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THE ATMOSPHERE

IN RELATION TO

HUMAN LIFE AND HEALTH.

BY

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THE ATMOSPHERE IN RELATION TO HUMAN LIFE AND HEALTH.

By Francis Albert Rollo Russell,[1]

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Part I.—Constitution and Conditions of the Air.

The atmosphere has been compared to a great ocean, at the bottom of which we live. But the comparison gives no idea of the magnitude of this ocean, without definite bounds, and varying incessantly in density and other important qualities from depth to height and from place to place.

Uninterrupted by emergent continents and islands, the atmosphere freely spreads high above all mountains and flows ever in mighty currents at levels beyond the most elevated regions of the solid earth. What is the composition of this encompassing fluid, and what its character? The work of the present century has gathered in a rich store of knowledge to answer the inquiry.

The atmosphere consists in the main of two gases, oxygen and nitrogen, and these are intimately mixed in the proportion of about 20.9 of oxygen to 79.1 of nitrogen by volume, and 23.1 of oxygen to 76.9 of nitrogen by weight.[2] These gases, which are each of them chemical elements, are not chemically combined with one another, but only mixed; each preserves its qualities, modified only by solution in the other. Gases have the property of diffusing among each other so completely, that no portion which could be conveniently taken, however small, would fail to represent the two gases in a proportion corresponding with that which they maintain in the whole atmosphere.

Another valuable constituent of the atmosphere, though varying greatly in amount at different times and places, is of no less impor-

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[1] Author of "London Fogs," "Epidemics, Plagues, and Fevers; their Causes and Prevention," "The Spread of Influenza," "Observations on Dew and Frosts," etc.

[2] M. Leduc gives the weights as follows: Oxygen, 23.58; nitrogen, 76.42. Dumas and Boussingault give the density of nitrogen as 0.09725. (Comptes Rendus, 1890.)

tance to mankind than the two elementary gases which make up by far the greater part of the volume and weight of the whole. This is vapor of water, the result of the process of evaporation of those vast watery surfaces which are always in contact with the lower strata of the air.

Deprive the air of any one of these three main constituents and human life becomes impossible.

Next in rank from the human point of view is carbon dioxide, or carbonic acid gas, which, though comparatively very small in amount, exists throughout at least all the lower ranges of the atmosphere, and has the same close and necessary relations with plant life as oxygen has, or rather as food has, with the life of animals. It presents on a great scale an example of the wonderful law of gaseous diffusion; for, though much heavier than air, in the proportion of about 2 to 1, it diffuses under natural conditions nearly equably through every part, whether the region of its origin be near or distant.

Stated in tons, the following are the calculated weights of the chief substances composing the whole atmosphere:

	Billions of tons.
Oxygen	1, 233, 010
Nitrogen	3, 994, 593
Carbon dioxide	5, 287
Vapor	54, 460

In addition to the above, we find in the air a variable and very small quantity of ammonia, chlorides, sulphates, sulphurous acid, nitric acid, and carburetted hydrogen, but some of these depend, where detected, to a great extent on manufacturing operations and on aggregations of men and animals.

Liquids and solids in great variety are also very important, widely diffused, and constant ingredients in the atmosphere. The solids are everywhere present in the condition of very minute microscopic or ultra-microscopic motes or dust, composed chiefly of sea salt, or chloride of sodium, sand, or fine silicious particles, various dusts derived from volcanoes, factories, towns, and the remains of meteors set on fire in their passage through the upper air. Some of the most beneficent functions of these microscopic and invisible motes will be considered later. Other solids present in the upper air over a large part of the globe and in the lower strata, especially in the Arctic regions, are small particles of ice, condensed either in clouds or in air which appears nearly clear. Explorers in high latitudes relate that on fine cold days the air is frequently sprinkled with shining crystals of ice which seem to fall from a blue sky, and, on the other hand, in heavy gales and stormy weather the lower air is filled with a fine icy dust, resulting from the freezing of the spray torn from the sea waves. In temperate climates very much of the rain which falls on the surface of the earth has existed previously at high levels in the state of snow or ice particles. The experience of mountaineers and balloon voyagers, and, in a mountainous country, the sight of peaks covered with fresh snow after a day's rain on the low ground, prove how commonly rain is melted ice or snow.

Other solid particles always present in great numbers in the lower air, and of great importance in relation to human, animal, and plant life, are various kinds of microbes, fungi, molds, and spores. At certain seasons the pollen of plants is very abundant. In some countries the air is thick in the dry and windy season with the dust of the soil. Agricultural fires cause a thick haze over parts of Germany, the United States, and other countries at certain times of the year. After great volcanic eruptions the air over many thousand square miles has been affected by a dense haze. This was notably the case in the summer of 1783, when, after an eruption in Iceland, terrestrial and celestial objects were dimmed by "dry fog" in western and central Europe during several weeks. In 1883, on the other hand, after the eruption of Krakatoa, near Java, the upper air, between 40,000 and 120,000 feet in altitude, was overspread with a semitransparent haze of a very remarkable character, consisting mainly of finely divided, glassy pumice. This haze stratum in the upper sky extended over all known countries and remained visible for several months.

Cloud globules are the most obvious and widely present liquid ingredients of the atmosphere. They possess properties of great interest in connection with the recently discovered ubiquitous atmospheric dust, with optical phenomena, and with the formation and distribution of rain.

The other familiar forms of water in the air are dry and damp fogs, mist, and rain. Haze is in most instances, at least so far as the present writer's observations go, in the south of England, a phenomenon depending on very small particles of water and on the presence of dust particles as nuclei.

Ozone, an allotropic and unstable form of oxygen, has been found to be constantly present, in very small quantities, in the open air in natural conditions, but can not be traced in the impure air of great towns, and is no doubt always greatly diminished where dwellings are thick together. Ozone consists of molecules, each supposed to contain three molecules of oxygen.

Peroxide of hydrogen is also supposed to exist in slight traces in the general atmosphere.

Minor impurities, arising from animal life, from manufacturing processes, and from the combustion of coal, are mostly not perceptible to the senses, except in the neighborhood of places where they are given off very abundantly.

The principal functions of all these various elements and substances of which the atmosphere is composed, may now be regarded in detail with special reference to their influence upon human life and welfare.

OXYGEN.

Oxygen, that wonderful element which constitutes very nearly half of the solid crust of the globe, combined as most of it is with the metallic and other elements of the earth, forms also, in union with hydrogen, the great body of water which covers three-fourths of the terrestrial surface. Water consists of two volumes of hydrogen and one volume of oxygen chemically combined. Stated by weight, out of nine parts of water eight are oxygen. But water, as we know it, always contains other matter, and chiefly atmospheric air, which is dissolved in it, and to a considerable extent changes its character. For the service of man, water, deprived of air, would have lost several important characteristics. Oxygen is dissolved in water to the extent of 2.99 volumes to 100 of water at 15° C., an amount sufficient to support the existence of fishes and hosts of other aquatic creatures, and to oxidize and render innocuous some of the common impurities which result from animal and vegetable processes and decay. Probably its power when dissolved in the liquid is greater than in the atmosphere, and it must be compressed into a smaller space. Fresh charcoal absorbs eighteen times its volume of oxygen, and a much larger bulk of organic vapors, especially ammonia; in this condensed state the oxygen acts so powerfully as to unite with hydrogen to form water vapor, and with sulphur to form sulphur dioxide. We may thus assume that water, as we use it and drink it, has important effects upon the body which would not take place if robbed of its contained oxygen. As an instance of the value of the air contained in water for many domestic purposes, its assistance in the making of tea may be mentioned; if the air be allowed to boil out of the water the beverage is spoiled. Recent observation, however, shows that oxygen is not altogether removed from good water by the process of boiling.[1]

Oxygen has a very strong chemical attraction for the elements; only one is known with which it does not combine. Hence, "to burn" in common language means combination with oxygen, and most substances in the crust of the earth are already burnt, or combined with oxygen. In its ordinary form it has no color, taste, or smell, according to most observers, but recently a faint blue color has been detected as belonging to it, when seen in sufficient quantity. It has a small refracting influence on light, and exhibits a magnetic property, especially strong in the liquid form, to which it has recently been driven by intense cold and pressure. The degree of cold required was – 140° C. under a pressure of 320 atmospheres.

The proportion, by weight, of oxygen in the air has been determined by Leduc as 23.58 per cent.[2]

The volume of oxygen in the air in different localities and conditions has been tested by various observers. On the western seashore of Scotland the percentage was found to be 20.991; on the tops of hills, 20.98; in a sitting room (close), 20.89; at the backs of houses, 20.70; at the bottom of shafts in mines, 20.44.

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[1] See Comptes Rendus, 1890. M. Muller.

[2] Comptes Rendus, 1890. A. Leduc.

The accurate determinations of Bunsen of the oxygen in the general air gave a mean of 20.93 per cent. Two hundred and three analyses by Reiset gave nearly the same result. Hempel found the amount at Tronso to be 20.92; at Dresden, 20.90; at Paris, 20.89. These amounts must be received with qualification, because in comparing one town with another more depends on the position in the town than on the situation of the town.

The average proportion of oxygen in the open country or at sea may be stated at about 20.95 per cent. In large, open spaces in London the amount of oxygen is nearly normal; in the streets, about 20.885; in Manchester, in fog and frost, 20.91; in the suburbs in wet weather, 20.96 to 20.98. These figures are merely approximate.

In the air of mines an average of 20 has been observed, and in extreme cases the amount was no higher than 18.6.

In the midst of vegetation on open ground, especially in the daytime, there is an excess of oxygen.

Angus Smith and others found the following quantities of oxygen in air in different situations:

On the Atlantic (Regnault)	20.918
In the Andes on Pichincha, about (Regnault)	20.949
Tops of hills, Scotland	20.98
Northeast shore and open heath, Scotland	20.999
Stockholm (Petersson and Högland)	20.94
Suburb of Manchester, wet day	20.98
Middle of Manchester, inclosed space	20.652
Manchester, fog and frost	20.91
Manchester, backs of houses and closets	20.70
Manchester, dense fog	20.86
Heidelberg (Bunsen)	20.924
Low parts of Perth	20.935
Swampy places, France and Switzerland	20.922 20.95
Bengal Bay, over bad water (Regnault)	20.387
Sitting room, rather close	20.89
Small room with petroleum lamp	20.84
Gallery of a theater, 10.30 p. m	20.86
Pit of a theater, 11.30 p. m	20.74
Court of Queen's Bench	20.65
Chemical Theater, Sorbonne, before lecture	20.28
Chemical Theater, Sorbonne, after lecture	19.86
In cow houses	20.75
In sumps or pits in mines	20.14
Worst in a mine	18.227
Very difficult to remain in many minutes	17.2

Recent experiments by Messrs. Smith and Haldane on impure air contained in a leaden chamber showed that with oxygen 20.19 and carbon dioxide 3.84 two men instantly got headaches on entering.

Oxygen is the breath of life, the element without which no human being could exist for a single hour. Brought into contact by every inhalation of the lungs, it revivifies the loaded blood, spreads over the body the warmth resulting from its combustion with the carbon contained in the blood and tissues, and gives to the whole physical being a vigor and freshness which is impossible where the element is deficient. Thus to mankind it is life-giver, warmth-maker, and purifier. Unlike food, which may be taken irregularly and at long intervals, oxygen is a necessity at all times and in all conditions, in every hour of the day and night; and upon its reaching or approaching the normal quantity in the air around us, our health and enjoyment directly depend.

By the law of diffusion of gases, which causes the interchange of position of gases separated by a thin porous partition, the carbonic acid gas brought by the blood to the lungs passes out and is then exhaled, while the oxygen breathed into the air cells passes in through the walls of these cells to the blood. The heart sends the impure blood derived from the circulation through the body to the lungs; this dark blood is loaded with carbonic acid gas; the lungs return the aerated and purified red blood through their blood vessels to another division of the heart, which again drives the vivifying blood through the system. Experiments have shown that a similar change in appearance from dark to bright red blood can be caused by passing a stream of oxygen through the dark venous blood of an animal. That a process of combustion, or, otherwise put, chemical union, goes on at the same time, is shown by the fact that the blood is raised one or two degrees by its contact with oxygen. The oxygen in its course through the body combines with the effete or waste products presented to it by the tissues, and so the heating effect of combustion maintains the temperature of the whole body at the normal, about 98.6. The waste gases given off by the lungs consist of carbonic acid gas, water vapor, and a very small quantity of ammonia and other organic matters.

The average volume of air breathed in at each breath is about 30 cubic inches, and the volume of air which may be easily breathed in by an effort, and by expanding the chest, is about 130 cubic inches, or about four times as much. After a very full inspiration about 230 cubic inches can be expired by a man of average height and in good health. The total capacity of the lungs, however, is much more than this—about 330 cubic inches. Thus in ordinary quiet breathing we only fill about one-tenth of the available air space of the lungs. After every outbreath, or expiration, a quantity of air is left in the lungs. This residual air amounts to about 100 cubic inches.

An adult at rest breathes about 686,000 cubic inches in the course of twenty-four hours; a laborer at full work, about 1,586,900 cubic inches—more than double. The amount of air passing into the lungs has been estimated at 400 cubic feet in a state of rest, 600 in exercise, 1,000 in severe exertion. The number of air cells in the lungs is estimated at 5,000,000 or 6,000,000, and their surface at about 20 square feet. The epithelium or membranous film between the blood and air is exceedingly thin, and in many parts the capillaries are exposed, in the dividing walls of cells, to air on both sides. The weight of air inhaled in the course of the day is seven or eight times that of the food eaten. The mechanical work of breathing represents energy expressed by the lifting of 21 tons 1 foot in 24 hours.[1]

From every volume of air inspired about 4½ per cent of oxygen is abstracted, and a somewhat smaller quantity of carbonic acid gas is at the same time added to the expired air.

Experiments on animals show that the amount of oxygen absorbed is very little if at all increased by an excess in the air surrounding them.

OZONE.

Ozone is an important constituent of the atmosphere, greatly contributing to its purity and freshness and to the vigor of human life. It is a form of oxygen in which the molecule is considered to be composed of three molecules of the gas.

Although existing in small quantity in the air, rarely exceeding 1 part in 10,000, the activity of ozone is so great and its function so beneficial that its presence in normal quantity is, in ordinary surroundings, a fair guaranty of the purity of the air and of healthy conditions so far as breathing is concerned. No ozone is found in the streets of large towns, in most inhabited rooms, near decomposing organic matter, and in confined spaces generally. In very large, well-ventilated rooms it is sometimes, though rarely, detected. Ozone is found in very small quantity a little to leeward of a large town. Even at Brighton, a town of about 110,000 inhabitants, ozone was barely discoverable on the pier when the wind blew from the town, but abundant when the wind was from another direction.

Ozone has the power of oxidizing to a much higher degree than oxygen, and vigorously attacks organic matter in a fine state of division. It is therefore a strong disinfectant. Its oxidizing power is the reason of its absence from confined spaces where organic matter, dust, or smoke is present, for such matter quickly uses up the small portion of ozone which enters with the fresh air. The walls, furniture, etc., are also covered with fine dust, which the ozone attacks. The difference we feel in going from a furnished room, however large, into the open air, is thus partly accounted for. There is somewhat more ozone on mountains than on plains, and most of all near the sea. Water is said by Carius to absorb 0.8 of its volume of ozone. An examination of sea water with a view to detect the amount contained in it would be difficult, but might give interesting results. A great excess of ozone is destructive to life, and oxygen containing one two hundred and fortieth part of ozone is rapidly fatal. The ordinary quantity even has bad effects in exacerbating bronchitis and bronchial colds and some other affections of the lungs.

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[1] Professor Haughton, Carpenter's Principles of Human Physiology.

Ozone is formed by the passage of the electric spark, and especially of the brisk discharge through oxygen, and is therefore found in unusual quantity after thunderstorms. It may also be formed by the slow oxidation of phosphorus, and of essential oils in the presence of moisture; also by the decomposition of water by a galvanic current. When formed by electric discharge in air, it is quickly turned back again into oxygen, either by further discharges or by the action of high temperature, about 230° C.; at the temperature of boiling water it is slowly decomposed in moist air. Its pungency of odor is said to make it easily perceptible when only present to the extent of 1 volume in 2,500,000 volumes of air, and the smell may sometimes be noticed on the seabeach. It has been liquefied at 100° C. under 127 atmospheres pressure. In this form it shows a dark indigo-blue color; gaseous ozone looked at in a tube 1 meter long also shows a blue color. Thus there can be little doubt that, in conjunction with oxygen and fine dust, it contributes to the azure hue of the sky.

NITROGEN.

Nitrogen, the gas which constitutes four-fifths of the volume of the atmosphere, takes no direct part in the sustenance of human life, but has two great functions to perform: first, the dilution of oxygen to the proper and tolerable strength for respiration, and secondly, the supply of food material to plants.

Although life is possible for many hours in pure oxygen, it is hardly conceivable that the human constitution could be so modified as to endure for long an atmosphere of so actively combustible a character. At any rate, nitrogen is indispensable in present conditions to the human race. Plants, with few exceptions, do not absorb nitrogen from the air, and, indeed, in the case of most of these exceptions the supply of nitrogen is in a transitional compound form. Nitrogen is brought to the plants in general by processes of decay, and by the action of microbes in the soil, which rearrange organic elements, forming nitrates and nitrites. These nitrogen compounds are largely applied to the roots of plants as manure. Only one or two classes of plants can take up nitrogen from the air. Certain low algæ, freely exposed to light and air, seem to absorb nitrogen directly. Leguminous plants, such as peas, vetches, lupins, beans, clover, etc., absorb nitrogen from the air in a very curious way. Nodules or swellings are found on the roots; these contain minute fungi or microbes; the bacteria absorb nitrogen from the air, and, probably at the expense of the energy of the carbohydrates, etc., which they oxidize, supply this nitrogen in the form of compounds to the plant. These recently discovered facts open out the prospect of obtaining scientifically from the air, in some cases at least, the nitrogen which is now applied in combination with oxygen, soda, etc., as manure. If by the aid of special bacteria parasitic upon the plant we can systematically obtain the chief element of manurial stuffs from the atmosphere itself, a great advance will have been made in agriculture and in the cheapening of food.

CARBON DIOXIDE.

Carbonic acid gas, or carbon dioxide, is found in small quantities everywhere in the air, and in about the same proportion at 11,000 feet as at the sea level. It is a colorless, transparent gas and does not support combustion or animal life. At 0° C. it may be liquefied under a pressure of 38.5 atmospheres. When liquefied and then allowed to escape it freezes into a snow-white solid in the air, and in a vessel under the vacuum of the air pump freezes into a transparent mass like ice.

One liter of carbonic dioxide at 0° C. and 760 mm. pressure weighs 1.97714, nearly double the weight of air, taken as 1.

At the ordinary temperature and pressure water dissolves about its own volume of the gas. Dissolved in rain it exerts in the course of time a very powerful disintegrating effect on rocks and minerals, so that the crust of the earth is greatly modified by the constant action of the solution.

The chief sources of carbonic dioxide in the air are the respiration of animals and the burning of fuel. A large quantity emerges from the earth in certain places, as in the Poison Valley of Java, and in many mineral springs, where it effervesces out of water escaping from pressure.

Saussure found the amount per cent in a wood near Geneva to be 0.0504 in the day and 0.0576 at night; in January, 0.0423; in August, 0.0568. In Geneva he found an average amount of 0.0468, compared with 0.0437 in the wood.

Schulze, Reiset, Levy, Armstrong, and Muntz, in different places, made several thousand observations, and the mean of all these shows during the day 0.0299, and during the night 0.0317. Reiset's long continued observations in the country 4 miles from Dieppe gave an average of 0.02942; and in June, above the crop of red trefoil, 0.02898; in July, above barley, 0.02829; near a flock of sheep, 0.03178.

Thorpe's very carefully conducted experiments agree well with the above values, and give for the air over the sea 0.03011. Armstrong, at Grasmere, obtained during the day 0.0296, and during the night 0.033. At the Montsouris Observatory the mean during 1877–1882 was 0.03.

In an unventilated barrack the following amounts have been recorded as the result of careful observations: 0.1242, 0.189, 0.195; in a hospital at Netley, 0.06 to 0.08; in the General Hospital, Madrid, 0.32 to 0.43; in a boys' school, 4,640 cubic feet and 67 boys, 0.31; in a crowded meeting, 0.365; in a schoolroom at Madrid, 10,400 cubic feet and 70 girls, 0.723; in a stable at Hilsea, cubic space 655 feet per horse, 0.1053.

It is not easily explained why the normal amount of carbonic dioxide in the free air has been so long assumed in scientific articles and textbooks as 0.04 per cent, or 4 volumes per 10,000, when the best recent observations show an average not exceeding 0.0317 per cent, even at night, and a general mean of about 0.0308, or 3.08 volumes in 10,000. All the most recent works on hygiene, however generally accurate, repeat this error.

Considering the value of small quantities in these measurements, especially where they affect human life, it is most desirable that the standard should be taken rather as 3 than 4 volumes per 10,000.

Although carbon dioxide does not itself support animal life, and we could do very well without it in the atmosphere so far as breathing is concerned, it is necessary to the growth of plants, and therefore through them an indispensable substance for the existence of the human race. The vegetable world not only needs a supply of this gas for its own sustenance, but by the selective action of its leaves keeps the air continually pure enough for the life of animals. Under the influence of sunlight every green plant absorbs the carbonic dioxide at its surface, breaks it up into carbon and oxygen, and returns some free oxygen to the atmosphere. In this way the two great kingdoms, the vegetable and the animal, mutually contribute, each to the other, the elements of life. The carbon drawn from the air, together with hydrogen and oxygen, forms the wood of the tree, the stalk of the plant, and the flesh of the fruit, and these, when burnt or eaten, again result in carbon dioxide and water.

The change from the compound gas to carbon and oxygen is brought about by small openings or pores filled with a green substance, chlorophyll, which during the daytime has the power to extract the carbon and set free the oxygen. At night, on the contrary, there is a slight expiration of carbonic dioxide, so that there is a real reason against keeping large green plants in a bedroom during the night. But the amount is very small compared with that exhaled by one person.

It is now known that plants, like animals, breathe oxygen from the air, while they use the carbonic acid as food.

About 1,346 cubic inches of carbonic dioxide are exhaled by a healthy man per hour. An adult gives off in repose about 0.7 cubic foot, and in active work about 1 cubic foot per hour. (Pettenkofer.)

It is a remarkable fact that this amount is much reduced when the air is already fouled with this gas; experiments showed that where the same air was rebreathed, as it often is, the reduction was from 32 to 9.5 inches per minute. Thus it appears that the elimination of waste products from the system is seriously checked by the presence in the air breathed of an excess of carbonic dioxide. Otherwise stated, air in crowded places may continue to sustain life while it fails to remove any but a very inadequate portion of the poisons with which the blood is charged.

The general surface of the skin of the body also gives out a considerable quantity of carbon dioxide, though, of course, very much less than the lungs.

About 67,200 cubic feet of carbon dioxide[1] are given off by the burning of every ton of coal. Since about 405,480 tons are burnt daily in England on an average (the quantity is much larger in winter), the air over the country receives daily about 24,728,256,000 cubic feet of the gas, or 1,200,000 tons.

The perfect burning of ordinary coal gas gives rise to 200 cubic feet of carbonic dioxide for every 100 cubic feet of gas consumed. Practically every cubic foot of gas burnt vitiates as much air as the respiration of one person. So that in a large town during the evening hours in winter the vitiation of the air is in main streets and in rooms many times larger than during the daytime.

Angus Smith, whose methods were not quite so precise as those later in use, found the following amounts of the gas in air in the situation described:

Hills in Scotland, 1,000 to 4,406 feet high	0.0332
Bottom of same hills	.0331
In the suburbs of Dundee at night	.028
In Dundee at night	.042
In London parks	.0301
On the Thames	.0343
Where fields began around London	.0369
In the streets in London in summer	.0380
In Manchester in usual weather	.0403
In Manchester in fogs	.0679
In workshops	.300
In the chancery court, 3 feet from the ground	.203
In the Standard Theater pit	.323
In very ill-ventilated Cornish mines	2.50

It appears from these figures that hill air, like that of the open country and of the seaside, contains little carbonic acid, but is not superior in this respect to the air of the central parts of large parks in towns. In the streets of a town the amount is decidedly larger by about 1 in 10,000 than the average amount of the country. During the prevalence of fogs, streets and confined places in towns often contain double the natural amount. The condition of the air of workshops, theaters, and crowded places generally is evidently foul and dangerous to health.

In the central parts of London, within the city, Dr. W. J. Russell found a mean of 0.0422 for three winters, and 0.0379 for two summers. During fogs the amounts were much higher, giving an average of 0.072, and on one occasion a measurement of 0.141 was recorded. The lifting of a fog was followed by a rapid decrease in the excess. On still dark days the amount was large. On fine days, in strong winds, and on holidays, the quantity was below the average.

The deficiency of oxygen and excess of carbonic acid, which are common to nearly all rooms, schools, churches, theaters, and workshops where many persons are gathered, are very favorable not only to the spread of various infectious diseases, but to the maintenance of a number

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[1] Reduced to about the average temperature of the air in England, 50°.

of minor ailments; and where the exposure to foul air is prolonged, as in workshops, offices, and mills, to a continued depression of vitality. Various artificial means have been tried for improving the air of crowded rooms, and some are successful, but, on the whole, the direct admission of plenty of fresh air in currents directed upward and the removal of bad air by flues of sufficient diameter give in the long run the most satisfactory results.

The worst condition of air to which people are often exposed would probably be found in closed railway carriages. The capacity of an ordinary third-class compartment in England may be put at 240 cubic feet; it is certainly not greater. Containing 10 persons, it provides for each person 24 cubic feet of air at the beginning of a journey. Supposing the air to be unchanged, in the course of one hour each person will have breathed 17.7 of these cubic feet. Therefore, at the end of one hour 177 cubic feet out of 240 in the compartment will have been breathed out of the lungs of its occupants. Since an average man breathes out 0.6 cubic feet of carbon dioxide per hour, the amount of excess of this gas in the compartment at the end of an hour is 6 cubic feet; or otherwise stated, the amount in the air, instead of the normal proportion of 0.03 per 100 cubic feet, is 2.53 per 100 cubic feet. At the same time the oxygen is reduced and a quantity of organic poison and vapor is taken in with every breath. Practically, however, we must take into account the facts that from the first minute every person in the compartment breathes not a fresh parcel of air at every breath, but an already contaminated product, and that an excess of carbon dioxide has the effect of at once diminishing the quantity expired. Thus the amount of carbon dioxide would not be so large as that calculated, but may be estimated at one-half—1.26 per cent. But the deficiency in the carbon dioxide breathed out tells of carbon and other matters remaining unoxidized in the human system. The case of the compartment supposed air-tight is an extreme one and not quite exemplified in practice, but some approach to the condition described occurs in thousands of railway compartments on every calm, cold, winter morning and evening. Again, in traveling to the south of Europe in the winter of 1893 it was noticeable that 48 persons were shut up in one long carriage with a communicating passage between the compartments and without any efficient ventilation even through a hole or chink, the windows and doors all being made to fit closely. Twelve hours of breathing the same air would be likely to bring the occupants to a worse condition than where ten persons sleep in one small bedroom, which is about the worst case actually occurring in large towns. Moreover, these carriages are largely used by invalids and consumptives, and must become sources of infection to delicate persons.

Experiment by means of the sense of smell has shown that air in a room seems fresh when the carbon dioxide does not exceed 0.05999 per cent, a little unpleasant when the proportion is 0.08004 per cent, offensive and very close at 0.12335, and extremely close, when the sense of smell can no longer differentiate, at 0.12818. In a railway compartment this amount is often greatly exceeded.

It is recognized by the best authorities that in order to keep the air in a room in a state good for respiration every person should be supplied with 3,000 cubic feet of fresh air in every hour. Thus, in an unventilated railway carriage occupied by one person, the whole of the air would require to be changed thirteen times an hour, and if occupied by ten persons, one hundred and thirty times an hour. Plainly, the ventilation provided by ventilators or by 2 or 3 inches of open window is incompetent to do this, and falls very far short of what is required when the wind blows in the same direction as that in which the train is moving, virtually resulting in a calm.

A space of 750 to 1,000 cubic feet in a room is properly required for each person, when the whole of the air is renewed by imperceptible and even ventilation about three times an hour. This standard is commonly not approached when several persons occupy a small room and windows and doors are closed. In a railway compartment the space for ten persons should be on the same scale—7,500 cubic feet, at least—and the air should be changed completely three times an hour, at least. As a matter of fact, the space is only one-thirtieth of this desirable quantity, and the whole air may in many cases be changed not more than three times an hour. Since the space can not well be increased, the alternative must be taken of largely increasing the flow of air through the compartment. Small, fixed openings above the windows and a ventilator in the roof would be the most efficient means of replacing foul air by fresh. The openings might be made to diminish in size in proportion to the strength of the wind encountered, and should be so situated as not to cause a perceptible draft. In rooms there is no better cheap ventilation for a mild climate than that obtained by thickening the lower part of the frame of a sash window so as to leave a space between the two sashes by which air enters and diffuses itself through the room, escape being provided by the chimney. Tubes of rather large size communicating directly with the outer air, and with their interior openings directed upward about 4 feet above the floor, are very satisfactory, and by means of a valve or damper can be regulated so as to admit more or less air, according to weather.

For large houses and cold climates, where more expensive apparatus may conduce to ultimate economy, a thoroughly satisfactory arrangement is the provision in the basement of a coke boiler with a system of hot-water tubes contained in a chamber into which fresh air passes, and is thence led through flues into the upper parts of the various rooms, where it becomes cooled and flows away with the products of respiration through openings near the floor into pipes connected with a shaft next the kitchen chimney, and so upward into the open air. But the boiler and stove require much attention, and the substitution of gas for solid fuel would sometimes be preferable.

Gas fires are good if the products of combustion are not permitted to mingle with the air in the room, but carried off by the chimney, as with coal fires. The poisonous gases, etc., generated by combustion are very apt to cause sore throats, headache, and other ailments, and may favor the incidence of diphtheria. Carbon monoxide, which is given off by charcoal, coke, and gas fires in small quantities, is a strong poison.

VAPOR OF WATER.

The atmosphere of vapor of water coexisting with and interpenetrating the atmosphere of nitrogen and oxygen is of no less importance to human life. Its physical properties are very different and its characteristic is variety of state, while that of the dry air in which it floats is uniformity of state. Air is solid at −328° F. under a pressure of 1,000 atmospheres; vapor of water is solid at 32° F. under a pressure of 1 atmosphere. Recent researches have proved that cohesion, the force by which bodies are held together, increases as temperature is reduced. At the exceedingly low temperature of 328° F. metals and other solids are firmer than at any higher degree. Heat is therefore a force by which the molecules of substances in general are driven further asunder in the whole range of temperature. The force of cohesion is less in gases than in liquids and solids; and, indeed, is not manifested at all at ordinary temperatures and pressures. By great cold and great pressure, however, all gases but one have been brought to the liquid condition, wherein cohesion obtains the advantage over heat, and it is almost certain that by still greater cold all gases would be enabled to exist as cohesive solids. The habitable state of our globe depends on the adjustment of temperature and atmospheric density so as to permit the elements of life to maintain their appropriate gaseous and liquid forms. It is the large diversity of melting and boiling points in different substances which makes life possible. Uniformity, or even an approximation to it, would be fatal.

Water vapor, instead of being nearly homogeneous and of equal density at equal heights above the earth, varies greatly in quantity at different times and in different places. Like a gas, it tends to diffuse itself uniformly through the atmosphere as in a vacuum, but the resistance of the air has the effect of retarding the rate of diffusion. Owing, moreover, to the never-ceasing operation of unequal condensation and evaporation, the distribution of vapor is very unequal, both in time and place. The average quantity near the sea level in most countries is from 60 to 75 per cent of that required for complete saturation.

While air is always a mixture of gases in a fixed proportion, very far beyond any possible cause of liquefaction or solidification, vapor is never far from its condensing point; that is, however high the temperature and however low the pressure, a moderate amount of cooling will always bring it into the condition of water or ice. The repulsive force in the perfect gas, or in air, is sufficient to keep it gaseous at the lowest conceivable temperatures in natural conditions; the cohesive force in water is sufficient to keep it, except to a comparatively small amount, in the state of a liquid. Yet this small proportion which flows through our atmosphere reaches the enormous weight of 54,460 billions of tons. Lighter than air, transparent, almost impalpable, vapor has an immense work to do in the sustenance of all that grows and breathes upon the surface of the earth. Like a good genius, it enables the air, the sunshine, the earth, to bring forth their riches, to cover the globe with verdure and gladness, and truly to make the desert blossom like the rose. Without vapor in the air, there would be no streams, no lakes, no wells. The land would be uninhabitable by man, except so far as fresh water might be condensed from sea water by machinery, and plants for his use be grown by the seashore. Even then the human system would hardly tolerate the parching influence of a perfectly dry atmosphere.

Water vapor, having a low temperature of condensation, was one of the last substances to fall, during the cooling of this globe millions of years ago, from the vaporous into the liquid condition, and consequently remains as a covering between the rocks, which were early solidified, and the air, which was not solidified at all. Water covers about three-fourths[1] of the whole area of the terrestrial ball. It has the remarkable property of being capable of existing in the gaseous, liquid, and solid states within a small range of temperature, and even of existing in all three states under ordinary conditions at temperatures which are common in winter over a large area, and which are easily borne by human beings.

In every cubic inch of water are many thousands of millions of millions of molecules, and all of these vibrate more or less rapidly under the stroke of heat. Some molecules, as a result of collisions among themselves, which are very numerous in every second, and as a result of their situation on the surface of the sea, are propelled with such velocity that they leap above the general surface, get beyond the retaining power of cohesion, and are taken up by the wind or by rising currents and carried aloft. The vapor rising from the water surface is warm, has in fact become vapor owing to being in more energetic vibration than the average of the particles of water. Moreover, vapor is lighter than air. So the lowest stratum of vaporous air near the tropical sea becomes lighter than the air above it for three reasons: First, by being in contact with the warm water which has absorbed the sun's rays; secondly, by being mixed with vapor which is lighter than the air it displaces, and thirdly, by this vapor coming from the warmest or most strongly vibrating molecules on the water plane.

The force of gravitation, it should be observed, is often of very little account where small particles such as these molecules of water are to be considered. A slight charge of electricity would be enormously more powerful in directing the motion of a single molecule. The reason

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[1] The proportion of water to land is about 145,000,000 square miles to 52,000,000 square miles.

of this is that gravitation diminishes regularly with the size of particles of the same substance; but electricity, since it resides on the surface, diminishes at a much slower rate. It is likely that electricity would often cooperate with heat differences in driving the vapor from the surface in an upward direction. Evaporation is increased by low barometric pressure, so that an area of depression to some degree on this account tends to maintain itself.

By the beautiful law of the diffusion of gases, according to which each gas spreads itself through a space as if that space were a vacuum, subject only to retardation of the rate of diffusion by another gas already permeating the space, vapor diffuses itself through air, not with great rapidity, but so as to produce a fairly equable mixture in the same locality. The molecules of vapor have to encounter thousands of molecules of air in every inch and millions in every second of their progress, and if weather depended on diffusion, without the bodily transferences of large quantities of air horizontally and vertically owing to perpetually changing distributions of heat, the conditions of climate would be extreme and intolerable.

A very common form of exchange set up where the heat and moisture are not excessive by contrast with neighboring masses is by thin streams, filaments, or spirals of lighter vaporous air rising into the upper region, while colder filaments descend toward the earth or sea. This movement occurs under placid conditions, with cloudless sky, and when observed in temperate climates may be taken as a sign of considerable stability in the disposition of the atmosphere.

At other times, also commonly in fine weather, the warmer, lighter strata below break during the daytime into the upper strata by means of small columns, of a good many yards in diameter. These are often capped with rounded cumulus clouds where they attain an elevation and refrigeration beyond their dew point.

Occasionally, but rarely, the lower air breaks suddenly in a large torrential eddy, which may be several furlongs in diameter, into the upper region. The disturbance may give rise to a cyclone, whirlwind, or tornado. This occurs when the condition is abnormal, the lower strata being very moist and warm and the upper relatively cold and dry, and when from some cause, such as the prevalence of superposed winds, the interchange of differing air volumes has been delayed. The conflict of currents from different directions near the surface may then give rise to an eddy, and this will be a favorable occasion for a rush of light air, as through a chimney, toward the high level. Air flows in from all sides, but can not easily reach the center, owing to the earth's rotation, the onward movement of the whirl, and centrifugal force. In the present writer's opinion, a cyclone may be started or maintained by the strong wind, of 100 miles an hour or more, which often blows at a great elevation in the tropics and neighboring parts. At one observatory in the United States a velocity of 180 miles an hour has been registered. The effect of a strong horizontal wind on a "chimney" of hot vaporous air would be to increase greatly the force of the upward torrent, as has been proved by anemometric experience with tall chimney shafts and domestic fires. The effect of the violent wind is exceedingly destructive, especially when the tornado is of small diameter. Some towns in the United States are particularly subject to these storms, and, as they generally come from one direction, the effect of building a perpendicular wall of 200 or 300 feet high on that quarter near the town, in order to break or divert its course, would seem worth trying.

