.

Having studied individually each of the important factors of climate, it is now necessary to consider them collectively as constituting, by their various local manifestations, the climate of any particular place. At the commencement of this chapter climate was defined as 'the sum of the local atmospheric and physical conditions in their relationship to animal and vegetable life,' and in the study of Climatology it is the aim of the investigator to compare together and classify the different varieties of climate and their effects upon health, as also upon other important economic conditions with which we are not here concerned. In chapter III. it was shown how *direct* is the connection between health or the reverse and the physical conditions obtaining at any place, and it is evident from what has been said previously in the present chapter, that the temperature, rainfall, humidity, and other climatic factors are

* Somewhat in the same way, one sample of water may be injurious to health owing to the quantity of impurity, *e.g.*, magnesium sulphate, whilst another sample may contain a very small quantity of impurity, but what there is may be of very injurious quality, *e.g.*, the poison of typhoid fever.

greatly modified by local physical conditions, which latter thus exert an *indirect* influence upon health as well. It is necessary, therefore, before going further, to say a few words regarding the geographical position and surface characters of this country in so far as they bear upon health, directly or indirectly.

Roughly speaking, the Indian Empire extends at its longest and broadest parts from the eighth to the thirty-sixth degree of north latitude and from the sixty-second to the one hundred and third meridian of east longitude. Disregarding for the present that part of the empire known as Burma, let the student examine carefully the position and form of the great peninsula which constitutes India proper. A little thought will show him that to its geographical position are largely due the varied climatic peculiarities it presents. Firstly, the larger part of it lies within the tropical zone and the remainder lies just beyond, and though the whole of it is situated to the north of the equator it is still one of the hottest places in the world. This is because the line of greatest mean heat—the so-called *thermal equator*—does not follow the course of the true equator but, in the longitude of India, bends northward, running up through Ceylon and the Peninsula to beyond the tropic of Cancer and passes through Sindh to the Arabian peninsula : furthermore, where this line traverses the low plain of S. India is one of its hottest portions.* Again, though the mean annual temperature is highest in Southern India, the highest temperatures of the year occur in the N.W. of India, and especially Sindh, during May and June.

The next point claiming attention is the peculiar relation of India to the rest of the great Asiatic continent, from which latter it projects, as it were, into the sea, so that to the north of it is an enormous extent of land, whilst to the south there is practically nothing but the open sea. Further, right along the north of India and for a consider-

---

* Blandford.

able distance along its N.E. and N.W. boundaries runs an immense series of mountains, amongst them the loftiest peaks in the world. From the Himálaya a vast tableland from 11,000 to 18,000 feet above sea level extends northwards for 600 miles and terminates in a desert. To this peculiar geographical position, as before stated, are due many of the curious and pronounced differences that exist in the climates of different parts of India.

Along the western side of the peninsula runs the great chain of mountains, forming the Western Ghâts (*Sahyádri*), which exercises such an important influence on the distribution of the annual rainfall. Across the country from the gulf of Cambay almost to the Bengal plain runs another series of hills, the Sátpura and Arvali* ranges and the highlands of Chutia Nagpore, which latter do not form a continuous mountain system but are in reality a belt of high land representing the remains of vast rock formations that have been worn down and denuded to the north and south. Lastly, along the E. coast there is a broken series of hills, not nearly so well-defined and continuous as is commonly imagined, which is known as the Eastern Ghâts and is probably similar in mode of formation to the Central Indian ridge.

Between the Himálaya mountains and the hills of Central India lie the great river systems of the Brahmaputra, Ganges, Indus and other rivers. South of the Sátpura and neighbouring ranges stretches the tableland of the Deccan, merging gradually into the plains of Southern India, whilst the Western and Eastern Ghâts converge to a point at Cape Comorin.†

Even from the foregoing condensed description of the most noticeable physical features of the country the student would be prepared to expect that the local conditions must vary greatly in different places. Such indeed is the case to a most remarkable degree and it may be

* Striking nearly S.W. to N.E. in Rajputana.

† Strictly speaking, the Eastern and Western Ghâts unite just to the south of the Nilgiri hills, whilst an irregular chain of hills runs down from there to the end of the peninsula at Cape Comorin.

said without fear of exaggeration that there is hardly a physical feature or condition met with in the various parts of the earth's surface that is not to be found somewhere in India. There are hills of every elevation from a few feet above sea level to the greatest height* in the world. There are hills whose peaks rise far above the line of perpetual snow, there are others clad with dense tropical and sub-tropical growths to their summits, whilst others are devoid of any larger plants than small shrubs and coarse grass. There are elevated tablelands from which the snow never melts, there is the jungle-covered tableland of Central India, the bare and rocky tableland of the Deccan, the grassy tableland of the Mysore plateau. There are immense rivers running through rich alluvial valleys, which yearly carry seawards the water from the melting snows, there are rivers which at certain seasons are raging floods at others a mere streak of water in a vast sandy bed, whilst many remain completely dry for months together. There are dry sandy deserts, rich plains well-watered by nature or irrigated by canals, the deadly *terai* jungle at the foot of mountain ranges, lakes, swamps and backwaters, and many other physical features peculiar to different portions of the country.

Classification of Climates.—Climates have been very variously classified by different writers. It might appear at first sight as if a classification by *latitude* was feasible, but a little consideration will soon show this to be impracticable :† so, also, by *isotherms*,‡ since two places with the same mean annual temperature may have very different climates, as already explained.§ No strictly scientific arrangement is possible. Probably the three most important points to be considered in classifying climates are (1) the latitude ; (2) the relative quantities of land and water surface ; and (3) the altitude above sea level. But there

* Mount Everest, 29,002 feet. † *v.* p. 286, *para.* 4.

‡ Analogous to *isobars* (p. 354), but indicating places with the same *mean annual temperature.*

§ *v.* p. 301.

are many other important things to be noted, such as the humidity, prevailing winds, ocean currents, etc.

The following classification is that adopted by an eminent authority, Dr. C. Theodore Williams.*

1. *Warm Climates: Equatorial; Tropical; Sub-tropical.*—Climate of regions lying between the equator and 35° latitude N. and S. Characterised by high temperature, with (as a rule) heavy rainfall, and dry and rainy seasons.

2. *Temperate Climates.*—Climates of regions lying between 35° and 50° latitude, with four well-marked seasons—a preponderance of rainfall in autumn and winter—having a mean temperature from 50° F. to 60° F. and considerable extremes.

3. *Cold Climates.*—Climates of regions lying between 50° latitude and the poles, marked by gradual reduction of temperature as the pole is approached, the greatest cold being 10° from it. The season there consists of a long winter of ten months and of a few weeks of summer. Rainfall small and generally in form of snow. Aurora borealis frequent.

4. *Marine Climates.*—Characterised by the presence of the marine influence—*i.e.*, coasts, islands, peninsulas washed by the ocean or salt seas, and owing their freedom from extremes to warm currents and the equalising influence of the ocean. Such is the climate of Great Britain, of Ireland, of Norway, and of many islands. We also include in this division the climate experienced in sea voyages.