Returning to the more normal conditions of the atmosphere, we may imagine the vapor, whether from land or sea, to have mixed much but not uniformly with the overlying air. The differences in the humidity of different masses or parcels of air, and the viscosity, friction, or resistance of the lower strata, where the pressure is 15 pounds to the square inch, prevent the interaction from being continuous and uniform, and consequently the ascending currents are local and variable, but when once fairly started, generally persist for a considerable time, moving all the while with the prevailing wind. When the vapor streams reach a certain height, they begin to condense, first and chiefly because they expand, and in expanding cool themselves, according to the laws of heat, and, secondly, because they mix with cooler strata. If the vapor be supposed to have ascended to a height of 3,000 feet, the pressure upon it has diminished from about 30 to 27 inches of mercury, or by about one-tenth, so that it swells, allowing for contraction by cold, to a bulk nearly one-tenth more than it had at the sea level. This is sufficient to produce a large diminution of temperature and the molecules vibrate so much less rapidly that some of them cease to maintain the condition of vapor. The vapor must condense, according to recent discoveries, not in contact with mere air, but upon very minute solid particles, motes, or dust, which may consist of ultramicroscopic sand, sea salt, or other material. So a cloud takes form. For each amount of curvature of a liquid surface there is a definite vapor pressure, and the pressure necessary for precipitation is greater as the surface becomes more convex, so that precipitation takes place more easily the larger the water globule in the presence of vapor. And so great is the pressure required for the condensation of vapor in free air that condensation can not take place except upon those small nuclei of dust which, more or less, are present throughout the lower atmosphere. Solid surfaces exposed to gases contract a film of gas upon their surfaces. Now, the dust of the air, owing to its minuteness, presents an enormous surface, and is moreover largely hygroscopic, so that the tendency to gather a film of vapor of water upon its surface becomes very important and effective. Without this fine dust in the air the world would hardly be tolerable or even habitable by the human race. The vapor would condense, not in the sky and in the form of clouds, but on the earth, on mountains, trees, houses, and clothes, so that the sun's rays would strike down upon us oppressed with an air cloudless and saturated, and all objects would be perpetually streaming with moisture. An approach to such a state of things sometimes actually occurs on high mountains when the air is saturated and at the same time remarkably free from dust.

Clouds are often caused and maintained by mixture of winds or currents at different temperatures, the colder current reducing the temperature of the other below the dew point. Such clouds may be very wide in extent, but are not often dense, except in sudden and violent disturbances.

Radiation from a stratum of highly vaporous air may produce a cloud, and, when once formed, every cloud which has a clear sky above it radiates strongly and tends to maintain its existence by the consequent deposition of vapor upon its particles which it induces. The intensity of radiation into space depends largely on the dryness of the air above; and since dryness increases rapidly with height, the radiation from a high cloud is much more rapid than from a low one. Otherwise high clouds would dissolve much faster than they do in the rather dry air about them. If the heat of the sun's rays falling upon a cloud exceeds the loss by radiation, the cloud diminishes in bulk and density. Thus a fog frequently dissipates toward the middle of the day. But the farther the fog or cloud lies from the surface of the earth, the less is the heating effect of the sun, for loss by radiation proceeds faster and is not compensated by terrestrial warmth.

Sometimes, but rarely, cumulus clouds may be seen to precipitate fine rain suddenly, about sunset, owing to the sudden, uncompensated loss of heat by radiation. The appearance may be compared to a veil suddenly let fall which does not reach the ground. An example of this phenomenon occurred in the south of England on April 13, 1894.

The edges of clouds are always changing, and, in fact, a cloud is in constant process of formation and solution. Sometimes, especially in fine weather, or with a strong wind, the edges are hard, rounded, and well marked. This may be owing to a property which has recently been discovered to belong to aggregations of very small drops when moderately or slightly electrified—they attract one another. The higher regions of the air are strongly electric, especially in stormy weather, and the particles are held in proximity by mutual attraction and by the attraction of the mass of cloud.

Fog and clouds of a stratiform character, and cumulus clouds, and cirrus may commonly exist without rain, and in most countries there are many days in the year wholly overcast but rainless. This happens most often in quiet and uniform conditions of weather. There is no strong disturbance in the upper air; horizontal currents of somewhat differing temperature give rise to a stratum of cloud about their borders, and this soon evaporates when carried into the drier air above or falling into the warmer air below. Cumulus may often be seen to sink and vanish at sunset, and stratiform cloud by itself is commonly the expression of moderate condensation under quiet conditions insufficient to precipitate vapor rapidly.

A cloud layer may continue for some days with strong wind, being caused by (1) a gradual ascending movement of the lower air so as to precipitate a small quantity of vapor continuously by expansion; (2) by contact of the upper surface of the lower current with a colder currant at a higher level; (3) by radiation from a rather moist stratum through dry upper air; or (4) by a warm, moist wind arriving, after a long passage, in cooler latitudes, and gradually becoming cooler by radiation and mixture.

In showery weather cumulus clouds are very often seen to consist of two or more masses at levels wide apart, and the upper mass, which is harder and firmer-looking than the lower, seems to move much less fast. Such clouds, even though heavy-looking, may pass over without rain, and it is generally, only by the appearance of rain in the air and landscape under them that they may be distinguished as actually shower-laden. Rain is, however, far more probable in these cases when the clouds are in tiers or separate layers; indeed, a single cumulus mass, simple and uncillified, seldom precipitates at all.

What, then, are the causes of rain; and why does it fall from some clouds more than from others?

The simplest and a very common cause of rain is the sudden elevation of moist air to a higher level, with the consequent chill by expansion. Standing on a mountain between the west and east ends of a loch in Perthshire, when a west wind is blowing, one may see showers frequently falling among the mountains westward, and failing to reach the flatter ground toward the east. The wind, even before it reaches the mountains, is tilted upward by the pressure of air in front of it, is consequently cooled, and precipitates moisture upon their western slopes. When the air descends in a drier and warmer condition toward the lower ground, the clouds quickly dissolve and thin out. The cloud-forming and the shower-forming effect is in general roughly proportional, between certain limits, to the height and steepness of the mountains. The great cliff called Slieve League, on the coast of Donegal, and the cliffs of Hoy, in the Orkneys, both about 1,800 to 2,000 feet high, cause clouds to be thickly formed sometimes fully half a mile to windward. Whether rain falls, and how heavily, depends chiefly on the moisture of the air and the coldness of the stratum into which it is forced.

A similar but little recognized effect is caused by opposing masses of air. Thus, let a moist warm southwest wind meet a cold northeast wind; the southwest wind is forced upward, especially over certain localities, and flows over the northeast wind, expanding very largely and rapidly and precipitating moisture heavily. The production of heavy thunderstorms may be fully accounted for by the local eddies and conflicts between opposing winds, which occur in summer when the moist warm air-mass is lifted to great heights.

Generally, we may state the formation and amount of rain to be dependent on the following conditions:

(1) The height to which the lower air is forced upward.

(2) The amount of vapor in the lower and upper air, respectively.

(3) The relative coldness of the stratum into which the lower air is projected.

(4) The freedom from vapor strata and from cloud of the upper air, allowing free radiation from the rain cloud.

(5) The electrical condition of the air and cloud.

Where mountains are high, the air warm and moist and blowing toward steep slopes, very heavy rain falls either continuously at certain seasons, or in thunderstorms, according to the character of the winds, the heat of the sun on the earth, and to a less degree the temperature of the upper air.

The ranges of hills south of the Himalayas, the Himalayas themselves, the mountains of eastern South Africa, and the Andes give examples of such effects. High mountains have the power of precipitating as rain or snow even the rather small quantity of vapor which has passed over a continent, and thus the central areas of countries remote from the sea are provided with perennial fountains which flow down from the high ground and pass through the land as fertilizing rivers.

Another cause of rain is the radiation into space of the heat of vapor and of water particles at a height. Recent discoveries have revealed the fact that vapor does not condense into cloud globules in ordinary conditions without the presence of a very fine dust which floats in the atmosphere. When this dust radiates freely and moisture is deposited upon it, and when a cloud is formed, the upper surface of the cloud parts with more heat than the surrounding air, and the cloud globules grow in size by contact with vapor.

Now, throughout the process of increase in size, electricity is accumulated more and more densely on their surfaces, for the electricity of each molecule or particle resides on its surface, and the relative surface of a globule diminishes as the size of the globule increases. If the condensation be rapid, the particles formed are very unequal in size. Since surfaces only increase at half the rate of bulk, electricity is much denser on the large drop. Now, it has been found by experiment that large drops attract small ones when similarly electrified, and each addition further increases the attractive power of the drop. The large drops fall through a cloud at a much greater rate than the small particles and collide with many more droplets in the same time. In the course of a fall of 10,000 or 15,000 feet through cloud, the drops may greatly increase in size.

The sizes of drops vary from 0.0033 inch to about 0.1 inch. An ascending current of 3 miles an hour would sustain small drops;

only a very strong upward wind would sustain the largest. A hailstone of 2.58 inches in diameter would be kept at a height of about 15,000 feet by an upward blast of hurricane force, 100 miles an hour. Drops can never reach the size of a hailstone, for the resistance of the air has the effect of breaking them up. The smallest drops would take about six hours and forty minutes in falling from a cloud 10,000 feet high, but we know that this scarcely ever, if ever, happens. In reality the smallest drops falling on the earth are nearly always derived from a slight elevation and very small drops falling from a great height would, except in an extraordinarily saturated state of the air, evaporate in their course. Ordinary small raindrops take about six minutes or somewhat less in falling through 10,000 feet.

Raindrops are perfectly globular in form. This we know in two ways—first, from the rainbow, which can only arise from the regular dispersion of white light by transparent globules; and, secondly, by means of instantaneous photographs. The sphere is the figure of smallest volume which can be assumed, and consequently we find that free liquids under the influence of cohesion, surface tension, or gravitation, are always spherical.

Since a raindrop is an aggregation of cloud particles it contains a number of solid particles or invisible motes, and generally a very small quantity of sea salt. Besides this "dust" it attaches to itself soluble gases contained in the air, the result chiefly of animal life, of decomposition of organic matter, and of manufacturing processes. Thus, ammonia, nitric acid, hydrochloric acid, sulphurous acid, and a little air and carbonic acid, are found in rainwater. Brandes found an average of 26 kilograms of residue in every million of rain evaporated, the amount being greatest in January (65) and least in May (8). The residual substances were chlorine, sulphuric acid, soda, potash, magnesia, ammonia salts, organic matter, lime, carbon dioxide, oxide of iron, and oxide of manganese. The solid matter amounts in France to about 147½ to 156 kilograms per hectare. The importance of these minute traces of gases and other substances in rain is enormous, especially in relation to the nutrition of plants and the disintegration of rocks. But no less important to mankind is the function of rain in clearing the atmosphere of these ingredients. Clouds and rain are at the same time purifiers, filterers, and nourishers. In the words of the ancient declaration, "the clouds drop fatness," and "the water returns not void." The upper layers of earth have a remarkable power of purifying water, so that what is useful to vegetation is retained near the surface and the purified water passes down into deeper ground, where it may be drawn from wells or emerge in springs. The process, first of washing the atmosphere and then of self-purification, is so complete that though the mold swarms with organic life the water which has passed through this upper earth may be described as practically pure and free from organisms.

Not only is the raindrop a composition of solids, liquids, and gases, but it is of unequal consistency if the inner be compared with the outer part. Every drop surrounded by air is compressed into the spherical shape by an outer film of water which partakes of the character of an elastic skin. In the free air cloud globules and small rain can not easily coalesce on account of this elastic film enveloping them. They may impinge against each other, but unless the concussion be forcible they rebound. Similarly the drops falling from a fountain may be seen to run along the surface of the water like pearls before they unite with it. So also small drops of water falling from an artificial jet rebound and do not unite on collision. But let a stick of sealing wax be rubbed on flannel and held at a distance of several feet from the thickly falling drops; they at once cease to rebound, they unite into large drops, or else the jet keeps falling as a continuous stream and does not separate into drops as before. Again, let the drops be strongly electrified, they do not unite but repel each other.

Large drops attract small drops similarly electrified, and drops unequally electrified attract each other. The weak charge of similar electricity, which causes the globules to approach each other forcibly, is sufficient to break the enveloping film, but a stronger charge produces repulsion of the drops. In these observed facts we have what seems a very satisfactory explanation of some of the phenomena of thunderstorms; for example, the sudden heavy downpour and sudden cessation, and the apparent effect of flashes of lightning on the rain or hail. Finely divided water exhibits another property which is of great importance in the formation of rain, hail, and snow. Down to a very low temperature, 10° to 20° or more below the freezing point, according to the size of the particles, it resists congelation. This property is of immense effect throughout nature, and the life of plant and animals to a great extent depends upon it. When globules of water below the freezing point are touched by a frozen drop or by a snowflake they are instantly frozen. A crystal of ice is the most powerful of all substances in congealing water below the freezing point. Very many falls of rain, hail, and snow are due to this cause. The minute crystal as it descends through dense cloud gathers particles on its way until it has grown to be a large snowflake; and whenever the lower air is warm enough, snowflakes thus formed melt and fall as rain. Rain is much more often than we suppose melted snow. The minute flakes which would melt and evaporate if they did not meet with the water cloud, grow rapidly in the cloud, which would of itself be incompetent to precipitate.

When a flake of snow or kernel of ice falls through dense cloud, such as the towering cumulus which stacks itself to a great elevation in a thunderstorm, it electrically attracts the particles of unfrozen water, below the freezing point, through which it passes, and every particle attached and instantly frozen adds to the electric charge, so that more particles are attracted with ever-increasing strength. In this way, in addition to mere impact, in the course of a fall of 10,000 or 15,000 feet,[1] are formed those large hailstones which devastate crops and kill animals· Taking Aitken's observations of the number of particles of water or droplets of fog, falling upon a square inch in a minute in a dense fog, as a criterion—say, namely, an average of about 10,000 droplets—and assuming that these drops fall at the rate of not more (it is probably much less) than 10 feet a minute, a hailstone falling through 10,000 feet of dense cloud would encounter if it began as a snowflake, 1 inch square, about 10,000,000 droplets, by mere impact. Some hailstones may result from the attraction of small spicules of ice and particles of water alternately as the nucleus passes through different strata, and these show concentric bands alternately opaque and clear. Similar bands may be formed by the passage of the hailstone through alternate spaces of thick cloud and of clear, unclouded, but saturated air. The latent heat brought into the sensible condition by condensation and congelation has been supposed to make such an accumulation in clear, saturated air impossible, but actual observation indicates that the rapid passage of the hailstone through very cold air speedily and continuously dissipates the heat thus set free. The appearance of spaces between successive tiers of dense cumulus cloud and the almost invariably excessive display of electric phenomena are characteristic of great hailstorms. It is very probable that between the dense clouds lie masses of saturated, or even supersaturated, almost dust-free air. A cold hailstone falling through these would accumulate ice in clear, alternate zones surrounding the nucleus. Large hailstones are generally spheroidal, small ones conical, with icy bases and a softer apex. The large hailstones are probably more dependent on electric attraction, and the small on the impact of descent, for their form and icy accumulations.

In a thunderstorm or shower, the lower clouds are generally negatively and the upper positively electrified. Before a hailstorm clouds of great significance may be observed, which may be described as turreted cumulus or cumulo-stratus. They are quite distinctive of hailstorm weather, though of course the hailstorm may not occur in the district where they are seen. They consist of hard-looking, sharply defined, generally white, and rather small masses of cloud, with projections towering upward and rather broader at the top than at the base, or equally broad. These peculiar clouds are worthy of note with the view of forecasting the probable occurrence of hailstorms.

Vapor, when it ceases to exist as a gas in the air, assumes several

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[1] The height of cumulus cloud may often be well observed and measured not only from the plain, but on mountains. The tower of cumulus cloud often exceeds 10,000 or 15,000 feet, and in great storms may be 25,000 to 40,000 feet from base to summit. Both observations from the earth and balloon ascents supply evidence to this effect.

different forms which are only obscurely understood. There seems to be a stage between the gaseous and the misty in which vapor is condensed into very minute transparent motes or into a condition corresponding to the critical state, the viscous interval, observed by Andrews in carbon dioxide under great pressure. Just above this critical point this gas behaved to some degree like its vapor and liquid below it with regard to pressure. The behavior of water vapor under varying pressure and when near saturation at different temperatures would be an interesting though difficult subject for research. Dry vapor is regarded by some experimental observers as diathermanous, like air; yet we certainly find that what seems to be invisible transparent vapor does largely arrest radiation from the earth. Therefore, it would seem much of the vapor of the air, when near saturation, must be in a condition bordering on mist or finely divided water. Only beyond a certain size, maybe, or when dust is thick, do the particles become large enough to give the effect of haze. It often happens that a thermometer freely exposed to the sky on a fine night suddenly ceases to fall, and rises several degrees without any apparent cloudiness or diminution of the luster of the stars, but this rise, in the present writer's experience, is a good indication of approaching rain after dry weather. Whether the screen in the upper air which reflects the radiation from the earth be a thin cloud or else vapor in a state of inchoate condensation, has not yet been ascertained.

Haze, fogs, and clouds are caused by the tendency of vapor to condense upon solid particles below a certain temperature. A change of state from vapor to liquid or liquid to solid occurs much earlier in the presence of "free surfaces" of other bodies than where these are absent. Saturated air, as we call it, can hold no more vapor in ordinary conditions, but apart from solids and dust particles it could contain much more vapor without precipitation. Similarly, if water could be heated by itself apart from solids and contained gases, it would rise high above the boiling point without boiling, and would eventually explode; so also the droplets of a cloud do not freeze, though many degrees below the freezing point, until they touch a solid object. Dust in the air offers the free surface which is required for condensation. Different kinds of dust differ greatly in the power of compelling deposition. Sulphur, magnesia, and common salt are, in the laboratory, at any rate, powerful fog producers. In the open air sulphur seems to have little appreciable effect; but salt, which is hygroscopic, or damp-attracting, and pervades the atmosphere, plays an important part. Smoke, again, or finely divided tarry matter, greatly favors fog formation, owing, probably, to its strong radiative capacity and to its coating the water globules so as to prevent evaporation.

Suppose the motes of dust or salt in heterogeneous air to be radiating freely, and therefore to be colder than the air, and suppose each of them to be frequently brought in contact with filaments of air and vapor at a higher temperature than the average, then it is conceivable that momentary deposition and reevaporation may occur. The result would be haze. With fairly homogeneous masses of air, as with a west wind, the contact of warm and cool air occurs here and there on a much larger scale and at once produces massive clouds, owing to the quick growth of particles in a moist air brought in block below the dew-point by ascent or otherwise. The interchange between differing air masses is in this case by large columns instead of by infiltration and filaments. The steam leaving the escape valve of a boiler at high pressure is at first invisible, then bluish and semitransparent, like haze, then opaque and white, like cloud. The influences which cause haze maintain the vapor in the second stage; it passes perpetually from molecular invisibility to the verge of particulate visibility and back to invisibility by swift evaporation. Clouds, on the contrary, result from cooling in large masses, as by ascent, and the humidity is too great to permit so rapid a return to the condition of vapor within their borders. When they evaporate they become invisible at the edge without perceptibly passing through the stage of haze.

Why the process of change of size of the particles differs so much in different states of weather is by no means clear.

Haze has long been a meteorological problem. If it be vapor, why does it so frequently occur in the driest weather? If it be dust, why should dust continue to affect the atmosphere in such excessive quantities during particular periods, often in calm weather, and with a gentle wind from uninhabited areas, either sea or land? The moistest winds are generally the clearest, the driest are the haziest.[1] Moreover, there is a thick haze which sometimes persists for many days in spring or summer in England, and neither increases nor diminishes perceptibly during the night, when radiation is active. In such weather the air is dry, and the wind, if any, commonly a light air from between east and north. Since neither the sun's heat nor the nocturnal cold affects it, we must ascribe it to one of two things—the presence of a large quantity of dry dust in an unusual state, or the development of vapor condensation in some unusual way, so as to depend little on the general temperature. On the top of Snowdon, 3,300 feet, the present writer has observed haze as thick as on the ground level, and extending 1,000 or 2,000 feet above the summit. It was similar, though less in degree, to the obscuration described in the annals of last century as having covered Europe for months after the great eruption of a volcano in Iceland in 1783. Mr. Conway has recently observed high above the Himalayas a sudden haze overspreading the sky like the smoky haze seen near a large city in England. The explanation probably is that the haze depends on the relative temperature of mixed portions of strata of air, and much less on the general air temperature.

Aitken has shown that when the wind blows from inhabited places

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[1] In England.

there is both more haze and more dust than when it blows from the sea or from uninhabited country, and in Switzerland a thick veil of haze seemed to hang in the air between the observer and the mountains on all days when the number of particles was great, and it became very faint when the number was small. When the wind blew from the plains the air was thick; when from the Alps, clear. Similarly, at Ben Nevis, on the northwest coast of Scotland, a northwest wind was clearest, a southeast wind haziest, and the dust particles were generally more numerous according to the amount of haze. "Of 'purifying areas' the Mediterranean gave for lowest values 891, the Alps 381, the Highlands 141, and the Atlantic 72 particles per cubic centimeter. Dampness of the air was found to increase the effect of dust, so that nearly double the number of particles are required to produce the same amount of haze when it is dry than when it is dampish." When the depression of the wet-bulb thermometer below the dry bulb was 2° or more the transparency was roughly proportional to the wet bulb depression; that is, to the dryness of the air. "The nearness of the vapor to the dew-point seems to enable the dust particles to condense more vapor by surface attraction and otherwise, and thus by becoming larger they have a greater hazing effect." The number of dust particles in square centimeter lengths of 10 to 250 miles required to produce complete haze in air giving different wet-bulb depressions was calculated to be as follows:

Wet-bulb depression.	Number of particles to produce complete haze.
Degrees.	
2 to 4	12,500,000,000
4 to 7	17,100,000,000
7 to 10	22,600,000,000

Since more particles are required to produce haze in dry than in damp weather, it becomes the more remarkable that thick haze is so common in dry weather and generally absent in a moist atmosphere.

The observations of the present writer for many years have shown that haze is most apt to occur when there is infiltration or mixture of differing air currents, and indeed that it generally expresses the juxtaposition and mixture of winds. A steady wind extending to the upper clouds is very seldom hazy, and, on the other hand, haziness may be taken as a sign of the existence of another wind above that prevailing near the ground, or of variable currents. So much is this the case that in southern England a hazy or misty east wind signifies generally a rather short period of its prevalence, but a clear east wind means continuance. Of course care must be taken to be situated on the windward side of thickly inhabited districts in making such forecasts. It seems, therefore, that when haze is not due to a large amount of dust, it must arise from some effect of the mixture of different currents. A wind from the Atlantic on the west coast of Great Britain generally has a west wind above it, and is fairly homogeneous, but an east wind generally has to encounter and drive back a westerly or southerly wind, and has an opposing current within 3 to 7 miles above. There must in these cases be a great deal of mixture of portions of air of different humidity, temperature, and electrical tension. The contiguous parcels of air produce at a number of points momentary deposition of vapor on dust particles, and the resulting effect is haze. The dew point is attained in the molecular environment by momentary contact of cold, dry, dust-bearing with moist, warmer, less dusty air.

It is well to bear in mind the large extent and small depth of the whole of the lower region of winds. Currents of air, say within 25,000 feet of the surface, extended over a territory 400 miles square, would be represented by a layer of water an inch deep in a basin 80 inches square.

On the east coast of Scotland an east wind often brings a thick haze which may last two or three days, and is followed by rainy weather. But a much less thick blue haze prevails during fine weather, with light or variable easterly breezes, both in Scotland and England. The density of the haze in these conditions depends less on the number of dust particles than on the mixture of differing currents and on the moisture and warmth of the one current, the coldness and moisture of the other. There is no reason for supposing that a wind blowing from the polar regions and over the breadth of the North Sea is heavily charged with dust, yet the haziness is as great looking seaward as over the land of Berwickshire or Fife.

The clear air of continental climates, such as the European and North American, is partially explained by the moderate amount of dust, the infrequency of a condition approaching saturation in the lower air, and the absence generally of local winds such as are produced by a varied distribution of land and sea. Haze is very often the result of the passage of air over water of a lower temperature, and the difference of the temperatures may decide whether the obfuscation shall be haze, fog, mist, or fine rain. No amount of dust is in general competent in a dry, uniform air to produce apppreciable haze beyond what is due to its own particles. Thus in Colorado there is often a great deal of dust in the air, but the air is clearer at such times than it commonly is in England; in the Punjaub dust winds obscure the air for a long distance; in the Sahara Desert there is often thick dust, but the hazing is not great except with strong wind; when, however, this dust is blown far out over the Atlantic, the haze becomes very considerable, and is a common phenomenon about the Cape de Verde Islands. Towns, again, such as Paris and Pittsburg, which produce a great deal of dust, by the test of the dust counter, are not affected by haze in clear, dry weather, and even London, in some states of the air and very often at night, is only covered by a barely perceptible light haze. But coal smoke, commonly has the effect of causing a very persistent haze, and this, in the case of London, spreads conspicuously with the wind to places distant 100 miles or more. Coal smoke, we must remember, is accompanied by a good deal of water vapor and sulphurous acid. Gas and wood, when burned in large towns, produce no fog and very little haze, though the dust counter might show as many particles as where coal is burned. Dust in general may therefore be acquitted of taking an important part in producing any but a light, thin haze, except where there is a mixture of currents at different temperatures, and then some haze would in most instances be produced in any case by the normal average amount of very fine dust which exists everywhere in the atmosphere. In clear, homogeneous air, even near saturation, much dust or smoke may be added to the air without causing haze; in dry, hazy air much dust may be added without much intensifying the haze. In certain conditions of wind and weather much haze may exist without an abnormal quantity of dust, and, except on rare occasions, there is always enough dust, maybe of almost molecular dimensions, in the lower strata of the air to admit of precipitation of moisture where conditions are otherwise favorable.[1] A great deal of this dust probably consists of chloride of sodium, or sea salt.

The following instances may serve to show how haze and cloud are successively formed by a conflict of differing currents of air. St. Fillans Hill is a small, steep, isolated, conical hill about 300 feet in height, standing in the middle of the valley of the upper Earn, in Perthshire, about 2 miles from the lower end of Loch Earn, and flanked by mountains about 2,000 feet high on each side of the valley. The author was on the summit about 5 o'clock one evening in August,[2] when the breeze, which had been blowing freshly from the west, with a clear air, suddenly began to slacken, and in about five minutes dropped altogether. Then down the valley, eastward, a blue haze began swiftly to climb the glens tributary to Strathearn, and the whole air eastward grew obscure. The calm only lasted a little more than two minutes, and then suddenly a strong wind from the east set in, and soon the air westward as well as eastward had turned thick. The east wind continued, and in a few minutes the tops of the hills rising precipitously from Strathearn to a height of about 2,000 feet were obscured with cloud banners which grew continuously, and descended till in about two hours not only the hills above a level of about 1,000 feet, but the whole sky, was covered with gray clouds. The duration of the neutral calm corresponded with the time usually occupied, according to my observations in the neighborhood of London, by a moderate east wind in driving back the opposing current. At Richmond, and between Richmond and London, such a

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[1] These observations are derived from many years' attention to the conditions of prevalence of haze and fog in and near London.

[2] About 1877 or 1878.

change is signalized in the neutral band of calm by a dense yellow haze, producing great darkness in winter, the result of a banking up of smoke to some altitude, together with the condensation of vapor by the mixture of currents differing in temperature. The darkness in such a band lasts much longer with lighter winds, and I have known a west wind to prevail at Richmond simultaneously with an east wind in London, both without fog, while at Wandsworth a calm continued for many minutes with dense, almost nocturnally black smoke fog, the pressure in each direction being apparently equal.

FOG, SMOKE, GASEOUS AND SOLID IMPURITIES IN THE AIR.

FOG.

Fog is the result of one or both of two principal causes. The first is active radiation into space from the earth and from the air contiguous to it, and the second is a mixture of winds and currents, or of vapor and air at different temperatures.

1. Radiation fogs occur commonly when the atmosphere above the lowest stratum is cold, dry, and nearly still, and when the lowest stratum is greatly cooled by contact with the cold radiating earth, and therefore precipitates vapor into the form of minute globules of water. These globules themselves have a large radiative capacity, so that they tend further to reduce the temperature of the air in which they float, which has no such capacity. The stratum of fog so formed, not extending very many feet above the ground, fails to reflect much of the heat radiated from below, and quickly disperses, by radiation into space, whatever heat it absorbs. Thus earth and fog continue rapidly to part with their heat through the clear sky into space. The stratum of fog often grows in height and density through the night, and continues till about noon of the following day, or disperses in the late hours of the morning. If extended over a plain and watched from a height above the upper level, a fog of this character, in somewhat damp and not typical radiation weather, may be seen gradually to move irregularly upward under the influence of the morning sun, and in various directions to present prominences like those of the upper edge of cumulo-stratus. Smoke issuing from a tall factory chimney rises through and above the fog, but in a very short time falls back upon its surface and meanders like a dark river on a white ground.[1] The persistence of the fog depends upon the coldness of the ground, which is shielded from the sun, and upon the very large difference of temperature, sometimes 10 degrees or more, between the fog and the stratum of air a few feet above it. When, however, the sun's heat absorbed by the water particles exceeds the heat lost by radiation, the fog lifts, that is, its uppermost stratum rises, owing to diminished specific gravity, and

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[1] These observations were taken during the prevalence of a ground fog, in the country surrounding the Malvern Hills, in February, 1890.

either clears at once or remains for some time as a light blue haze.[1] The strata below it, submitted to the same influence, successively rise and take its place, and the evaporated moisture mingles with the general air.

Fogs of this kind locate themselves in low-lying valleys, basins, and plains, for the air, chilled by contact with the radiating ground, sinks by gravitation into such situations and in them is least likely to be disturbed. Sometimes a white fog may be seen pouring down an open and rather steep ravine like water.[2] Slopes of hills, especially their southern sides, some hundreds of feet above the plain, are comparatively free from these fogs, and are much drier and warmer during their prevalence than lower places in the neighborhood. Such an elevation is more favorable on this account to the human constitution; both the daily and yearly thermometric range is much smaller. Dense fog and frost often remain throughout the day on the northern side of hills when the southern slope is bathed in sunshine. This has been observed on several occasions on Hindhead, Surrey, the air in the fog keeping much colder than the air above it and on the southern slope.

In the still air which precedes and accompanies radiation fogs the number of dust particles is high above the average, owing partly to their becoming gathered by undisturbed precipitation into the lowest strata. On several occasions when the dust particles were counted they amounted to between 45,000 and 80,000 per cubic centimeter. Each of these is a nucleus for the deposition of vapor. The water particles are so small that they evaporate before touching solid objects during the daytime, the objects being warmer than themselves. For this reason these fogs have no wetting effect. In a fog, when objects were invisible at 100 yards distance, 19,350 droplets sometimes fell on a square inch per minute, but the average was much less than this, and the smallest number about 1,900 per minute.[3] The large number of particles favors the formation of fog. Considerable numbers of living organisms no doubt exist among the water particles of the fog, but are not known to be a cause of ill-health in the country remote from towns. Nor is great cold combined with fog productive of much illness in the country. In smoky towns the case is far different. Thus, in London the death rate was raised in a single fortnight, from January 24 to February 7, 1880, from 27.1 to 48.1 per thousand. The fatality and prevalence of respiratory diseases were enormously increased. The excess of deaths over the average in the three weeks ending February 14 was 2,994, and in the week ending February 7 the deaths from whooping cough were unprecedentedly numerous—248—and from bronchitis numbered 1,223. At least 30,000 persons must have been ill

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[1] This haze may be taken to be caused by the aggregated nuclei of dust left after evaporation of the water which condensed upon them.

[2] This was seen by the author with remarkable distinctness near Alum Bay, in the Isle of Wight.

[3] Aitken.

from the combined effect of smoky fog and cold. The present author was in London during the whole period, and noted especially the unusual number of days during which the darkness and stillness continued, and the tenacity with which the fog clung to the cold ground on the shady sides of squares and streets, when a warm, gentle current from the south improved and cleared the air above a height of 20 or 30 feet.[1] The large excess of carbonic acid, of sulphurous acid, and of micro-organisms and effete organic products was partly concerned in these ill effects, but the factor of greatest importance was the finely divided and thickly distributed carbon or carbonaceous matter, which irritated the breathing passages and lungs. The results corresponded rather closely with the more gradual ill effects of dusty trades. The lungs of a man who has spent his life in London or Manchester are found, post mortem, to be choked with black matter. In some parts of London there is sometimes no more light at noon than in the darkest night. After a fortnight of dense fog the deaths in London for one week, ending January 2, 1892, exceeded by 1,484 the average number, being at the rate of 42 per 1,000. Increases took place in the following diseases: Measles, 114 per cent; whooping cough, 173; phthisis, 42; old age, 36; apoplexy, 58; diseases of the circulatory system, 106; bronchitis, 170; pneumonia, 111; other respiratory diseases, 135; accidents, 103.

These results are in the main attributable to the concentration of the ordinary constituents of London air, with moisture and intense cold to help their deadly work. The majority of the fatal cases were in weakened constitutions, though many were among the robust. The experience of large towns always is that the power of recovery after illness is much less within their confines than in the country. In the fog the evil influences of town air are many times multiplied. The blackest fogs, which are local, are the result of variable or opposing currents which carry up the discolored mass to a height of hundreds of feet, where they condense their moisture in a stratum of unusual thickness or height. By a converging flow of currents, a huge column of blackened fog particles rises vertically to a height where it may remain or whence it may move slowly from place to place. A fog need not always be resting on the ground, but may hang after the manner of stratus cloud at some level, often a few hundred feet above it. This happens when the ground is not much colder than the air. The smoke of a steamer may be seen sometimes thus to form a dark streak, remaining about the same level for an hour or more. That domestic fires at least rival manufacturing works in the production of dark fogs is proved by the intense darkness which has prevailed in London on Sundays, and once on Christmas Day. Factory fires are out on Sundays, but domestic fires are larger and more numerous. Smoky fogs invade houses and even warm rooms, showing that many of the nuclei are solid particles large enough visibly to obstruct light even when dry.

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[1] London Fogs. R. Russell. Published by Stanford, London, 1880.

At a distance of 10 miles from London, the smoky particles are small and show quite a thick haze in a room with a fire, when a gentle current is moving from the town. Professor Frankland has shown that if a little smoky air be blown across the surface of water evaporation is retarded 80 per cent. The water globules may be similarly coated with tarry matter, which hinders the warmth of the sun from evaporating them. Moreover, every particle of carbon is a good radiator and in the early morning tends to increase the cold in the air around it; moisture is deposited upon it, in the opinion of the present writer, and can only with difficulty evaporate, so long as radiation is active and while the heat and light of the sun are stopped by smoke. The effect of finely divided carbon in stopping light may be tested by holding a piece of glass for a few moments above the flame of a candle; the black film deposited enables us to look at the sun easily, and it appears well defined, like a red orange, as in a fog.

The imperfect combustion of coal is the cause not only of fogs being specially dangerous to life, but of their persistence in duration far beyond those of the surrounding country. The removal of coal smoke would mean much less fog and much less evil in that which remained. Cities which use wood as fuel, or anthracite, or gas, or oil, are no more visited by fogs than the surrounding country, although the fine "dust" above them is, according to Aitken, very greatly in excess of the normal.

Pittsburg had a black climate till it used natural gas, and thenceforward has had a clear air, and no special liability to darkness and fog. In London, of 9,709,000 tons of coal used annually, about 1 per cent escapes into the air unburnt and 10 per cent is lost in other volatile compounds of carbon. The bright sunshine, compared with that of Kew, 9 miles distant, was, in the four years 1883–1886, 3,925 hours, against 5,713 at Kew, and about 6,880 at St. Leonards, about 80 miles distant. From November, 1885, to February, 1886, inclusive, the sunshine in London was 62 hours, at Kew 222, and at Eastbourne 300.

Town fogs contain an excess of chlorides and sulphates, and about double the normal, or more, of organic matter and ammonia salts.

During the last fortnight of February, 1891, the previously washed roofs of the glass houses at Chelsea and Kew, the former just within, and the latter just outside, London, received a deposit from the fog, which was analyzed and gave the following results:

Substances.	Chelsea.	Kew.
	Per cent.	*Per cent.*
Carbon	39	42.5
Hydrocarbons	12.3	4.8
Organic bases (pyridines, etc.)	2	....
Sulphùric acid (SO_3)	4.3	4
Hydrochloric acid (HCE)	1.4	.8
Ammonia	1.4	1.1
Metallic iron and magnetic oxide of iron	2.6	....
Mineral matter (chiefly silica and ferric oxide)	31.2	41.5
Water, not determined (say difference)	5.8	5.3

The weight of the deposit was at Kew 30 grams in 20 yards. At Chelsea the same area gave 40 grams, which is equivalent to 22 pounds to the acre, or 6 tons to the square mile. A large proportion of the deposits of fog in smoky towns clearly arises from the imperfect combustion of coal. On plants the deposit is sticky, like brown paint, and is not washed off by water. A country fog is harmless in a greenhouse; a town fog most destructive, killing soft-wooded plants, and greatly damaging others. A very large number of plants will not thrive in smoky towns. In Manchester, the deposit collected from aucuba leaves gave 6 to 9 per cent of sulphuric, and 5 to 7 per cent of hydrochloric acid, mostly in a state of combination. Three days' fog deposited per square mile 1½ hundredweights of sulphuric acid and 13 hundredweights of blacks.

Among the results of smoky air in towns may be mentioned: The discouragement of cleanliness and ventilation; the constant deficiency of light; the damage to plant life, so that only a few trees and plants can live; the destruction and disfigurement of stone, cement, iron, paint, wall papers, clothing, etc., and the depressing effect of dirt and blackened streets on the people; losses to artists of all kinds who depend on light; the lowered vitality of a large portion of the population, and a contributory influence toward the rapid degeneration and extinction of town families.