5. *Mountain Climates.*—Characterised by diminished barometric pressure, increased diathermancy, and by extremes of temperature.

---

* *v.* S. and M., p. 203. It is much the same arrangement as that of Dr. Henry Bennett, *v.* Quain's *Dict. of Med.*, article 'Climate.'

In the above classification it will be seen that the first three divisions are arranged according to latitude; in the fourth, latitude is practically disregarded whilst the influence of a large surface of water, such as the sea, receives the chief place; in the fifth, elevation above sea level is the principle feature.

Another great authority, Dr. Hermann Weber, makes the presence or absence of the 'marine influence' the primary basis of classification and arranges them thus:

A. *Marine Climates* (Island and Coast climates).

1. Humid Marine Climates { Warm / Cool.
2. Marine Climates with Mean Humidity.
3. Dry Marine Climates.

B. *Inland Climates.**

1. Altitude or Mountain Climates.
2. Lowland or Plain Climates.

From the above the student can see how different are the proposed arrangements and how empirical or incomplete the classification adopted, but he will be enabled to form some idea of the leading types of climate and what points receive special attention. Very full information can be obtained from any of the articles alluded to.†

The main object of the study of climatology is to ascertain the nature of the relationship that undoubtedly exists between certain climates or climatic conditions and certain diseases, in the direction of favouring or checking the development of the latter. Thus, the various diseases known under the generic name of phthisis require very different climates for their improvement, according as they are of tubercular or pneumonic origin, and a climate very

* "The great varieties of climates comprised in this division might be sub-divided into many groups, according to meteorological characters and therapeutical effects on invalids, but considering the great drawbacks of all classifications we humbly resign ourselves to two rather primitive sub-divisions." H. Weber, *Book of Health*, Article 'Climates and Health Resorts.'

† Especially that by Hermann Weber, *op. cit.*, and by the same author in Ziemssen's *Hand-book of Therapeutics*.

suitable for a person suffering from chronic bronchitis may be extremely unsuitable for a case of rheumatism, and so on. And this question has a double aspect, for, on the one hand, a patient already afflicted may be specially ordered to leave one place and to go to another for the purpose of arresting or lessening his disease—the therapeutic use of climate in an individual case—whilst on the other hand careful study of the relationship between the climatic factors of any locality and its prevalent diseases may demonstrate the liability of the inhabitants of that locality to particular diseases at certain seasons, according as one factor, such as temperature, humidity, etc., is specially prominent—the study of the seasonal prevalence of disease amongst the population generally—a most important but very complex question.* As stated before,† the study of the seasonal prevalence of diseases in India, and their correlation with other factors, is worthy of far more systematic study, and of official help and encouragement towards the same, than have yet been accorded to it.

Climates of India.—Only a very brief summary of the chief climates in India proper can be given here; for fuller information the student must consult the excellent works of Blandford—from which the following tables and most of the information are derived—of MacNamara, Fayrer, Baikie, Lord, Moore, and others.

The first point, which will not be unexpected by any one who has studied the remarks previously made on the geography and physiography of India, is the wonderful variety of the climates in this country. "Northern or extra-tropical India alone, in its most easterly and most westerly provinces, in Assam on the one hand and in Sindh

---

* Dr. A. Buchan, a very able and competent authority, has taken up this difficult subject, in connection with the health of London, and has found it necessary to divide the year into six periods of which the first is characterised by dampness and cold; the second by cold; the third by dryness and cold; the fourth by dryness and warmth; the fifth by heat; and the sixth by dampness and warmth; and for each of these there are certain diseases which are specially prevalent and give rise to the greater part of the mortality during those seasons. *v. San. Record* for 19th August, 1893.

† *v.* p. 327.

on the other, present us with the greatest possible contrast of dampness and dryness, a contrast greater than that of the British Isles and Egypt; and when, further, we compare the most northerly province, the Punjab, with the most southerly, such as Travancore or Tenasserim, we have in the former a continental climate of the most pronounced character, extreme summer heat alternating with winter cold that sometimes sinks to the freezing point, and in the latter that almost unvarying warmth in conjunction with a uniformly moist atmosphere, that is especially characteristic of the shores of a tropical sea. To speak, then, of the climate of India as we might speak of the climate of Ireland, as if such expression denoted certain definite conditions of heat and moisture, varying only within moderate limits, and nearly uniform in the several provinces, would be as misleading as if we were to speak of its inhabitants in terms implying that they are a homogeneous race, alike in ethnic and social characters, culture and belief."*

It is probable that these varied climates of India could be arranged with considerable accuracy under the three headings of (1) Island climates; (2) Continental (or Inland) climates; and (3) Hill climates, but no rigid classification under any system will be here attempted, and, with the exception of a general description of the climates of hill stations, the remainder will be arranged according to locality, proceeding from north to south, with tables giving the meteorological data of one or more representative stations within each area.

The Hill Climates of India are in general damper and cooler than those of the neighbouring plains, and as a consequence, are specially acceptable to robust and healthy Europeans and to those who are simply suffering from the debility following upon long residence in the plains. Certain of them, such as Ootacamund, Wellington, Simla, etc., are above the level of malaria, whilst others, such as

* Blanford.

Yercaud, Pachmari, Mount Abu, etc., are either known or suspected to be below it. This is a most important matter and demands very careful attention in the selection of any fresh hill station. With regard to the real hill sanitaria situated at a level of 5,000 feet and upwards, they are suitable, as before stated, for those suffering from malaria, or from general debility following acute disease or hard work in the plains, and they form delightful places of resort to those who can obtain leave. But cases in which there are serious organic lesions of the cerebral, thoracic, or abdominal viscera, are quite unsuitable, and such should be retained under medical treatment till strong enough to travel and then sent for a change to England or Southern Europe.

Between the climates of the sanitaria on the Himálayas and Nilgiris there is one very marked difference. At the former the weather is perfect for some months, extremely cold and wet during others, whilst at the latter, the climate is far more equable and the rainfall more evenly distributed throughout the year. The climate of the Niligris is the nearest approach to that of S. England to be found in India.* For the thinly-clad and poorly-nourished Hindu the climates of the hill stations are far from attractive, and many of them die of pneumonia, dysentery, etc., but others with stronger bodies and in easy circumstances soon become used to the lowered temperature and feel a vigour of mind and body much beyond that to which they are accustomed. The following tables will repay careful perusal, illustrating as they do the chief climatic features of four very different hill stations. Shillong has been chosen in place of Darjiling as likely to prove much the more important sanitarium (*v.* tables 1—4).