In London the extra expenditure entailed is about £1 a head, or more than the value of all the coal burnt in houses. The extra washing, painting, and repairs, and the loss of unburned carbon, etc., are among the principal items in the account.

The intensity of the ground fog depends largely on the amount of cooling which the earth has previously undergone. At the beginning of February, 1880, the ground in London was hard frozen with the intense frost which had prevailed for some days. A moist southerly current supervened and the temperature rose several degrees above the freezing point. On the shady side of squares the fog then produced between the ground and 10 or 20 feet above it was so dense that at 10 a. m. a lamp-post 4½ yards distant was invisible. In an ordinary thick fog, such as that of January 11, 1888, objects are visible at thirteen times that distance. Above the shallow stratum of ground fog the air was nearly clear and the smoke escaped.

Such fogs are due partly to radiation into space, but also largely to the mixture of the warm current with air which has become cold by contact with the ground, and to radiation toward the ground.

All radiation fogs disperse or greatly diminish when the sky becomes clouded and reflects some of the warmth radiated from the ground. They are not formed under a cloudy sky.

2. Fog is frequently produced, sometimes on an enormous scale, covering an area exceeding that of the British Isles, by the mixture of opposite currents of small velocity. The condition of atmosphere often

resembles that which produces haze in summer; a slow infiltration of currents of different temperatures brings different laminæ into contact. A cold earth and a sky clear above the low clouds increase the intensity of such a fog, but are not necessary to its existence. A southerly wind is too warm to produce fog by itself unless it meets with a cold surface, and a northerly wind is too dry by itself to be reduced below the dew-point. When, however, two opposite currents, one of which is colder than the other, diffuse into each other slowly, as when the colder current over an extensive area sinks into the warmer current below it, a fog may be produced which is less thick than a radiation fog, but may continue with little change through several days and nights, and commonly declares its character by the height to which it extends and by its moisture. It deposits much more moisture on trees, etc., than most radiation fogs, and, though no visible mist or rain may fall, the ground under trees often becomes very wet. Thus precipitation of moisture is increased in forests. In cold climates or at high levels every exposed object accumulates ice. A wet or mixture fog disappears under cover, and is thinner in large towns than in the country, for the particles of which it is composed are almost pure water and evaporate when the air is a little raised in temperature. On mountains in Great Britain wet fogs are very common, and may occur with strong wind; moisture or ice is deposited on the windward side of all objects. Continuous damp mist may be produced in Great Britain by a northeast wind blowing beneath a damp southwest or south current, and such mists produce very disagreeable weather. In September and the first half of October, 1894, southern England was immersed for weeks in a mist so produced. The northeast wind was not of very distant origin, and, not being dry, its mixture with the very damp southerly current overlying it produced dense mist, cloud, and occasional rain.

Many fogs, such as those over rivers or valleys, and over the cold ocean current near the Bank of Newfoundland, are due partly to mixture and partly to radiation. The sea fog originates in the cooling of air by contact with the colder surface of water and by mixture with the cold air which lies near the water. At many coast places on a hot summer day a sea fog frequently comes up on a cool breeze which mixes with the warm air above it from the land. On the other hand, when a sheet of water is much warmer than the air above it, a thick mist or fog may be formed, which is largely condensed steam.

Fog is less common in summer in the interior of continents or of large islands than on the coast, but in winter, owing to the greater loss of heat by the surface of the earth than by the surface of the sea, fog is more common inland. In many countries in the temperate zone the stratum of cloud or fog does not lie often upon the ground, but at a height of hundreds or thousands of feet; the sky remains quiet and overcast for days and weeks together. The elevation of the cloud, which would be fog on the ground, depends on the height at which the dew-point of the air is reached, or else on the height of the boundaries of a lower and upper current differing in temperature. The lower air is too dry to permit the condensation of vapor within its borders. A warmer and moister upper current condenses vapor by contact with the cold upper boundary of the lower air. The cloud canopy prevents excessive loss of heat from the surface of the earth.

A mist, in the usual meaning of the term, is the name given to very small rain, or to a cloud of which the globules are large enough to fall perceptibly. Near the surface of the earth it seldom, if ever, grows from radiation fog or from the haze of anticyclonic conditions, but very frequently is a result and direct growth from wet or mixture fogs. It may be considered as fine rain, which falls from a cloud undergoing cooling and consequent aggregation of particles. In hilly country near the sea, where the wind arrives after having blown over a large breadth of warm ocean, misty rain is very common.

At Kingairloch the number of dust particles was always very low in such weather, showing that the majority were being used up by the mist. The transparency of the air, or "visibility," so often preceding rain is due first to the paucity of dust particles brought by an ocean wind which is made purer than it otherwise would be by the clouds and rain of the area from which it blows; secondly, to the homogeneity of the air and the tendency to form large cloud globules or drops of rain when near saturation, the proportion of vapor to dust particles being high.

In quiet winter weather, a long-continued damp mist or else a very fine steady rain has, in the present writer's experience in England, preceded intense cold, and may be supposed with great probability to be caused by the gradual descent of very cold air upon the lower strata.

PARTICLES SUSPENDED IN THE AIR.

The atmosphere contains an immense number of substances suspended in it in the form of visible and invisible dust, but only a small proportion of these require attention as affecting human life. Deserts, dry and sandy tracts, and wind-swept plains yield a continual supply of fine motes of silica, aluminium silicate, calcium carbonate, calcium phosphate, etc. Volcanoes pour forth sand, fine mud, sulphur, sulphuric acid, silicon glass, etc., into the upper air, by which they are carried over all quarters of the globe. Meteors and small aerolites burn up as they daily pass through the high and rare atmosphere at heights from 30 to 200 or even 300 miles, and the products of their combustion, iron oxide, magnesia, silica, or other fine dust, fall impalpably toward the ground Clouds of unburnt carbon perpetually rise from towns, factories, steamships, and scattered houses; in manufacturing districts and towns particles of iron, steel, stone, and clay are abundant; so are fragments of vegetable tissue, cotton, hair, wool, skin, and starch. Even coal gas, which shows no smoke in its combustion, fills the air where it is burnt with millions of particles in every cubic foot. The whole atmosphere is pervaded by particles of salt derived from the spray of the seashore and of ocean waves. In summer, pollen seeds, odors of earth, trees, flowers, and hay, and the spores of an immense variety of fungi float on every breeze. Most of these have no special interest, but some of the spores and pollen are capable of setting up great irritation in the human system, almost amounting to diseases. Hay fever is the result of the action of grass pollen on the breathing passages.

LIVING GERMS IN THE AIR.

Much more important are the living germs, the microbes, bacteria, fungi, and molds, which are found very unevenly distributed, and especially abundant at low levels in populous places and habitations. Miquel found in a cubic meter at Montsouris Observatory, near Paris, 85 of these organisms in spring, 105 in summer, 142 in autumn, and 49 in winter. On other occasions the numbers were 70, 92, 121, and 53, respectively.

In the Rue de Rivoli, in Paris, the number was about 5,500. In air collected at 2,000 to 4,000 meters high (about 6,300 to 13,600 feet) no bacterium or fungus spore was found. Pasteur exposed 20 flasks of clear broth in the open country of Arbois, 20 on the Lower Jura, and 20 near the Mer de Glace, at a height of over 6,000 feet. Of the Arbois flasks, 8 developed organisms; of the Jura, 5; and of the Mer de Glace, 1 only.

Miquel's experiments proved that microbes were much more abundant in the town than in the country. In rooms the number was eight times, and in hospitals twelve times the number in the open air. These experiments refer to hospitals in Paris only. In hot countries, after a prolonged period of dry hot weather, microbes diminish. In M. Miquel's view the places where there are most microbes are centers of infectious disease; the curves of mortality to a great extent correspond with the curves of the number of microbes and follow them after a short interval. In 1 gram of the dust of his laboratory he found 750,000 germs, and in that of a room in Paris 2,100,000. In the air of hospitals microbes of suppuration have been found. Devergie found an "immense amount" of organic matter in the air in the vicinity of a patient with hospital gangrene. Dr. Dundas Thompson found, in the air of a cholera ward, starch, woolen fibers, epithelium, fungi, or spores of fungi, and vibriones. Scaly and small round epithelia are found in most rooms, and in large quantity in hospitals. The dust of a hospital ward at St. Louis contained 36 to 46 per cent of organic matter, largely epithelium cells. Parkes similarly detected large quantities of epithelium in the air of barracks and hospitals. In 1 gram of dried earth Miquel found 800,000 to 1,000,000 microbes. Recent research shows the number is especially great on the surface near dwellings, and rapidly decreases with depth, so that at 1 meter down there are few. Ninety per cent of these soil microbes are bacteria, chiefly in the form of spores. It is easy to understand how these may be carried into the air, especially in dry weather, as dust by wind and by evaporative forces.

It has been calculated that in a town like London or Manchester, a man breathes in during ten hours 37,500,000 spores and germs.

In Berlin an investigator found 3 colonies of bacteria and 16 molds in 25 liters from an open square, and 37 colonies of bacteria and 33 molds from a schoolroom just vacated. Professor Tyndall exposed for a short time 27 flasks containing an infusion of turnip, etc., to air on a ledge of rock above the Aletsch glacier in Switzerland, an altitude over 8,000 feet, and then carried them to a kitchen stove with a temperature of 50° to 90° F. In the same way 23 flasks were exposed to the air of a hayloft near the same altitude and placed with the others in the stove, due precautions being taken in all cases to prevent the kitchen air from contaminating the flasks. Of the 27 flasks opened in free air not one showed a sign of organic life; of the 23 opened in the hayloft, 21 were invaded. Many other experiments in London and elsewhere convinced him that the air of an ordinary room swarms with germs of life, and that if infusions of flesh, fish, or vegetable be exposed even for a short time to the dusty air they become turbid and putrid within a few days. Exposed for months to air "optically pure," that is, deprived of dust, they remain clear and sweet for months, in fact, do not putrefy at all. Some of the germs or spores in the air have a very remarkable resisting power and will germinate after several hours' boiling; others are killed in five minutes. The spores of bacillus subtilis, which is common in hay or in the air of haylofts, is not killed by prolonged boiling. But bacilli themselves, which are soft and unprotected, are killed by boiling water within a few minutes. The small size of the germs and bacilli may be to some degree realized when we note that in Tyndall's estimation the number in a single drop of turbid infusion is probably 500,000,000 "many times multiplied." The evaporation of such a drop would then conceivably permit the launch into the atmosphere of more than one thousand million organisms. The natural processes of decay in most places on the surface of the earth must be incessantly nourishing immense numbers of microbes in very great variety, and wherever drying or heating takes place quantities of colonies of all sorts which can flourish in daylight must be raised into the air and widely disseminated.

Percy Frankland counted the number of microbes falling on a square foot in one minute in several situations, with the following result:

Roof of Science Schools, Kensington, March	851
Roof of Science Schools, Kensington, when the wind was stronger	1,302
Roof of Science Schools, Kensington, after rain	60–66
Roof of Science Schools, Kensington, during thick fog	26–32
Burlington House, during Conversazione	318
Burlington House, on following morning	108

Natural History Museum, Entrance Hall, Whitmonday	1,755
Hospital for Consumption, morning	18
Hospital for Consumption, afternoon	66
Railway compartment, open window, 4 persons	395
Railway compartment, window 4 inches open, 10 persons	3,120

In experiments made with the object of finding the number of microbes in a certain volume of air, he found at a height of 300 feet on Norwich Cathedral, only 7 in 2 gallons; on the gravel near the cathedral, 18: at the top of Primrose Hill, 9; at the foot, 24.

Dr. Fischer found, in experiments made at sea, that at 120 miles from land, in eleven out of twelve experiments, the air was quite free from germs; that at 90 miles from land, in seven cases out of twelve, there were germs, but very few. Practically it appears that at 120 sea miles distant from land the air is pure and free from microorganic life.

Angus Smith roughly calculated the amount of organic matter, living and dead, to weigh, in pure air on high ground, 1 grain in 209,000 cubic feet; in a bedroom. 1 grain in 64,000 cubic feet; in a closely packed railway carriage, 1 grain in 8,000 cubic feet.

He obtained some curious results by shaking up air in different places with water. The air of a cowhouse gave an effect only produced by fifty to one hundred times the quantity of good air, and contained a mass of débris, hairs, etc. The air behind houses in streets was worse than in front of them.

Moisture collected from the air above marshes has been found by Italian observers to contain multitudes of seeds of algæ and of microscopic infusoria. The condensed dew exhibits a surprising quantity of spores and sporangia.

Other observers agree in noting decaying organic matter in abundance, vaporous and solid, together with living minute forms of animal and vegetable life, floating in the air; these consist of algæ, diatoms, fungi, bacteria, and other microorganisms.

The subtilis, or hay bacillus, is always present in the open air, but the bacilli generally keep to low levels and do not extend so high as the mold fungi.

Cunningham, at Calcutta, found spores and other cells constantly present in the free air, usually in considerable numbers. The majority were living, capable of growth, and seemed independent of moisture and direction of wind.

Mr. Greenleaf Tucker found that outside the City Hospital of Boston 10 liters of air contained on an average 10 colonies of bacteria, 7 of molds, in November; 13 of bacteria and 3 of molds in January. The number of bacteria was less on rainy days. The hospital itself contained few bacteria, owing to constant care and cleanliness, but the number was much increased after sweeping and bedmaking.

Carnelley found in clean one-roomed houses 180 bacteria per 10 liters; in dirty houses, 410; in very dirty, 930; in schools, from 300 to 1,250, according to ventilation; in the Royal Infirmary, Dundee, 10 to 20.

The greater part of the dust of clean habitations, consisting of motes derived from mineral, vegetable, and animal substances, has little apparent effect upon health. But it certainly tends to reduce vitality by some small amount, and gives extra work to the breathing organs. Consequently, to invalids and delicate persons it is important to reduce this dust by all reasonable means. A beam of strong light, sunlight or the electric lamp, shows the air of most inhabited rooms to be so crowded with dust as to be almost opaque to vision. Aitken found 41,000,000 particles in the cubic inch in a room where gas was burning. Rooms with polished wooden floors, painted hard plaster, glazed paper, or wood-paneled walls, and not containing fluffy fabrics, evolve much less dust. They are more healthy not only on this account, but chiefly because they provide much less pabulum and protection for the growth of noxious microorganisms.

De Chaumont found in the air at Paddington and in University College Hospital particles composed of the epidermis of hay, of pine wood, linen, cotton, epithelium, charred vegetables, and minerals.

Tichborne, of Dublin, found in a street 45.2 per cent of organic matter, and at the top of a pillar 29.7 per cent. Most of it was finely ground manure.

The spores and mycelium of *Achorion schonleinii* and of *Tricophyton tonsurans* have been found in the air of a hospital for diseases of the skin.

The surface of the ground in streets, squares, courts, and gardens, and the sweepings of dwellings and stables, contain swarms of the germs of the bacillus of tetanus, a disease fatal to man. These chiefly infest the droppings of various domestic animals, and may be carried through the air to wounds; commonly they infect by contagion and not through the air. Drying, light, and putrefying matter do not kill the bacillus, nor does a temperature of 80° to 90° C. Tetanus has caused great mortality among soldiers who have lain wounded at night on the field of battle, probably owing to the lifting of the bacillus by emanations from the ground and its deposit on open wounds.

SEWER AIR.

Sewer air contains molds, fungi, bacteria, and animal and vegetable débris. The microbes do not exceed about 6 per liter in a good sewage system. In ordinary drains, however, they are much more numerous, and are borne into the interior of houses in company with highly poisonous gases. The gases of sewers are sulphuretted hydrogen, ammonium sulphide, carbon bisulphide, a very little marsh gas, compound ammonias, with traces of ptomaines and leucomaines.

AIR OF MINES.

The air of mines contains only a few molds, fungi, and bacteria.

GROUND AIR.

Ground air contains microorganisms in abundance, according to locality and conditions, but has hitherto been little examined. It contains an enormous quantity of carbon dioxide, which is at its maximum from July to November. The foul air of cesspools is sometimes drawn into houses through 20 feet of earth.

When organic substances decompose in the air, they are first attacked by molds, then by bacteria. These last cause odorous gases to be emitted, which are oxidized by the air. If the air has access to the substances, aerobic organisms multiply; if only slight access, as in masses of filth in a drain, anaerobic multiply, such as those of putrefaction, of tetanus, and of malignant œdema.

ORGANISMS, ETC., IN THE OPEN AIR.

The open air in populous places contains much dust of suspended matter and many living organisms. Débris from wool, silk, fibers, hair, feather particles, dried epithelial cells, epidermic scales from the skin, pus cells, pyogenic microorganisms, fragments of insects, and fecal particles are among the former, and living minute ova or infusoria, minute amœbiform organisms, etc., which may even *grow* in the atmosphere, are among the latter. All these are of animal origin. Of vegetable origin are the following: Soot, fibers, hairs, cells, starch, straw in powder, spores of molds, fungi, diatoms, and bacteria; living pollen seeds, spores of fungi, molds, diatoms (which may live and grow in the atmosphere), and, rarely, mycelium of fungus, algæ, bacteria, and their spores. In woods in September basidiospores are abundant. Of mineral matter, sodium chloride, or common salt, is always present.

MICROORGANISMS IN ROOMS.

Many living microbes float in the air of all dwelling houses, but in rooms which are old, overcrowded, and dirty, the numbers are very much higher. These come for the most part from the sides and floor, and not from persons, but they are much more numerous when the dust is disturbed than when the room has been quiet for a short time. In schools, large numbers of microbes find a nidus under and between the boards of the floor if these are not close-joined. Bacteria chiefly abound, but many mold and yeast fungi are also present. The latter belong more to the external air, the bacteria to the internal air, and since the bacteria are the heaviest, the air of a room which is left quiet contains a preponderance of molds and yeasts. Pathogenic or disease germs are nourished to a great extent by the floors and walls of rooms, and for this reason the material should be smooth and easily washed. In schools and places which are frequently crowded, cleansing should be frequent, and no opportunity of extensive growth of bacterial colonies should be tolerated. An inquiry into the relative impurity of air in differently constructed buildings would be useful.

The clothes of scholars should be clean and washable, and there should be no crowding together in the class rooms.

SEWER AIR.

Sewer air in sewers of good construction, in good order, and at ordinary temperatures, contains very few living organisms discoverable by the usual methods. Microbes are not easily given off from sewage unless it be in a state of fermentation, and those which escape soon attach themselves to the wet surfaces of the sewer and drains. Yet there may be microorganisms which are not capable of cultivation and observation by means hitherto tried, but which are the agents concerned in the putrefactive and disease-causing changes set up in organic substances exposed to sewer air.

Moreover, the presence of a very few pathogenic microbes may be sufficient, when inhaled with the noxious gases in which they float, to set up typhoid and other dangerous disorders.

It is well to guard against the assumption that negative evidence proves anything in these cases. The bacilli or organisms of smallpox, measles, whooping cough, malaria, etc., are either undiscovered or very difficult to see and to identify. Drinking water which may be clear, bright, and pronounced by microscopic analysis to be pure and excellent, may poison by the invisible germs of typhoid which it contains. Analysis of water and of air is sometimes a less trustworthy arbiter than the senses, or than knowledge of suspicious circumstances.

Often a family lives in a badly drained house for a long time without suffering anything worse than headaches, diarrhea, sore throat, or loss of appetite. These ailments may be due either to habitual inhalation of the poisonous gases, or to the gases joined with slightly virulent microbes. Depressed vitality gives a strong presumption, if other conditions are wholesome, that drain air enters the house.

When drains and sewers are out of order, or fermentation is going on, or where there is old sediment, it is probable that a large number of microbes of a disease-producing kind are evolved and carried by the gases and air into houses. The process of decomposition and fermentation sets free small bubbles of gas in the liquid and on the wet surface, and these bubbles in bursting scatter a number of small particles into the air. The force with which liquid particles are scattered upward may be observed in the breaking of minute bubbles such as those which rise to the surface of a glass of effervescing water. Experiments on various drying and putrefying liquids could hardly fail to furnish interesting results. There seems to be great probability that bacteria or their spores are thrown in quantities into the air from viscous putrefying or fermenting liquids. Certainly a fermenting brewer's vat scatters multitudes of yeast germs into the air, and the case seems strictly comparable.

VAPOR AND ORGANIC MATTER FROM LIVING BODIES.

The lungs and skin together give off about 30 ounces of vapor in the day, or about 550 grains an hour, enough to saturate about 90 cubic feet of air at 63° F. Estimates naturally differ as to average amounts, but Professor Foster states that the water given off from the lungs in the day is about 1.5 pounds and from the skin 2.5 pounds. Vapor in a room ought not to exceed 4.7 grains per cubic foot at 63° F., or 5 grains at 65°. This vapor is practically not pure, for it is associated with minute portions of organic gases and solids, and condenses with them upon the walls, ceiling, and furniture, whence it emerges again with organic dust when these are warmer than the air of the room.

Organic matter is given off from the lungs and skin, of which neither the exact amount nor the composition has been hitherto ascertained. The quantity is certainly very small, but of its importance there can be no doubt. It darkens sulphuric acid, decolorizes permanganate of potash, and makes pure water offensive when drawn through it. Collected from the air by condensation of vapor in a hospital, it is found to blacken platinum and to yield ammonia; it is therefore nitrogenous and oxidizable. It has a very fetid smell and is only slowly oxidized by fresh air. It is molecular or particulate; it contains epithelium and fatty matter from the mouth and pharynx, sometimes effluvia from the stomach. Damp walls, moist paper, wool, and feathers are capable of largely attracting or absorbing it. Experiment shows that it bears a nearly constant proportion to the carbon dioxide in inhabited rooms, so that this gas is conveniently taken as an indicator of the amount of the organic matter in the air. Since this organic matter has been proved to be highly poisonous,[1] even apart from carbon dioxide and vapor, we may safely infer that much of the mischief resulting from the inspiration of rebreathed air is due to the special poisons exhaled from the body, their fatal effect being accelerated by the depression of vitality caused by the gaseous products of respiration and by the want of oxygen. Air thus organically vitiated and confined in places long inhabited, which are subject to continual condensation on their surfaces, without proper cleansing, appears to play a very large part in the propagation of disease in man and animals.

The quantity of particulate organic matter given off has been estimated at 30 to 40 grains for each adult. This is certainly sufficient for the nutriment and sustenance of a very large number of micro-organisms, which may grow, in the presence of moisture, upon it and upon other dust deposited upon the walls, floor, and ceiling. Water through which breath has been passed, and kept at rather a high temperature, gives off an unpleasant smell, and putrefaction is set up.[2] It does not appear to be definitely ascertained whether the breath and

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[1] Dr. A. Ransome and others.

[2] Carpenter; Douglas Galton.

skin actually and normally emit in good health living microorganisms, either pathogenic or harmless, but the probability is considerable when we remember that the mouth and air passages are inhabited by various species, and that warm evaporating surfaces exercise a repulsive force on minute particles. Foster states that the aqueous product from the breath is very apt to putrefy rapidly, owing to the presence of microorganisms. It is not generally assumed, however, that living microbes are exhaled to an appreciable extent. The subject is an important one and demands inquiry, but the ultra microscopic minuteness of the germs may defeat direct observation. As to the frequent emission of a deadly particulate poison, however, no doubt whatever can exist.[1] It is a dangerous and pernicious element in all aggregations, and, combined with carbon dioxide, produces, when in moderate quantity, depression, headache, sickness, and other ailments; when in large quantity, as in the Black Hole of Calcutta, and in various prisons of which there is record, rapid death in the majority and fever in the survivors. Its action upon the development of living germs when deposited upon outside objects has not been ascertained. Probably it may be favorable to some and unfavorable to others. Some of the most deadly human and animal diseases certainly are capable of virulent growth in their presence, and of passing more easily in a potent condition through air in which they are abnormally concentrated.

ORGANIC EMANATIONS FROM THE SICK.

Hospitals, when not well ventilated, contain a very large quantity of organic matter floating in the air and deposited on walls and floors. This gives rise, in the most impure air, to hospital gangrene and erysipelas, increases the severity of many diseases, and prolongs convalescence. Gangrene having once appeared, is very difficult to get rid of. Thorough ventilation and hygiene of the building where the sick are received and treated prevents these evils from arising.

ORGANIC EMANATIONS FROM THE SKIN.

Sweat contains salt, lactate, butyrate, and acetate of ammonium; calcic phosphate, ferric oxide, volatile fatty acids, e. g., sometimes valerianic and caproic acid, and sometimes leucin. Perspiration gives off into the air a large quantity of vapor, about 2 pounds in the twenty-four hours and a little over 1 per cent of this quantity of solid organic matter. Fatty acids, inorganic salts, neutral salts, ammonia, and particles of epidermis are constantly passing from the skin into the air. In the sick the matter emanating from the skin is often largely increased and is very offensive.

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[1] Some recent experiments of Smith and Haldane seem to show that carbon dioxide is the only element of mischief, but the conditions of ordinary life are so various and so difficult to imitate in experimental investigation that the inquiry needs to be widely extended.

The poisonous matter emanating from the skin of healthy people and animals, if thrown back upon the body by accidental or artificial means, causes death in a short time, not only in the case of rebreathing, but in cases where the pores of the skin are stopped, as by gold leaf or plaster of paris. Sheep have died in large numbers after being dipped in a resinous compound. The poison returned upon the body by the stoppage of the pores by finely divided soot may be a cause of the excess of cancer in chimney sweeps. Dirty bedding used after having been rolled up for two months has given fever.

The relation of the organic matter of respiration to disease can not be doubted, and, indeed, it seems probable that much of the mortality of infant and adult life may be due to the rebreathing of poison excreted by breath and skin. These are known to be, mediately or even sometimes directly, a great cause of consumption, pneumonia, and bronchitis. The recent experiments on the development of typhoid fever by the respiration of sewer gas lead naturally to the inference that other poisons besides that of sewer gas may play a very important part in laying the system open to the attack of disease germs either from within or from without the body. The chemistry of the expired breath deserves full investigation in many different cases and circumstances.

Gaseous emanations from sewers, drains, cesspools, and foul refuse cause diarrhea, vomiting, and prostration, or a low state of health. Children are more susceptible than adults, and when they breathe the gases largely diluted may suffer from languor, sore throat, and diarrhea. These results may be due simply to chemical or inorganic poisoning. Where the specific organism is present, typhoid, epidermic diarrhea, or diphtheria may result. Well-managed sewage farms do not seem to cause illness in their neighborhood. Sodden and neglected farmyards, on the other hand, are both common and pernicious. A great deal of illness, affecting both man and animals, arises from them. Thus "circulation," as in sewage farms, versus "stagnation," as in farmyards, shows its great superiority, even where other circumstances are apparently adverse.

The air close to certain crowded burial grounds has had a very bad effect on people living near them; it has greatly aggravated any disease from which they suffered.

The effluvia from decomposing corpses produces dysentery, diarrhea, or a low fever, and in some circumstances diseases of a more severe character.

SULPHURIC AND HYDROCHLORIC ACIDS.

Sulphuric and hydrochloric acids exist to a small amount in the atmosphere, but are not easily discovered except when brought down to the ground dissolved in mist or rain. Hydrochloric acid is one of the most soluble gases known, water at ordinary temperature absorbing five hundred times its volume. At Rothamsted, about 23 miles from London, the sulphates in rain were 0.0027 in the summer and 0.0032 in the winter; the chlorides were much less in summer than in winter. The average of sulphates in a certain period of thirteen months was 0.004, of chlorides 0.0033. Seven samples collected near Horsham, in Sussex, gave sulphates 0.0048, chlorides 0.0041. A sample collected on Dartmoor during a gale from the southwest gave the following results: Sulphates 0.0005, chlorides 0.0087. Proximity to the sea evidently increases the chlorides and reduces the sulphates. At St. Bartholomew's Hospital, in central London, the sulphates were 0.0388, the chlorides 0.0179, and the amounts were greater in summer than in winter. The quantities of these impurities in the air of a large town are much above the average of the country. The rain does not give acid reaction, but wherever it is contaminated with soot it becomes distinctly acid after a few hours. Soot, then, being acid and becoming moistened by rain, must play an important part in the corrosion of buildings and other materials on which it has been deposited. Experiments were made by Dr. Russell by means of a conical vessel filled with ice, to ascertain the amounts of impurities condensed from air in London. The results were remarkable; sulphates 0.1344, chlorides 0.0506, ammonia 0.006; and in fogs the amounts were 0.2480 sulphates, 0.1215 chlorides.

ARSENIOUS ACID IN RAIN.

A gallon of rain in the city of London has been found to contain 0.00021 grain of arsenious acid.

AMMONIA IN THE AIR.

Ammonia is always present in the air in minute traces, either free or combined. It is a chemical compound of 14 parts by weight of nitrogen and 3 of hydrogen, and arises from the decomposition of organic matter. It is lighter than air in the proportion of 8.5 to 11.47. Although the quantity rarely exceeds 3½ parts in 10,000,000 of air, this is sufficient to be of very high importance to the growth of vegetation, for the gas is soluble to quite an extraordinary amount in water, and is thus continually being brought down from the atmosphere in rain and dew. Brandes found, by evaporation of rain, in each million kilograms from 8 (May) to 65 (January) kilograms of residue, of which ammonia salts formed a considerable portion.[1] Rain, according to Boussingault, contains about three-fourths of a milligram of ammonia per liter, equal to 7 kilograms per hectare per annum. Dew contains about 6 milligrams, equal to about 29 kilograms per hectare per annum; fog, about 50 milligrams, and in Paris, 138 milligrams. Water dissolves from 700 to 1,000 times its volume of ammonia, according to the temperature. Representing the quantity of ammonia in rain at Valentia, in Western Ireland, by 1, the quantity inland in England was 5.94, at Glasgow 50.55. The albuminoid ammonia was: Valentia 1, Manchester 7.38, London 6.23.

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[1] Pierre.

In summer the amount in the air is highest, in winter lowest. In large coal-burning towns it is considerably more abundant than in the country, and is deposited with carbonaceous, sulphurous, and organic matter on exposed surfaces during the prevalence of fogs. Foggy air in these towns contains an excess of sulphates and chlorides, but a still greater excess of organic matter and ammonia salts, often double the normal. The ammonia contained in the deposit on glass roofs in Chelsea and Kew after fogs was respectively 1.4 and 1.1 per cent. The processes of combustion, both in manufactories and in domestic fires, of coal and of coal gas, give rise to ammonia.

Only traces of ammonia are evolved from the lungs, and a little from the skin and in perspiration.

The smell of ammonia is distinguishable in most stables, but where strong we may be sure that ventilation is deficient. Main streets, especially where wooden pavements are used, often smell offensively of ammonia; on still, dry days the ammoniacal dust is thick in the air, and in windy weather is blown about in clouds. Analysis has shown that 95 per cent of the dust from wooden pavements in main London thoroughfares, consists of horse dung. This is breathed into the lungs and often produces sore eyes and sore throat. Such pavements should either be kept scrupulously clean throughout the day or be properly watered, in order to reduce harmful dust, and an occasional coating of tar would not only prevent the emanation of noxious matter, but would preserve the wood.

Ammonia, being everywhere present in the air and extremely soluble in water, may truly be said to be attached to all exposed surfaces where moisture is also present; in the neighborhood of human habitations and decaying animals or vegetable matter it has been found on all objects; in a room, if a perfectly clean glass be suspended, traces of it appear after an hour and a half. Evolved in small quantities from the skin and lungs, it must be deposited with condensed vapors on the walls, ceilings, and floors of dwelling houses.

NITRIC ACID IN THE AIR.

Nitric acid also pervades the air in minute quantity, and, with ammonia, plays a great part in the development of plants. It results partly from the combination of nitrogen and oxygen in the atmosphere caused by thunder storms and partly by the oxidation in loamy soil of the ammonia of decomposing organic matter. It seems probable that many forms of bacteria or molds may be favored in their growth by the presence, with moisture, of these two nitrogenous substances. Within human habitations, cow sheds, etc., we must regard the walls, and all surfaces as covered with a thin top-dressing of moist organic dust and ammonia. Within the soil ammonia appears to be oxidized to nitrites by one set of microorganisms, while another set oxidizes nitrites to nitrates. To the latter the presence of ammonia is a hindrance.

LOCAL GASEOUS IMPURITIES—SULPHURETED HYDROGEN—SEWER AND DRAIN AIR.

When certain animal and vegetable matter undergoes decay, the small quantity of sulphur which it contains combines with hydrogen and forms the gas, sulphureted hydrogen, which, even in mere traces, is very offensive to the sense of smell. It also forms some offensive organic sulphides. The sulphureted hydrogen gas set free often bears with it germs of disease, so that it has been treated as a danger signal. Drain or sewer air, however, does not always contain the gas in appreciable amount, when dangerous germs are being given off, and the faint smell of an old filth deposit may exceed in morbific effects the unpleasant odor of fresh putrefactive processes. Nor does sewer air, even if it be poisonous, often contain virulent germs of disease. Dogs and horses are rapidly prostrated by 1.25 to 4 volumes of sulphureted hydrogen per 1,000 of air, but men can breathe a larger quantity. In large doses, nausea, headache, convulsions; in small doses, low febrile symptoms follow its inhalation. The frequent inhalation of small doses produces chronic poisoning; 1 per cent is at once destructive of life.

The air over some of the most pestilential marshes in Italy contains an unusually large quantity of the gas. In mines it produces convulsive, narcotic, and tetanic symptoms.

SULPHUROUS ACID.

Sulphurous acid in the air of cotton and worsted manufactories apparently tends to produce bronchitis and anæmia. It destroys vegetation in the neighborhood of copper works.

CARBURETED HYDROGEN.

Carbureted hydrogen, breathed in small quantities, as in the air of some mines, does not seem to cause ill effects, and experiment has shown that for a short time it can be breathed in the proportion of one volume to four of air.

HYDROCHLORIC ACID.

Hydrochloric acid vapor is very irritating to the lungs. In some processes of making steel this gas, with sulphurous and nitrous acids and chlorine, cause bronchitis, pneumonia, destruction of lung tissue, and eye diseases among the workers. It destroys vegetation for a long distance when given off in large quantities from manufactories.

CARBON BISULPHIDE.

Carbon bisulphide vapor, given off in vulcanized india-rubber factories, produces, in those exposed to it, headache, giddiness, pains in the limbs, nervous depression or excitement, and complete loss of appetite.

Carbon monoxide is a very poisonous gas arising from the consumption of coal, coke, coal gas, and especially charcoal. Less than 0.5 per cent is fatal to animals. Fatal consequences from the use of charcoal stoves where ventilation is defective are common in some countries.

Carbonic oxide is given off by iron works, brick fields, copper furnaces, and cement works. It is dangerously present in the cheap illuminating gas known as "water gas."

ORGANIC VAPORS.

Organic vapors of various composition are given off by marshes, wet forest ground, "made soil," soil containing organic matter under warm sand, and by many manufactories for the conversion of animal refuse, etc. The effluvia from tanneries, glue and soap works, slaughterhouses, pigstyes, etc., are apt to lower the health of people living near them and to aggravate disease.

SOLID ARTIFICIAL IMPURITIES.

Many severe forms of disease, especially of the respiratory organs, are caused by the dust inhaled in various trades and occupations. These are generally proportionate to the sharpness and angularity of the dust and its quantity. Coal dust is among the least harmful. Among lead miners, bronchitis and lead poisoning; in copper mines, gastric disorders; in pottery works, in stone cutting, steel grinding, in flax and cotton factories, in shoddy works, and in metal polishing, lung diseases are common, and the death rate is high.

Thus the comparative mortality of file makers was 300 compared with 108, that of gardeners; of earthenware .makers 314, compared with 139, that of grocers; of cutlers and scissors makers 229, compared with 129, that of paper makers. The dust of soft woods and of flour seems to have little bad effect.

As regards phthisis and lung diseases the figures of several trades are as follows, when compared with fishermen, 100: Carpenters, 170; bakers, 201; cotton workers, 274; file makers, 396; stone and slate quarrymen, 294; pottery makers, 565; northern coal miners, 166. The injuriousness of the dust in cotton mills is increased by the use of mineral substances for sizing. The mortality of cutlers, etc., from these diseases is almost as great as that of fishermen from all causes put together, including accidents. The comparative exemption of colliers in well-ventilated coal mines deserves investigation, for there would appear to be some ground for the supposition that it may be owing to an inhibitive action of this particular dust upon the development of tuberculosis; on the other hand, it may be simply through living in fairly good air of an even temperature, where the specific germs of phthisis are few or absent. The homes of the men are generally comfortable, and much larger fires are kept up than in the south, so that their rooms are dry and well ventilated.

PART II.—CLIMATE, AIR, AND HEALTH.

MALARIOUS AND INFECTIOUS DISEASES: THEIR CONNECTION WITH AND DESTRUCTION BY THE ATMOSPHERE — THE INFLUENCE OF CLIMATE ON NATIONAL HEALTH.

The spreading, infectious, or epidemic diseases in the animal world and in mankind depend to a very great extent upon aerial influences.[1] Microscopic fungi or microbes, the prime causes of these disorders, are sensitive to dryness, moisture, heat, cold, and sunlight, and a study of their relations to the atmosphere has led and will lead to results of the very highest importance to human welfare. Many of them reach the living body, upon which they lodge, through the air; many are partly nourished outside the body by the gases and moisture which the air brings to the seat of their growth. But as a whole the pure atmosphere works energetically and unceasingly for their destruction; dry air and sunlight deprive most species of disease organisms of their vitality. This great generalization may best be appreciated by a brief review of the principal endemic, epidemic, and pandemic maladies to which the human race is subject, dealing especially with the manner in which they are developed, restrained, diffused, or annihilated by the qualities of the air.