The climate of the Punjab is characterised by an alternation of decided hot and cold seasons, and by a light rainfall, which latter, however, varies very much in amount

* "Among all the pleasant memories of more than 30 years of Indian life, and an experience of all parts of the empire from Peshawar to Sibsagar and Point de Galle, I can recall no more charming scene and climate than those of the Nilgiri Hills." Blandford.

in different years and in different parts of the same province. Lahore is chosen as a fairly representative station (*v.* table 5).

Sindh, the "great plain traversed by the Lower Indus from the Punjab frontier to the sea, is at once the driest and, as a whole, the hottest of all the provinces in India." Jacobabad (*v.* table 6) is the hottest and driest of the principal towns, Hyderabad, situated in a very exposed position, is a little moister and cooler, and Karachi within 8 miles of the sea, is the coolest of all.

The climate of Rajputana is intermediate between that of Sindh and the Central Indian Plateau, and the hot and cold seasons are not so strongly contrasted as in the Punjab.

Coming next to the North-West Provinces and Oudh, formed by the great alluvial valley through which run the Jumna and Ganges with their numerous tributaries, and which extends to Behar in Bengal, we find, as might be expected, a remarkably rich and fertile tract of country in which are situated many very important towns. The climate is different in many ways from that of the Punjab on the west and of Bengal on the east. The cold season is well marked, but not so much as in the Punjab, and it is also less rainy and cloudy. In March strong and very dry* west winds begin to blow. In May these are sometimes tempered by slight showers of rain—the so-called *choti bursàt.* Towards the end of June the rains begin, and wet days alternate with 'breaks' of moist and steamy weather till September, when they cease. The most remarkable climatic peculiarity of the North-West Provinces is the liability of the rainfall to fail almost completely in any year, especially in the Gangetic plain (*doab*) proper. The disastrous effects of this are guarded against, so far as possible, by the Ganges Canal—the greatest irrigation canal in the world—but in spite of this the liability of the district to suffer from severe famine, though greatly lessened, as compared with former times, continues (*v.* table 7).

* The relative humidity may sink to as low as 6 *per cent.*

HILL STATIONS.

1. Leh—Elevation 11,503 feet.

	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
				M. Range.							
—	Mean.	Mean Max.	Mean Min.	Daily.	Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	18	35	11	25	44	61	6·4	0·2	4	19·64	·07
February	19	35	9	26	48	61	6·7	0·2	5	·58	·08
March	31	46	20	26	50	56	6·5	0·2	2	·67	·08
April	41	57	31	26	43	42	6·4	0·1	1	·67	·08
May	47	64	36	27	44	40	6·5	0·1	2	·68	·08
June	56	74	44	30	50	37	4·9	0·2	1	·64	·09
July	62	80	51	29	44	44	5·1	0 5	3	·60	·10
August	60	80	50	30	45	48	5·1	0·4	3	·63	·11
September	52	72	42	30	46	44	4·0	0·2	1	·69	·11
October	40	59	30	29	47	41	3·9	0·5	...	·73	·10
November	30	47	20	27	43	50	4·0	0	...	·72	·09
December	23	39	13	26	41	58	5·3	0·1	2	·70	·08
	40					49	5·4	2·7	24	19·66	

Mean highest temperature of year 90°
,, lowest ,, ,, −4°
,, annual range of temperature 94°
Highest recorded reading (10 years) 93° (1876)
Lowest ,, ,, ,, −17° (1878)

Absolute range of temperature 110°
Rainfall of wettest year (11 years) 5·4″ (1879)
,, driest ,, ,, 0·4″ (1876)
Rainy days in wettest year (8 yrs.) 43 (1886)
,, ,, driest ,, ,, 8 (1878)

HILL STATIONS.

2. SIMLA—Elevation 7048 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean. Max.	Mean, Min.	M. Range. Month.	M. Range. Daily.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	41	54	38	16	36	58	5·0	2·8	3	23·29	·06
February	41	53	36	17	34	56	5·0	2·7	5	·24	·05
March	50	63	45	18	40	53	5·0	3·0	6	·27	·05
April	58	72	52	20	38	51	4·6	2·8	6	·26	·05
May	64	77	57	20	39	49	4·1	4·7	9	·22	·05
June	67	79	61	18	36	64	6·1	7·9	10	·15	·05
July	64	73	61	12	22	88	8·5	19·3	21	·12	·05
August	63	71	60	11	20	91	8·6	18·1	22	·16	·05
September	61	72	58	14	23	82	6·2	6·0	12	·25	·05
October	56	68	51	17	28	53	1·0	1·4	2	·33	·06
November	49	61	43	18	31	50	1·5	0·3	1	·32	·06
December	45	57	40	17	30	47	3·5	1·1	2	·31	·06
Year... ...	55					62	4·9	70·1	99	23·24	

Mean highest temperature of year 88°
„ lowest „ „ 25°
„ annual range of temperature 63°
Highest recorded reading (11 years) 94·4° (1879)
Lowest „ „ „ 19·7° (1883)

Absolute range of temperature 74·7°
Rainfall of wettest year (24 years) 94·9″ (1864)
„ driest „ „ 52·1″ (1867)
Rainy days in wettest year (12 years) 136 (1884-1885)
„ driest „ „ 74 (1877)

HILL STATIONS.

3. SHILLONG—Elevation 4792 feet (4 years).

—	Temperature.			M. Range.		Hum.	Cloud.	Rainfall.	
	Mean.	Mean Max.	Mean Min.	Daily.	Month.	Mean.	Mean.	Ins.	Days.
January	51	62	42	20	31	70	2·5	0·4	1
February	54	64	46	18	30	65	3·4	0·8	4
March	62	71	54	17	32	59	3·1	2·0	5
April	65	74	58	16	29	65	5·2	3·7	11
May	68	76	63	13	22	77	6·6	10·0	21
June	69	76	65	11	18	84	7·8	17·0	24
July	69	76	66	10	16	87	8·6	14·0	22
August	69	76	65	11	17	88	8·5	14·4	23
September	67	74	64	10	20	89	8·1	15·4	22
October	63	72	58	14	25	86	6·2	6·2	13
November	57	66	49	17	30	76	3·4	1·0	3
December	51	61	42	19	31	75	3·2	0·4	1
Year...	62					77	5·6	85·3	150

Mean highest temperature of year	82°	Absolute range of temperature . .	51·5°
„ lowest „ „	34°	Rainfall of wettest year (20 years) .	121·2″ (1867)
„ annual range of temperature . .	48°	„ driest „ „ .	53·6″ (1873)
Highest recorded reading (4 years). . .	84° (1872)	Rainy days in wettest year (18 years)	191 (1883, 1884)
Lowest „ „ „	32·5° (1872)	„ driest „ „	109 (1868)

HILL STATIONS.