Microbes have been divided into two main classes, aerobic and anaerobic, the first growing best in the presence of air and the second growing best in substances and in positions to which free air has no access.

Some of the first class, such as the hay bacillus (subtilis), grow best only with a copious supply of air; some grow better when the air supply is not large than when free air is admitted; some of the second class can grow in the absence of free air, but thrive more when some air is admitted; and others, which are fully anaerobic, grow only when free air or oxygen is shut off. Examples of these last are the bacillus of symptomatic anthrax, of tetanus, and of the malignant œdema of Koch.

A large class of bacilli or bacteria are killed by dry air, by light, by artificial heat, and by prolonged intense cold, but are capable, when adverse influences act upon them, as by deficiency or inappropriateness of the nutritive medium, of forming spores, minute germs which are scattered abroad in a condition of far stronger defense, and capable of resisting for some considerable time prolonged exposure to sunlight and even to boiling water, to drying, to various antiseptic chemicals, and to any possible natural cold. The spore-bearing faculty belongs to a variety of species of bacilli, both pathogenic and harmless.

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[1] "The atmosphere is the most universal medium or vehicle" of their poisons to the breathing organs and intestines. (Professor Corfield, medical officer of St. George's, Hanover Square, London.)

Spore formation takes place at temperatures between 16° and 45° C., and these are in general the extreme limits. Bacilli which do not form spores—for instance, those of typhoid fever, glanders, and fowl cholera—are easily killed outside the body by a number of natural and artificial agencies. Among these agencies the most efficacious are drying, exposure to dry air and oxygen, high temperature, sunlight, the presence of other species of microbes, the poisons evolved by themselves or by other species, cold weather, exhaustion of their appropriate nutriment, and various inimical substances which inhibit growth or actually kill. In the very fatal diseases of cattle known as anthrax, and when transferred to mankind, as wool sorter's disease, the bacilli which infect the blood of the dead animal are killed by mere drying, without exposure to air; but if the blood be for some little time exposed to the air, spores are formed which may remain upon the pasture, or upon wool, or hides, or elsewhere, and infect fresh cattle or human beings at some distant date. The putrefactive process in the carcass also kills the bacilli, but will not kill the spores if these are allowed to be formed.

Anthrax is known to be in many cases communicated through the air from one animal to another or to man, and among wool sorters, butchers, and others enters the body through a wound, or by the lungs, or by the alimentary canal.

Spore formation is generally favored by a copious supply of oxygen. It is a process by which the degeneration and destruction which takes place in a colony of nonspore-bearing bacilli is prevented, and by which the seeds are set adrift, to be planted and grow again into bacilli in more favorable surroundings.

The process of growth from a spore into a bacillus has been experimentally observed in favorable conditions to be completed in periods varying from half an hour to two hours. The bacillus introduced into an appropriate medium multiplies by fission at an enormous rate, so that, for instance, 248 microbes of the pathogenic species *Staphylococcus pyogenes aureus* in a cubic centimeter increased to 20,000,000 in twenty-four hours, and 20,000 bacilli of fowl cholera multiplied in the blood of a rabbit to about 1,200,000,000 in twenty hours.

Microbes vary greatly in size not only between classes and species, but between individuals, according to the medium and circumstances of growth. Ordinary dimensions lie between about 0.5 and 5 micromillimeters in length and 0.1 to 0.5 in breadth. The spores are in many cases much smaller. Clearly, an organic living dust of less than one thousandth of a millimeter in diameter is capable of existing in great numbers on very small areas, even on small, almost invisible, dust, and of being wafted long distances by gentle aerial movements without sinking. In perfectly still air inclosed in a box in the laboratory Tyndall found that all visible dust sank within three days, and nutrient media then exposed were unaffected by bacterial growths, so that the microorganisms originally present must have settled down. But in nature not only is such a calm unknown, but processes are continually taking place which launch fresh organisms into the atmosphere. Moreover, there is good reason to suppose that several disease microbes or their spores are still lighter than those which have been subject to similar experiments. The influenza microbe is extremely light. Its length has been given at $\frac{1}{50000}$ and its breadth at $\frac{1}{250000}$ of an inch. Disease microorganisms have in the laboratory passed from room to room through the air, and accidentally infected animals inoculated with other kinds. Light dust falls at so slow a rate through the viscous air that even in a room the downward motion is scarcely perceptible; yet in a few hours all the grosser particles are deposited if drafts, movement, and shaking of the room are prevented. Most pathogenic microbes are carried down with this dust or sink of their own gravity, and soon subside, but in ordinary conditions there is too much disturbance to permit effective purification by subsidence. The light dust of the volcano Krakatoa, which was visible as a haze, took a year to fall even out of the rare upper strata, and many disease microbes are equally small, and fall still more slowly through the dense strata near the ground. Particles of smoke may perhaps be compared with the spores of bacteria, and tobacco smoke not only floats long in the air of a room, but passes through passages and through chinks into rooms above and below.

Among animal diseases of an intensely infectious character and disastrous to agriculture, cattle plague, pleuro-pneumonia, and foot-and-mouth diseases are perhaps foremost. Two, at least, of these are communicated not only by infected articles, but by transmission through air for a short distance of particles derived from an actual or previous case. These diseases, or some of them, have formerly been widely held to come from some unusual epidemic constitution of the air, but they are now thoroughly proved to be preventable by the admission of plenty of external air and rigid precautions against contact or proximity of infected articles. They are frequently spread by attendants passing from one herd to another without complete systematic disinfection; frequently also by imperfectly disinfected sheds. No animal plague has been proved to be capable of passing effectually through a long stretch of atmosphere, and the free atmosphere in all cases tends to diffuse and destroy the poison. There is reason to regard certain low alluvial lands and swamps as the original breeding grounds of the saprophytic microbes which cause some of the worst animal plagues, for these plagues have followed immediately the subsidence of floods and the drying up of marshes. Since the neighborhood of these places is not exempt, the organisms concerned must be capable of transport in a potent state for a short distance by moist air. The filthy condition and foul, unventilated air in which cattle are kept have also been shown to be the cause of their gravest maladies. Tuberculosis in animals depends to a very high degree upon the absence of proper ventilation and upon proximity to each other. In the open air and wild life it does not seem to occur. It has been well ascertained that the microbes of cattle plague may cling so persistently to infected places that whitewashing, scraping, and ordinary disinfection may be insufficient. Similarly, tuberculosis of cattle occurs again and again in particular stalls, showing that the infective matter remains in a virulent condition on the walls, floor, or ceiling, and probably infects not only by contact, but through air. The breath of the animal condensed on the walls would no doubt form pabulum for the increase of any remnants of a former multitude which might light upon them or emerge from the pores of the material. In France, epizootics greatly increased after the introduction of railways, owing to emanations from and contact with incompletely disinfected cattle trucks, yards, sheds, etc., and the diffusion of infectious cases by increased movement.

INSUFFLATION OF ANTHRAX, ETC.

The inbreathing of the bacilli of cowpox, anthrax, clavelee, and suppuration is sufficient to give each of these diseases to sheep and cattle. But there is no evidence to show that any animal plague is transmissible through any long distances of air or by the general atmosphere; on the contrary, animals are in thousands of instances kept within a mile or less of others which are stricken, and with due precautions remain well.

TUBERCULOSIS.

Many of the epizootic diseases which occur in animals may be transmitted to men, but they often occur in a modified form and are either more or less severe. Some may have been originally human maladies. Fifteen at least are said to be thus interchangeable. The most important, widespread, and fatal of these is consumption, phthisis, or tuberculosis. The bacillus tuberculosis kills about 1 in 8 of the population of Great Britain and America, and about an equal proportion, one-seventh, according to a very high authority (Hirsch) of the people of the majority of other civilized countries. It is the greatest and most constantly present plague of man. It has been considered ineradicable, constitutional, hereditary, and attributed by many authorities to some vice in the atmosphere. Now, we know that it is a nationally self-inflicted, unnecessary, and preventable pestilence, of which the great and certain prophylactic is pure air in plenty; no foul air, foul dwellings, and overcrowding. Overcrowding, the rebreathing of expired air, dirty, dusty dwellings, moist or organically polluted walls, floors, ceilings, and furniture, and the careless habit of spitting account for a very large part, perhaps the majority, of cases of consumption. The breath in fetid air, the emanations from cultures of the bacillus on the walls, curtains, carpets, etc., and, most potently, the dust of the dried sputum itself of consumptives, may infect healthy persons, but mostly those who have some tissue delicacy or predisposition. But another very common cause, especially in the largely fatal tuberculosis of infants, is the use of milk from infected cows. Now, these cows are themselves diseased through media very similar to those which disarm the human subject, rebreathed foul air and dirty places; in fact, want of cleanliness, and, above all, want of fresh air.

Well-ventilated cow sheds, and immediate separation of sick animals, prevent the spread of tuberculosis among cows; thus children are saved from the danger of tuberculous milk. The breath of the consumptive in well-ventilated rooms may be considered harmless. Animals have been infected by breathing the dust of sputum disseminated in the air, and no doubt the same mode of infection is very common among mankind, but only in close association with the sick or in stuffy apartments. The State board of health of Maine has issued valuable instructions to prevent the practice of expectoration except in spittoons, which may be wooden or pasteboard, and should either be burned daily or cleansed with boiling water and potash soap.

The reduction of consumption by such means and by better regard for ventilation is not only probable, but certain. In England the death rate has considerably declined with sanitation. From 1851 to 1860 it was 2,679 per million per annum. In 1888 it was 1,541. In New Hampshire, United States, the deaths from the several diseases named were as follows: From 1884 to 1888, consumption, 4,039; diphtheria and croup, 983; typhoid, 750; scarlatina, 187; measles, 160; whooping cough, 109; smallpox, 2. Here the very large proportion of deaths due to consumption, and the importance of effecting a reduction, are strikingly shown; but a similar proportion exhibits itself in every thickly inhabited State, both in Europe and America.

Rooms occupied by consumptives should be periodically disinfected and always kept clean. The danger is there, but it can be averted. The experience of the Brompton Hospital shows that with proper hygienic precautions cases of infection from patients are very rare. Koch has shown that enormous multitudes of bacilli may be distributed on the ground and in the air from only one patient, and how infection is explained by their long survival in a moist or dry state. Cornet showed how the walls and carpets, cornices, etc., retain them still potentially virulent. Thus certain houses remain for a long while centers of infection, and newcomers are attacked out of all proportion to the cases among neighboring uninfected dwellings.

Prisons, barracks, etc., which when crowded and badly ventilated were very fatally affected with consumption have been rendered wholesome by thorough ventilation and greater cleanliness. Out of an average prison population of 4,807 in the year 1890 in England, only 9 died of phthisis, excluding cases in which sick prisoners were removed home.

The mortality of the British army in barracks from consumption in the ten years 1837 to 1846 was 11.9 per thousand. After the report of a royal commission in 1858, ventilation and air space were greatly extended, and the mortality immediately and rapidly fell; in 1888 the consumption rate was only 1.2 per thousand.

The disease prevails more on wet, cold, clayey ground and damp places generally than on high and dry sites, and all causes of chills and colds give an opportunity to the infection of the specific bacilli where they are present in sufficient numbers and strength.

Cold countries are rather less subject to the disease than temperate and warm climates, but everywhere the most important factors are the habits of the people. A moist atmosphere, with wide daily range of temperature, favors its prevalence. In Greenland, Labrador, Iceland, Spitzbergen, Nova Zembia, Finland, Siberia, and the northern parts of North America the disease has been rare; also especially on mountain ranges, high plateaus, and little-visited districts, such as the Soudan. In Algeria the nomad Arabs were free from it. The Bedouins who exchange their tents for stone-built houses suffer to some extent. Many uncivilized tribes are exempt until they adopt the clothes and way of living of civilization. Outdoor life in the free air, and clean, spacious sleeping quarters almost or quite annihilate consumption if animal sources are excluded. Soldiers on campaign, fishermen, hunters, engine drivers, gardeners, and farm laborers are least attacked; workers in gritty stone or metallic dust, in hot, close, crowded, and damp rooms or factories or mines, and dwellers in damp houses, back-to-back houses, and close courts furnish the largest number of victims. In the old town of Havre, with its airless, narrow streets, the mortality is three times as great as in other parts of the town.

It has been shown that in proportion as a population, male and female, is drawn to indoor occupations, the death rate from consumption increases.

An elaborate investigation for official purposes by Dr. Ogle showed the mortality from phthisis and lung diseases of men from 45 to 65 years of age working in pure and vitiated air in England, to be as follows:

	Phthisis.	Other lung diseases.	Total.
Pure air:			
Fishermen	55	45	100
Farmers	52	50	102
Gardeners	61	56	117
Agricultural laborers	62	79	141
Confined air:			
Grocers	84	59	143
Drapers	152	65	217
Highly vitiated air:			
Tailors	144	94	238
Printers	233	84	317

From these figures the effect of the breathing of foul air on respiratory diseases is conspicuous. But the differences represented would have been much greater if the class described as living in pure air had not been subject, during that part of their lives which was spent within doors, to the bad air of close apartments or cabins, and to the occasional infection of places of assembly and resort.

That demonstrable bacilli are given out by the breath of persons suffering from consumption and other diseases, has been proved by Ransome and others. The possibility was doubted by Cornet and other authorities on the grounds that nonvolatile substances can not be exhaled, that many good observers have failed to find them, and that where observed errors may have crept into the experiments. But Cornet himself has shown that the bacilli are exhaled in small numbers by patients, and that they and their spores are given off in great numbers from handkerchiefs, bed linen, furniture, floors, etc., of rooms in which consumptive persons live.

Klein has shown that guinea pigs exposed to a spray of tubercular matter in the air, or else kept in the shaft of a ventilator in a consumption hospital, acquire the disease. It has been proved by Straus that nurses of consumptive patients have tubercle bacilli deposited on their breathing organs. These last experiments are not proofs of the exhalation of the fatal microbes. But we have the most convincing proof in everyday facts of the possibility of the exhalation of the bacilli or germs of several infectious maladies. The breath is one of the most common vehicles of transference of infection from person to person. Moreover, Ransome finds much indiffusible organic matter, such as epithelial scales, in the condensed aqueous vapor of the breath. The breath of consumptives, however, contains very few bacilli, and the particles of sputum which fall from the mouth in expectoration or in speaking are more dangerous.

Tuberculosis has been produced in animals by causing them to inhale air vitiated by subjects of phthisis. Glass slides, wetted with glycerin, show the presence of tubercle bacilli in the air of consumption hospitals. Tuberculous particles inhaled are found to be more capable of infecting than particles swallowed. The air does not often, at any rate, convey infection from the mere breath of a patient in an ordinary clean room, and the temperature must be rather high to maintain the vitality of the germ. In hot climates, under similar conditions, the danger is greater, but generally the better ventilation reduces it.

Consumption and leprosy are caused by similar microbes, and have much in common in their behavior. In phthisis the contaminated air conveys the bacillus to the air passages, and in scrofulous glands to the nearest sore; in leprosy the exposed parts, hands, face, and feet, which have received some scratch or wound, are first attacked. As leprosy has been got rid of not only by improved conditions of living, but by segregation of the victims, so consumption and tuberculosis will be exterminated wherever the utmost care is taken in providing for fresh air, good and well-cooked food, clean dwellings and clean byres, and in segregating or specially controlling and caring for affected individuals. Close courts, back-to-back houses, damp cottages, tuberculous meat and milk, overcrowding, and dusty occupations in heated air deserve either total condemnation or most rigid precautions. Rooms should be constructed so as to be easily and frequently cleaned and constantly aired. The habit of wetting envelopes, ledger pages, etc., from the mouth should be prohibited. Notification of cases should be required as in other infectious diseases. Light, air, space, exercise, and cleanliness should be made easy of attainment and common to every human being.

TYPHUS.

Another disease intimately associated with bad air and with crowded dwellings is typhus. It does not arise at all among persons living in the open air and in well-ventilated rooms, but spreads with fatal effect in the crowded, dirty apartments of the poor, in filthy jails, ships, and lodging houses. The disease was formerly very destructive in England, infesting the prisons, and was sometimes communicated to judges and lawyers into whose presence prisoners were brought; but better conditions of living, greater cleanliness, and more regard for ventilation have resulted in its almost complete extermination. So sensitive is the microbe to fresh air and disturbance of foul surfaces that the crowding and dirt which remain, bad as they are, are scarcely sufficient to maintain its virulence. Typhus is not conveyed far by the air, and as a rule only infects those who are very near to the victim. All the staff of the Fever Hospital, in London, were attacked at some time through this infection, but during eight years no case occurred among the staff of the Smallpox Hospital, which was in close proximity. Even the attendants in typhus wards run little risk when these are spacious, well ventilated, and not overcrowded. Poisonous microbic emanations from the lungs and skin are thus in an almost incredible space of time rendered harmless by the action of fresh air.

The winter has generally been the season of greatest prevalence of typhus, owing probably to the greater distress and crowding in the cold months. The infection remains for some time on clothing, walls, etc., so that the air does not apparently disinfect or destroy where the organism has sufficient moisture and nourishment.

THE PLAGUE.

The plague, a very severe pestilence which has been common in the East and in North Africa, and has visited Europe with the most appalling mortality, arises in districts where filth abounds to the most extent, where dwellings are overcrowded, and where famine and undernourishment are frequent. It is both miasmatic and contagious. In 1603 it hardly ever entered a house but it seized all living there. Prolonged breathing of the sick-room air was the most effectual means of infection.

A moderately high temperature is most favorable to the breeding of this pest; above 86° F. it declines. Moist, alluvial soils; the banks of great rivers, such as the Nile and Euphrates; a warm, humid air; great accumulations of putrefying animal and vegetable matter in the vicinity of dwellings; dwellings surrounded by heaps of manure and almost hermetically sealed—these are conditions favorable to the growth of plague. Once started, it spreads by infection much after the manner of typhus. Care for the purity of air in and around dwellings abolishes plague altogether, as has been proved locally in the Himalayas and generally in the retrogression of the disease from Europe.

CHOLERA.

Cholera is to a great extent a disease of air poisoning. It arises from the soil in certain districts of India, where it is endemic, and from which it occasionally has the opportunity, through favoring climatic influences and the movements of travelers, of invading temperate regions, in which it may cause great mortality in a few seasons, but can hardly establish itself permanently in the soil or water. It does not, as was long supposed, travel from place to place through the air, and has no epidemic existence beyond its breeding places apart from human agency. The cholera microbe, the comma in all probability, thrives in a damp, organically polluted soil, such as that of the delta of the Ganges and the flat lands around Madras, Bombay, and Shanghai; of the valleys of the Brahmaputra, the Nerbudda, the Tapti, the Indus, and the Euphrates, and in a temperature of from 25° to 40° C. In the delta of the Ganges the temperature of soil and air appears to be so favorable that it never dies down; at Shanghai it regularly infects the air and water after the heat of July and August. It is aerobic. A freezing temperature prevents its growth, but does not destroy it. Kept moist, it may live for months after growth has ceased; dried for a few hours, it dies. In temperate climates it is spread by the entrance into water and air of the organisms derived from growth in the dejections of cholera patients, some cases being only recognized as diarrhea, but still being capable of spreading the poison. The destruction of the dejecta is, therefore, the safeguard in all cases. The power of extension of cholera through the air alone in the neighborhood of cholera patients where due hygienic precautions are observed is very small, but every article used must be washed or sterilized. The general atmosphere does not convey it either from person to person or from soil to soil, unless, possibly, in rare cases and for a short distance. In fact, free air, unless very humid, soon kills it. The atmosphere of the Gangetic delta, the chief endemic area of cholera, is remarkably damp. There are probably a number of places in India where the soil is to some extent infected, but where mischief arises only in certain seasons.

The conditions of soil and air favorable to the growth and exhalation of the cholera germ may be concisely summed up as follows;

Permeability of soil to air, moisture of soil not excessive, average soil heat at 6 feet deep about 79°, a moderate amount of contained organic matter, and little putrefaction or ordinary decomposition; mean annual temperature of air about 72° F. The minimum water level, otherwise the maximum of soil ventilation, and the maximum of cholera coincide. Dry or saturated soil are unsuitable for the continuous growth of the bacillus.

DIARRHEA.

In an inquiry conducted about thirty-five years ago[1] regarding the prevalence of diarrhea, a disease which in England is fatal to very large numbers of children, it was found that there are districts in which endemic diarrhea is unknown, and others in which it prevails extensively every year. The excess of mortality coincided in all cases with one of two local conditions, the tainting of the atmosphere with the products of organic decomposition, especially human excrement, or the habitual drinking of impure water. Since the time of the report a large amount of evidence has accumulated which goes to prove that summer or infantile diarrhea is caused by the infection of air and food by emanations from a damp organically contaminated soil raised above a certain temperature. Houses built on or near a subsoil containing decomposing organic matter, or where sewers leak, are particularly subject to diarrhea. The nature of the soil is important. Sand, loose fine gravel, deep mold, and permeable soils generally, where organic matter is abundant, are productive of the disease; houses built upon rock, without fissures, are generally altogether exempt. "Made ground," containing organic rubbish, on which so many houses in the outskirts of large towns are built, emits products of decomposition into the interior of houses and is a fruitful source of suffering. The practice of building on rubbish heaps should be made a criminal offense. The absence of free ventilation within and around houses greatly increases the mortality from this cause. Deep drainage has been followed by a marked fall in the prevalence of the disease. Paving, impervious flooring in houses, cleanliness in the storage of food, with ventilation, are important measures for its reduction. Purity of air, indeed, in this as in so many other cases, is the remedy to be sought.

Diarrhea in the epidemic form arises under conditions very similar to those of cholera. It may be in fact a very near relation of that microorganism, but is milder in its effects and has the quality of developing at lower temperatures. When polluted, damp soil at 3 or 4 feet deep reaches about 56° to 60° C., as it generally does in England in June or July, the cases of diarrhea mount up rapidly, for the diarrheal microbe is then multiplying in the subsoil and emerging through the upper stratum, and may indeed be developed in decaying organic matter on the surface. Settling upon articles of food and drink, such as vegetables, water, and milk, it multiplies and develops the poison

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[1] Second Report to the Privy Council, London, 1859.

which belongs to fungoid growth. When ingested with food, and even when breathed with the air, it causes the disease. The air of that part of a town which was subject to diarrhea has been proved to contain germs which cause the disease, and to contain 2,000 to 7,000 bacteria and micrococci in the cubic meter. The deaths in this part of the town, containing one-third of the population, were 216 out of a total of 256. The remedies for diarrhea are principally draining the ground to a considerable depth, paving, ventilation of dwellings and of places where milk and food are kept with air from some height above ground, cleanliness generally, and a good water supply. Cows, farmyards, and dairies need similar attention. Diarrhea is much less common among the Irish population of large towns, owing to their infants being almost invariably suckled by their mothers and not from the bottle.

The general air soon nullifies the danger from strata near the infected ground, and the germ seems to be incapable of enduring conveyance in a potent state through any considerable distance in the free atmosphere.

TYPHOID FEVER.

Typhoid fever, like cholera and diarrhea, depends to a great extent on the growth and cultivation in neglected human refuse by human agency (unwilling but effectual) of germs which thrive in damp, polluted soil or in foul water. Warmth and exclusion from free air favor the development of the bacillus, supposed to be the cause of typhoid. It can grow, however, in the presence of free oxygen, and then develops the saprophytic habit and great resistant power. In direct sunlight it is killed in six to seven hours, and in diffuse daylight growth is very slow. The mode of entrance of typhoid is both through air and water contaminated with the products of the intestinal discharges of persons sick with the disease.

During twenty years preceding 1883, the average annual number of persons who died of typhoid in England was about 13,000, the number of those who suffered from it about 130,000. In many continental cities, the proportion is much higher. Although bad water accounts for a large number of cases, bad air, the emanations from drains through defective traps and waste pipes, also infects in very many instances. Recent experiments of great interest have shown that sewer air is capable of so poisoning the system as to lay it open to the attacks of the typhoid bacillus, which is doubtless frequently present either in the foul air or in the intestines. In this way many outbreaks are caused by the combined influence of drain air and specific microbes. The condition of farmyards near dairies whence milk is supplied to cities is too often so filthy that both air and water are poisoned. Milk has a remarkable power of absorbing gases and vapors, and is also a cultivating medium of various fungi and bacteria.

Typhoid germs, like so many others, are soon rendered innocuous by mixture with fresh air, and there is some evidence to show that oxidation by the air in running water has a good effect where the noxious matter is largely diluted and the stream pure. In London, New York, Paris, Berlin, and perhaps the majority of places in the northern temperate zone, typhoid fever is most prevalent in the late summer or autumn, when the ground at a little depth, and water in shallow wells, are at their highest temperature. In India it occurs mostly in the hot, dry months before and after the rains, and may in part be attributed to the wind blowing up the dust of filth deposited in the fields, but chiefly to the same conditions as prevail in England and to the introduction of the virus, often from slight and unsuspected cases.

The great majority of houses in civilized places resemble inverted, slightly ventilated bell jars, connected with a system of pipes on which deadly organisms may grow, and from which they may be conveyed by the poisonous gases to the bodies of the inmates. It should be a primary object to make the entrance of these gases difficult and of the outer air easy. The bacillus concerned in typhoid fever is probably widely diffused, but, whether often present or not in an innocuous form in the human intestines, does not attack life where air and diet are pure. With the aid of impure air from drains, middens, and foul sinks it acquires deadly power. Cleanly disposal of refuse and abundance of fresh air are the great securities against this disease.

MALARIA.

Malaria is the most general, constant, and destructive of endemic diseases in tropical climates and over a very large proportion of the inhabited globe. Millions die of it every year in India, and in Africa and South America it is terribly prevalent and fatal. Vast numbers of people are crippled and diseased for life in consequence of the fever, and in many districts the whole population looks debilitated and anæmic. It depends on the emission of living organisms, probably amœbiform, from warm, damp soil, rich mold, sand, or other suitable ground containing a little organic matter. It haunts open and narrow valleys, dried water courses, the country at the foot of many mountain ranges, sandy coasts in certain climates, mangrove swamps, deltas, marshes, and even in certain districts dry, sandy plains at a considerable elevation. The organism appears to exist either in an active or latent form in nearly all hot countries where the soil contains sufficient organic matter, and that need not be much. Where soil is efficiently drained, naturally or artificially, malaria is rare or absent; and where irrigation works increase the dampness of the soil, there also malaria increases or develops itself. Cultivation, with the exception of rice growing, in general diminishes or abolishes malaria within the area cultivated. Lowering of the water level and aeration of the soil reduce malaria notably. Drainage in East Anglia has almost extinguished ague, which is a similar or the same disease. Some sandy, semidesert districts, such as Western Rajpootana, are subject to malaria, although the water is several hundred feet below the surface. But here the sand is found to be damp a short distance below the surface, and probably the same condition prevails elsewhere in sandy tracts where malaria is present. The rainfall is scanty, but the great range of temperature probably causes a good deal of dew-condensation on the sand.

Sometimes, though rarely, rocky surfaces emit malaria, but probably the habitat of the organisms in these cases is in clefts or disintegrated rocky detritus. The efficiency of attack on the human body depends in great measure on the concentration of the organisms within a few feet of the surface of the earth in the evening hours, the difference between day and night temperature, the high temperature of the soil, and the suddenness of the fall of temperature. Although the strongest men in the best of health may be stricken, yet, in most malarious countries, the avoidance of fatigue, of indigestion, and of any chilling of the surface of the body, is an important safeguard. The conditions in which malarious germs are emitted from the soil and concentrated in the nethermost strata of the air are further considered in relation to the emanation of vapor from the earth and the deposition of dew.

YELLOW FEVER.

Yellow fever results, in all probability, from a fungoid or microbic growth, but the particular microbe concerned has not been certainly identified. It prevails habitually in the West Indies and on the coasts of the Gulf of Mexico, and these have been regarded as the original breeding grounds. But it has also long been endemic on the west coast of Africa, especially at Sierra Leone. It is easily capable of transportation, especially in the case of particular outbreaks and in particular seasons, and it has in several years, like cholera, attained almost a world-wide prevalence. When transplanted to favorable places (and these are mostly seaports with very poor sanitary conditions) it takes root and breaks out in succeeding years as if it were multiplying on the polluted soil. As a matter of fact, it thrives on damp organically contaminated soil, on the walls of houses, and on the wood of ships, in foul holds. It haunts the vicinity of drains, banks of rivers occasionally dry, harbors, and crowded rooms or houses. The manner of its growth a good deal resembles that of cholera, but its areas of prevalence are smaller, and it is more largely communicated through the air, each case of yellow fever becoming a focus of prevalence in tropical and foul conditions. It requires a high temperature for its propagation, and is arrested, but not destroyed, by frost. Strangers are much more liable to attack than residents, but residents are not always immune. The living cause of the disease clings with great tenacity to ships, walls, etc., for a long time, and is conveyed, in very many instances, by the air to persons who approach the infected object. The organic poison seems to multiply outside the body, upon foul surfaces, and thence to infect. It is not transported by the wind—at any rate to a distance—but depends on human movements, on overcrowding, neglected refuse, and absence of proper ventilation. It seems probable, from its persistence on the coast, on the banks of tidal rivers, and on ocean-going ships, that it finds a favorite pabulum in slightly saline deposits.

DIPHTHERIA.

Diphtheria, now one of the most fatal maladies of children, both in Europe and America, is equally preventable by purity of air; but since it is commonly caught by infection, and susceptible persons are attacked through slight doses, absolute prevention is difficult. Its propagation depends to a great extent on schools and close aggregations of children, some of whom may be affected by the disease in a mild form, such as slight sore throat. Some cases arise from a disease of the cow, which is not easily identified, but the great majority of cases of the disease are certainly due to the emission into confined air of the microbes from persons already suffering with sore throat or diphtheria, and therefore the great majority of cases would not occur if schools and dwelling houses were well cleansed and ventilated, and if children with suspected throats were as far as possible isolated. The gradual growth of diphtheria in villages and towns and its frequent recurrence indicate an infection of the air in houses either from a contaminated surface soil, from floor or walls, or from the breath of persons who have had the disease and in whose throats the microbe lingers after their recovery. Diphtheria does not occur at all in clean, dry places, unless introduced by some person or imported article carrying the infective organism. The germ is certainly not present in a potent condition in the outer air. Newly inhabited countries and places have always remained free from diphtheria until the germ has been introduced by human agency.

Diphtheria and scarlet fever are among the most widely and constantly prevalent, and most fatal, of all diseases in temperate climates. They are both communicable through the air in proximity to a patient, and this is a very common mode of conveyance. But they have never been known to pass across any considerable space through the outside air. The evidence leads very strongly to the conclusion that they are rarely if ever caught by exposure to infected air which has been very largely diluted in the free atmosphere. Predisposition to diphtheria, and probably to a less extent to scarlet fever, is favored by drain air, sewer air, and the emanations from heaps of decaying animal or vegetable matter, dust heaps, and by the various causes of sore throat. And it is probable that the microbe of diphtheria, which has been identified, frequently infects the surfaces whence the foul emanations proceed. It is certainly present in very many places, especially in houses and localities where the disease has formerly prevailed. Measles are often followed by diphtheria, though no source of infection can be discovered. Many persons after recovering from diphtheria are still capable of giving infection by the breath, for the bacillus may remain for months in the mouth and throat. Cases of sore throat which may be slight often communicate to other persons, in consequence of aggregation in foul air, severe sore throats and diphtheria. It seems that the disease may be a slight one until by the effects of rebreathed air it develops fatal virulence. For this reason, and owing also to the opportunities of ordinary infection in confined air, diphtheria is a disease which largely depends on schools for increase and propagation. It haunts the surfaces of objects which have been exposed to it, and thorough disinfection is required to remove it. The autumn and winter season, damp dwellings, damp soil, dirty farmyards, privies, etc., favor its development; but its continual increase has been due to increased school attendance, meetings, etc., and to the increase in the number of infected places, and in the means of quick traveling. Ventilation, much more thorough than any now generally practiced, combined with the better disposal of refuse, must be the principal hygienic measure to reduce its prevalence. Investigation of the conditions under which it survives in places and houses, and of the effect of ventilation and proper space in schools in preventing its propagation, is much needed.

PNEUMONIA.

Two or more different diseases are known under the name of pneumonia. The temperature of the air is an important factor in its production, but all countries are subject to it. The maximum number of deaths from this infection occur in December, the minimum in August. Cold is a strong predisposing, but not the ultimate cause. Overcrowding, the want of ventilation, emanations from sewer and filth, play an important part in epidemic outbreaks. Certain bacilli or micrococci are concerned in the production of epidemic pneumonia, and possibly the commonest form of pneumonia is due to the opportunity given by cold or by foul gases for the attack on the body of an organism frequently present in the breathing organs. There is little evidence as to the exemption of persons living entirely in the open air and thoroughly well-ventilated dwellings, and not exposed to infection from others, but the probability appears to be that many persons have in themselves a cause of a certain sort of pneumonia which may attack them through a chill, but that the breathing of purer air and the prevention of infection through the breath would greatly reduce the number of victims. The typhoidal character of some forms of pneumonia and their mode of origin and spread suggest a connection with soil poisoning and contamination of superjacent air. On these points investigation is needed.

Pneumonia is very apt to occur after colds, measles, typhoid, malaria, and especially influenza. If it be due to a particular micrococcus, the organism must be very widely disseminated. But probably several different organisms are capable of thus affecting the weakened constitution, and the disease named pneumonia is the result of different causes which need more distinct classification than they have yet received.

Dusty trades and smoky fogs favor the incidence of pneumonia.

BRONCHITIS.

Bronchitis, one of the most prevalent and fatal of all diseases in cold and temperate climates, is often directly due to the effect of cold and of a sudden fall of temperature. Although much less common and fatal among people living in healthy conditions, it nevertheless often attacks strong constitutions, even in the purest atmosphere. Fatigue predisposes. A great deal of preventable bronchitis results from imprudence in clothing and in diet—for instance, alcoholic excess—but much also from breathing dusty and smoky air. A smoky fog of some days' duration in cold weather in London causes a heavy mortality, while a fog in the country has little effect. Much bronchitis results from weakness and chill following illness and fatigue. Changes in the blood and accumulation of waste products are apt to follow excessive exertion. The importance of warm clothing and of breathing air free from smoke and dust, especially the dust given off in the manufacture of hardware, pottery, lead mining, etc., is great in the prevention of this disease. Close rooms where gas is burned contribute largely to bronchial attacks, and in general purity of air is one of the first conditions tending to immunity. But cold and damp seem to be quite sufficient to produce bronchitis in some constitutions, and in young children and old people, apart from anything like infection from outside. Indeed, it seems likely that an excess of ozone, or else a cold, bracing air, often determines an attack, and these qualities are beyond doubt sufficient greatly to exacerbate symptoms resulting from a slight cold or chest weakness. A soothing, soft, warm, damp air, on the contrary, quickly ameliorates the condition of a sufferer from bronchitis, cold, or cough; the extraordinary power of a whiff of cool, fresh air to increase the malady, and the ill effect of even a glass of cold water, seem to show that the bronchial tubes, capillaries, and air passages are in a highly sensitive state and that temperature is a matter of extreme importance. Experimental investigation of the temperature and condition of air most tending to rapid recovery from bronchitis might disclose facts of importance in the connection of inflammatory states with the atmosphere. It seems not unlikely that an absence of ozone, deficiency of oxygen, and excess of vapor of water, and of nitrogen or carbon dioxide, might prove favorable.

RHEUMATISM AND RHEUMATIC FEVER.

Few diseases are more common or cause more suffering than rheumatism, acute or chronic. A great deal has still to be discovered respecting its external causes. It prevails much more in some districts than in others, and certainly in many cases the mischief is brought into the human system through the air. Damp and cold in soil and air, and chill in the body, especially when feeble or fatigued, are main factors. As in so many other maladies, the specific cause in rheumatic fever may be the entrance of a micrococcus or other germ by means of a chill, either in hot or cold weather. An inquiry into the distribution of rheumatism, with regard especially to soil, climate, air, and dwellings, and eliminating as far as possible predisposing human habits, would furnish results of much value. There is some indication, as in the case of malaria, that air near the ground in low places has much to do with the incidence of the disease. Damp dwellings and clothes conduce to an attack, and to the chronic form. It seems very probable that it would be found that persons removed from ground air, as in the attics of high buildings, are exempt from attack, except through food and drink.

MEASLES AND WHOOPING COUGH.

Measles and whooping cough are spread chiefly through the air to persons in the immediate neighborhood of the sick, and of articles, especially clothing, which have been exposed to the infective matter. Segregation, ventilation, and avoidance and disinfection of materials which may disseminate the disease are effective in prevention, where they can be carried out. In the early stage of measles, as of influenza, even while the symptoms are slight, the germs of the disease may infect through the air, and therefore measures of precaution are difficult. The best preventives against widespread and severe attacks are habitual regard for sufficient air space and warmth and immediate isolation.

DENGUE.

Dengue is a disease somewhat resembling influenza in its symptoms, but prevalent only as an occasional epidemic in tropical countries. It is apparently spread by infection in the air from case to case, but not through the general atmosphere. The reason of its failure to extend beyond hot climates is quite obscure, but it would seem as if it required, like yellow fever, a high temperature outside the body in order to grow and disseminate germs fitted for infection.

SMALLPOX.

Smallpox has been ascertained by several careful investigations to be capable of passing through long distances, at least half a mile or a mile, of fresh air without losing its power of infecting susceptible persons. The experience of hospitals in London and Paris is well known. Recent observations on the spread of smallpox from a hospital near Leicester, containing 49 patients, showed that a number of cases which occurred in a suburb about 300 yards distant were in all probability due to transport by the wind. The epithelial scales and dust of smallpox cases are rather peculiarly protected from atmospheric influences, and the conditions of the survival of exposed germs need inquiry.

INFLUENZA.

No disease of the epidemic character has seemed to depend more on the constitution and infection of the general atmosphere than influenza. Its rapid spread, its apparently capricious outbreaks at places wide apart, the almost simultaneous attack, as it seemed, upon a large fraction of the population of a country, masked the true method of progress. But when its track and behavior were carefully followed, these facts became clear—that it never traveled faster than human beings; that many mild cases existed in every large town long before it was generally recognized; that it took at least six weeks to attain its maximum after the occurrence of the first cases; that its rapidity of advancement from east to west and from town to village corresponded roughly and generally with the rapidity of means of transit; that large numbers of people not exposed to personal infection escaped; that islands unvisited through the period, deep-sea fishermen, and lighthouse keepers escaped, except in a very few instances where they had been ashore or received communications from infected places; that susceptible persons very easily caught the pest within a few days after exposure to infection in the ordinary sense; that infection was sometimes conveyed by parcels, letters, clothing, etc., from patients or infected places; that ships which had cases on board were the means of starting it in islands at which they stopped; and that in previous epidemics the spread was often so very slow as to be quite unaccountable by any atmospheric quality. Moreover, when the bacillus of influenza was identified, it became easy to comprehend how the countless multitudes of exceedingly small organisms alive in the sputum and saliva might be disseminated in the air of buildings and of public conveyances and transmitted from place to place by commerce and the post. The general atmosphere either diffused them to harmlessness or killed them, for there was no evidence of influenza reaching an isolated community by means of wind blowing from a place where it was prevalent. But in confined or foul air they were capable of passing through many feet without losing their capacity of infection. They were experimentally shown to thrive abundantly on the gum of an envelope,[1] and since many patients wrote letters, this must have been rather a common mode of transmission, the organic motes flying upward to the breathing organs of the recipient on his breaking the fastening. There is no difficulty in explaining the quick diffusion of an epidemic having the qualities of influenza among a susceptible population. The minuteness of the bacilli, their vast numbers in the breathing organs, the short period of incubation, and the early infectiveness, and in modern times the immense daily communications between distant places, have to be taken into consideration. If examination of matter of the

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[1] Dr. Klein, British Medical Journal, February, 1894.

tenuity of smoke particles, or of the minutest microbes, could be undertaken, with a view to determine the rate and extent of its diffusion by human communications, it would probably be found that very few districts in the country are out of microbic touch, as it were, with all the chief centers of population for a single day, and none for so long as a week; and certainly the air inclosed in a packet from an infected place, when suddenly liberated, would be likely to bear with it active seeds of mischief. But the great majority of cases of influenza were due to proximity to a person already attacked. Most people in the course of a day come into association with ten or twenty others in more or less confined spaces of air. If only one in five catches the influenza, and so on in the same proportion, a fourth part of a large city may be struck down in a very few weeks. In general, one-half or three-fourths escape, being insusceptible, or less susceptible than others, or less exposed to the virus. Where large numbers of persons work together in one ill-ventilated building, the proportion of attacks is much higher, other things being equal, than where people work at their own homes. But the frequent opportunities of infection at meetings, social gatherings, public houses, in public conveyances, churches, and chapels tend to reduce the inequalities which would otherwise be conspicuous. The distance of air through which influenza can strike has not been well ascertained, circumstances being very different, and some forms, such as the catarrhal, being apparently more easily diffused than others. The maximum distance in the recent epidemics, for susceptible persons, could hardly have been less than 100 feet in close air, and 4 feet in the open. Isolation, where practiced, was successful in so far as it was strict. But the intercourse of ordinary life makes isolation impossible for the general population when once an epidemic of influenza has been allowed to attack a number of centers. Strong measures against importation from other countries and immediate isolation and supervision of the few cases which would occur might succeed in staving off a national infliction, for the precautionary measures would not need enforcement beyond the brief period of its prevalence in neighboring countries. Not only the high mortality, but the enfeeblement of millions of breadwinners for months, years, and even for life has to be considered in connection with the expense of preventive measures. This expense would only be a small fraction of the losses incurred by permitting the pestilence to rage unchecked.

As regards weather and climate, cold is distinctly conducive to the spread of influenza, probably for several reasons: (1) The stillness which often prevails in frost; (2) the closing of windows, etc., and the closer association; (3) the greater prevalence of colds, bronchitis, etc., laying open the breathing organs to attack. The first epidemic in London, at the end of December, 1889, was ushered in by fog and frost, and apparently rapidly reduced in severity by the mild and strong winds of the latter half of January, 1890. The epidemics in succeeding years were much more severe, although they came upon a population to some extent protected. At the same time there can be no doubt that an epidemic may occur in any climate and in any weather. The tropics are not exempt. An instructive instance of the subtle diffusion of influenza occurred in a village of Central Africa, which was attacked immediately after the arrival of two natives from an infected place far distant. But outdoor life and less constant communications prevent the quick diffusion and wide prevalence which belong to civilized nations in temperate climates.

The manifest, at present the only practicable and yet difficult, measures for preventing these great and very destructive epidemics are: Precautions against the introduction of the pest by travelers and by articles sent from infected districts; immediate compulsory notification, without fee, of all cases occurring in a district to the medical officer of the district and through him to the central board; isolation so far as can be arranged of all the early cases in a district at the homes of the patients; prohibition of attendance of infected persons at any assemblage; and publication of the importance of ventilation, and of living, warmly clothed, as much as possible in the open air, unless actually stricken. During the period of illness, and for some time after recovery, the greatest care is required to avoid chill, which often induces pneumonia or other evils. The fresh outer air can only be safely breathed when the symptoms have subsided and when the strength has partially returned. It is remarkable that cold air alone, however pure, seems capable of causing a relapse when the system has been greatly enfeebled and the breathing organs left in a highly sensitive condition.

COLDS.

Colds and sore throat have never received the attention they deserve from an etiological point of view, owing probably to the slight character of the majority of cases. Yet they are important, first for their wide diffusion, endemicity, and frequency, and secondly for their effect in giving opportunity for the attack of more serious disorders, among which may be mentioned diphtheria, measles, pneumonia, bronchitis, and consumption. Close observation for many years has led the present writer to the conclusion that though primarily a chill, that is exposure, insufficiently clad, to a draft or cold air, is very frequently sufficient to give a slight cold or sore throat, or the feeling of one, yet severe colds are caught in general either (1) in marshy or low and damp situations, or in conditions somewhat similar to those which produce malaria; or (2) by infection from persons after the manner of other infectious diseases. It would appear as if the microorganism, or one species of microorganisms, which sets up a sore throat and severe cold, inhabits the upper layer of earth, especially in damp or marshy places, where decaying vegetable matter abounds, and passes into the air, especially in summer and autumn evenings when the earth and water are still warm and the air is rapidly cooling. When the microbes are dense in the humid and misty low stratum of air, and when the human body is being quickly chilled, they are able to attack successfully. The microbe is probably a very common and widely diffused one, and may be present in comparatively small proportion and in less vigor in the lower air generally over the land. At sea it would be absent, and indeed there is good evidence that it does not bear long transport in a virulent state in the free air. Colds are scarcely ever caught on the open sea, even if the clothes be wet with salt water, and breezes straight from the Atlantic do not seem capable of inducing sore throat or cold. But, of course, to make an experiment crucial, previous life in the open air, disinfection of clothes and if possible of the breathing organs, would be necessary. It is not improbable that the microbe of colds, like that of pneumonia, may be frequently present in the mouth. The experience of St. Kilda,[1] which used to be absolutely free from colds until the annual boat arrived from the mainland, points to the ordinary presence of the infective particles on clothes or in the breath. The islanders were nearly all struck down with severe colds within a day or two after welcoming their visitors. Probably a similar dose of infection would be quite insufficient to prostrate persons on the mainland who were accustomed to the petty assaults of the microbe, and protected by scarcely noticed symptoms of catarrh.

An exactly similar thing occurs in the case of influenza. Hundreds of instances were observed in which the proximity of persons who had had influenza or had been near cases of influenza gave it to others, and often persons lately arrived in a place which had passed through the epidemic were struck down while the great majority of the resident population remained protected, at least for some months.

Colds protect against their own recurrence in most people for some months. Severe colds go through a house after the manner of an infectious disease, and can be similarly guarded against by isolation. The air certainly conveys a cold for several feet through confined air, and in a closed railway carriage susceptible persons who have been free from colds for some time are easily infected. An attack is often attributed to a chill felt at the beginning of the infliction, but in reality the cold has usually been caught some hours or a day or two before, and the feeling of chill is simply the beginning of the disorder, as in other infectious maladies. On the other hand, there may be a real chill, which gives opportunity to the microbe to make its attack and produce a feverish cold in a day or two. Foul air and crowded rooms are eminently conducive, especially if combined with drafts, to disseminate colds.

Persons arriving in town from the pure air of the country or from a sea voyage are very apt to catch cold. They have been living apart

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[1] And other islands. See Darwin's "Naturalist's Voyage." Report of the Local Government Board; Epidemic Influenza, London.

from the constant presence, and, as it were, the vaccinating influence, of the germs in bad air. From similar reasons horses, when brought from the country to London stables, very frequently fall out of sorts to the extent, it is said, of 95 per cent, and sheep, when placed among imported apparently healthy sheep, often fall sick. Texas cattle fever is caught from apparently healthy cattle. The first intercouse between Europeans and natives is attended with the introduction of fever, dysentery, or other diseases.[1]

SEASONAL AND GEOGRAPHICAL DISTRIBUTION OF INFECTIOUS DISEASES.

Many of the spreading diseases are more or less wont to rise toward a maximum and to fall toward a minimum at certain times of the year, and these seasons are generally nearly the same in similar climates in the same hemisphere, but there are many particular instances of variation.

Scarlet fever is a disease chiefly prevalent in the northwest of Europe, moderately prevalent in Russia, North America, and parts of South America, the coast of Asia Minor, Italy, Turkey, and Greece, and quite uncommon in Asia and Africa. It is not frequent in Australia. Its maximum in London occurs in October, its minimum in April. In New York its maximum is in April, its minimum in September. In England, generally autumn is the time of maximum prevalence. In the whole of Europe and North America 29.5 per cent out of 435 epidemics are recorded as having occurred in the autumn, and 21.8 per cent in the spring, the period of minimum; the remaining 48.7 per cent took place in summer and winter. A dry air with little rain seems to increase the prevalence of scarlet fever.

Measles, in London, has two maxima, one in December and a lesser one in June, and two minima, one in September and one in February. Measles occurs nearly all over the world since the great extension of commerce, and seems to be little affected by climate. Cold weather, however, favors it, as might be expected, since it infects through the air of close rooms.

Influenza, typhus, relapsing fever, smallpox, whooping cough, croup, pneumonia, not only prevail most in cold weather, but in cold countries, where there is least outdoor life and least fresh air in rooms and most crowding. Diphtheria increases with the cold weather of autumn, but tends to decline in February, and is at a minimum during the hot months. Cerebro-spinal fever, which is a good deal connected with crowding in large numbers in institutions, etc., not only attacks most in cold weather, but in cold or temperate countries. The relation between the temperature and the disease seems to be indirect, and the causation and dissemination of the malady are obscure.

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[1] Williams, quoted by Darwin, "Naturalist's Voyage."

Consumption or tuberculosis is most prevalent where the air is moist and the daily range of temperature large.

Typhoid or enteric fever is most common in the autumn and much less prevalent in May and June. There is a sharp decline in its prevalence in London in December. In New York, and in large towns in Europe, the maximum is decidedly apparent in late summer or autumn. The variation of prevalence according to season seems to show a distinct connection between the development of the bacillus and the temperature of soil and water, and considering the long incubation and duration of cases the maximum of infection must take place at the very time when the temperature of the soil at 1 or 2 feet deep is about at its highest.

Cholera, diarrhea, yellow fever, and malaria, the poison of all of which arises from the soil and surroundings into the air, are much more prevalent in the hot season and in hot countries.

CONDITIONS OF INFECTION THROUGH THE AIR.

In order to obtain a true conception of the manner in which the virulent matter of infectious diseases may be conveyed through short distances of air, either directly from a patient or indirectly from objects which have become infected, we have to consider those cases in which susceptibility is greatest, for these afford the truest criterion of the capability of the survival of pathogenic microbes, and the best measure of the precautions which should be adopted to exclude not only persons of average susceptibility, but the most susceptible, from the area of danger. In cases of pyæmia, of puerperal fever, and of small-pox, not only ordinary measures of disinfection, but abstinence from attendance on susceptible persons for some time, is recognized as needful. In cases of influenza, diphtheria, and scarlet fever less care is exercised, except in regard to certain susceptible states. In all of these diseases, however, transmission is far too frequent, and as a matter of fact the required precautions are not duly observed. The strict regulations of dress and washing enjoined upon nurses are almost equally applicable to medical attendants, and the use of clothes of a washable material and smooth surface by all persons in the presence of infectious cases would give greater security to all patients visited, and, indeed, to the general population. A square inch of cloth can easily hold upon its surface 10,000,000,000 microbes of influenza, so that it is quite conceivable that a man may carry on his clothes many more of these organisms than there are inhabitants on the globe, and that many scores of thousands of these pass into the air of every room which he visits.

Similarly, in the cases of other diseases which pass largely by the breath and by deposited particles, there must always be a certain number on every person who visits the sick room, and although the majority of people fall victims only to rather large numbers or a high degree of virulence, still, in order to avoid the setting up of fresh centers in susceptible people, disinfection and washing are indispensable.

The most remarkable instance of immunity from infection of a maternity hospital is that of the Grand Duchess Catherine, at St. Petersburg, one of the most carefully regulated in the world. Every utensil, instrument, and article of clothing is rendered aseptic and kept so. A vacated room is at once stripped and disinfected. The floors are mosaic concrete, the walls tiles and parian cement. Floors and walls are thoroughly washed. The result of this extreme care was that during three years there was only one case of puerperal fever, and that was brought in from outside.

A boiled vegetable or animal infusion in a test-tube may be kept an indefinite time without change or fermentation when ordinary air and objects are excluded, but a mere touch of the finger or of some object which has been lying in a room infects with microbic life and the fluid goes bad. The comparative infrequency of the conveyance of some of the infectious diseases from one to another by means of a third person is less due to the absence of the germs than to the average resisting power of the human body. The precautions taken to prevent the spread of foot-and-mouth disease in sheep and cattle well illustrate what is necessary for the protection of human beings. In an outbreak in England in 1892, a strict watch was kept to prevent the passage of any infected article, and no one was permitted to come in contact with cases of the disease excepting those persons who were provided with a proper dress, which could be easily disinfected. If these and similar measures had been customary for some years for the prevention of epidemics in man, the belief in an "epidemic constitution of the atmosphere" or in "aerial transmission" by wind for long distances could hardly have survived. The recent pandemic of influenza has given occasion for the revival of these hypotheses, which were successively overthrown in relation to consumption, the plague, cholera, yellow fever, smallpox, and even rabies or hydrophobia. Recent investigations have, however, proved beyond all doubt that the atmosphere does not, except possibly in the rarest instances, convey the virulent matter of epidemics from place to place, and that there is no security against infection so great as life in the open air and good ventilation. In fact, the atmosphere is the great reservoir of purifying agents and the most important of all disinfectants. In close places the air, deprived of some of its oxygen, filled with moisture and the impurities of respiration, can not exercise its beneficent function, and in crowded rooms infection becomes easy. So, also, cholera and other infectious matter retains its virulence in packages or stored clothing. Under the open sky and in pure air few species of pathogenic germs can pass many feet unscathed.

Consumption is typical of the class of endemics which can be caught either directly from a patient or indirectly through infected objects in close air. People who live entirely in the open air and in well-ventilated, clean places do not suffer from it, except in the few cases where it may be inherited or introduced from without. It is a disease of civilization, and many countries have been unaffected until the virus has been brought by human agency.

Soil is not concerned in the prevalence of most endemic and epidemic diseases, though many may have originally sprung from the soil, and some have located themselves in certain areas from which they spread over the globe. The small part played by soil emanations in the great majority of spreading diseases is exemplified by the extension of epidemics and of endemics like consumption, diphtheria, measles, and whooping cough, in countries which are covered with snow and congealed with frost. When once introduced they pass among the population whose habits are favorable to their growth. In islands, again, when an infectious disease, such as measles or influenza, is introduced, it spreads as fast as in countries where the soil might be supposed to nourish the bacillus or micrococcus independently of the human body. On board ships and in isolated institutions where opportunities are given by association, many infectious diseases spread just as they might in inhabited places, whatever the soil. At the same time endemicity is largely a matter of soil and habitation. Infection from person to person, and to a great extent through confined air, may thus be separated off as the main condition of prevalence of infectious diseases.

Diseases capable of transmission for a short distance through the air may, for present purposes, be divided into the following classes:

(1) Those which arise from damp soil or subsoil in alluvial plains, deltas, valleys, mangrove swamps, certain sandy coast districts, and other situations. Malaria, intermittent fever, and ague are the chief diseases of this type, and are in general not transmissible from person to person. They are transmissible a few miles through the air from the locality of origin. Colds and sore throats probably arise from similar conditions, and are infectious through a short distance of air to susceptible persons. Forms of dysentery and certain diseases of the liver, etc., seem to be due to conditions largely corresponding with those of malaria.

(2) Diseases which arise in somewhat similar conditions, but seem to have required not merely vegetable matter, but a large population and neglected filth in the soil and water for their development. Cholera belongs to this class, and depends to a great extent on human filth in the soil and befouled water. Cholera is infectious from person to person through the air, but only to a slight extent, and depends for its existence beyond its habitat on access to filthy soil, water, or places where it grows, multiplies, and infects the air, as well as other matter, which gains access to the body. Typhoid grows on damp human filth and may infect persons who breathe the air arising from such filth, especially in houses and confined places. The air in the neighborhood

of a typhoid case does not appear to convey the disease, apart from excremental matter exposed to the air. Yellow fever seems to grow in conditions somewhat resembling those which are favorable to cholera—filthy, damp surfaces in great heat—and infects the air in the neighborhood of its growth, especially banks of rivers, harbors, holds and bilges of ships, and dirty, dark, crowded streets. It sometimes infects direct from a patient. These three saprophytic or semisaprophytic diseases may be supposed to be propagated a short distance from place to place through the air without the intervention of a human subject, but have never been known to be carried far independently of human transporting agency.

(3) Diseases which arise from deposits of organic matter from the lungs and skin, and also probably from other excrementitious filth. Typhus and the plague may be named in this class, but other conditions of filth are powerful in their genesis. Plague is both miasmatic and contagious, and, where concentrated, seems to be capable of passing through several hundreds of yards of air. Prolonged breathing of the sick-room air both in plague and typhus is the most effectual means of infection. Damp, alluvial soils; streets, walls, and floors with damp organic deposits sticking to them; carcasses and refuse lying unburied around houses; in these situations the plague fungus flourishes. Diphtheria arises probably from somewhat similar breeding places, from heaps of house refuse, from middens, drains, ash heaps, and polluted ground, floor, and walls, and is transmitted a short distance through the air, probably seldom more than 10 or 20 yards. It is very often, probably in the majority of cases, carried by the air from person to person through a short distance, most easily in damp, close, or confined air, like so many other infections. The diphtheria fungus, when it has been once introduced, sticks to certain places, damp houses and damp organically polluted sandy soil seem to favor it. It is improbable that it is ever conveyed far from place to place through the air to persons except by human agency and the movements of domestic animals. Pneumonia may possibly depend on somewhat similar conditions, and may be caught by one person from another through the air. Consumption, phthisis, or tuberculosis, depends to a very great extent on conditions similar to those of typhus, and is spread through the air a short distance in the dried matter of saliva and sputum.

(4) Scarlet fever, measles, whooping cough, influenza, and dengue arise from conditions outside the body which are unknown, but decaying organic matter may provisionally be assumed to have been their original breeding ground. They are now almost entirely dependent on transmission from person to person, and to a very large extent on transmission through a short distance of air. It is very seldom that these maladies are caught in the open air, so that the medium of transmission is the confined and more or less foul air of schools, houses, churches, and theaters. They are never caught in isolated positions in

the open air, in islands to which no infection is brought by human agency, and in well-ventilated institutions where every possible precaution against infection from without can be rigidly maintained. Even the Isles of Scilly, near the southwestern coast of England, were free from measles, scarlet fever, and smallpox for ten years, the only district exempt out of over seven hundred in the whole country. It was also one of the seven districts in which no death from diphtheria occurred.[1] Since communication has become frequent, owing to a great increase in trade, the immunity does not continue, and influenza broke out there only a few weeks later than on the mainland. Another island, Alderney, was affected early by influenza through the examination of goods by custom-house officers, who caught the infection soon after the arrival of the steamer.

PREVENTION OF SPREAD AND PREVALENCE OF VARIOUS MALADIES.

Prevention of the spread of these various classes of disease, the reduction of some and the extinction of others, may be effected by the following means:

1. *Malaria class.*—Drainage, cultivation, planting, proper disposal of refuse and carcasses. In places where a small area of moist ground or small marsh gives off the dangerous exhalations, the surface might be covered with a film of crude petroleum to prevent the escape of the germs. Other experiments on the treatment of the surface of the ground with antiseptic mixtures might lead to valuable results. Powdered charcoal, and lime, might be tried.

2. *Cholera class.*—Proper disposal of refuse, drainage of soil, cleanliness and airiness of streets, houses, quays, ships; prompt disinfection and cleaning of places where first cases occur; prevention of overcrowding. Where any damp surface, as in a midden, pool, or drain, is suspected of giving off dangerous emanations, crude petroleum might have the effect of imprisoning the germs by an impervious film. Experiments are needed on means for the exclusion of living organisms from the air, where they are numerous, by treatment of the surface soil; also on substances inhibitive of their growth, which might be used on a large scale.

3. *Typhus class.*—Cleanliness and good ventilation of dwellings and of their surroundings and avoidance of overcrowding in houses, schools, etc., prevent this class of disease from arising, but ordinary personal infection has to be attacked also by isolation on the occurrence of the first symptoms. The inside walls, floors, etc., should be of some impervious material, easily and frequently washed. A dense cement or hard wood may be suitable; but, whatever the material, liberal ventilation and cleansing are required to prevent deposition of organic matter and growth of fungi. In schools, etc., the walls should be of smooth cement,

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[1] Public Health Reports. Sir John Simon.

glazed ware, glass, or metal, and the floors of close, hard wood or common tiles. The bacteriological examination of various wall and floor surfaces, and of the air inclosed within them, would be of great service with a view to the prevention of organic deposit and emanations.

4. *Measles class.*—Cleanliness of surroundings and ventilation are required as in the last class. Isolation on the occurrence of the first symptoms, use of glazed or washable materials for the room where a case is treated and for the outer clothing of attendants, absence of carpets and hangings, and frequent thorough sweeping, cleaning, and airing would greatly reduce the number of centers of infection. Where many people work or meet together, the air must be kept as fresh as possible. Influenza is best reduced by immediate isolation or segregation of the first cases in any place, and by avoidance of meetings in confined spaces. The distance of air, confined and open, through which various infections common among mankind and animals can pass should be determined by comparison of records and by actual experiments on animals.

The effects of the free air in healthy regions, neither very low nor very high, neither very hot nor very cold, may be summed up as supremely beneficial to human life and health. The most healthy class of people are fishermen, sailors, and gardeners, yet some of these are affected by close cabins, and others by surrounding zymotic diseases. The most healthy creatures are the birds and wild animals in fairly warm climates; a little less healthy are the sheep and oxen which are never stalled; much less healthy are the stalled cattle and horses; least healthy of all the higher orders of living beings are men in crowded places.

The conditions of greatest security against endemic and infectious diseases are also the conditions which conduce most to robustness, physical and mental vigor, and enjoyment. Outdoor life with sufficient work or exercise can not, with impunity to the race, be forsaken for purely intellectual and sedentary pursuits.

IMPORTANCE OF FRESH AIR TO HORSES AND CATTLE.

Mr. Fred. Smith, professor of the Army Veterinary School at Aldershot, has shown the great importance of fresh air to horses in stables. The air of buildings in which animals are kept has received very little attention except in the army, but the results obtained by better ventilation wherever tried are remarkable. Warmth derived from the animals only, in a cowshed or stable, is evidence of foul air; ventilation should be by good-sized opposite windows, and by roof-ridge exits; and if necessary, artificial heating should be employed. Cubic capacity per head should be 1,600 feet. The majority of preventable diseases among animals are traceable to food and feeding, but "certainly next to this comes impure air." By good ventilation and care for cleanliness glanders has been entirely got rid of, a disease from which hundreds previously died annually; pneumonia has been greatly reduced in prevalence and intensity; ophthalmia has nearly disappeared, and the animals are much less susceptible to colds and coughs. "Cattle plague, pleuro-pneumonia, variola, and probably tuberculosis are undoubtedly spread by the medium of the air in infected areas." This class of disease can therefore be absolutely stamped out, and there are other diseases, such as horse influenza and pneumonia, which, with better knowledge of atmospheric influences in connection with the specific cause, may come into the same category. Infected places should be treated as if in a state of siege.

Port inspection, as regards some of the worst animal diseases, it is impossible to estimate too highly; for instance, in the years up to 1886 the number of cases in Great Britain of foot-and-mouth disease was 1,993,149; since that year almost the only cases occurring have been those which had escaped detection at ports in a very few instances, and certain other cases which had been in their proximity. All these were traced and most severely isolated, so that the country is saved from great agricultural disasters by the constant vigilance of the central and port authorities. Since many animal diseases, including tuberculosis, glanders, foot-and-mouth disease, anthrax, actinomycosis, scarlet fever (a slight eruption in the cow), and diphtheria, are transmissible to mankind (some of them, but to a very small degree so far as is known, through the air in proximity), the immunity of animals from disease concerns not only the wealth, but the health of the community. Further inquiry is needed as to the transmissibility of horse influenza and pneumonia through the air, and as to the connection, if any, of these with human maladies of a like character.

THE INFLUENCE OF CLIMATE ON MENTAL AND PHYSICAL QUALITIES AND ON NATIONAL HEALTH.

The influence of atmospheric qualities upon the bodily constitution and health, upon the mind, and upon the enjoyment of life, is eminently worthy of consideration. When we come to examine closely into the manifold causes which contribute toward human happiness, we find that, upon the whole, comparing acclimatized races, the differences in the results in regard to all except extreme varieties depend at least as much on human, artificial, and removable causes as on climate and on atmospheric conditions. The peasant of Norway may be as healthy and as happy as the peasant of Italy, the native craftsman or the ryot of India as contented though not so vigorous as the woodsman or farmer of Canada, the African negro of the equatorial zone and the uncorrupted Greenlander may physically enjoy life as much as the English or American laborer. The peculiarities and tendencies of race can hardly be separated in the account from the effects of climate. Broadly speaking, however, we may safely affirm that, apart from the special and preventable evils of a high civilization, the most vigorous, flourishing, intellectual, healthy, and progressive people of the world are those which inhabit the temperate zones. Within the tropics the strongest and most energetic peoples, bodily and mentally, are those living in the mountains or at high altitudes. The inhabitants of low ground in hot climates are inclined to be listless, uninventive, apathetic, and improvident. They live for the day, shut their eyes on the future, and have a leaning toward fatalism. An equable high temperature with much moisture weakens body and mind. No long-established lowland tropical race is a conquering race in the widest sense of the term, or forward in the march of intelligence. But certain nations have the power of resisting, at any rate for a long time, the enervating influence of a moist, warm climate, with the malarious fevers which commonly belong to it. The Arabs and Chinese evince extraordinary power in this respect. The Arabs not only thrive in their own hot, dry country, but on the coast and in the interior of Africa, where the negroes are driven like sheep before them. The Chinese make excellent and most industrious laborers, even in the climate of Java, Sumatra, and Borneo, and where neither Malays nor Europeans persist in the hard work of cultivation. Their fare is rather scanty, and, as a rule, entirely vegetable. The Italians and Spaniards, again, can withstand hot climates better than most Europeans. The Spaniards have greatly multiplied in Cuba, the Portuguese do not desert the oppressive forest regions of Brazil. The natives of the South of France thrive in Algeria better than natives of the North of France. On the other hand, the people of northern Europe, if they do not themselves suffer much in the tropics, rapidly degenerate, and the race either becomes extinct or greatly enfeebled in a few generations. In Java, Europeans do not live beyond three generations. It was shown many years ago by a distinguished lady, and has now to some extent been long recognized by military and civil authorities in India, that a very large part of the excessive British mortality in India was owing in the first place to removable insanitary conditions, and in the second place, to faulty diet and personal habits. The realization by the governing authorities of the true and possible conditions of living in a hot climate has led to a large reduction in the rates of sickness and death. Stokvis has shown how in recent years Europeans have lived much better than formerly in the tropics. Even children to the number of one hundred or more, from the age of infancy to the age of 18 have grown up well in an institution in Calcutta, where they were carefully tended. The improper and excessive consumption of animal flesh, spirits and beer, and the disregard of simple hygienic rules, still continue to give to climate an ill name which fairly belongs to habit. Making full allowance, however, for these preventable causes of disease and degeneration, the fact remains that children can only with difficulty grow to due strength and capacity in the climate of India and the lowland tropics generally. They begin to flag after their fourth year. Common experience demonstrates the impracticability of colonizing the equatorial zone with the races of the cooler temperate regions. Even the high stations on the hills, where the temperature may not be above that of the home country, are not sufficiently favorable to the continuance of the family and to permanent settlement. The air, though cool at night and agreeably warm by day, is somewhat too much rarefied, and the sun shines vertically. At 7,500 feet the pressure and density of the air are lessened by one-fourth, and the sun's heat increased by many degrees.

Australia is not yet proved to be equal to the Mother Country as a permanent home for the Anglo-Saxon race; indeed, there is some evidence that the British standard is not maintained, but this is largely accounted for by causes which may be considered within human control.

Hot climates are not favorable to emigrants above 44 years of age or to children under 16, and field labor can not well be undertaken.

While Europeans visiting hot, moist climates are apt to be attacked in the bowels, the inhabitants of hot climates visiting Europe and North America are especially attacked by, and often succumb, to diseases of the respiratory organs. The cold countries are unfavorable to the establishment of tropical races. A similar relation seems to hold here between cold and respiratory diseases and heat and bowel diseases, as we have seen to prevail in winter and summer in temperate climates, but the effect is accentuated when the subject is unacclimatized. That the natives of tropical Africa can increase and multiply in subtropical or moderately warm climates is proved by their increase in the Southern States of North America.

Tropical islands are not in general well adapted for colonization by northern Europeans, for though their climate is more moderate than that of the mainland and tempered by sea breezes, fever often infects the valleys, and the moisture of the atmosphere has a relaxing influence. But many islands not considered wholesome would be far more congenial if proper hygienic measures were taken and the most suitable food and clothing habitually used. The Sandwich Islands are favorable for settlement, and may be compared with tropical highlands of moderate elevation.

The most remarkable instance of the permanent settlement of English people in the tropics is that of the inhabitants of the Barbados and of Tuagua, one of the Bahama Islands. The former are descendants of rebels sent from England for slavery between 1650 and 1700. They have survived through conditions of great misery and severe exposure. The islanders are now chiefly occupied in fishing. Deterioration there has been, but this may fairly be ascribed to poverty and improper food rather than to climate. In Tuagua the people, some of whom belonged to families settled there since the time of Charles II, appear to have maintained somewhat better health and physique.

It is noteworthy how in some circumstances a seemingly small change of climate does harm or good and in others a very great change has no ill effects. Invigoration immediately follows a change from southern England to the Alps, the Scotch Highlands, Norway, or the open sea; a change for the worse, and loss of vigor overtakes natives of the north of England or of Scotland who fix their abode in the Thames Valley or near cities in the south. On the other hand, English crews may winter in the Arctic regions, where temperature is 60 degrees below what they are accustomed to, and diet coarse and unvarying; yet they maintain perfect health. Food untainted and moderate in quantity and abstinence from alcohol probably have much to do with health maintenance in any climate.

Temperature falls about 1° F. for every 270 feet altitude on the average.[1] Other conditions being equal, a place at 6,000 feet high has a temperature fully 20° lower than the plain at the sea level.

Generally, the range of temperature increases from the equator toward the poles, from the coast toward the interior, and from mountains in the tropics to mountains in northern countries. Humidity is less at high levels, but relative humidity may be greater than at low levels, and saturation may prevail for long periods. In Europe the level of maximum rainfall is about 3,000 to 4,000 feet; in the tropics, also, the lesser mountain ranges have more rain than the highest, and the maximum rainfall is about 6,000 feet. Mountain valleys are less healthy than high plateaus.

The "vital" or lung capacity diminishes from about 266 to 246 cubic inches in the ascent from sea level to 2,000 feet, and the pulse beats faster by fifteen to twenty in the minute. At 2,000 feet the pressure of air on the chest is reduced by over 200 pounds. Since vital capacity is also diminished by high temperature, the hill station can not equal in this respect the temperate climate, but there is reason to believe that the lung capacity increases in course of time so as to be fully equal to its value at the low level. Evaporation from the skin and lungs increase, and digestion and sleep are generally good.

Strength is naturally greater in hill people. Life is hard, and the weaker members perish; the pure air invigorates; the changes of temperature refresh; good water is plentiful; the exertion of climbing and the deep breathing expand the chest and increase the lung capacity; the food is wholesome and not in excess; activity and alertness are generally expected. On the other hand, in high mountain valleys malaria is often found, also goitre, asthma, ophthalmia, inflammation of the lungs, and diseases of the kidneys. Dysentery, acute bronchial catarrh, typhus, albuminaria, and diabetes are rare; also the many zymotic and other diseases more or less dependent on aggregation.

In a period of thirty-four years the mortality of the Dutch-Indian army was, on low ground, 5.27 per cent, on high ground, 3.66 per cent.

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[1] The decrease would be less than this—about 1 degree for each 400 feet, up to 1,000 feet.

MENTAL AND PHYSICAL QUALITIES IN RELATION TO CLIMATE.

Distinguished observers[1] maintain that the white man can not flourish in the tropics, and will not work where an inferior race works; that in Ecuador and Brazil the white race dies out in the third generation; that in Southern and Central America, north of Uruguay, the colonies break up through fever and climate; that in Panama and other parts of Central America the air is so pestilential that even the Chinese succumb at an enormous rate, and that the most fertile parts of the earth, which are bound to be the most populous, can not possibly be the homes of the Aryan race, or of any higher race whatsoever. There can be no doubt that mental and bodily qualities are very largely affected by the atmosphere, with its various constitution of density, temperature, moisture, cloudiness, fog, wind, and organic pollution. Extended investigation of the effect of climate upon human health and welfare would lead to results of the highest importance. The inquiry might be directed, in the first place, to an historical examination of the movements of nations, races, tribes, and individuals, and of the effect upon them of change of climate, separating as far as possible the results due to preventable circumstances and change of habits, from results which might be regarded as necessary in the relations of the atmospheric and the human constitution.

Secondly, the fitness of various races for removal to various climates under modern conditions might be examined, and the effects of tropical highlands be compared with those of lowlands.

When we recollect the evil reputation of many localities and climates which in the first half of this century were spoken of as deadly, and when we consider that these have lost their bad name solely by the exercise of local and personal hygiene, we can not despair of the power of man for reducing the unhealthiness even of large areas and tropical climates. Last century a troopship, a prison, and a barrack may each habitually have rivaled the worst tropical country in sickness and mortality; to-day they are as healthy as a country village; the prison, indeed, is a model of salubrity.

The fact has been extensively realized that cultivation and draining may often do for a pestilential tract what cleanliness and ventilation do for an infected building. A scientific inquiry into the results of cultivation, draining, and irrigation in improving or harming the health of districts subject to malaria in various parts of the world would afford information of great value. The nature of the soil, the height of the subsoil water, the microbiology of the soil and of the superincumbent air, and the effect of atmospheric conditions should be tabulated and compared. We already have evidence of the frequent recrudescence of malaria through artificial irrigation in India, and in Egypt

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[1] Pearson, National Life and Character, Wiener's Perou et Bolivie. Orton's Andes and Amazon, Curtis's Capitals of South America.

the possibility of the revival of plague through irrigation can not be lost sight of. What malaria means in India is best realized by a glance at the mortality statistics, which show that 3,000,000 natives annually fall victims to this most fatal of all endemic diseases, and we know that where one dies many are enfeebled for life.

Looking at the available evidence, we may fairly infer (1) that the inhabitants of temperate climates are, on the whole, intellectually and physically superior, and that they owe this position largely to atmospheric conditions; (2) that in the tropics and commonly in the temperate zone the inhabitants of the mountains are physically the strongest; (3) that tropical countries are not favorable for rapid permanent colonization by the races of northern Europe and of the Northern States of America; (4) that the maintenance of healthy conditions in persons passing from one kind of climate to another very different climate depends to a great extent on the observance of hygienic method and a change of habit, but also on the time taken to make the move, rapidity of transition being inimical to health; (5) that tribes or races have moved from hot to cold, and cold to hot climates, occupying centuries or thousands of years in their progress, and have not invariably suffered or degenerated, and that therefore, and on other grounds, it is probable that fairly healthy hot or cold countries may in the course of centuries be colonized by races which have successively and slowly occupied lands warmer or colder than their own; (6) that people long subject to extreme variations of temperature, as between winter and summer, and day and night, are better able to colonize than those who are subject to more uniform temperature.

MODE OF ATTACK OF MIASMATIC DISEASES.