4. Ootacamund—Elevation 7252 feet (13 months).*

—	Temperature.			M. Range.		Hum.	Cloud.	Rainfal.		Barometer.	
	Mean.	Mean Max.	Mean Min.	Daily.	Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	48	66	35	31	44	55	1·9	0·5	1	23·20	·06
February	51	68	39	29	42	61	4·2	0·2	...	·22	·07
March	55	71	44	27	45	46	3·3	1·2	1	·23	·08
April	58	72	51	21	29	64	5·6	3·9	11	·20	·08
May	59	71	53	18	31	70	6·4	6·2	16	·16	·09
June	56	65	53	12	23	84	8·7	6·0	17	·13	·06
July	55	62	52	10	20	84	9·2	5·6	23	·14	·05
August	55	63	51	12	24	82	8·6	4·2	19	·14	·07
September	55	63	50	13	25	79	8·0	3·7	13	·16	·07
October	54	64	50	14	24	89	8·7	9·8	22	·21	·09
November	53	63	47	16	35	90	6·7	2·9	16	·20	·07
December	51	64	42	22	35	71	4·9	1·6	4	·18	·07
Year... ...	55					71	6·3	45·8	143	23·18	

Highest recorded temperature ... 77·3°
Lowest „ „ ... 25·3°
Range during year ... ... 52°

Rainfall of wettest year (10 years) 58·4″ (1830)
„ driest „ „ 33·7″ (1867)

* The rainfall is the mean of 11 years.

THE PUNJAB.

5. Lahore—Elevation 732 feet.

	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
				M. Range.							
	Mean.	Mean Max.	Mean Min.	Daily.	Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	54	68	43	25	39	60	3·2	0·7	2	29·34	·08
February	59	71	46	25	32	57	3·4	1·1	3	·28	·08
March	69	83	57	26	48	48	3·1	1·1	2	·18	·08
April	81	95	66	29	48	37	2·5	0·6	3	·05	·09
May	88	102	73	29	48	33	2·4	0·9	3	28·92	·08
June	93	107	81	26	45	37	2·9	1·8	3	·77	·09
July	89	99	81	18	39	58	4·2	7·4	7	·78	·09
August	88	98	80	18	32	61	3·7	4·6	6	·85	·09
September	85	97	75	22	34	55	1·7	2·4	4	·97	·09
October	77	93	62	31	46	46	0·8	0·6	1	29·15	·08
November	64	81	49	32	48	47	1·2	0·2	1	·30	·08
December	55	71	43	28	41	56	2·0	0·5	2	·35	·08
Year... ...	75					50	2·6	21·9	37	29·08	

Mean highest temperature of year . 117°
,, lowest ,, ,, . 34°
,, annual range of temperature . 83°
Highest recorded reading (11 years) . 120·3° (1879)
Lowest ,, ,, ,, . 29·8° (1878)

Absolute range of temperature . . 90·5°
Rainfall of wettest year (27 years) . 37·8″ (1875)
,, driest ,, ,, . 8·7″ (1871)
Rainy days in wettest year (12 years) 47 (1881)
,, ,, driest ,, ,, 26 (1875)

SINDH.

6. Jacobabad—Elevation 186 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	57	74	43	31	48	46	2·4	0·2	1	29·89	·12
February	62	77	48	29	51	39	3·2	0·2	2	·82	·12
March	74	90	60	30	54	41	3·3	0·3	1	·70	·13
April	83	99	68	31	51	38	3·1	0·2	1	·56	·13
May	91	108	76	32	50	36	1·4	0·1	1	·42	·12
June	96	111	83	28	44	42	1·1	0·1	...	·26	·12
July	94	107	83	24	37	53	2·2	1·4	3	·24	·12
August	91	103	81	22	33	58	2·4	1·4	4	·33	·11
September	88	101	76	25	39	55	0·9	0·3	...	·47	·11
October	78	96	63	33	51	46	0·4	...	...	·67	·11
November	65	84	50	34	52	45	0·9	0·1	...	·82	·11
December	58	75	43	32	47	48	1·8	0·1	...	·90	·12
Year	78					46	1·9	4·4	13	29·59	

Mean highest temperature of year . 118°
" lowest " " . 32°
Mean annual range of temperature . 86°
Highest recorded reading (9 years) 120·9° (1882)
Lowest " " " 29·2° (1881)

Absolute range of temperature . 91·7°
Rainfall of wettest year (26 years) 12·1″ (1869)
" driest " " 0·7″ (1881)
Rainy days in wettest year (9 yrs.) 35 (1878)
" " driest " " 5 (1880)

N.W.P. and OUDH.

7. Lucknow—Elevation 369 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	61	74	46	28	42	59	2·7	0·8	2	29 68	·11
February	66	78	50	28	47	52	3·0	0·3	2	·61	·11
March	77	91	61	30	52	43	2·7	0·3	1	·50	·11
April	87	101	71	30	47	35	2·1	0·1	1	·37	·11
May	92	104	76	28	44	42	2·0	0·9	2	·27	·12
June	92	103	82	21	38	54	4·7	5·0	7	·15	·11
July	86	93	80	13	26	74	7·7	10·8	16	·15	·10
August	85	92	79	13	23	77	7·4	10·4	15	·22	·10
September	85	93	77	16	27	72	5·4	7·1	9	·31	·11
October	79	91	65	26	42	60	1·5	1·4	1	·50	·11
November	69	83	52	31	44	53	0·8	...	...	·63	·11
December	61	75	45	30	41	58	1·8	0· 5	1	·69	·11
Year... ...	78					57	3·5	37·6	57	29·42	

Mean highest temperature of year .	. 114°	Absolute range of temperature .	. 82·9°
,, lowest ,, ,, .	. 38°	Rainfall of wettest year (20 years) .	. 64·9″ (1871)
,, annual range of temperature.	. 76°	,, driest ,, ,, .	. 14·4″ (1877)
Highest recorded reading (10 years)	. 117·3° (1878)	Rainy days in wettest year (14 years)	. 77 (1874)
Lowest ,, ,, ,,	. 34·4° (1878)	,, ,, driest ,, ,,	. 27 (1876)

The Central Indian Plateau has been alluded to in the short description of the physiography of the country already given. In many parts the climate is very pleasant and the stations healthy. During the cool season, from November to the end of February, the weather is delightful, especially towards the eastern part of the plateau, between Jabalpur and Benares (*v.* table 8).

The climate of Behar, a densely populated and highly cultivated province, is intermediate between that of the N.W.P. and Lower Bengal, but is more akin to the former. The rainfall is moderate and the cold weather pleasant. The climate of Chutia Nagpur is much the same, the rain-fall being slightly heavier than in most parts of Central India.

The provinces of Bengal and Orissa are largely made up of the deltas of the Brahmaputra, Ganges, Mahanadi and other rivers. "Intersected by innumerable river channels and abounding in swamps, while open to the damp winds from the bay, which begin to blow on the coast as early as February and gradually penetrate farther inland with the increasing heat, the climate of Bengal is as characteristically damp and relaxing as that of North-Western India is the reverse. The dry westerly winds that play so great a part in the meteorology of the Upper Provinces are felt only occasionally and intermittently in the province of Bengal, during the spring months and chiefly in the warmest hours of the day, and even then with a reduced temperature and of a less parching character, owing to the moisture taken up from the surface over which they blow. The customary division of the year into three seasons, the cool season, the hot season, and the rains, holds good in Bengal as in the more westerly provinces, but the first is shorter and less bracing, and the heat of the second, if less intense, owing to the greater dampness of the air, is on this account, perhaps, more trying to the European constitution. The rains are also longer and more copious." The climate of Calcutta (*v.* table 9) is fairly typical of Bengal generally.

CENTRAL INDIAN PLATEAU.

8. Saugor—Elevation 1769 feet.

—	Temperature.			M. Range.		Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	Daily.	Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	63	77	51	26	40	46	1·4	0·6	2	28·24	·10
February	67	81	54	27	43	39	1·5	0·5	1	·18	·11
March	78	93	64	29	41	32	1·3	0·2	...	·11	·11
April	85	101	72	29	39	28	1·4	0·2	1	·02	·11
May	89	104	76	28	39	28	2·0	0·6	3	27·92	·11
June	85	100	77	23	37	50	4·1	6·3	11	·82	·10
July	78	86	74	12	24	77	6·1	16·8	19	·80	·09
August	77	85	73	12	20	83	5·9	11·2	18	·86	·09
September	77	87	71	16	26	78	4·3	7·3	12	·95	·10
October	75	87	66	21	33	55	1·4	1·3	2	28·12	·10
November	69	82	56	26	36	42	1·0	0·4	...	·20	·10
December	64	76	51	25	38	45	1·0	0·7	1	·24	·10
Year	76					50	2·6	46·1	70	28·04	

Mean highest temperature of year.	.	110°
„ lowest „ „ .	.	42°
„ annual range of temperature	.	68°
Highest recorded reading (8 years)	.	111·4° (1881)
Lowest „ „ „ .	.	40·1° (1883)

Absolute range of temperature .	.	71·3°
Rainfall of wettest year (31 years) .	.	70·1″ (1867)
„ driest „ „ .	.	22·1″ (1848)
Rainy days in wettest year (11 years)	.	106 (1884)
„ „ driest „ „ .	.	56 (1879, 1880)

BENGAL AND ORISSA.

9. Calcutta—Elevation 21 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	65	77	55	22	33	71	1·4	0·4	2	30·02	·13
February	70	82	61	21	37	69	2·2	1·0	3	29·95	·13
March	79	91	70	21	38	69	2·2	1·3	3	·86	·14
April	85	96	76	20	33	71	2·8	2·3	5	·75	·14
May	85	94	77	17	30	76	4·4	5·6	10	·66	·12
June	84	91	79	12	25	84	7·0	11·8	18	·55	·10
July	83	88	78	10	17	87	8·1	13·0	24	·54	·09
August	82	87	78	9	16	89	8·2	13·9	24	·60	·10
September	82	87	78	9	17	88	7·1	10·0	18	·68	·11
October	80	87	75	12	23	83	4·2	5·4	8	·83	·11
November	72	82	64	18	29	74	2·4	0·6	2	·96	·12
December	65	76	56	20	31	72	2·0	0·3	1	30·02	·13
Year	78					78	4·3	65·6	118	29·78	

Mean highest temperature of year . . 102°
,, lowest ,, ,, . . 48°
,, annual range of temperature . . 54°
Highest recorded reading (8 years) . . 105·3° (1879, 1885)
Lowest ,, ,, ,, . . 45° (1878)

Absolute range of temperature . . . 60·3°
Rainfall of wettest year (57 years) . . 93·3″ (1871)
,, driest ,, ,, . . 43·6″ (1837)
Rainy days in wettest year (34 years) . 154 (1861)
,, ,, driest ,, ,, . . 72 (1853)

Assam, including Cachar, Sylhet, and certain hill tracts on the Indo-Burmese frontier, consists of two main alluvial plains through which run the Brahmaputra, Baràk and smaller rivers, and of the aforesaid hills—the Khasi, Naga, Lushai and Manipur ranges, etc. The greater part of the province still consists of jungle and swamps, but large areas, such as the plain of Sylhet, have been cultivated for a long time, whilst other parts, in Assam proper and Cachar especially, have been cleared of jungle and its place taken by numerous tea gardens. The soil is extremely fertile, the natural products valuable, and the zoology and botany very varied, but these very qualities, the result of a heavy rainfall combined with the physical features, made the province an extremely unhealthy one to the pioneers of civilisation. "The European pioneers of tea planting in the Darjiling and Bhutan terai suffered severely; many perished from malarious fever and its sequelæ, and from the non-observance of approved dietetic, hygienic and sanitary principles. But now that ever-increasing areas are being denuded of forest, of rank and impenetrable jungle, and reduced to a state of good husbandry and cultivation; that the evils of intemperance in eating and drinking are better understood, and avoided accordingly; that drinking water is purified by boiling and filtration; that sleeping accommodation is provided in rooms well raised above the ground—in the most elevated portion of the estate—sometimes on adjoining spurs, at a considerable height; that the dry, or dry-earth system of conservancy is enforced; that the head and spine are thoroughly protected from the direct action of the sun; that woollen under-clothing is worn at all seasons; and that prophylactic doses of quinine are often employed during the malarious months; tea planting, if not quite so healthy as occupations in other localities on the plains, is nevertheless profitably carried on by Europeans on terai land where only a few years ago, under the old conditions of jungle, forest, swamp and waste, their lives could scarcely have been maintained throughout a single cycle of

ASSAM.

10. Silchar—Elevation 104 feet.

—	Temperature. Mean.	Temperature. Mean. Max.	Temperature. Mean. Min.	Temperature. M. Range. Daily.	Temperature. M. Range. Month.	Hum. Mean.	Cloud. Mean.	Rainfall. Ins.	Rainfall. Days.	Barometer. Mean.	Barometer. Daily Range.
January	64	77	52	25	35	75	2·7	0·6	2	29·94	·13
February	67	79	55	24	38	70	3·1	2·6	6	·89	·13
March	73	85	63	22	36	72	4·0	7·9	12	·81	·14
April	78	87	69	18	30	76	5·1	13·0	17	·72	·14
May	80	87	72	15	30	81	6·1	15·7	19	·65	·13
June	82	89	76	13	24	85	7·5	19·1	22	·54	·11
July	82	89	77	12	21	85	7·6	20·6	25	·53	·12
August	82	89	77	12	22	86	7·6	18·2	25	·58	·13
September	82	89	76	13	24	84	6·9	14·2	19	·66	·13
October	80	88	72	16	28	81	4·6	6·4	9	·78	·13
November	73	84	64	20	32	77	3·2	1·0	2	·88	·12
December	66	78	55	23	36	76	2·8	0·7	1	·94	·13
Year... ...	76					79	5·1	120·0	159	29·74	