It is very desirable that the various diseases which affect the inhabitants of moist countries in the tropics should be traced to their original haunts, and their favorite channel of communication be ascertained. Is the condition known as tropical anæmia mainly a result of temperature or of an emanation from the soil in the air? Are dysentery, diarrhea, hepatitis, and liver disease due mostly to organisms swallowed in food or drink, or inhaled in the air overlying soil rich in organic matter, or are they produced by merely physical properties of the atmosphere acting on imperfectly healthy bodies, by means of over-fatigue, insolation, or chill? It appears likely that both air and water are capable, in the case of several tropical diseases, of conveying the poison. Thus, at Sierra Leone, improved water lowered the death rate, but it still remains high; in the villages of the Najagarrh hills in India, a drain-cut reducing the flood level by 3 feet greatly improved the health of the people, and splenic enlargement cases were reduced to less than one-sixth of their former prevalence; in the canal-irrigated country in India fever is both more prevalent and more virulent, and a great difference in the health of the people is observed between places where the water level is high and where it is low; the mere neighborhood of a swamp, without any pollution of water supply, is often sufficient to prostrate troops. There can indeed be no doubt that air infected from the ground very commonly causes a widespread epidemic of malaria. When the waters of a flood subside, the fever extends over a wide area and beyond the limits of the flood; and exposure to night air without any other source of contamination is a frequent cause of fever even to the robust. Considering the large number of varieties of bacilli residing in mold and in damp earth covered by sand, the relation of diseases to the air and vapor emanating from the ground is a subject worthy of national or international research.

All over the world there are indications, if not such evidence as amounts to proof, that where the air stagnates or is confined in valleys without exposure to frequent winds, the condition of robust health in a population is not well maintained. In certain valleys of Switzerland, of the Pyrenees, of Derbyshire, in England, and of parts of India goiter and cretinism have been common; in low-lying clay districts in England cancer has been shown to be prevalent above the average, and in limestone or chalk districts to be below the average. Valleys lying across the direction of the prevailing wind and not well ventilated are liable to an excess of heart disease. Whether these effects are in any degree due to stagnant or miasmatic air or wholly to difference in the water supply it is uncertain, and the subject demands inquiry.

Climate has often been credited, even by great writers, with effects on the human constitution which statistics have failed to indicate. Most people have supposed that suicide in England must be most frequent in November or in winter when the dark foggy air depresses the spirits. As a matter of fact, however, in England and in Europe, as a whole, suicides are most frequent in the summer half of the year, and especially in May and June, when the aspect of nature is most cheerful and the air bright and pleasant. A very distinct and considerable rise in suicides, crimes, and nervous diseases takes place in the spring and early summer. The first cold weather in autumn produces a temporary and smaller increase. Montesquieu assumed that the number of suicides is excessive in England, and attributed them to depression, caused by the dark, cold, damp climate. As a matter of fact, the suicides in England are not excessive when compared with France and central Germany, and the climate is not often dark and damp for long periods. Esquirol and Cabanis asserted that a rainy autumn following a dry summer is productive of violent deaths; Vilemais maintains that nine-tenths of suicides happen in rainy and cloudy weather. Quite a different order of things is revealed by a comparison of the figures for suicide, and especially for the suicide of insanity, for the different months. The quick increase of the temperature of the air, the dryness and sunshine of the spring have the effect of precipitating mental alienation and increasing nerve instability; the organism is least robust when the winter passes away.

Suicide predominates in the central part of Europe between latitudes 47 and 57 and longitudes 20 and 40. In the southwest and northeast of Europe the tendency is much less. Italy, Spain, and Portugal have a minimum number. The distribution appears to be little affected by climate, and very largely by mental advance and cultivation, so that the climatic factor, if existent, is concealed. But there is sufficient reason in Europe, at least, to attribute an excess of nervous diseases when other conditions are equal to periodic hot and dry weather and alternations of heat and cold. Countries either very hot or very cold are less subject to suicidal tendencies than the temperate region. But inquiry is needed to dissociate the climatic factor from the many others which confuse the evidence in civilized countries.

The influence of climate upon health and upon national character has never been very fully studied, and is worthy of the attention of Government and of science. The effect of change of climate has already been touched upon in another part of this essay.

The degree of cold which the human body can easily bear is surprising. A temperature of —70° F. with a dry and still air is less trying than a temperature of 20° with damp and strong wind. The present writer has had experience on a mountain in Italy of a temperature of 17° F., with sunshine, which was quite pleasant and not too cold for sitting out. Even invalids can sleep with windows open and sit out, without very heavy clothing, when the thermometer shows several degrees of frost. The purity of the air as well as the dryness seems to invigorate the frame and prevent the sensation of chill. Voyagers in the Arctic regions endure prolonged cold without in any way suffering in health if judicious in their mode of life, and mountaineers are seldom the worse for exposure unless they have greatly fatigued themselves or have been overtaken by rain or snow. The tolerance of heat is also very remarkable where the air is dry and pure and direct sunshine avoided. The temperature of the body rises about 0.05° F. for every increase of 1° F. above the ordinary temperature. The amount of air respired is less in hot than cold climates, in the proportion of 8.157 to 10 ounces of carbon. The total effect of heat and of cold on the human body has never been fully investigated. The net result, however, of a very complex series of changes induced by different temperatures on the inhabitants of different lands seems to show that a moderate or medium temperature is most favorable to health and strength, apart from telluric and constitutional factors, and from diet, training, and habits. Yet there can be no doubt that some race of mankind may attain very great strength and health in any nonmalarious climate.

PART III.—VARIOUS ATMOSPHERIC CONDITIONS AND PHENOMENA.

TEMPERATURE AND HEALTH.

The relation of the temperature of the air to health has already been noted in the case of various diseases. Thus malaria, dysentery, liver diseases, cholera, yellow fever, and dengue belong especially to hot climates. Anæmia and general enfeeblement affect the inhabitants of colder regions when stationed in the tropics. Hot weather in northern Europe increases the prevalence of several diseases, and with drought increases the death rate in towns and damp places. Diarrhea becomes prevalent, and in less degree scarlet fever and diphtheria. Diseases of the intestines increase. Cold, dry, still weather is generally healthy except in towns, and to old people, and to persons whose lungs are delicate. A cold winter in temperate climates increases the death rate, and a mild winter is healthy in northwestern Europe. Influenza, pneumonia, and bronchitis are more fatal in cold weather. Diseases of the circulatory system, heart disease, and phthisis are at their maximum of fatality. Cold, clear, still, frosty weather is, on the whole, healthy and much less fatal in towns than cold with fog.

The most favorable temperature to health in temperate climates is about 55° to 70° on an average; natives of the tropics probably thrive best at a temperature of about 65° to 80°.

DRY CLIMATES AND HEALTH.

A perennially dry air is almost universally favorable to human life, and dryness in a sparsely inhabited and well-watered country is wholesome in several ways, especially, perhaps, in its preventive effect on epidemic and lung diseases. In towns, dry weather without showers is much less favorable, in fact it is distinctly unfavorable. Very damp and rainy countries with moderate temperature are often healthy; for instance, western Ireland, western Scotland, Cornwall, and the lake district of England. The deaths from consumption, etc., are much fewer in these districts than in the drier districts which are more thickly inhabited, though not less, perhaps, than in equally sparsely inhabited drier country districts. That they are so numerous as they are depends probably very much on the tendency to aggregation and bad ventilation in the dwellings in bad weather. Tropical or warm countries, and warm seasons, in many localities, are unwholesome when there has been much rainfall, and this is succeeded by hot weather. Much moisture in a calm air helps greatly to spread various epidemic diseases and malaria. Dry air is favorable to the healing of wounds, and probably to the oxidation or death by desiccation of noxious living matter in the air.

The exemption of many tribes and races living in dry climates from phthisis and other disorders of an infectious nature may be, and probably is, partly due directly to the dry air which does not permit the growth of the bacillus on solid substances or soil, but must also be attributed to the migratory habits of the people, the outdoor life, and the absence of centers of infection. Arabs, who were exempt from phthisis and scrofula in their camps, died at the rate of 50 per cent when they were located in French prisons. This is only one of many instances which go to prove that the infective matter of consumption clings to solid surfaces and thence invades the human system through confined air.

HEALTH AT HIGH ALTITUDES.

The effect of living at high altitudes has been variously stated, but on the whole it seems probable that most persons become acclimatized to the rarity of the air, diminished pressure, lower temperature, lessened humidity, and increased sun power. Above 6,000 feet the pulse and respiration rates are slightly increased. Dr. Marcet gave as the chief outcome of several years' experiments on the amount of carbon dioxide and air expired at high altitudes the following statements:[1] The effect of altitude and cold combined increases the amount of carbon dioxide expired, but where the cold does not become appreciably greater, as on the Peak of Teneriffe, the amount remains the same as at the sea level. At altitudes above 10,000 feet the amount is lessened. Less air is expired at high altitudes. It appears that the blood more readily acquires oxygen at high altitudes than near the sea level. The body can gradually accommodate itself to altitudes much above 10,000 feet. Recent laboratory experiments by Dr. Loewy showed that the diminution of air density and pressure to about 17.717 inches is well borne, greater rarefaction being balanced by deeper inspiration. A similar compensation occurs when carbon dioxide is added to the air. Animals breathing air rarefied to half an atmosphere eject the same amount of blood from the heart as under normal pressure.

The expansion of the chest and increased action of the heart add to strength and vigor, and the mountain races, with the exception of people living in deep or flat valleys, are generally fine in build. In the tropics, Quito is an example of a large population doing well at a height of 10,000 feet. For some forms of consumption, consumptive tendencies, and several other diseases, such as anæmia, altitude is beneficial; for others, including nervous irritability and heart weakness, it is harmful. The elements which are concerned in these effects have not been identified. For old people and those who can not take much exercise, mountain heights are clearly not well adapted.

SEA AIR AND HEALTH.

Sea air is very beneficial to the great majority of people, and has a wonderful restorative power in many ailments and illnesses. It is free

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[1] Proc. Roy. Soc., 1878, 1879.

from all kinds of infective germs, and therefore epidemic diseases are unknown at sea, except in so far as they arise from the material, provisions, or water of the ship, or have been brought on board by crew or passengers. Much of the benefit which would otherwise be derived from a sea voyage is often counteracted by the small space and difficulties of ventilation of sleeping berths and cabins. The temperature of the tropics has a bad effect upon the crew and passengers of ships from colder climates, and loss of weight results; but, in general, the weight and strength of passengers are increased by voyaging in a fair climate. Much depends, of course, upon the accommodation and diet, as well as upon the atmospheric conditions.

THE IMPROVEMENT OF CLIMATE WITH SLIGHT ELEVATION.

From a certain number of experiments and from a review of observations taken by meteorologists of differences between temperature and humidity at different heights above the ground, the present writer came to the following conclusions,[1] shortly stated:

The mean temperature at a height of about 100 feet above the ground does not differ sensibly from the mean temperature at 5 feet, but seems to be slightly in excess.

The means of daily maxima at heights of 69 and 128 feet fall short of the mean maxima at 10 feet, and still more of the maxima at 4 feet. The means of daily minima at the greater heights exceed the mean minima at the smaller heights.

There is a certain altitude, apparently about 150 feet above the ground, at which, while the mean temperature is equal to that at 4 feet, the maxima are lower and the minima higher than at any lower point.

On an average of nineteen months, the mean of maxima was about 1.5° F. lower at 128 feet 10 inches than at 10 feet, and the mean of minima about 0.55° higher.

In cyclones the higher, and in anticyclones the lower, points generally have the lowest mean temperature.

The mean night temperature is always highest at the higher points, and the mean day temperature always lowest.

About sunset in clear or foggy weather, when calm, temperature falls much faster near the ground than at some height above it.

Equality of lower and upper temperature seems to occur about two hours before sunset and after sunrise, but varies with the season.

In clear weather and low fogs, between sunset and sunrise, temperature is always, or nearly always, higher at heights varying from 50 to 300 feet above the ground than at heights from 2 to 22 feet.

In bad weather the higher points are coldest by day and night. In foggy weather, especially with ground or radiation fogs, temperature is very much the lowest near the ground, and within the fog much lower than above it.

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[1] Trans. Sanit. Inst. of Great Britain.

The mean daily range at 128 feet approaches closely that of the English seacoast, and at 69 feet is about midway between that of coast and inland stations.

Mean humidity is more than 1° less at 69 and 128 feet than at 10 feet surrounded by trees. Humidity by day is a little greater, by night much less, 2° or 3°.

Places on hills or slopes from 150 to 700 feet above a plain or valley, especially with a southern aspect, have a much smaller annual range, and also a smaller daily range than places on the flat. At 545 feet a superiority of 12° or 13° in the extreme minimum has been registered. Thus we find that at a height about equal to that of the upper rooms of a high house a more equable and drier climate prevails than near the ground, and that conditions on sloping or well-chosen natural elevations are on the whole similar.

The importance to delicate persons, and indeed to the majority of people, of living at some height above the ground, especially in places which are damp, subject to fog, or to unwholesome emanations from the ground, has yet to be appreciated.

EFFECT OF IMPURITIES IN THE AIR OF TOWNS ON MENTAL AND BODILY HEALTH.

A dense population in manufacturing and other large towns is accustomed to breathe a compound mixture in the air which in course of time profoundly affects the health of the race. The oxygen is deficient, the ozone absent, carbon dioxide in excess, hydrocarbons, animal and mineral dust, sulphurous acid, chlorides, ammonia, and microorganisms in pernicious abundance.

The small tenements or crowded rooms produce the high death rate, an enormous proportion of deaths in childhood, and of diseases of the lungs at all ages. The best model dwellings, on the contrary, have a lower death rate than the mean of the town, although the population to the acre is dense.[1] In New York, about twenty-five years ago, 495,000 persons lived in tenement houses and cellars, most of them dark, damp, and unventilated. By hygienic measures, largely by ventilation, the death rate was reduced in twelve years from 1 in 33 to 1 in 38.

Townspeople spend much more of their lives indoors than the peasantry. At their work and in their rooms they breathe dust of many sorts, particles of skin, organic poisons, and often many pathogenic germs which would develop in their bodies if they had not already passed through the specific disorder. The air being deprived of its exhilarating power, they seek stimulants in food and drink, and go to mischievous excess in the consumption of animal flesh and alcohol. Hence many internal diseases. Children are never seen of the right sturdiness and color which is common in the country. Most children

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[1] The corrected death rate of infants in the dwellings, chiefly blocks, of the Metropolitan Association for Improving the Dwellings of the Industrious Classes in London, has been for some years past much below the average.

born and bred in the crowded parts of towns are sickly, pale, feeble, unnaturally sharp and wizened, their voices are of bad quality, and their height and weight deficient. The elder people become reckless, often depraved, dirty, and scarcely ever free from ailments. Their whole bodily, mental, and moral nature deteriorates. As a consequence, it is difficult for native townsfolk to obtain employment in competition with immigrants from the country. In general, policemen, laborers, domestic servants, and several other classes of employees are found to be most fitted for their duties if country born, and thus perpetual immigration is stimulated. The best and strongest people are constantly migrating to the great towns, bringing their health and youth to supply the demand for good work, and reducing the death rate, so that the true proportion of victims of town air and town conditions fails to be realized. As a matter of fact, it has been ascertained that very few families survive in central London for more than four generations, and that many die out in two or three generations. A true Londoner of the fifth and even of the fourth generation is rare. A very large proportion, probably the majority, lose the fine stock of health they brought with them from the country within two generations.[1] This is a matter of national and international importance, and the fact should be clearly understood by the public and by legislators that the desertion of the country by the best blood involves the rapid consumption of the finest physical, mental, and moral qualities.

We have, in fact, in our midst areas—climates, if we may so strain the term—of which the properties come into close competition with the influences of the tropics in bringing about the decline and extirpation of families. If the inner circle of a great city were to exclude immigration for a generation, the poverty of its health resources would stare it in the face, and the falling value of a day's labor would startle it into the promotion of hygienic reform. Room and space would be demanded as a necessity for the proper development of human beings.

The rate of mortality is greatly increased by the bad air of towns, and especially by the close, foul air of dwellings and workshops. But the rate of sickness is still more increased above that of the breezy country. In one part of the parish of St. George's-in-the-East, in London, there are nine cases of sickness to one death, but in the worst part of the same district there are twenty known cases of sickness to one death, and a sickness rate of 620 per 1,000. There is, in fact, no good health in the people of the crowded streets, unless it may be for

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[1] Defining a Londoner as one who habitually resides in London, with only few holidays, and whose great-grandparents, grandparents, and parents were Londoners, it is exceedingly difficult to find such a specimen among 5,000,000 people. Even true Londoners of the third generation are very disproportionately small in numbers and feeble in health and strength. These facts, however, do not prove that the inhabitants of large towns must of necessity decay unless recruited from without, for with better homes, houses, more air, reduced hours of work, more holidays, and better hygienic conditions of suburban as compared with central quarters, the prospect of continued vitality greatly improves.

a short time among newcomers from the country. "They are perpetually on the trudge to the hospitals, and get patched up again and again and live on."[1] Much of this most deplorable state of things may be owing to excess of alcoholic drink, but the excess is in many cases the result of a demand for a stimulant which pure air might have prevented. About 1,000,000 out of 4,000,000 persons are treated at London hospitals and dispensaries in a year, and probably this represents fairly well the sickness of great towns in general. A great amount of the lassitude and idleness of the lowest population of cities has been traced by Dr. Richardson to want of ventilation, in their own and former generations. "Tell them," said Mr. Chadwick, the great sanitary reformer, "that when they hear of that disease called consumption they ought to know that it comes constantly from bad administration, which permits dwelling houses to be built on damp and sodden and rotten sites, and which permits industrial workers to breathe, but not to live, in foul airs, gases, vapors, and dusts. Tell them that in model dwellings a death rate of 15 in the 1,000 has replaced one of 30 in the 1,000." Dr. Louis C. Parkes, medical officer for Chelsea, states that much of the anæmia, the pale faces and disordered digestions, and many of the wasting diseases of children in the great towns are to no small extent due to a condition of atmosphere which prevents the perfect action of the lungs and the complete oxygenation of the blood, and so lowers the tone of the body and the ability to repel disease. These facts ought to be impressed upon the population. In England it has been computed that the amount now annually spent on intoxicating liquors might double the actual house room for every family.

The causes of physical degradation in towns are no doubt complex, but that bad air and want of light are very powerful factors, is proved by the following considerations:

Children placed in every respect in equally good conditions in town as they have had in the country, with the exception of the difference of town air, in many cases lose health, grow pale and weak, and in fact do not thrive as they do in the country. Children brought up within the central area of large towns are less robust than children brought up in the country; the children of the poor especially suffer, for though they may have the chance of more flesh meat and often of more food, the air they breathe both without and within doors is inferior, and this affects them not only directly, but indirectly, as through loss of appetite. Very many children in towns have poor and unwholesome appetites. Children in small, crowded towns in various countries, e. g., Italy or Spain, where the streets are narrow and the air foul, often look unhealthy and feeble, and bad air alone, both in town and country, is known to give similar results. Children who are ailing or simply pallid and unhealthy, after the pattern of the alley, very soon gain in health and appearance when moved to country air. The experience of very many adults is similar to that of children, and they rapidly or

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[1] Evidence of a doctor in the East End of London.

gradually lose their accustomed vigor during a period of employment in crowded or badly ventilated places. The air of workshops, printing rooms, mills, etc., sometimes changes young, vigorous looking men almost beyond recognition in the course of one or two years. Outdoor work in towns is far less pernicious, and if houses and streets were more spacious, and work places more airy, the physical degradation would be much less perceptible. The mental and moral effect of living in bad air can hardly be estimated, mixed up as it is with the various other conditions which generally accompany it. The wits are certainly dulled when oxygen is wanting and carbonic acid in excess, but social contact tends perhaps more powerfully to sharpen them. Sharpness, cunning, and alertness increase in towns, but great work demanding sustained intellectual effort is not favored, but vitiated, by bad air. In schools, the loss of attention, the difficulty of keeping on long at a task, and the sympathetic weariness, are very frequently the result of bad ventilation. The schoolmaster has great power to improve the quality, or rather the scope, of his pupil's brains by the admission of plenty of air. School-masters and teachers as a class are not in the list of healthy occupations, although they are above the average of strength when they enter their profession. The air they breathe must be concerned in the disorders which especially attack them. Town air seems to tend to weaken the power of the will, the self-command, and the exhilarating sense of freedom and content which distinguish independent yeomen or the peasantry of the hill country, who breathe the vital atmosphere. But here again, we fail to discriminate between the effects of physical and of social differences. Since "self-reverence, self-knowledge, self-control" are among the highest human attributes, and most essential for future progress, the effects, direct and indirect, of vitiated air on character might with advantage form the subject of extended and carefully conducted scientific inquiry.

Intemperance in drink has been commonly attributed to foul air among other influences. There can be no doubt that many a man has become enfeebled by working in bad air, and has taken to drink in the vain hope of keeping up his strength, or with the deliberate intention, for the moment justified, of stimulating his faculties occasionally when they flag. Where the air has so little freshness, mind and body are more likely to crave for artificial and less wholesome sustenance. Whether on the whole the indoor workers consume more alcohol than the outdoor may be doubted, but the effect upon them, beyond question, is worse.

An investigation of the effect of air on mental qualities might be undertaken on the following lines: A number of schools in which ventilation is good to be compared with schools similar in class of scholars, etc., but with bad ventilation of less space, the character of the work and of the scholars to be compared; schools where great improvements in ventilation have been made to be examined as to any notable progress following the improvements; workshops of similar classes to be compared, respectively good and deficient in ventilation or space, the results as regards health, vigor, intemperance, and efficiency.

WIND FORCE AND HEALTH IN A LARGE TOWN.

In an inquiry made quite recently by the present writer, but hitherto unpublished, concerning the relation between the health of London in winter and the force of the wind, the conclusion was arrived at that on the whole, the mortality is greater in calm than in windy weather, and that there is much less variation in the death rate during the prevalence of strong winds than during the prevalence of gentle winds and calms. The period examined was from November, 1872, to December, 1893. In January, 1890, and in the first quarter of 1892, influenza greatly raised the mortality above the normal, but since this is one of the zymotic diseases, of which the prevalence is increased by calm weather, the figures for these periods have not been omitted. The months of October, November, and December, in 1879 and in 1889, were the least windy periods recorded, and each was followed by a high death rate. Several calm periods coincide with great cold and fog, and it is these in combination which have the worst effect upon health in a smoky town.

Further investigation is required to ascertain which diseases are most apt to spread in calm weather, and the relation of particular winds to particular diseases.

The following table represents roughly and approximately the rates of mortality in the periods mentioned:

Minima, hourly horizontal movement less than 11 miles.

Period.	Death rate.	Death rate in five weeks following.
December, 1873 (22 calm hours, cold and fog)	28.2	23.1
February, 1874 (33 hours calm)	24.6	23.1
November, 1874 (34 calm hours)	27.2	31.4
February, 1875 (no calms)	25.7	23.2
October and November, 1876 (no calms)	21.4	22.4
February, 1878	25.4	24.3
December, 1878 (36 calm hours)	28.1	26.8
October, November, and December, 1879 (131 calm hours)	26.6	31.2
January, 1880	31.2	31.7
November and December, 1885	20.64	22.5
February, 1886	24.9	26.9
January, 1887	21.8	19.3
December, 1888	19.8	23.2
January, 1889	20.3	18.2
November and December, 1889	19.48	28.1
December, 1890	24.7	28.5
Quarter ending April 2, 1892	28.2	....
October, November, and December, 1892	18.5	....
Total	24.42	25.25

Maxima, hourly horizontal movement more than 15 miles.

Period.	Death rate.	Death rate in five weeks following.
November, 1872 (no calms)	22.8	24.5
January, 1873 (37 calm hours)	19.2	24.8
February and March, 1876 (no calm hours)	24.6	23.4
January and February, 1877 (17 calm hours)	21.6	27.6
November, 1877 (no calms)	22.3	25.3
January, 1878 (24 calm hours)	26.6	25.4
November and December, 1880	21.9	25.0
November, 1881	21.18	23.1
November, 1882	21.26	23.5
January, February, and March, 1883	21.9	23.6
November and December, 1883	21.23	20.4
January and February, 1884	21.22	19.9
December, 1884	21.6	23.2
February, 1885	19.6	22.0
December, 1886	20.9	21.8
February and March, 1888	21.2	19.0
February, 1889	18.2	18.6
January, 1890	28.1	21.4
Total	22.15	23.1

DEW AND FROST—EXHALATION OF VAPOR FROM THE EARTH.

From an investigation conducted by the present writer during the two summers 1891 and 1892, the following were among the conclusions arrived at:

Calm or a light air is favorable to dew formation. Wind prevents the deposition of much dew and evaporates much of what is formed. Free radiation or an exposed situation is, on the whole, perhaps the most effectual cause of dew on very many nights of the year. In a level country those parts of a field which are least sheltered by trees and hedges gain most dew on perfectly calm nights. Those parts of any flat substance with the most exposure to the sky are on calm nights most bedewed. The tops of bushes, posts, railings, pans, etc., are on calm nights more bedewed than the sides. Greater cold by greater radiation in these cases produces greater deposition. Radiation from fine points, however, is often not sufficient to counteract in air which is not very humid the effect of the continual impact of air above the dew-point and higher in temperature. Close to the ground the case is generally different, for the movement of air is less and the humidity and cold greater. With fog or a very humid air the points are most bedewed. In dry weather the dew is deposited most on the leeward side, in moist air or fog on the windward side of objects.

Nearly all the conclusions of Wells were confirmed. But a very remarkable amount of evidence soon accumulated from the experiments that a great proportion of the dew formed near the ground is condensed from vapor derived from the earth. A large quantity of dew was invariably found on clear nights in the interior of closed vessels inverted over grass and sand, very little or none in vessels inverted over plates lying on the ground. The inverted glasses or vessels, however much their rims were embedded in the ground, gave similar results. More dew was found on the lower surface of plates of glass or earthenware or boards slightly raised above the ground than on the upper surface. The lower sides of stones, slates, glass, and paper on the ground were more bedewed than the upper sides. The lower half of stones lying or embedded in sand was more often bedewed and frosted than the upper half. The interior of closed vessels inverted on the grass and covered with two other vessels of badly conducting substance was thickly bedewed, and the grass in the three inclosures was also thickly bedewed. The deposit on the interior of vessels was much less over dry garden earth than over sand or turf. A great deal of dew was deposited on the interior of vessels over dry sand or dust, the earth being somewhat moist an inch or two inches below. Pebbles, etc., lying on a dusty road became quite wet underneath early in the evening, and over grass the underside of a square of glass is clouded soon after the grass loses the sunshine. A very great difference of temperature was found soon after sunset after hot days between the temperature of the soil at a depth of 2 or 3 inches and the temperature of the air close to the ground, just above the blades of grass. On one evening at 11 p. m. the temperature of the exposed grass was 36; of the soil at 15 inches, 60.5.

The author became convinced by these experiments and other considerations, that a great deal of dew comes from vapor from the soil and from plants, and at sea from vapor from the surface of the sea; that malaria and some other diseases are largely caused by emanations from the soil at night bearing organisms into the air, which are then retained by the damp air in a cold stratum near the ground, and that sand overlying damp earth permits air and vapor to rise easily through it. Also, it became evident that a great deal of soil-air may be drawn into houses through pervious soil, and that the neighborhood of damp ground may be thickly infected with organisms contained in the air and vapor which emerge from the soil. A dry covering of sandy earth is not only little impediment to the exhalation of vapor, but may serve to protect micro-organisms from the killing action of dry air and sunshine.[1]

EXHALATION OF GASES AND PARTICLES FROM THE EARTH.

It is generally assumed that evaporation or distillation of water gives rise to pure vapor and leaves behind all impurities, but, as a matter of fact, in many natural conditions this is far from being the case. When earth becomes heated, moisture forces its way as a vapor through a

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[1] The author has treated this subject more fully in Trans. Sanit. Ins. for 1892: The Exhalation of Vapor from the Earth.

porous superficial layer, and carries with it spores or minute organisms which have multiplied or germinated in the passages through which the vapor passes. A moderate degree of moisture and rather free aeration of the soil are favorable to the growth of many kinds of microbes. We know that cotton wool, unless tightly packed, will not stop the passage of microorganisms; sand and porous soil allow both air and water to pass without depositing all their particulate contents. The filter beds of water companies are efficient not by the action of the sand, but by the retention of particulate bodies in the slimy covering soon deposited above the sand.

Cold nights following hot days seem to favor very much the exhalation of vapor from the earth.

Wind may very likely have an effect in drawing out the gases from the soil, but this action is less important to human health, for malarious germs are dispersed and much less dangerous in windy weather.

Aitken has shown by his experiments on the formation of small, clear spaces in dusty air that bodies warmer than the air drive away dust from their surfaces and create the dust-free black envelope which surrounds them. He further showed that an evaporating surface has a similar influence, and that dust was driven more than twice as far from the wet part of an object as from the dry, the object being above the temperature of the air. The necessary conditions for the repulsive effect to be strongly shown are that the air must be acquiring heat and moisture from the surface. Very little heat with moisture gives a thicker dark plane than double the heat would do. Dust passes through small openings with surprising ease; "any opening which admits air allows the passage of the finest particles." The air contains enormous multitudes of particles so small that the concentrated light of the sun does not reveal them.[1] We may fairly infer from these facts that no inconsiderable part of the fine dust of the air, mineral and organic, is derived from below the surface of the ground. Some interesting experiments made a few years ago showed that the dust deposited in tightly closed cupboards is brought in by the movements of air induced by changes of temperature. Similarly, changes of temperature must draw in and expel fine organic dust from and to air and soil.

The present writer's observations led him to conclude that a great quantity of vapor issues from the earth even in dry weather, and when the surface down to 2 inches or more is dry and dusty that the emission is very large in the evening, but that the maximum appears to take place in the early hours of the morning in dry weather; that soon after sunset in England in summer the temperature of short grass and contiguous air may be 9° to 15° or 20° colder than that of the earth at a depth of 1 to 15 inches, and that about sunrise the temperature of the top grass of a pasture field may be 20° to 30° colder than that of the earth at a depth of 9 to 15 inches and lower, and that the emission of

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[1] Formation of clear spaces in dusty air. By John Aitken, Proc. Roy. Soc., 1877.

vapor is very much less through mold than through sand or dust. In hot climates, such as India and Italy, on bare sandy ground and in valleys it seems probable that the differences in temperature between soil and surface air may amount at night to between 30° and 40°, and in malarious places the flow of impure vapor toward the surface may be equal to the evaporation from a marsh. These facts have a very distinct bearing on the generation and prevalence of malaria, diarrhea, dysentery, and other diseases.

Herr Singer, at Munich, found that the maximum temperature of the soil (59.3) at 4 feet 3 inches, was reached on August 24, and Fodor's results gave a maximum temperature at depths between half a meter and 1 meter in August. Liebenberg observed that sand is warmed throughout more rapidly than clay and that the richer a soil in organic matter the greater its power of absorbing heat. Pettenkofer's observations show that a very large amount of air is contained even in firm soils and that effluvia from decomposing organic matter may pass for a long distance through very loose soils. Permeable soils are sandstones, loose sands, and chalk, and are generally healthy unless they contain much organic matter or are superposed upon a clay or other impervious stratum which holds up the water near the surface. Movement of subsoil water of course greatly affects the quantity of earth vapor given off during certain periods. The dried beds of water courses are well adapted for the evolution of malaria, for the superficial layer is usually permeable, the soil contains much organic matter, the water level is not far from the surface, cold air collects over the valley and is often moist and stagnant. In the dry regions of Australia it is well known that water may be found at a little depth below the dry channels of rivers.

Vegetable mold near the surface of the earth is very rich in saprophytic bacteria, and Flugge states that infusions made from manured fields and garden earth contain thousands of bacteria in every drop, though diluted one hundred times. But the observations of the present writer tend to prove that the retention of heat and moisture by this kind of earth is much greater than that of other soils, and that much less emission of vapor takes place from it into the air, so that the organisms which might be expected to invade in excess the air over cultivated ground may in reality be scarcely capable of entering it.

GROUND AIR.

The amount of air in the upper layers of the earth is very considerable, but varies greatly with the nature of the soil. Gravel and sand contain a large quantity of air, which has been estimated at one-third of its bulk. A bird has been experimentally inclosed in a glass cylinder with a solid bed of gravel below and above it, and was not affected, the air which passed through the earth being sufficient to maintain life. The proportion of carbonic acid, however, in some soils, especially where there is much organic débris, much exceeds that in the atmosphere, and would prevent the success of such an experiment. Ground air passes easily through earth, especially through gravel and sand, so that in the neighborhood of decomposing organic matter houses built on such soil are liable to invasions of poisonous gases. Carbon monoxide has been known to pass 20 or 30 yards through the earth into a house, causing severe illness. But the worst results follow the infamous practice which has been in vogue at the outskirts of large towns of selling turf and gravel on building sites, allowing the excavations to be filled in with rubbish and refuse, and building dwelling houses over these sources of disease. Probably many houses in towns where fever persistently breaks out owe their unwholesomeness to this cause. Even where the soil is natural and undisturbed beneath the foundations, there should always be a layer of impervious material, such as good Portland cement or rock asphalt, between the house and the ground; or else a good space through which the outside air may freely flow. Dwellings well raised above the ground escape many dangers associated with ground air, damp, and drainage. A damp basement is a frequent source of trouble. Hollow skirtings, casings for pipes, bell wires, etc., frequently give opportunities not only to rats and mice, but to deadly gases, to make their way into the apartments.

Inquiry is needed to discover the actual quantities of vapor emitted from different soils and subsoils, at different temperatures of air and soil, at different barometric pressures, at different times of day and night, and at different seasons, and at varying levels of subsoil water. An examination of the different species of microbes or amœba-like organisms emitted would also be of interest.

EMANATION OF ORGANIC PARTICLES FROM EVAPORATING FLUIDS.

The spread of infective organisms into the air from the surface of evaporating liquids is a subject worthy of investigation. It has been generally stated and assumed that an evaporating liquid contaminated with impurities leaves behind it all foreign ingredients and passes into the air as pure vapor. This is very far from being universally true, if evaporation be understood not as a laboratory process carefully conducted, but as a process subject to the various interferences which must occur in natural conditions. Evaporation from the sea may give pure vapor into the air, so long as the sea is tranquil and no bubble breaks on the surface, but the breaking of waves on the ocean and on the shore, and the evolution of gases from animal and vegetable life and organic decay cause evaporation to be accompanied by a considerable emission of sodium chloride, and of other substances in solution, into the air with the bursting of foam and bubbles and the tearing off of spray by the wind.

Marshes give off various gases, especially in the drying process, besides vapor. The upward movement of the air from the drying ground, the generation of gases in the viscous fluids and in the earth below them, the bursting of countless small bubbles and films, the development of electricity in the evaporation of an impure liquid, the repulsion of small particles by a warm evaporating surface, all help to carry into the lower air a large quantity of microscopic and ultra-microscopic dust. In a research made by the present writer into the diathermancy of thin films of water[1] he was much struck by the force with which the thinnest film snapped; a slightly soapy film of 1½ inches diameter and about one-millionth of an inch in thickness broke with an audible sound. In the viscous fluid of drying marshes there must be millions of thin films breaking and throwing their minute spray into the air which carries off the contained organic particles. Moreover, there must be a continual evolution of very small bubbles of gas from the muddy earth through the liquid above it. The scattering force of small bubbles is surprising. If a glass of effervescing water be watched, the minute bubbles which rise to the surface of the liquid will be seen to throw particles of water to a height of several inches in the air. The smell of drying marshes probably proceeds not only from gases, but from particulate products. Indeed, many organisms and vegetable and animal débris have been actually observed microscopically in the air above marshes. Many living germs are probably beyond the range of visibility. The manner in which spores are scattered from the hyphæ of molds, etc., may represent a similar process in the ejection from marshy surfaces of various microorganisms. The formation of gas bubbles by the *Bacillus coli communis* may be only one example out of many in which such action takes place. This characteristic of coli communis has been used by Klein as a mark of differentiation between it and the bacillus of typhoid.[2]

The influences, or some of them, which have been named as helping to carry small organic particles into the air over marshes may be capable of launching infective matter from the lungs and air passages of persons suffering from such diseases as scarlet fever, measles, diphtheria, and consumption. Certainly organic matter and living particles have been observed in the condensed vapor of breath. Thus walls on which the breath condenses may become culture grounds for disease germs which it contains.

PERMEATION OF BUILDING MATERIALS BY AIR AND VAPOR.

The ordinary materials used for floors of dwelling houses are quite ineffectual to prevent the permeation of gases and microorganisms from the soil into the air of the dwelling. By experiments made with several different materials used for flooring, with a view to determine the rate at which air would pass through them into the Torricellian

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[1] Proc. Brit. Association, Cardiff, 1881. Abstract.

[2] Journal of Pathology and Bacteriology, November, 1893; Centralblatt für Bakt. and Parasit., Vol XV, Nos. 8 and 9. Local Government Board Reports, 1892–93.

vacuum over mercury, it was ascertained that mortar is practically merely a coarse sieve and permits the rapid and easy passage of gases, that plaster of paris is also highly permeable, 75 per cent compared with mortar; roman cement permeable to the extent of 25 per cent, and portland and hygienic cement to the extent of about 10 per cent. The rate of diffusion of gases through porous septa is, by Graham's law, in the inverse ratio of the square root of their gravity. If the gases in the earth below the flooring be heavy compared with the air of the room, upward diffusion through the flooring material must be rather slow, unless other apertures for the ingress of outside air are insufficient to supply the draft of fires. When the ground is warm, as in autumn, and contains certain light gases and vapor, there may be considerable aspiration from the ground through the floor into the room. It seems probable that mortar and other porous material would permit the passage or penetration not only of gases, but of microbes, but that good cement would not permit the passage or penetration of microbes to any important extent. Asphalt is still better, and effectually shuts out both gases and germs. Coal gas has been known to pass a considerable distance through the earth under frozen ground and to enter a house through the flooring, and there can be no doubt that much ground air enters houses in this way, especially in autumn and winter. A good concrete layer, 4 to 6 inches thick, or asphalt, under every house would do much to diminish diseases caused by ground air. The reduction of two courses of bricks, which would be saved by diminishing the air space between floor and ground, would partly balance the additional cost.