Mean highest temperature of year . .	99°	
,, lowest ,, ,, . .	45°	
,, annual range of temperature . .	54°	
Highest recorded reading (11 years) .	101·8°	(1886)
Lowest ,, ,, ,, . .	43°	(1880)
Absolute range of temperature . . .	58·8°	
Rainfall of wettest year (29 years) . .	188·2″	(1866)
,, driest ,, ,, . .	65·3″	(1863)
Rainy days in wettest year (18 years) .	187	(1874)
,, driest ,, ,, . .	137	(1882)

the seasons, and would not have been worth more than one year's purchase."* In addition, the sanitary condition of the general population, and of the imported coolies employed in the tea gardens, has received a good deal of attention from the Government and planters, so that, though far from perfect, it is infinitely better than formerly. The mortality and disablement from malaria disease is still enormous, and will remain so for many years; whilst the deaths from cholera, intestinal parasites and other diseases are excessive.†

The climate varies considerably in different parts. Allusion has already been made to the enormous rainfall at Cherra Punji‡ and details of the hill station of Shillong (*v.* table 3) have been given. For the lower altitudes the climate of Silchar is fairly representative (*v.* table 10).

The Central Provinces are made up chiefly of the three great plains of Berar, Nagpur, and Raipur (Chhatisgarh), which stretch away south from the foot of the Satpura range and are drained respectively by the Poorna, a tributary of the Tapti, the Waigunga, a tributary of the Pranhita and Godaveri, and the Mahanadi. These plains, composed of black cotton soil, are cultivated in parts, clothed with scrub jungle in other parts, and to a slight extent with forest, the latter being a Government reserve and encouraged to spread as rapidly as possible. In some respects the climate may be considered as representative of India: the hot, rainy, and cool seasons are well marked, and camp life during the last season, from November till the end of February, is as perfect as can be imagined (*v.* table 11). The most unhealthy season, as in most other parts of India, is during the period between the cessation of the rains and the commencement of the cold weather. The climate of the stations situated upon the various hill ranges—Chindwara, Seoni, Betùl, Pachmari, etc.,—is reasonably cool. Thus, at Seoni, the mean temperature for November, December and January is 64° F., and for the year 74° F.

---

* *v. I. M. G.*, Oct., 1893, p. 350. † Sir J. Fayrer. ‡ *v.* p. 326.

CENTRAL PROVINCES.

11. Nagpur—Elevation 1025 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	69	83	55	28	42	51	2·2	0·6	1	28·97	·14
February	73	89	59	30	46	42	2·0	0·4	2	·91	·14
March	82	99	67	32	49	32	2·5	0·6	2	·83	·15
April	89	105	75	30	42	28	3·1	0·5	2	·73	·15
May	93	108	80	28	42	30	4·1	0·8	4	·64	·14
June	86	98	78	20	38	60	7·1	8·8	15	·56	·11
July	79	88	75	13	25	80	8·6	13·3	20	·56	·10
August	79	88	75	13	23	78	8·3	8·9	18	·61	·11
September	79	89	73	16	24	76	7·4	7·8	15	·67	·12
October	77	90	68	22	35	60	4·0	2·3	3	·82	·12
November	71	84	59	25	39	52	2·6	0·4	1	·94	·12
December	67	80	54	26	38	52	2·4	0·5	1	·98	·12
Year... ...	79					53	4·5	44·9	84	28·77	

Mean highest temperature of year . 115°
" lowest " " . 46°
" annual range of temperature . 69°
Highest recorded reading (10 years) . 117·7° (1883, 1885)
Lowest " " " . 43·1° (1883)

Absolute range of temperature . . 74·6°
Rainfall of wettest year (39 years) . 65·3″ (1831)
" driest " " . 25·5″ (1868)
Rainy days in wettest year (13 years) . 119 (1884)
" " driest " " . 61 (1876)

The West Coast of the peninsula, from the gulf of Cambay to Cape Comorin, more especially the belt of land extending from the western slope of the Ghâts to the Sea (Konkan and Malabar), is noteworthy as having a climate at once the dampest and most uniform in India. Although the area included runs from 8°—21° N. lat., the mean annual temperature is almost the same throughout, but the extremes are greater in the north, *e.g.*, at Surat, and diminish by degrees, till at Cochin the mean temperature for January, *viz.* 79° F., is two degrees higher than that of July, the difference being probably due to the smaller rainfall and lesser degree of humidity in the former month. The climate of Mercara, in Coorg, is that of the summit of the Ghâts and is distinguished by its enormous rainfall and high degree of cloudiness* and humidity. The important, but very malarious, district of the Wynaad is situated on the Ghâts immediately to the south of Mercara, and runs down to the foot of the hills. The climate is similar to that of Coorg but slightly warmer owing to its lower elevation. Bombay (*v.* table 12) is fairly representative of the climate of the W. Coast, the extremes being Surat in the north and Cochin in the south, as already explained.

Within a distance of less than fifty miles from the eastern slope of the Ghâts the heavy rainfall that deluges the west-coast is almost entirely unknown.† From the Ghâts there slopes a vast tableland eastwards drained by the Godaveri, Kistna, Cauvery and other rivers which discharge their waters into the Bay of Bengal. To the south and south-east of Bellary is a large tract of 6,000—7,000 square miles, on which the mean annual rainfall is less than 20 inches. This district has frequently suffered from dire famine, the last occurring as late as 1892. It is not to be understood, however, that the climate of this great plateau, which includes Khandesh, the Deccan, and Mysore, is unhealthy—or even unpleasant—throughout, for though there are certain parts where malarious fevers are very preva-

---

* *v.* p. 324. † *v.* p. 330, *para.* 2.

THE WEST COAST.

12. Bombay—Elevation 37 feet.

—	Temperature. Mean.	Temperature. Mean Max.	Temperature. Mean Min.	M. Range. Daily.	M. Range. Monthly.	Hum. Mean.	Cloud. Mean.	Rainfall. Ins.	Rainfall. Days.	Barometer. Mean.	Barometer. Daily Range.
January	74	82	68	14	24	70	1·5	0·1	1	29·95	·12
February	75	82	69	13	26	69	1·3	...	1	·92	·12
March	79	85	74	11	22	73	1·8	...	...	·88	·12
April	82	88	77	11	17	75	2·3	...	...	·81	·11
May	85	90	80	10	15	75	4·1	0·5	2	·77	·10
June	83	88	80	8	17	82	7·9	20·8	20	·67	·08
July	81	85	77	8	13	87	9·1	24·7	29	·67	·06
August	80	84	77	7	13	87	8·8	15·1	26	·73	·08
September	80	84	76	8	13	86	7·5	10·8	21	·78	·09
October	81	87	76	11	18	81	4·3	1·8	7	·84	·11
November	80	86	73	13	22	71	2·2	0·5	1	·91	·11
December	76	84	70	14	23	70	1·8	0·1	...	·95	·12
Year	80					77	4·4	74·4	108	29·82	