MECHANICAL VENTILATION IN SCHOOLS.

From a paper by Professor Carnelley on mechanical ventilation in schools, Sir Henry Roscoe drew the following conclusions, briefly summarized:

By mechanical ventilation the microorganisms were reduced to one-tenth, the organic matter to one-seventh, and the carbon dioxide to one-half; the temperature was kept higher without draft, and cold drafts were excluded. In badly ventilated schools microbes increase up to a certain point with increase of wall space; in mechanically ventilated schools the microbes decrease with increase of space. Scrubbing or washing floors had no effect in reducing the emission of microbes into the air, and it was found that the infection of a school with these organisms takes place very gradually, old schools being much more infested than new buildings. Similar facts have been observed by Miquel as regards houses. It is clear that walls and floors and perhaps ceilings also should be faced with an impervious material, adapted for frequent washing, and without interstices. As regards mechanical ventilation, however, it has not yet been proved that proper natural ventilation can advantageously be superseded.

The floors and walls of rooms must often be very suitable culture grounds for the microbes of disease. Many fungi grow upon damp plaster, damp wall paper, the interstices of floors, and upon rough surfaces and ledges in empty and also in occupied rooms. The *Chætonium chartatum*, for example, develops on paper and on the binding and insides of books wherever they are near a damp wall. Paper and size are well adapted to the settlement and multiplication of molds and probably also of some pathogenic microbes.

Bricks, mortar, plaster, and paper are all highly porous, and admit the passage of air continually through them. A common brick can absorb a pound of water, and plaster is also hygroscopic. We have, then, this condition in a room, that it is surrounded by damp, porous material, largely contaminated with organic dust and gases from the interior condensed within the walls and in the flooring or carpets. The resemblance to porous, damp, contaminated ground which is a known source of disease, is sufficiently close to make it highly desirable that better provision should be made (1) against damp in walls, (2) against the penetration of organic vapors and dust into the material of walls and into the interstices of floors, and (3) for the easy cleaning of walls with soap and water, and of floors which should be without interstices, by dry rubbing or with paraffin or otherwise.

AERATION AND SELF-PURIFICATION OF RIVERS.

The oxygen of the air contained in water has been supposed to play an important part in getting rid of the contamination of organic substances and in diminishing the number of pathogenic microbes in the water of streams used for drinking. A large number of experiments have been made in different countries with the object of determining the degree of safety with which water may be used for public supply which has run in the open air for various distances after contamination with sewage and other impurities.

The investigation is by no means a simple problem, and where the bacteria are found to have greatly diminished in number in the course of a few miles, the result is often due to other influences besides aeration, of which gradual dying out of the organisms is one, and sedimentation commonly the most efficient. Frank's experiments on the River Spree, at Berlin, showed that, though in flowing through the city, the river contained hundreds of thousands of bacteria in the cubic centimeter, the water some miles lower contained only 3,000 to 8,000, about the same number as in its upper course. In the Isar, below Munich, the number fell from 15,231 to 2,378 in the course of 22 miles. In the Thames and the Ure, Frankland did not find any considerable diminution. The Massachusetts State Board of Health found in the course of 23 miles a diminution of free ammonia from 1,728 to 1,299, of albuminoid ammonia from 826 to 382, of total nitrogen from 3,000 to 2,156, and an increase of nitric acid from 218 to 457. Oxidation to an important degree is shown in this case, but the result is not altogether favorable to the efficiency of aeration. In observations made on the River Limmat before and after passing through Zurich the following were the results:

	Distance in kilometers.	Number of bacteria per cubic centimeter.
Outflow from lake	0	225
Station 1	1.86	1,731
Sewer outlets	2.175	296,670
Station 4	2.485	12,870
Station 5	2.796	10,892
Station 6	3.417	5,902
Station 7	5.903	4,218
Station 8	6.214	2,346
Station 9	8.078	2,110

Miquel found in the Seine above Paris a rate of 4,800,000 microbes in the liter; below Paris, 12,800,000; in sewer water, 80,000,000.

Instances of outbreaks of typhoid through the use of river water contaminated miles above the intake are not rare. Gloucester suffered by the poisoning of the river by Kidderminster, 20 miles higher up. A single case of typhoid produced the disease in a Scottish town by the drawing back up the course of the river, owing to the obstruction of a weir, of the sewage which had entered below. At Providence, R. I., an epidemic was caused by the very slight pollution of a large and rather rapid stream 3¼ miles above the intake. When Lowell, Mass., has had a fever outbreak, Lawrence, lower down, has had a similar attack a little later. The Merrimac River has given several instructive examples of typhoid following pollution, and the Schuylkill, which is contaminated many miles above the intake of Philadelphia, appears to be the chief cause of the prevalence of the disease in that city.

Experiments on the artificial aeration of water by the Massachusetts Board of Health, and on natural aeration below Niagara Falls by Professor Leeds, show that little or no diminution of organic particles, and no chemical purification, is brought about.

Dr. Percy Frankland has found that various disease-causing bacilli present no uniformity in their behavior in potable water. Many preserve their vitality for a considerable time—days and weeks—and some, which form spores, for an indefinite time. Gaffkey's typhoid bacillus preserves its vitality even in distilled water for about fourteen days.

Altogether, aeration can not be trusted as effectual in rendering polluted water fit for drinking, and the diminution of organisms which to some extent does take place must be attributed to other causes.

ACTION OF BACTERIA AND OF THE AIR IN CONNECTION WITH DECOMPOSITION AND PLANT GROWTH.

Bacteria, or microbes in general, of an immense number of different kinds are almost ubiquitous on the whole surface of the earth and on all exposed solids. The favorite habitat of most kinds is the moist surface of some substance of organic origin undergoing decomposition. But some sorts appear to flourish on almost any kind of solid exposed to the air. Thus panes of glass, rocks, metals, tiles, and sand will furnish a crop, the richer, no doubt, for any slight deposit from organic liquids or gases. The chief work, and a very vast one, of microorganisms is the transformation of dead organic matter into "inorganic" substances. All the dead vegetable and animal substance lying exposed or where air has access is being transformed into mineral matter by this agency. Decomposition generally consists of oxidation by a class of microbes which take their oxygen from the air, and then the transformation and use of the oxygenized products which sink deeper into the earth by another class of microbes, the anaerobic, which not only themselves detach oxygen from its new compounds, but allow of its being united with products which are formed by chemical changes as a result of their activity. The whole process converts the nitrogenous elements into ammonia, nitrous and nitric acids, carbonic acid and water, and produces also phosphoric acid. It takes place most readily in porous, somewhat moist earth and at a high temperature. It is a necessary preparation of the soil for the life of plants. The active bacteria of this decomposition, nitrification, or mineralization do not extend to any great depth, generally not so deep as 12 feet, below which the ground is sterile. The rapid oxidation going on near the surface leaves little free oxygen for the use of bacteria even at the depth of a few feet. The decomposition effected chiefly by the aerobic bacteria in the upper layers enables plants to draw nutriment from the new products, and thus the presence of air and bacteria in the mold are necessary conditions for the growth of vegetation. These newly discovered facts must have a very important bearing upon agriculture. The relation of air supply, soil, temperature, and moisture to the microbic life in the earth, and consequently to growing crops, will become a fruitful subject of research to chemists, bacteriologists, and scientific farmers.

Most of the diseases of plants are dependent to a very great extent on conditions of weather, and many are transported by the air to new situations where they spread as from a center. Thus they differ from the spreading diseases of animals, which are not, on the whole, mainly affected by the character of a season, and are not carried so far through the atmosphere. The number of plant diseases of an infectious kind, depending on fungi or microbes, is very great. The vine alone is attacked by more than a hundred species. Some species live in alternate generations on different plants; thus the rust of wheat requires the barberry plant for one of its stages of development. The spores of mildews and microscopic fungi are generally ejected in great numbers and with some force into the air, and are carried from plant to plant, or field to field, by the air, as, for instance, the potato disease, *Peronospora infestans*, and the mildew of the coffee plant. Heat and moisture, dew and gentle rain, are favorable to the growth and spread of most diseases of plants. The fungus of dry rot grows in damp, unventilated places on badly seasoned wood, and when about to produce spores, seeks the light; its sporangia dry up and discharge innumerable spores. The common ferment of grape juice, the *Saccharomyces ellipsoideus*, grows on the surface of the grape, and when it gains access to the fermenting vats develops enormously by budding and division; when its development is hindered, as by drying up of the liquid, spores are formed, which are capable of resisting dryness, high temperature, and various conditions without losing their power of germination. They may thus be carried alive to a new habitat. This action is characteristic of a great number of ferments, of minute fungi, and of microbes generally, and explains the transmission of many diseases both of plants and animals. The globular spore case of mold, such as appears on fruit, jam, bread, etc., scatters its spores in all directions, each spore being about one three-thousandth of an inch in diameter. These float in the air in great numbers. The spores of oidium, again, a vine disease, escape into the air as fine dust, and spread with extreme facility. The sudden appearance of potato disease in a field is due to the field having been sprinkled with the spores of the peronospora in dry weather, and to the quick development of the zoospores when favored by damp, either rain or dew. The smut of corn produces extremely light spores, about one five-thousandth of an inch in diameter; these float in the air, and have so strong a resistent power that they will germinate in water after having been kept for years in a dry place. The peziza of the lily disease fires off ascospores which are carried by the wind to rich soil where they germinate, produce hyphæ, bore into the tissues of the plant, and shed millions of spores around. A disease of the pine is associated also with the groundsel, on which the fungus spends a portion of its existence. The hop mildew is borne by the wind, and has been found to be to some extent averted from threatened fields by thick woods or large hedge rows.

A great deal of disease in plants and forests is produced through wounds, to which the air conveys fungi which accelerate decay. The decomposed organic matter becomes a suitable soil for the development of fungi, which are not parasitic on living parts, and spores from these are very abundant. The hyphæ of the disease fungus follow up the poisonous action of the juices of the mold fungus and spread into the contiguous wood. True wound parasites also alight on the damp surface of a cut or broken branch and extend their mycelium into the living tissues, gradually bringing about the death of the tree.

These and very many other spreading diseases in plants can only with difficulty be controlled when their spores are given off in large numbers, and when the vegetation on which they alight is damp or in a vulnerable condition. Various applications have been tried to save plants, such as potatoes and vines, from attack, and though partially successful, they involve much trouble. The best security is the prevention of the emission of large numbers of the disease spores into the air from decaying or affected plants, and to cultivate only those varieties of plants which are most immune from infection. The extent to which plant diseases are transmissible through the air has never been ascertained. It seems probable that, with the exception of wide-spread disease in exceptional seasons, the diffusive action of the wind would, in general, so disperse the germs as to render them harmless to healthy plants not too near together. If this be so, then the careful destruction of centers of infection as early as possible would very greatly reduce the prevalence and damage of the diseases of plants. The preservation of fruits, such as apples, is only successful where care is taken that they are not too near together, and that those attacked are speedily removed. But in damp, warm places the spread is too rapid for such measures to be effectual. Dry, sterilized air might be found a valuable means of preserving fruits, vegetables, and provisions generally.

INFLUENCE OF WEATHER ON INSECT PESTS.

The effect of a particular kind of season on insect pests is worthy of more attention than it has hitherto received. The importance of attacking in time and as far as possible destroying the insect life which, if neglected, inflicts incalculable damage on crops and gardens, has scarcely been realized, owing to the blight being generally regarded as a necessary evil, not to be foreseen or prevented. The development of insect pests is generally favored by dry weather. Stunting of the growth, and overmaturation of the sap of plants induce early changes in the maturing and structure of aphides; the insects multiply without the interference of the ordinary destructive influences of bad weather, and delicate maggots, etc., which are generally drowned in very large numbers by storms of rain, emerge unharmed. At the same time it may happen that corn and other crops may be enabled by earlier hardening of the case, stalks, etc., to protect themselves against attacks which in wet years would bring serious damage. In some countries, and in respect to some crops, it is customary to arrange the date of maturity with special regard to the protective power of the plant and the period of expected attacks from insects. The whole subject is at present too little under scientific observation, and great benefit might result if the following branches of inquiry were systematically investigated: (1) The influence of different kinds of weather in developing insect pests; (2) the time of appearance of crop insects in different seasons in relation to the weather, and the time at which crops are most open to attack in different seasons, according to the weather; (3) the treatment of the ground in drought with a view to destroy threatening pests in their early stages, and, in general, the conduct of agricultural operations with regard to the probable development of particular pests resulting from particular kinds of weather; (4) the issue of forecasts of insect prevalence, derived from a careful study of the habits of various species of insect pests, and of the weather of present and previous seasons.

ACTION OF PLANTS ON THE AIR.

Plants in general take up free oxygen from the air and during the night exhale a small quantity of carbon dioxide. They also give a large quantity of oxygen to the air by the breaking up of carbon dioxide into carbon and oxygen through chlorophyll. The oxygen is set free, while the carbon is retained. Experiments have been made on various plants with the object of ascertaining the amount of oxygen which they absorbed at different temperatures. The following are some of the results:

Five seedlings of *Tropœolum majus* absorbed 1.04 cubic centimeters carbon dioxide of oxygen per hour at 35° C.

Four seedlings of wheat absorbed 0.088 cubic centimeter of oxygen per hour at 15.4° C.

Each plant has its temperature of maximum absorption. Wheat evolved 37.6 milligrams of carbon dioxide per hour at 40° C. The maximum amount of carbon dioxide evolved at the temperatures does not correspond with the maximum of oxygen absorbed. Variations in the composition of the atmosphere do not interfere with the respiration of plants, and the relations of the amounts of these gases absorbed and evolved, unless those variations are extreme, and not occurring in natural conditions.

Plants have been placed under glass shades, with their roots immersed in water containing free carbonic acid and certain salts, and with their upper parts exposed to a north light in carbon dioxide, hydrogen, and nitrogen. In the carbon dioxide they did not thrive. Convolvulus throve very well in nitrogen, mixed with a third part of carbon dioxide, and after three weeks these gases were found to be mixed with so much oxygen as to approach the proportions in the atmosphere. The power of plants to produce in a closed space an atmosphere resembling that of the globe might well form the subject of research on a great scale.

THE INFLUENCE OF FORESTS ON CLIMATES.

The influence of forests on climate is now much better ascertained than it was thirty years ago, at any rate with regard to temperate regions. But the importance of preserving trees, woods, and forests is far from being recognized as it ought to be by Governments and by the people generally.

The annual average temperature within forests is slightly lower than in the open. The difference is greatest in summer, least in winter. The day temperature is less, the night temperature more, than in the open. In summer, a beech forest is more effective for cooling than fir or spruce. The soil temperature is lower in forests, especially in summer, when the difference may amount to 14° F. The mean annual relative humidity is from 3½ to 10 per cent greater than in the open. Nearly one-fourth of the rainfall is intercepted by the trees and evaporated or slowly conducted to the ground. Forests somewhat increase rainfall, especially on high ground. The humus formed from fallen leaves diminishes the evaporation from the soil by more than one-half. The whole effect of forests is to retain and more equably distribute the moisture throughout the year, so that streams flowing from them are not torrential, and not subject to heavy floods, but are kept well and moderately supplied. By the prevention of excessive heating of the soil by the sun, and by the diminution of range of daily temperature and of sudden changes, malarious fevers are reduced. The mitigation of strong winds, of hot sunshine, of blizzards, and intense frosts is favorable to health, and generally the shelter and amenity of well-distributed woods, copses, and forest trees are of great hygienic and agricultural importance.

CERTAIN PHYSICAL QUALITIES OF THE ATMOSPHERE.

It is a law of gases that the volume of a given mass is inversely as the pressure; otherwise stated, the density at a constant temperature is proportional to the pressure. The resistance to compression, then, is proportional to the pressure. Yet the law is not exactly true at various pressures and temperatures. Air follows it very closely. Air and nitrogen are, for pressures up to 20 atmospheres at least, more compressed than if this law were exactly true. Amagat, by a fine series of experiments with a tube of mercury extending about 1,000 feet into a deep coal pit, found that air is slightly more compressed up to a pressure of about 80 atmospheres, and then begins to be somewhat less compressed. At about 400 atmospheres the deviation on the side of less compression is nearly one-fifth of the volume, the value pv, or the pressure multiplied into volume, being 1.1897 compared with the original unit. For pressure diminished below that of the normal it appears, so far as experiment has hitherto gone, that the value pv is practically constant down to at least one eight-hundredth of an atmosphere. No determination has been fully verified for pressures below one-thousandth of an atmosphere. The air at a height of 90 miles is still sufficiently dense to set meteors on fire by friction, but can not exert more than one three-thousandth of the ordinary pressure, unless, indeed, the atmosphere be surrounded by some lighter gas. Both air and meteor are at a temperature below —180° C. before contact takes place. The experimental difficulties of ascertaining the values at these low pressures are exceedingly great.

PROPAGATION OF SOUND IN AIR.

The rate of propagation of sound in air is believed, on theoretical grounds, to increase in some slight proportion with the intensity of the sound. The mean velocity of the explosion sounds and air waves of Krakatoa, in the eruption of 1883, was about 700 miles an hour, or less by about 23 miles than the velocity calculated for sound in air at 0° F.; it corresponded with the theoretic velocity at between —20° and —30° F. How was the rate affected by the temperature of the upper air, and what mean value of temperature can be assumed in that total propagation? The rate of movement diminished in the second and third circuits of this great air wave round the globe; the rate for the first passage in one direction was 10.23 per hour; for the last, 9.77 per hour; in the other direction, 10.47 and 10.27, respectively; so that a diminution of rate with diminishing intensity does seem to have occurred. The high temperature of the tropics does not appear to have raised the rate, as might be expected, above the rate in the temperate zones. Nor did the air wave travel faster, so far as can be deduced, than ordinary sound, although, considered as a very low note, it might theoretically be expected to do so. The velocity of the wave in the tropics toward the east was retarded; in the extratropics toward the west was retarded toward the east accelerated; from the data available in the report of the Krakatoa Committee of the Royal Society of London it appears that in the tropics there was an excess of general movement of air from east to west of about 14 miles an hour, and in the extratropics an excess of 14 miles from west to east. Thus the propagation of the air waves throws some light on the mean air movement within and without the tropics. The effect of cold in the regions both of the South and North Poles was not what might have been expected; there was no discoverable retardation by the low temperature. All these results have yet to be interpreted, but may perhaps themselves contribute toward a better knowledge of the laws of the transmission of sound and great waves in air.

The sounds of Krakatoa, which were audible over an area exceeding twice that of Europe, were not very loud in some places in the immediate neighborhood of the volcano. It seems as if the mass of falling ashes, pumice, mud, etc., and the great variations of temperature and humidity in the midst of the hot materials must have exerted a powerful dulling effect. Striæ or laminæ of alternate hot and cold air seem to be very capable of diverting and reflecting sound waves.

With regard to the conveyance of ordinary sounds in air in various kinds of weather, Professor Tyndall and others have arrived at certain results of much scientific interest and practical importance. The condition of the air varies very greatly with regard to transmission of sound, and often without any apparent cause. Fog, rain, hail, and snow do not sensibly diminish sound. The most powerful cause of stoppage is nonhomogeneity of atmosphere, or aerial reflection by a number of currents, columns, or laminæ of different density. On one day guns and sirens were heard at 10½ miles; two days later were inaudible at 3 miles. Water in the state of vapor mixed with air, in nonhomogeneous parcels, acts powerfully in wasting sounds. Not only clouds, but layers of transparent air, may produce echoes both intense and long. The power of the particles of cloud to produce aubible echoes has been doubted by Tyndall; but we may observe that a grove of trees in leaf, even of larches and pines, has a very strong effect in reflecting sound and in heightening its pitch. Let any passenger by railway note the marked rise of pitch as the train passes between woods of beech or oak. The sound resembles that of a small cascade, or of wind among rustling leaves.

The blasts of the fog siren have hitherto been found to be most effectual of all sounds tried for prolongation, penetration, and small cost. Its audibility is good at a range of 2 miles under all conditions. Experiments are still needed in order to attain a higher efficiency in sound propagation for maritime and other purposes, and to ascertain the effect of air in various conditions. The transmission and collection of sound through a few miles by means of suitable exciters, polished funnels, and acoustic mirrors of large size has not been developed as it might be.

AURORA BOREALIS AND AUSTRALIS.

The aurora borealis or australis is very far from being understood. The height of the luminous arch has been variously estimated and calculated as between 33 and 281 miles, and no doubt greatly varies in different latitudes and in different displays. The greatest height estimated was 500 miles. But in high latitudes the aurora has been observed to emerge from the tops of hills and even as a rule from the ocean, but not from ice floes. Loomis has given much information concerning the distribution of the aurora over the globe in the Smithsonian Report for 1865. Near latitude 40 in the United States only 10 auroræ, on an average, are seen annually. Near latitude 42, about 20; near 45, about 40; and near 50, about 80 are seen. Between latitude 50 and 62 auroræ are seen almost every night, as often to the south as to the north. Farther north they are seldom seen except in the south, and from this point northward they diminish in brilliancy and frequency. Near latitude 78 the number is reduced to 10 annually. In the meridian of St. Petersburg the region of 80 auroras is found between 66° and 75°. The region of greatest auroral action is a zone of oval form encircling the North Pole. This zone resembles a line everywhere perpendicular to a magnetic meridian. In Europe auroræ are much rarer than in North America. Some auroral displays, such as the remarkable one of March 30, 1894, are visible both in Europe and America. It seems that an exhibition around one magnetic pole is often simultaneous with a similar exhibition around the other magnetic pole of the earth.

The aurora appears to be the result of the agitation and vibration of particles of air under the influence of the passage of an electric current, diverging from the magnetic polar regions. The current passes where the resisting power is least, that is, in highly rarefied air, dense air and a vacuum both offering too much resistance to be used for the course of the current. It strongly affects telegraph wires and corresponds with earth currents of uncommon intensity. It has been supposed by Sabine and others to be connected with disturbances in the sun, which, again, depend on the position of the planets. Sun spots and auroræ were considered to be at a maximum in periods of eleven years; auroræ and earth currents to be due to small but rapid changes in the earth's magnetism; the upper conducting strata of the air to behave like a secondary coil, and the sun to act like a primary current which produces magnetic changes in the core of a Ruhmkorff machine. There seems to be no doubt of a connection between the periods of sun spots, of the variation of the magnetic needle, and of auroræ.

Some observers have noted a connection between these lights and great cyclonic storms, but they are certainly not always followed by bad weather, and in North America have been associated with clear skies. Moreover, the height at which they traverse the air renders it unlikely that they should be either the cause or effect of disturbances in the lower air.

Occasionally the elevation of moisture and cirrus cloud to a great height may afford a readier than ordinary means of transit to electric currents. Generally, however, cirrus cloud does not extend to one-tenth of the calculated height of the aurora, and can hardly aid in forming a passage for the current. That some visible effect of induction may be produced on cirrus and high cirro-cumulous, which are themselves electrified, is not improbable. The present writer was once greatly struck by a very extraordinary arrangement of high cirrus and cirro-cumulus clouds in closely packed, detached, reticulated, and nearly rectangular compartments, covering the whole area of the sky overhead, from 9 to 9.50 a. m. on November 17, 1882, in London, and learned afterwards that at about 10 a. m. a great magnetic storm had occurred over the country. The radiant point was about north. The appearance of the clouds was represented on paper at the time, and the diagrams were afterwards submitted to members of the Royal Meteorological Society.

The simultaneous appearance of an aurora in northern Europe and in America rather discounts the supposed connection between this phenomenon and the weather, for changes very rarely take place about the same time and in connection with each other over this wide area. March and October, the months of maximum display, happen to be months which are often windy in England. The cause of the aurora is rather to be sought in changes which come within the scope of astronomical inquiry. The spectroscope has not given much information regarding the nature of the substances which emit the light. The appearance of the aurora greatly resembles the passage of voltaic electricity through Geissler's exhausted tubes.

Observation is much needed in relation to these matters. The aurora, from a meteorological point of view, is interesting as a proof of the great height to which the atmosphere extends. Estimates of the height of the phenomenon exceeding 100 miles have, however, not been fully verified.

METEORS AND AEROLITES.

Meteors, or shooting stars, are within the domain common to both astronomy and meteorology. The moment they enter the atmosphere they are objects of special interest to the meteorologist. It is known that they traverse the air, where it is dense enough to raise them to a white heat, at very great velocities.

Many calculations have been made of the height of particular meteors which have been observed over a wide stretch of country. The statement by one astronomer many years ago as to the enormous numbers[1] which enter the atmosphere daily has been repeated so often, without confirmation by the actual observation of others, that it would be well to obtain independent values for particular areas on which to base fresh estimates. The majority of shooting stars are probably telescopic objects and of very small dimensions, perhaps not larger than pebbles. Particles weighing only a few grains become visible to the naked eye if they enter the air at a velocity of 40 miles a second. Many nights pass in which, with a clear sky, only a very few shooting stars cross the field of view.

It has been suggested by a distinguished astronomer that meteors or aerolites are the products of terrestrial or lunar volcanoes, which have been shot out to so great a height that they escaped from the retaining power of the earth's gravitation. In remote ages the density of the air and the amount of vapor, and consequently the friction, must have been greater than at present; but meteorology offers no objection to the theory, and the problem of their terrestrial or extraterrestrial origin is rather one for geology to assist in elucidating.

ATMOSPHERIC TIDES.

There can be no doubt that large tidal effects are produced in the atmosphere by the sun and moon, but they are not easily detected, for the barometer only registers the weight of the air and not the height, and the weight of a column of certain height is diminished under the crest of a tidal wave. Practically, however, solar and lunar gravitation and their atmospheric tides have no important influence on weather. Provisionally, the barometric effect of the lunar tide has been calculated from observation to be from 0.003 to 0.004 inch. The interest of the question lies rather in its astronomical bearing. The range or

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[1] Four hundred million has been given by one computation.

differences of thickness of the stratum of air through which the heavenly bodies are viewed must be considerably greater at spring tides than at the opposite phases.

THE ZODIACAL LIGHT.

The zodiacal light still remains very much a mystery. It may be a reflection, by a multitude of exceedingly small and light solid particles driven off from the sun, of the solar beams, and, indeed, it seems highly probable that the development of electricity in the chromosphere may be sufficient to propel small particles with much greater force away from the sun than gravitation can exercise in restraining them. When the surface is large compared with the mass, as in the smallest particles larger than molecules, the electric forces need not be disproportionately great to exceed by many times the force of gravitation even of the sun. If the interplanetary spaces be filled with reflecting and nonreflecting motes derived from sun, and moving at a speed much exceeding that of aerolites, we must suppose that our atmosphere is always receiving within its borders multitudes of these particles which are instantly consumed by friction. Moreover, if such emission proceeds continually from the sun, a similar process takes place from the more distant stars, and the whole of recognized space is traversed by small elementary particles traveling at an enormous speed. The phenomena of the tails of comets tend to corroborate this opinion. In fact, considering the immense number of comets in space, it seems impossible that such small particles can be absent. Compared with their extension, their united mass may be very small indeed within the orbits of the planets. Like meteor swarms, they do not apparently affect the motion of comets or of planets. None the less, the part they fill in the economy of the universe may be considerable.

HEIGHT OF THE ATMOSPHERE.

Meteors which have been calculated to pass with ignition through air at a height sometimes as great as 300 miles; auroræ, of which the height has been estimated by careful observation sometimes to exceed 281 miles; and the duration of twilight, with polarizing effects of the sky, giving a height of 198 to 212 miles, agree in showing a much greater altitude for the extension of our atmosphere than was formerly supposed. First 5 and then 45 miles was generally stated as the outside limit. And we have to remember that at this great altitude of about 300 miles the atmosphere is dense enough to produce very palpable effects. It would be a bold proposition to assign a limit to the atmosphere within 1,000 miles.

ATMOSPHERIC DUST AND THE REFLECTION OF LIGHT.

Atmospheric dust, or particles large enough to arrest the movement of light waves, exercise a very important function in the illumination of the air and sky, which would otherwise be dark except in the direction of the sun, moon, and stars. The beauty of land and sea and of atmospheric effects would be vastly reduced if the reflecting particles were absent, and houses not facing the direct sunshine would be inconveniently dark. Ozone and oxygen molecules, in some state probably of aggregation, are concerned in the reflection of blue rays, so that an elimination of the coarser dust would not entirely darken the atmosphere. A complete removal of reflected rays would slightly diminish the terrestrial warmth derived from the incidence of light rays from the general atmosphere, and slightly increase that derived from the direct rays of the sun. Invisible, or barely visible, vapor particles are probably still more efficacious in producing similar effects.

SUNLIGHT AND THE EARTH'S ATMOSPHERE—ABSORPTION AND REFLECTION.

The light of the sun which reaches the earth has passed through two atmospheres, one of the sun and one of the earth, and each of these atmospheres robs the light emitted from the sun's body of some of its brilliancy and an unequal proportion of color, so that the original color of the sun is modified by the successive subtractions from parts of the spectrum before it reaches our eyes. The sun's atmosphere arrests more blue rays than red, and the light from the middle of the sun's disk is more blue than that which reaches us from the limbs, for it has to traverse less of the solar atmosphere. Prof. S. P. Langley has shown that the effect of the invisible solar atmosphere is so important that its diminution by a third part would cause the temperature of the British Isles to rise above that of the torrid zone. The earth's atmosphere, also, has the effect of scattering many rays, and principally those waves which form the most refrangible end of the visible spectrum and gives the impression of blue. By the use of an exceedingly delicate instrument, at a height of 15,000 feet, Professor Langley was able to show that at this elevation, where nearly one-half of the absorbing mass of the air was got rid of, the ray 60, near D, had grown in brightness in the proportion 2 to 3, that the blue end of the spectrum had grown in intensity out of all proportion to the rest, and that a very great length of invisible spectrum became recognizable beyond the visible rays below the red. The amount of energy in this invisible extension is much less than that of the much shorter visible end. The conclusions to which Professor Langley arrived as the result of his investigations on the solar light was that the sun is blue, that the solar heat is greater than was supposed, and that the total loss by absorption in the atmosphere is nearly double what had been estimated. The sun he calculates to be competent to melt a shell of ice 60 yards thick over the whole earth annually, or to exert 1 horsepower for each square yard of the normally exposed surface. The existence of life on the planet, and especially of the human race, must clearly be dependent on the capacity of the atmosphere for modifying and absorbing the radiant energy of the sun.

An investigation of the principal elements concerned in arresting and reflecting the sun's rays would yield results of much interest. The absorptive and reflecting capacity of vapor in the free air has not been determined. The power of any constituents of the air, e. g., ozone and ammonia, apart from dust particles, to scatter the rays of light, is not known. The reasons of the variations in radiation from the surface of the earth on different days when the weather continues clear and apparently unaltered have not been fully made out. Much information might be gained by regular observation at two stations, one on the summit of a high mountain and one on the plain below, of the radiation value by day and night, and by comparing the results with the weather, humidity, and any meteorological phenomena which might be connected with them. Thus, for instance, a comparison of the radiation from the stations on two clear days, one dry and the other humid, would give some idea of the effect of invisible vapor in arresting radiation. If true vapor in a dry state is found in the laboratory not to stop heat rays, the inference would have to be made that vapor in the air often exists in a different but still invisible condition.

WINDS AND TEMPERATURE AT GREAT HEIGHTS.

Balloon observations have shown that a variety of currents are often met with in ascending from the earth to 10,000 or 20,000 feet, and also remarkable changes of temperature, not always in the direction of cold. On September 15, 1805, the air near the earth was 82°, and at 23,000 feet was 15°. On July 27, 1850, after passing through a cloud fully 15,000 feet thick, 17.1° was noted at 19,685 feet, and —36.2° at 23,000 feet. On July 17, 1862, at 10,000 feet, 26°; at 15,000 feet, 31°; at 19,000 feet, 42°; then a little below this height only 16°. Thus it seems that the air may be not seldom divided into adjacent masses differing by 26° or more. On March 21, 1863, up to 10,300 feet the wind was east, between 10,300 and 15,400 feet, west; about 15,000 feet, northeast; higher still, southwest, and from 20,600 to 23,000 feet, west. The changes of humidity are also sudden and great. Rain falls sometimes 4,000 feet above falling snow, at 15,000 feet. At 37,000 feet the dryness of the air indicated an "almost entire absence of vapor," yet cirri floated high above this altitude. On July 27, 1850, the balloon passed through about 7,000 feet of ice-cold water particles, and ice needles formed only at —10°. On March 21, 1893, a small balloon with registering apparatus was sent up to a height much greater than any of which there was previous record, and a temperature of —51° C. was recorded at about 45,500 feet; the air at Vaugirard at the time being at 17° C. This very promising experiment of sending recording balloons to great altitudes seems likely to lead to valuable information on the condition of the air up to 50,000 or 60,000 feet in various kinds of weather.

RANGE OF TEMPERATURE AT GREAT HEIGHTS.

Observations by mountaineers on the Andes and in the Himalayas have shown that the difference between night and day temperatures, at heights about 20,000 feet and over, is extraordinarily great, and that changes are very sudden. The interposition of a cloud of ashes from a volcano produced on Chimborazo a fall from 50° to 15° F. in two hours. The effect of the shadows of clouds on the air and clouds below must be very considerable.

ELECTRICITY AT HIGH ALTITUDES.

Electricity is highly developed in the upper regions. The observations carried on for some years at Pikes Peak, Colo., 14,132 feet above the sea, and about 8,000 feet above the plain, proved that snow and hail are always accompanied by electric manifestations. That St. Elmo's fire, or the brush discharge, occurs when the air is damp with rain, snow, or hail, and that the sparks are often almost continuous in storms of snow and hail, the flakes and hailstones being highly electrified.

The appearance of cirrus suggests the shaping of this cloud by electrical forces, and there can be no doubt that the air above 5 or 6 miles is strongly charged with electricity, which has not yet been experimentally accounted for. The origin is generally attributed to evaporation, by which the evaporated water and the water surface take electricities of different signs, and there is some, but not sufficient, experimental ground for the hypothesis. Gases consist of a vast number of molecules which may be considered as separated from each other, and these can receive an electric charge in such a manner as to make the whole mass of a gas so charged electric. The minute particles of water floating in the air, being better conductors, become more highly charged and present comparatively smaller surfaces with a denser charge continually as they grow in size. In fine weather the air is usually positive, in broken weather more often negative. The upper air is considered to be positive and the earth's surface is negative. Electricity increases very rapidly with height; thus Sir W. Thomson found the potential to increase from 23 to 46 volts for a rise of 1 foot. Clouds in showery weather are strongly electrified and the change of sign is often rapid. In showers and thunderstorms streams of sparks run off from the end of an elevated collecting wire, and sometimes from telegraph wires. Valuable information for the forecast of storms and weather generally might be obtained from observation of the electric character and potential of clouds, obtained through instruments near the surface of the earth.

ATMOSPHERIC CURRENTS ABOVE 40,000 FEET.

The observations of extraneous matter in the upper atmosphere after the eruption of Krakatoa, showed that a current from east to west, of hurricane force (80 miles an hour), prevailed in August and September over the equatorial region, and that a slower movement of the upper air from southwest and west prevailed in autumn over the northern temperate zone. Investigation of the currents of the atmosphere at heights exceeding 40,000 feet is likely to lead to valuable results. Exploring balloons might even show the ultimate possibility of rapid communications between distant places by means of steady upper currents.

Part IV.—Subjects for Research.

The following subjects for research seem likely to yield valuable results in connection with the welfare of man. The bearing of some of the points suggested may be slight or remote, but are not on that account altogether negligible:

The topographical features of different countries in relation to climate and weather, and a comparison of the effect on weather and climate of similar physiographical features and circumstances in different zones and climatic areas.

The influences of forests and cultivation on weather, on humidity, on atmospheric electricity, rainfall, thunderstorms, soil moisture, and the flow of rivers.

The influence of the radiation from different soils and surfaces on climate, as, for instance, of grass compared with fallow, and of sand compared with rock and clay.

The heat received by the soil from the sun in different climates and at different altitudes.

The intensity of solar radiation at different latitudes and altitudes.

The intensity of terrestrial radiation into space by day and night at different altitudes, and the temperature of small objects suspended at high altitudes in sunshine and at night. This might be obtained by exploring balloons.

The temperatures of clouds of different thickness and different character in their upper, lower, and central parts, and at a little distance outside them.

The causes of the down rush and increase of horizontal movement of the air often observed before heavy showers and hailstorms.

The dynamical and thermal consequences of the rising and falling of masses of air.

The action of air in motion, or wind, on calm or stagnant air near their bounding surfaces; the manner in which by friction and by impact masses of air influence other masses whether at rest or in motion, and the effects of the collision of meeting masses of different specific gravity and humidity.

The influence of clouds of various thicknesses and heights on the radiation from the earth's surface.

The nature of the vapor or invisible water screen which often arrests radiation on clear nights.