Mean highest temperature of year . . .	95°
„ lowest „ „ . . .	61°
„ annual range of temperature . .	34°
Highest recorded reading (37 years) . .	100·2° (1857)
Lowest „ „ „ . . .	53·3° (1847)
Absolute range of temperature . . .	46·9°
Rainfall of wettest year (40 years) . .	114·9″ (1849)
„ driest „ „ . . .	40·6″ (1871)
Rainy days in wettest year (11 years) . .	123 (1883)
„ driest „ „ . .	82 (1876)

S. INDIAN PLATEAU.

13. Poona—Elevation 1849 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	72	86	54	32	43	41	1·8	0·2	1	28·13	·14
February	76	90	56	34	50	33	1·7	...	...	·09	·14
March	83	98	64	34	47	29	2·5	0·2	1	·05	·14
April	86	101	69	32	43	31	2·4	0·6	2	27·99	·14
May	85	100	71	29	41	42	3·0	1·6	2	·94	·12
June	79	89	72	17	27	69	7·6	5·6	13	·88	·09
July	75	81	70	11	19	79	9·0	6·6	21	·87	·07
August	75	83	69	14	22	79	8·7	4·1	20	·91	·08
September	75	83	68	15	23	77	8·1	4·3	15	·97	·10
October	78	87	66	21	33	58	4·9	4·1	8	28·05	·12
November	75	85	59	26	41	46	2·8	0·8	2	·10	·13
December	72	83	54	29	41	41	2·7	0·2	1	·14	·13
Year	78					52	4·6	28·3	86	28·01	

Mean highest temperature of year . . . 106°
" lowest " " . . . 44°
" annual range of temperature . . . 62°
Highest recorded reading (8 years) . . . 109·2° (1886)
Lowest " " " . . . 40·8° (1881)

Absolute range of temperature . . . 68·4°
Rainfall of wettest year (43 years) . . . 56·9″ (1861)
" driest " " . . . 14·2″ (1844)
Rainy days in wettest year (11 years) . . . 94 (1883)
" " driest " " . . . 71 (1876)

14. Bangalore—Elevation 2981 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	67	79	56	23	33	60	2·8	0·2	1	27·04	·12
February	72	85	59	26	36	52	2·3	0·1	...	·02	·13
March	77	90	64	26	37	49	2·6	0·6	2	26·99	·13
April	80	93	69	24	32	52	3·5	1·3	3	·94	·13
May	79	92	69	23	33	61	4·5	5·0	10	·90	·12
June	74	85	67	18	27	73	5·7	3·2	13	·88	·10
July	72	83	66	17	24	77	6·2	4·0	14	·89	·09
August	72	83	66	17	24	77	6·1	5·9	17	·90	·11
September	72	82	65	17	25	76	5·9	6·3	13	·93	·12
October	72	82	65	17	24	75	5·7	6·4	13	·96	·12
November	70	79	62	17	27	73	4·9	1·9	7	27·00	·12
December	67	78	59	19	29	68	4·0	0·7	3	·04	·12
Year	73					66	4·5	35·6	96	26·96	

Mean highest temperature of year . . . 98°
" lowest " " . . . 51°
" annual range of temperature . . . 47°
Highest recorded reading (10 years) . . . 99·4° (1882)
Lowest " " " . . . 45·8° (1877)

Absolute range of temperature . . . 53·6°
Rainfall of wettest year (51 years) . . 56·7″ (1874)
" driest " " . . . 16·0″ (1838)
Rainy days in wettest year (11 years.) . . 149 (1878)
" " driest " " . . . 73 (1876)

lent and others where the heat is excessive, many of the healthiest and most favourite stations in India are here situated, such as Poona, Belgaum and Bangalore (*v.* tables 13, 14). In the southern portion of the plateau, especially Mysore, the rainfall is sufficient to permit of the growth of large forests of teak, sandal wood and other valuable trees, but the jungles are extremely malarious and the inhabitants suffer severely. Poona and Bangalore are chosen as examples not so much for their representative climatic characters as for their importance. The former station forms a delightful retreat, during the rains, for dwellers in the western presidency who object to the excessive moisture of Bombay and other places, whilst the climate of Bangalore* is the finest of any so-called 'plain' station in India.

Coming, lastly, to the Carnatic, which forms the eastern and south-eastern boundaries of the great plateau just described, and includes the country drained by the lower portion of the Cauvery, and the numerous hill ranges of Southern India, we have a climate which presents important differences to those of other parts of India. What this difference is can easily be understood from a study of the geographical position of this portion of the peninsula and from the descriptions already given of its rainfall,† and of its relation to the summer and winter monsoons.‡ It is not so uniform a climate as that of the west coast, but, on the other hand, it is rarely very hot and never very cool. The most unpleasant months are April, when the damp and relaxing 'long-shore' winds blow, and August and September, when it is very close and 'muggy' before the advent of the winter monsoon. For the ordinary European it is a wonderfully healthy climate, but to some it is too relaxing, whilst for others, who are accustomed to the cloudy and rainy west coast, it is too warm. The town of Madras (*v.* table 15) has a climate fairly typical of the Carnatic generally, but in the interior of the country (*v.* table 16) it is drier and less relaxing.

---

* "A climate second only in attractiveness to that of the Nilgiri hills." Blandford. † *v.* pp. 330–1. ‡ *v.* p. 373.

THE CARNATIC.

15. MADRAS—Elevation 22 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	76	85	68	17	26	72	4·1	0·9	3	29·99	·12
February	77	87	68	19	28	71	2·8	0·3	1	·97	·13
March	81	90	72	18	29	73	2·5	0·4	1	·91	·14
April	85	93	77	16	27	72	2·9	0·6	1	·82	·13
May	87	98	81	17	32	67	3·9	2·1	3	·74	·13
June	88	99	81	18	31	61	6·5	2·1	10	·70	·12
July	86	97	79	18	28	64	7·1	3·9	14	·72	·12
August	85	95	77	18	27	69	6·4	4·6	14	·75	·13
September	84	94	77	17	28	70	6·2	4·8	11	·77	·13
October	81	89	75	14	25	77	6·2	10·5	14	·84	·13
November	78	85	72	13	25	79	6·3	13·5	14	·92	·12
December	76	83	70	13	23	77	5·4	5·3	9	·98	·11
Year... ...	82					71	5·0	49·0	95	29·84	

Mean highest temperature of year . . .	108°
,, lowest ,, ,, . . .	60°
,, annual range of temperature. . . .	48°
Highest recorded reading (27 years) . .	112·9° (1880)
Lowest ,, ,, ,, . . .	57·6° (1876)
Absolute range of temperature . . .	55·3°
Rainfall of wettest year (74 years) . .	88·4″ (1827)
,, driest ,, ,, . . .	18·5″ (1832)
Rainy days in wettest year (26 years) . .	119 (1847)
,, ,, driest ,, ,, . .	73 (1876)

THE CARNATIC.

16. Trichinopoly—Elevation 275 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	76	87	67	20	30	68	4·2	1·0	1	29·71	·14
February	78	92	68	24	34	62	2·9	0·5	...	·70	·16
March	83	98	73	25	36	58	3·1	0·7	1	·66	·16
April	87	101	78	23	33	54	4·4	1·8	1	·57	·16
May	88	102	78	24	33	56	5·6	3·8	5	·52	·15
June	86	99	78	21	29	57	7·4	1·3	3	·50	·12
July	85	98	78	20	27	57	7·7	2·2	3	·51	·12
August	84	96	76	20	28	61	7·8	4·4	7	·53	·13
September	83	95	75	20	27	63	7·4	5·3	8	·55	·14
October	81	91	74	17	26	73	7·8	7·8	11	·59	·14
November	79	87	71	16	26	76	7·4	5·2	9	·65	·13
December	76	85	69	16	27	74	5·9	3·1	6	·70	·13
Year... ...	82					63	6·0	37·1	55	29·60	

Mean highest temperature of year . .	106°	Absolute range of temperature . . .	51·3°
,, lowest ,, ,, . .	60°	Rainfall of wettest year (33 years) . .	95·3″ (1863)
,, annual range of temperature . .	46°	,, driest ,, ,, . . .	17·1″ (1845)
Highest recorded reading (12 years) . .	107·9° (1876, 1881)	Rainy days in wettest year (11 years) . ,	70 (1877)
Lowest ,, ,, ,, . .	55·6° (1884)	,, ,, driest ,, ,, . .	31 (1876)

CEYLON.

17. Colombo—Elevation 40 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
				M. Range.							
	Mean.	Mean Max.	Mean Min.	Daily.	Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	79	86	72	14	21	74	4·9	3·0	6	29·88	·12
February	80	87	73	14	22	73	4·2	1·7	4	·88	·13
March	82	88	75	13	18	76	4·7	5·5	9	·87	·13
April	83	89	77	12	18	77	5·6	8·8	13	·82	·12
May	83	87	78	9	18	79	6·8	13·2	20	·81	·10
June	82	85	78	7	14	81	7·6	8·2	17	·82	·08
July	81	85	77	8	14	80	6·8	5·5	12	·83	·08
August	81	84	77	7	13	80	7·0	4·5	13	·84	·09
September	81	85	77	8	13	80	6·9	4·9	14	·86	·11
October	81	85	76	9	15	80	6·8	12·9	21	·86	·11
November	80	85	74	11	16	79	6·2	12·7	17	·86	·11
December	80	85	73	12	19	76	5·9	6·4	13	·87	·12
Year	81					78	6·1	87·3	159	29·85	

Mean highest temperature of year . . 93°
" lowest " " . . 68°
" annual range of temperature . . 25°
Highest recorded reading (12 years) . . 95·8° (1885)
Lowest " " " . . 65·8° (1880)

Absolute range of temperature . . . 30°
Rainfall of wettest year (17 years) . . 139·7″ (1878)
" driest " " . . . 57·0″ (1874)
Rainy days in wettest year (12 years) . . 195 (1885)
" " driest " " . . 125 (1876)

LOWER BURMA.

18. Rangoon—Elevation 41 feet.

—	Temperature. Mean.	Temperature. Mean Max.	Temperature. Mean Min.	M. Range. Daily.	M. Range. Month.	Hum. Mean.	Cloud. Mean.	Rainfall. Ins.	Rainfall. Days.	Barometer. Mean.	Barometer. Daily Range.
January	75	88	64	24	35	66	2·4	0·2	1	20·96	·13
February	77	93	65	28	38	62	2·2	0·1	1	·91	·14
March	81	97	71	26	37	64	2·2	0·1	...	·87	·15
April	84	98	76	22	31	68	3·6	1·8	4	·80	·15
May	83	93	77	16	27	76	6·5	10·9	16	·75	·12
June	79	86	77	9	18	88	8·8	18·4	28	·73	·09
July	78	85	76	9	16	90	9·0	21·3	29	·73	·08
August	78	85	76	9	16	91	9·0	18·6	27	·75	·09
September	78	85	76	9	16	89	8·3	16·0	26	·79	·11
October	80	88	76	12	18	85	6·2	8·1	14	·84	·12
November	78	87	73	14	24	80	4·5	3·4	6	·89	·11
December	76	87	68	19	29	74	3·2	0·1	1	·94	·12
Year	79					78	5·5	99·0	153	29·83	

Mean highest temperature of year . . 104°
,, lowest ,, ,, . . . 58°
,, annual range of temperature . . 46°
Highest recorded reading (11 years) . . 106·7° (1877)
Lowest ,, ,, ,, . . 55·7° (1883)

Absolute range of temperature . . . 51°
Rainfall of wettest year (17 years) . . 143·4" (1871)
,, driest ,, ,, . . 69·1" (1874)
Rainy days in wettest year (10 years) . 161 (1880, 1882)
,, ,, driest ,, ,, . . 132 (1878)

Of the climates of Ceylon and Burma it is impossible to say much here. The former has an extremely uniform island or 'humid marine' climate (*v.* table 17), whilst that of Lower Burma (*v.* table 18) resembles the climate of the West coast of India and that of Upper Burma approximates to the climate of Assam. There are, however, many important exceptions. There is promise of several excellent sites for hill stations among the Shan hills on the Burma-Siam frontier. Memyo is already occupied, and Byingyi, at an altitude of about 6,000 feet on a spur of the Shan hills, has been favourably reported on.

The above can only be regarded as a very brief summary of the more important of the climates of India, but it will serve to give the student or the newly-arrived medical officer some idea of the wonderful variety of climates afforded by the Indian Empire. For many districts and localities special hand-books have been written by former medical officers, civilians, and others, of which the name and other particulars are obtainable locally. There is a great want in many places of up-to-date and easily accessible information* regarding the local climate, diseases, customs, ethnography and other points of value to the hygienist, and it is extremely desirable that a complete and authoritative series of manuals, containing the latest obtainable information relating directly or indirectly to the science and art of hygiene, should be compiled by selected medical officers and published officially for the use of all concerned with the medical and sanitary work of the various districts.

---

* The *District Manuals* which are written and published officially for many places are most useful, and should be studied by every medical officer, subordinate or otherwise, when appointed to a district; but the special information required is often absent, scanty, or quite out of date. The Madras District Manuals are now undergoing revision. Some are of a most unwieldy size and not so useful to the medical officer as the original topographical hand-books published many years ago. *V.* also many papers in the transactions of the Bombay Med. Phys. Soc., the Madras Journ. of Med. Sci., Census Reports, etc.

END OF VOL. I.

INDEX.

(NOTE.—To Student.—*If the word looked for is not present as a separate heading, refer to the chief heading of the subject :* e.g., *for 'constant' method of water supply, see* WATER, *etc.*)