The capacity of vapor and water of existing in various states in the air, and the reasons for the great differences of state observed, whether as dry or wet fog, mist, haze of several sorts, clouds of many sorts, ice particles and snow crystals of very many different forms, snow flakes of various shapes and sizes, hailstones of various shapes, construction, and sizes, and soft hail, or graupel.

The temperature of fogs and of their bounding edges.

The climatic and geological effects of coverings of ice and snow.

The relation of the temperature of oceans, seas, and lakes to the climate of the neighboring parts.

The variations and ranges of temperature with height in different latitudes and climates.

The extension of soundings of the high atmosphere with thermometers and other instruments by small balloons on the plan recently successful in Paris or at Vaugirard.

The observation by means also of small balloons and recording instruments of temperatures at various heights above the ground in different kinds of weather, say at 2,000, 4,000, 6,000, 8,000, 10,000, 12,000, 14,000, 16,000, 18,000, 20,000, 24,000, and 28,000 feet. Such observations may give very valuable information for the purposes of forecasting, for there is reason to believe that certain kinds of stormy weather are characterized by very great differences between adjacent strata, especially in cold weather and at high altitudes, and that these differences are diagnostic symptoms in many cases. In fine, settled weather the changes are probably much more regular with increase of height.

The absorption, in air, of radiant heat of low refrangibility in different kinds of weather both along horizontal planes and vertically, and obliquely; and the relation of absorption to actual and following weather. The amount of absorption, which might easily be measured by a thermopile and galvanometer directly toward a constant source of heat, or by a bolometer, would be an interesting subject of inquiry in connection with obscure states of vapor and water in the air, and with the forecast of weather.

The loss of heat by drops passing through a known distance of air, both dry and humid, in a certain time. The relation of the rapidity of the loss of heat to the size of the drop, and the difference between the temperatures of the drops and of the air. Similar experiments could be made with ice bullets. The results might elucidate some points in connection with the evaporation and growth of raindrops and with the growth of snowflakes and hailstones. A high tower in frosty weather, or a shot tower, might be convenient for these experiments; or a cliff of sufficient steepness and height.

The effects of the mixture, on a rather large experimental scale, of masses of air of different temperatures, humidities, and electrical states, and of different electrical sign. The resulting humidity, fog formation, and electrical state.

The effects of mixture of invisible steam of different temperatures, of visible steam at different temperatures, and of each of these in different electrical states. The growth of size, and the color, of the steam particles and the effects of absence and presence of much dust or smoke.

The true results of the electrification of jets of steam or cloudy masses, the relation of the size of the deposited vapor particles to the electrification, and the optical effects of various degrees of electrification in air.

The effect of an electric field on the surface tension of drops of water, and the various effects of varying amounts and proximity of the electricity of the charged surface on drops of different sizes. When the electrical field is uniform the surface tension of the drop is only slightly diminished, and the diminution is independent of the size of the drop. Very small drops thus preserve their high surface tension in the neighborhood of an electric field. But when there are a number of charged atoms surrounding the droplets the effect is different; the diminution of surface tension which is brought about varies inversely as the square of the radius of the droplet. The whole subject of the electrification of gases, dry and moist, the electrification of drops of water and their behavior under electrification, and the relation of surface tension in cloud globules and drops to electricity in natural conditions, requires investigation. The "cloudy condensation" of steam, and the optical effects in electrified steam have hitherto led to conflicting inferences, and careful observation has not yet proved a diminution or increase in the size of the water particles or a recombination of dissociated molecules of oxygen and nitrogen. The question is of great interest in many respects, and may have a bearing on thunderstorms, rainfall, evaporation, and chemical problems.

Shortly stated, there are three principal views of the apparent action of electricity on steam. Mr. Aitken believes that the thick condensation, coloration, etc., of a jet of electrified steam is due to the prevention of the coalescence of the very small condensed particles which would occur without electrification. Mr. Bidwell believed that the effects were produced by the conglomeration under electric excitement of particles which would otherwise have evaporated unseen, not becoming large enough to cause visible obstruction of light. These views are related to Lord Rayleigh's discoveries on the behavior of drops under electrification; the drops coalesced when weakly, and repelled each other when strongly electrified.

Prof. Paul Carus holds a very different view, and considers that the condensation effects depend on the action on steam of exceedingly small particles of dust. "One may estimate," he says, "that pure dust-free, unconfined steam at 100° would require a pressure of 10 or more atmospheres to condense it. Add to this dust particles less than 0.000001 centimeter in diameter, and the pressure sinks to 15 centimeters of mercury; in the case of particles of 0.00001 centimeter diameter, to 1 or 2 centimeters of mercury, that is, to pressure increments certainly met with in steam jets. The fact that nuclei of a few hundred molecular diameters are needed is the very feature of these experiments, and explains why smoke and other coarse material is useless, and why the condensation-producing dust must be so highly specialized." Glowing charcoal and red-hot platinum produce effects similar to those of flame, owing, according to Professor Carus, to the escape of clouds of exceedingly minute particles from these objects. "Dust-stimulated condensation differs merely in degree, not in kind, from jet condensation in air," for air always contains fine dust. "Air nominally purified needs only a higher degree of supersaturation to evoke condensation running through the whole gamut of colors." Mr. Bidwell found the following substances active in the condensation of the jet: Air, oxygen, or nitrogen, in which the electrical discharge was occurring; burning and incandescent substances; fumes from phosphorus; hydrochloric acid; sulphuric acid vapor; nitric acid vapor; acetic acid vapor. The following were inactive: Air, etc., in which the electric discharge had ceased for about ten seconds; smoke without fire; bottled phosphorus fumes; ozone, steam, alcohol vapor; formic acid vapor; sulphurous acid. Finding that the effects of a discharge in nitrogen and in oxygen separately were the same as in air, Mr. Bidwell concluded that the action is due in some way to dissociated atoms of nitrogen and of oxygen. Robert Helmholtz suggested such an explanation, having discovered that flames and incandescent substances generally cause dissociation of the molecules of the surrounding air; and Mr. Bidwell hints at the possibility of the necessity of the presence of water, as in so many chemical reactions, to recombine dissociated atoms.

The whole subject is an important one to meteorology and merits a searching and full investigation.

The difference of weight in drops after falling through a measured height in different states of the air, dry and moist, and the relation of loss or increase of weight to size of drop.

The gain or loss in weight of drops similarly let fall, but previously strongly or feebly electrified. These experiments to be tried in saturated and in foggy air.

The increase in weight and bulk of particles and bullets of ice allowed to drop through saturated and foggy air and through misty rain at a low temperature. The ice bullets to be cooled, before falling, down to several degrees below 0° C., and the effect of electrification to be tried.

Similar experiments to be tried in the laboratory; e. g., frozen spheres of water to be rotated rapidly through freezing fog artificially produced in a closed space; the icy spheres and the fog to be electrified, and the gain in weight of the ice sphere to be noted, also the relation of rapidity in rotation and differences of temperature and electric state to the observed increase.

The development of large ice crystals to be attempted in the laboratory, such as sometimes form on the outside of hailstones. Electrification, saturation of air, and great rapidity of movement would seem needful.

The study of the movement of convection currents over a soil or surface heated to various degrees above the temperature of the air. Smoke might to some extent show the manner in which the currents rise and the height to which they reach in continuous streams. The effect of wind, at some height above the surface, in promoting or retarding the unbroken ascent of currents might be observed, in connection with such phenomena as showers, tornadoes, and the formation of cumulus. The effect of a calm above a moving air mass might similarly be shown on a small scale.

The radiation of air and of vapor, separately and together, and mixed in various proportions; also the absorption. Experiment might give information respecting the radiation and absorption of air and vapor in respect of light and of heat in general of various refrangibility.

The radiative and absorptive power of fog or cloud. Experiments might give useful results both in the laboratory and in natural conditions. The effects of dust and smoke mixed with the fog might be observed, and the comparative loss of heat in unit of time by dusty or smoky and dust-free air.

Observations are needed on the geographical distribution of thunderstorms and hailstorms, the influence of mountains, forests, and local winds, and on means of forecast and warning against damage.

The elaboration of plans for the mechanical use of wind power for pumping, irrigation, factories, mills, and traction or propulsion, and for the conversion of wind power into electrical energy. The geographical distribution of wind force, and the areas in which steady, strong winds blow continually or for long periods, need to be ascertained in order to place windmills in economically advantageous positions. The heights above the ground at which wind is strongest should also be ascertained.

Mr. Symons notes that the Hon. R. Abercrombie, in 1875, summed up the results of a study of the oscillations of the barometer in thunderstorms, and concluded that there are two classes of storms in this country—one in which the barometer rises, in the other it falls. The rise is always under the visible storm, and the greatest rise is under the greatest uptake, or ascensional column of air. Dr. Fines, of Perpignan, established a Redier baragraph in 1875, and in a memoir published in 1883 gave reproductions of the traces of several storms. He found that before heavy rain at Perpignan there is usually (1) a decrease of pressure and temperature; (2) with the rain, sudden increase of wind, rapid rise of barometer, and fall of temperature; (3) at the end of the storm rain, reversal of the last three phenomena.

It appears probable that a fall of the barometer before thunder or hail storms may be caused by the increased amount of vapor in the column of air above it, and the rise, in most cases, is simply explained by the condensation of vapor permitting drier air to flow in, and still more by the existence of a cold, heavy mass of air at some rather high altitude, which, indeed, is one of the main causes of the storm. The barometer may very probably in most thunder or hail storms be acted upon oppositely by the two coexisting conditions, a humid column of ascending air and a descending block of upper air colder than the average of its level. Hence the mercury is either stationary or oscillates within narrow limits. The rise under the ascensional column may also be frequently caused by the rapid ascent of a column of air which takes an appreciable time to expand to the lower density of the upper levels. A study of the temperature and barometric movements before storms of different kinds, and with different winds, might lead to a useful prognosis of the course and character of storms, tornadoes, and heavy rains.

Observations on the rate of change of ocean temperatures at different depths in relation to the temperature of the air and to the influence of currents are needed, and also of the rate of cooling and warming of air currents passing over a sea surface of lower or higher temperature.

Experiment is needed in extension of our knowledge respecting the amount of ground air and gases in various soils, their expansion under variations of atmospheric and ground temperatures, of atmospheric pressure, and of natural processes of decomposition. Smoking or scented substances buried in the ground might afford some useful information. Also, respecting the production of gases by bacteria in the soil, the movements and permeation of ground air or gases through various soils, the emission of microbes into the air at different seasons and hours, and the density of microbes in the air near the ground. Also, respecting the depth in various soils at which organic matter best undergoes harmless decomposition, so as not to give out noxious products to the air to a degree dangerous to health, or offensively, so as not to poison wells, and so as to be of maximum benefit in agriculture. The relations of ground air to the ground water.

The amount of dew derived from the earth, directly, in various temperatures, soils, and circumstances; the amount exhaled by various plants, and the amount of organic matter and microorganic life in dew in particular situations, such as malarious tracts and water courses. The depth from which dew may be derived, as, for instance, the measurement of the depth at which the soil begins to be moist on sandy elevated malarious plateaus, where dew vapor emanates from the ground, but the surface down to several inches is dry.

The discovery of some means of determining the amount of moisture belonging to dew proper and to deposition from very humid air on solids in certain states of the atmosphere.

The emission of solid exceedingly minute particles from wet evaporating and drying earthy and other surfaces at different temperatures of air and ground. The emission of organic particles from marshes and drying edges of pools, etc.

The amount of organic matter and number of microbes in the air in different situations, hours, and seasons, as, for instance, in malarious valleys and tracts, and on hills and house tops compared with a height of 3 or 4 feet from the ground, on sandy malarious plains on still evenings, in places subject to cholera, diarrhea, and rheumatism, in low meadows and by river banks at sunset in summer, in places some miles to windward and to leeward of great towns, in streets, in old and new houses, in crowded places, in railway cars and in cabins, and in schools.

An investigation of all the phenomena and physics of evaporation from liquid and solid surfaces. The development of electricity, the effects of differences of temperature, of surface tension of slight impurity and slight films of oily matter, the phenomena of the dust-free envelope, and the conditions of evaporation from the human body would be within the scope of the inquiry.

The determination of the resisting power (1) in pure fresh air, and (2) in foul or rebreathed air in a room, of the various microbes concerned in various diseases of an infectious nature. The effect of dryness of air, of sunshine, of the presence of a minute trace of organic matter, of the character of the material, whether mineral or organic, on which they rest. The effect of ozone, of nascent oxygen, and of the vapors of various antiseptic or "disinfecting" substances. The capability of growth of various disease microbes on culture material intended to imitate the organically contaminated walls or rooms, etc., and the discovery of means for preventing such growth and emission into the air of inhabited places. Examination and culture of microbes and experiment on microbes found on walls of closely inhabited rooms. Cultivation of microbes on size used for papering, and on paper, and on plaster. The observation of the number of microbes in air over various kinds of street pavement. Examination of systems by which the air of sewers and drains may be prevented from entering dwelling houses, and of means by which the drain may enter the sewer from underneath, so that the drain may effectually and permanently be sealed by contained water or sewage.

A very interesting branch of research, and one to which little attention has hitherto been paid, is the formation of ice crystals, snow, and hail. In the free atmosphere, beautiful crystals develop themselves in great variety, mostly hexagonal or six-rayed, but some few with three or twelve rays, and some of less regular shape. At least two hundred different shaped crystals have been observed and drawn, many of the most exquisite delicacy and regularity. Often a single shower yields several different species of snow crystals, but generally there is great similarity in the crystals which fall about the same time. The cause of the difference in shape has not been made out, and indeed is not likely to be fully accounted for by any means at our disposal, but the present writer has been led by many personal observations to the conclusion that the crystals are differently developed according to (1) the amount of dust or nuclei in the air, (2) the electric state, (3) the humidity of the stratum where they have their origin and of the lower strata, and (3) the suddenness or slowness of their growth. He found that in a clear air on a hill crystals on vegetation were clearer, simpler, and more glassy than in the rather foggy neighboring valley; that in the neighborhood (10 miles) of London, where the air was smoky, the crystals on trees were very much more feathery, branching, and opaque, and yielded smoky water on melting. The upper air varies greatly in the amount of contained dust nuclei, in free electricity, and in differences of temperature between strata. A moist southerly wind beating back a cold northeast wind in England generally yields broad, heavy, irregular, conglomerated flakes; a dry gentle wind, with uniform conditions, yields regular crystals, small and thin; a very dry and cold air in the early days of a severe frost sometimes gives showers of pellets of various sizes, roughly hexagonal or polygonal, very dense, thick, opaque, and like a number of superposed plates. In March, and sometimes in April, a soft hail or dense pellets of snow fall in showers with a northeast or north wind, and dry air, the showers alternating with bright sunshine. At great heights in the Alps, the snow in winter is small and powdery; in summer the flakes are much larger.

Hail is often the result of a sudden condensation of very warm, moist air by great reduction of temperature at a great height. The dust nuclei are soon all occupied by moisture condensed upon them, and as the vapor falls to and below saturation point in a high column, it has not sufficient nuclei on which to condense in cloudy form, and precipitation takes place at a great rate, either on the cloud globules or on the snow crystals which fall through from the upper part of the cloud. Since the whole or a great portion of the column of the topmost cloud is below the freezing point, the globules as they come in contact with the falling crystals instantly freeze, and so the crystal grows and falls ever faster, accumulating bands of ice and snowy particles according as the air is clear and saturated, or else densely cloudy, through which it passes. The electric charge being much denser comparatively on a large drop or crystal than on a small one, and the vapor pressure being less, the hailstones grow very quickly, and since they fall rapidly through very thick clouds, they add much ice by mere impact at their base. The radial structure so often observed indicates the origin of the hailstone from a radial snowflake or hexagonal plate. Hailstones of large size are produced in circumstances of great electric disturbance.

Sometimes a hailstone has been found with finely developed hexagonal ice crystals growing like stalactites from a matrix. Possibly the attachment of a flat hexagonal crystal at a certain stage in the fall of the hailstone and the action of electricity in the rapid passage through the air are sufficient to account for these large ice crystals, but they have not been observed in other conditions in nature. Small, long, clear crystals are formed on vegetation in a clear, moist air by radiation. It would be interesting to endeavor experimentally to produce ice crystals of large size by strong electric charges in saturated air below the freezing point and in rapid motion.

THE BEARING OF ATMOSPHERIC INFLUENCES ON PLANTS.

The connection between atmospheric conditions and the development of plants, especially of staple crops, is strongly realized by every farmer in countries where weather varies from year to year. But the subject is an immense one, and its branches extend in many directions, some of which have been little explored, and most of which have only recently come under systematic scientific inquiry in a few places. Most valuable work on agricultural meteorology has been done in the United States, in France, in Germany, and in England. The Climatology of the United States, by Louis Blodgett, published in 1857; The Signal Service Tables of Rainfall and Temperature Compared with Crop Production; the Compendium of Phenological Observations, by Ihne, in Sweden; the work of Lawes and Gilbert at Rothamsted, in England; Wollney's Researches in Agricultural Physics; Adamson's and Boussongault's various and interesting observations on plants; the great work of Sachs on temperature in connection with plant life; and Hoffman's extensive work in the same field afford an excellent ground for further researches, which ought to be based as far as possible on a common plan and to be both national and international.

As regards temperature, the following points may be considered to have been ascertained with respect certainly to a large number of plants of agricultural value. A particular temperature or a narrow range of temperature within certain limits is required for the quickest germination and most rapid growth of each kind of plant. Growth is retarded in proportion to the deficiency or excess of temperature. For each plant there is a minimum and maximum temperature and a temperature most favorable to growth. The sums of the temperature required for a certain growth of similar plants in two places are in proportion to the sum of the temperatures above zero at the places. Plants in high northern latitudes grow more quickly with the same temperature than the same kinds of plants in lower latitudes. Capability of resisting cold seems to increase with the age of the plant, and plants containing much water seem least capable of resistance. Seeds of northern-grown or mountain-grown plants germinate and develop earlier than similar seeds in warmer situations when both are planted together in the warmer place. There must be a maximum fruit formation and growth for some period of time best adapted to the plant or crop. Blossoming and ripening of certain plants, beets and potatoes, however early sown, coincided with that of the planting which took place when the minimum temperature of germination of the plant had been exceeded by the ground temperature. This result discourages very early planting. The highest results in Austria-Hungary were obtained from both beet and potato planted on May 1 as against earlier and later dates. When the necessary earth temperature has been reached, then the seeds should be planted.

The observation of ground temperature ought to be a very important branch of agricultural practice. The temperature at depths of 1½ to 3 inches should be taken daily, and in course of time, when observations and experience have been accumulated, and a classification made of the results for various crops, this will become a more useful and trustworthy guide to the farmer than the temperature of the air. The aspect or exposure, and also the character of the ground, have of course to be noted in connection with these inquiries. In dry ground temperature increases in some ratio according to the size of the particles up to a certain point, and then decreases. This holds good for the warm season. Oscillations of temperature follow in a similar relation. In moist ground the temperature also increases, up to certain limits, with the size of the earth particles, and the ground in a crumbly condition is warmer than in a powdery or fine state of division. In the cold season the coarser ground is colder and follows changes of temperature more quickly than the less aerated or firmer ground.

Fine earth can contain more water than coarse earth, but also evaporates more, and allows less water to sink through it. Penetrability and evaporation are frequently inversely related to each other.

Perhaps some results of ground temperature and moisture observations arrived at by the present writer may be here briefly alluded to, though they were on a small scale. When grass or earth is covered over at night by an impermeable material, the moisture from a little below the surface of the earth exhales, but does not escape, and is deposited on the undersurface of the material and on the grass blades. Plants might thus be kept moist, when desirable, by a covering which could be removed at any convenient time in the afternoon and replaced in the evening. Hollows, depressions, and sheltered parts near the hedges are much more bedewed on most nights, excepting the calmest, than fully exposed places, and the intensity of frost and the sun's heating effect a little below the surface is also generally greater—in fact, the daily and annual range of shallow-earth temperature is greater, but all these results depend on the amount of wind at night in the particular district. Dew, though copious under a close covering, is very much below the normal on the earth under loose coverings or under trees. Since moisture combined with frost is often fatal to plants when frost alone is not, it is important to discover the driest and airiest situations for delicate or early vegetables; if frost and fog with calm are probable, but if the climate is subject to frost, fog, and wind, or frost and wind, a more sheltered situation is desirable, according to the nature of the plant, for some suffer more by cutting winds and others by freezing fog. The southern border, even to some yards' distance, of a thick, high hedge of evergreen, such as holly, is much warmer than other situations, and is most warm on sloping ground. Pasture land, replacing arable, increases the cold due to radiation at night, and also the relative humidity near the ground, for the dew-point is quickly reached over grass. The difference of temperature between the top of moderately long grass (a few inches) and the surface of the earth or bottom of the blades is often very great in the evening and night, 10° or more occasionally, and at 2 inches deep in the ground the temperature of the roots of grass, even in England, may be 26° higher than that of the blades. The temperature close to the surface of the earth under grass rises very quickly immediately after sunrise. The temperature at 15 inches deep was high, 59° to 62°, and nearly uniform in August. These experiments were made on sandy soil, and in the mold of a pasture field.

The relations of the various qualities and conditions of the atmosphere to plant growth in various soils and situations have still to a great extent to be determined. Agriculture depends not only directly, but also indirectly on weather. A certain kind of season has a compound effect on a great number of crops, on each a somewhat different result, and this result has its effect upon the crops of succeeding years. It may be favorable to a weed or to a species of blight, mold, rust, or parasite, as well as to the crop attacked by such pests, and the net gain or loss for the present and future may not be easy to determine. If a particular character of spring is found to have a particular effect, either in hardening a crop for resistance or in developing a pest at some critical time, or in rendering the ground fit for some other crop than one of which the planting seems likely to fail, then valuable results will have been gained. The co-relation of a variety of plants, of birds, of insects, of fungi, with each other, and the relation of each of these to weather and season, have still, for the most part, to be made out. Accurate observations of the times of planting, the times of gathering, and the character of seasons, may render it possible for specialists to inform farmers with a large percentage of success of the best time for their operations in various localities. Weather conditions are exceedingly important in the cutting and carrying of certain crops—hay, for instance, and there must be a particular time of the summer which is most favorable for each district, in view of which grass should be sown and cut, without, of course, any interference with the individual judgment as to the right time, which must vary with the aspect of weather and crop. It would be desirable to use some standard method of obtaining the actual temperature of plants at a little height above the ground, as well as in their roots. The amounts of rainfall and the relation to plant growth in various soils should be systematically recorded. The amount of sunlight and "actinic" energy with relation to various crops has still to be investigated on a large scale; some valuable results have already been obtained.

ABSORPTION AND EMISSION OF WATER FROM THE LEAVES OF PLANTS.

M. Boussingault showed some years ago that plants absorb from the earth and exhale to the air an enormous quantity of water. He calculated that a field of cauliflower, 1 hectare in extent, can emit in twelve hours 20,000 kilograms. M. Deherain states that a young blade of wheat evaporates in one hour a weight of water equal to its own. *Eucalyptus globulus* is supposed to be capable of evaporating eleven times the rainfall of the area which it covers, provided, no doubt, that the rainfall is not excessively large. Oaks are also great evaporators and grow best in wet clay. M. Fautrat, inspector of forests, has found that the quantity of vapor in the air over forests is much greater than in the air over the open country. But exact comparative observations of the amount of water evaporated within and without forest areas in various climates are wanting. Forests have been planted in certain parts of southern France with excellent results in the improvement of health, and malaria has diminished in several instances in consequence of judicious planting. The question of planting in connection with human health is a very important one, and the influence of forests and trees on the steadiness of the water supply makes it very necessary that forests should be carefully guarded by the State in many countries. Vegetation, large or small, should never be hastily destroyed. Trees and hedges are very useful in breaking the force of strong winds, in giving shelter to animals, and promoting the growth of fruit trees and vegetables, and they add greatly to the amenity of the country.

The exact conditions of climate most suitable to each kind of useful crop, tree, or plant, have yet to be determined, though they are in many cases fairly well known. The development and selection of hardy specimens would be aided by trial of the effect of transplanting or obtaining seed from various climates of each species examined. The gradual acclimatization of plants might, under scientific inquiry, be found to be capable of furnishing better results than have hitherto been obtained.

The amount of water collected by trees from the air in misty and damp weather has not been determined, although in some districts, especially where warm, moist winds from the sea prevail, with frequent mist, it must be considerable.

The exact manner in which the spores of dry rot, potato disease, vine diseases, rust, and other plant fungi are conveyed through the air, and how far they may be carried in a potent state through dry and moist air, requires investigation; also the influence of ozone, of sunlight, and of drought upon them when deposited on their host.

The relation of the air supply, air temperature, and moisture to the microbe life in the soil, in connection with the growth of crops, with biological chemistry, with soil emanations, and with diseases.

The assimilation of atmospheric nitrogen by bacilli connected with certain plants; the results of the fermentation; the possible synthesis within the microbe cell of atmospheric nitrogen and nascent hydrogen, resulting in ammonia.

The influence of different kinds of weather in developing insect pests, especially those which are destructive to crops. The cultivation of crops in such a manner as to render them as far as possible proof against such pests, by choice of varieties best adapted for resistance and by planting and maturing them at times least adapted for insect attacks. The issue of forecasts of insect prevalence, derived from systematic study of the habits of noxious insects and of the weather of present and previous seasons.

Experimental investigation of the respiration of plants.

Germination of plants; its dependence on temperature in a great variety of seeds from different localities and latitudes. The influence of temperature of the air on the formation of chlorophyll, and the activity of assimilation and growth in artificial atmospheres differently composed.

The relation of wind to health, as regards force, direction, and duration, and with relation to temperature and moisture. The health of cities as affected by mean horizontal movements per hour and by the number of calms; different periods in the same cities to be compared, and the same periods in different cities. The relation of wind and calm to infectious and malarious diseases, taken separately, and to rheumatism, neuralgia, bronchitis, and colds. The generally better health of towns, villages, and dwellings in high situations; how far owing to difference of soil and how far to difference of climate, especially temperature, daily range, and wind. The comparative healthiness of the upper stories of houses, especially as regards diarrhea, typhoid, rheumatism, malaria, and tuberculosis. The bodily and mental conditions, such as breakdown, fatigue, or depression from overwork, anxiety, or other causes, and all cases of ill health, in which (1) a fine, placid climate and (2) a windy, changeable, moist climate is most beneficial. A comparison of the health and diseases of inhabitants of wild, windy climates, such as those of northern and western Britain, with the health and diseases of the inhabitants of calm, bright climates, if possible not far removed in latitude. A comparison of the health of sailors on board ships with good, airy quarters with the health of the same class of people in the country on shore in about the same latitudes.

MALARIA.

The relation of malaria to various soils, to the aeration of the soil, height of water level, ground respiration, and plant life, with its evaporative power and emission of oxygen. The distance to which malaria can be conveyed over land and sea, and over fresh water, by the air without losing its infective power. The dependence of the vitality of the organism on moisture in the air, on temperature of the air, on darkness or light. The effect of belts of trees, walls, and muslin screens in breaking its potency. The effect of dried air, as in a room with a fire, in enfeebling the organism and nullifying its power to infect. The effect of ozone and of nascent oxygen upon it, and the effect of antiseptics such as thymol, cinnamon, toluol, and aromatic vapors.

Inquiry into the infective power, if any, of malaria from person to person through the air, a few instances having been recorded.

CHOLERA.

The extent to which cholera may be regarded as endemic in parts of India and other countries, the nature of the soil over which air is infected, the most favorable amount of aeration and moisture of the soil, the atmospheric conditions most favorable to its growth and to its invasion of the air and of persons. The atmospheric conditions most favorable to its extension over Europe and America, and the special precautions needed to prevent the transport of the poison in such conditions. The possibility of a system of international warnings of the prevalence of the epidemic at any centers and of forecasts of seasons or types of weather in connection with its probable spread. The experimental use of some liquid, such as crude petroleum, for blocking the pores of earth where cholera is endemic, and preventing the emission of germs into the air. The effect of cultivation of various moisture absorbing and evaporating plants and trees in endemic areas.

YELLOW FEVER.

The transmissibility of yellow fever through the air from person to person and how far, and its dependence on moisture, temperature, wind, and other conditions of the air. The character of soil and surface on which the microbe develops, the aeration of soil, etc., and the possibility of checking its growth and emission into the air by spraying with petroleum or some viscous disinfectant or antiseptic. Since yellow fever germs seem to be aerobic and to grow largely on surfaces, the treatment of street surfaces, walls, ships, harbors, etc., in this way seems promising.

THE PLAGUE, TYPHUS, TYPHOID, AND PNEUMONIA.

The extent to which the plague, typhus, typhoid, and pneumonia are severally capable of passing through and infecting in outside air, and also confined air. Their dependence on infected soils and surfaces, and on aerated or nonaerated soils; on atmospheric conditions, especially temperature and moisture, and on the seasons. Their dependence on human habits and previous life, whether mostly in bad or in fresh air. The influence of breath poisons on the growth and spread of typhus, and of drain or sewer air and gases on animal and human vulnerability by typhoid and pneumonia. Cultivation of whatever germs there may be in stinking air from old drains, middens, putrid sink water, etc., and identification of disease germs if possible.

DIPHTHERIA.

Examination of air for detection of the diphtheria bacillus over polluted surfaces of sandy soil, over ash heaps, decaying vegetable and animal matter, and above drain outlets. Relation of the bacillus to atmospheric conditions where it grows on soil, organic matter, dirty floors, or walls, etc.; how far it is aerobic; how far it may pass through air in different conditions, and how much it loses virulence in dry air, in moist air, and in confined and open spaces. Effect of exposure or aeration in causing it to form spores, if any. Effect of sunshine on the bacilli, with and without air; the diphtheritic poison is rapidly weakened by air with sunshine, but only slowly by sunshine alone. Effect of coating a cultivation of diphtheria bacilli with a very thin film of oil or viscous disinfectant, so as to prevent growth and passage into the air. The favorable temperature, a rather low one, the exclusion from light and air, and the presence of certain other organisms furnish useful points of departure for an investigation of climatic and local conditions of prevalence of diphtheria.

SCARLET FEVER, MEASLES, WHOOPING COUGH, INFLUENZA, AND SMALLPOX.

Distance through which each of these diseases has been known to pass in air in various conditions. Experiments especially with respect to vaccine in relation to the conveyance of smallpox through long distances of outer air. Accumulation of experience and new observations on the virulence of the lymph in dry and humid air, and a comparison with the virulence of pathogenic bacilli of different kinds exposed to like surroundings. Dependence of most of these diseases on air in confined and ill-ventilated spaces for effective spread. How far can ventilation, and how far can diffusion of ozone, disinfectants, and various aromatic substances and vapors counteract the infectivity of the germs?

INFECTIOUS, CONTAGIOUS, EPIDEMIC, AND ENDEMIC DISEASES IN GENERAL.

A full investigation into the comparative health of persons living in fairly isolated places, such as islands or institutions having little communication with populous places, would lead to useful results. The occasions of any outbreak of disease could probably be accounted for and the medium of conveyance identified. The degree of human susceptibility to various infections could be much better made out than in ordinary situations. Moreover, those diseases, such as bronchitis, rheumatism, and cancer, which do not seem to depend for the most part on infection, but on constitutional or atmospheric conditions, could be better accounted for, the possible causes being few. The immunity of children living in several large and very well-managed institutions from the ordinary diseases of children is instructive, and, on the other hand, the frequent prevalence of ophthalmia in pauper schools indicates an effect of bad ventilation upon crowded children of poor vitality. A great sanitary authority demonstrated the enormous fall of mortality following ventilation of crowded places, and another fall following regular daily head-to-foot ablution and insistence on clean clothing.

A comparison of different atmospheric or climatic influences upon similar branches of the same race, through long and short periods. Thus the effect of moving northward to a colder region upon a branch of a race still established in low northern latitudes, and the effect of living at a greater altitude in several different parts of the world might be traced, and the particular elements in climate which produce a change in race characteristic might be to some extent ascertained. The effect of the same climate upon a number of immigrants from different climates; regard to be paid to direct atmospheric action on the constitution and to indirect action through induced change of habits.

An inquiry into the most suitable food for full health and mental efficiency in various climates, and the relation generally of amount and kind of food to climate. How far simple, unvarying food and temperate and active habits and how far a bracing air contribute to the vigor of mountain people.

The effect of sea and mountain air on the majority of civilized people and brain workers; the effect of pure country air on dwellers in large towns; of habitually breathed fresh air on bodily and mental health; and the possibility of greatly increasing the alertness and work power of a nation by better provision for fresh air in schools, offices, factories, workshops, and dwelling houses. The effect of good and bad air respectively upon tendency to alcoholic intemperance. A comparison of well ventilated with badly ventilated schools, and of schools before and after good ventilation, both as regards specific maladies and as regards mental brightness and progress.

The degeneration of the natives of temperate climates when settled in tropical countries, and the grounds for a belief that gradual migration in the course of generations from cold to warm countries may enable them to continue and flourish. The relative capacity of families from Great Britain, from Australia, from the Northern and from the Southern States of America, and from the West Indies of enduring tropical climates, such as those of India and Central Africa. The degree of toleration of hill climates in the tropics by Europeans, and the endurance of families.

How far the diseases of the bowels, liver, etc., which attack settlers from cold climates in the tropics, and how far diseases of the lungs, which attack settlers from the tropics in cold climates, are due to microorganic infection and the slow or quick poisoning resulting therefrom, or simply to hot and cold air, respectively.

The diseases resulting from chill, both in hot and cold climates, and the means of guarding against it.

The effect of climate, both direct and indirect, upon the tendency to nervous diseases and mental diseases, and upon the tendency to suicide.

The influence of climate, direct and indirect, upon national character. The effect on health of clear, dry, intensely cold calm weather, such as prevails in high latitudes and on high mountains, and the effect of dry, hot climates as distinct from moist. Both hot and cold dry climates seem to be healthy and tolerable. Separation of the malarious disease effects of hot, moist climates from the mere effects of heat and moisture of the air.

An investigation of the causes of the healthiness of cold, wet summers in western Europe, and of the means by which some of their beneficial results may be artificially imitated.

A comparison of the healthiness of the different seasons in the same and different portions of the United States, and of the relation of zymotic and other diseases to the condition of the air, and to the temperature of the soil and of the ground air. The variety of climate and extent of surface of North America, and the great system of the Signal Service make that country peculiarly adapted for such an inquiry.

The reasons of the arrest of certain spreading diseases, such as yellow fever and dengue, by lower temperature.

The climates and qualities of air most beneficial to persons suffering from nervous diseases, nervous irritability, and heart disease. An attempt at a classification of climates most suitable, in most cases, for each kind of malady or ailment, separating as far as possible the purely climatic from the human factors, such as accommodation, food, etc. The elaboration of a complete medical climatology, applicable not only to persons, robust or invalid, but to families and races, with regard to temporary or permanent settlement.

An examination of the conditions under which, in the crowded quarters of large towns, population deteriorates, so as to become in a short time, if not recruited from the country, physically and mentally enfeebled, and in a few generations almost extinct. The part played by the continual breathing of bad air, and by the crippling produced by attacks of various maladies most rife in crowded places and bad air.

Contrasted with country air, town air contains an excess of carbon dioxide, less oxygen, no ozone, many gaseous and solid impurities and vapors and an immensely greater number of motes of the finest dust. The air is also heated by pavements, etc., so as to become less bracing. The parts played by these various factors in diminishing vigor might be to some degree allocated.

The effects, direct or indirect, of daily or constant breathing of vitiated air on the mental powers, the will, self-control, and temperance.

The effects of vitiated air on the mothers of families, their ability to feed their infants, their strength, and the health of their offspring.

The diseases most prevalent during calm and during windy weather, respectively. The comparative wholesomeness of similar houses or streets in the most exposed and most sheltered situations in towns and country.

The normal aeration or permeation of walls and building materials by external air and by internal air with its impurities; the fitness of many porous contaminated substances lining dwelling houses for the growth of pathogenic organisms.

Research and experiment as to the best means of ventilation, natural and mechanical, for various climates.

The elaboration of a scheme of aero-therapeutics, including experiments in oxygenation, etc.

The effect, whether great, slight, or practically nil, of the aeration or exposure to natural oxygen of contaminated water, and also of various pathogenic microbes in rivers, lakes, and ponds or reservoirs.

The cause of milk turning sour in "thundery weather" and an examination of air at such times with regard to its microorganic contents, its putrefactive influence, and its effect not only on milk, but on various animal and vegetable infusions. Certain kinds of fungi or germs which affect milk may be enabled to survive in warm, moist air, when they would be killed by dry air; in that case the "thundery weather" would turn milk sour simply because the air is then commonly warm and moist.

Animal flesh and other provisions do not putrefy or turn bad for a long time in dry and desert air; apparently moisture is necessary in the air for the conveyance of live microbes and for their attack on the substance.

Wounds heal very well and rapidly in the desert, and disease is very rare among wandering tribes; inquiry seems to be needed to ascertain how far this is due to absence of microbic life in the air and on substances to which the air has access.

If some diseases and putrefaction and such changes as occur in milk and organic infusions are owing to presence of microorganic life in the air, then those changes and fermentations should not occur in mid-ocean, where care is taken that only air which has not been in contact with any part of the ship, etc., gains access; for the air on mid-ocean is considered to be practically free from living germs. Experiment might best be made on small islands or exposed rocks, such as Rockall, which may be assumed to be sterilized.

The antiseptic treatment of wounds is now recognized by the greatest surgeons[1] to depend less on the sterilization of the air about wounds than on the sterilization of all objects, including the hands, instruments, bandages, etc.; so that it seems that the open air is practically

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[1] See recent addresses of Sir Joseph Lister and others.

harmless to wounds, except, no doubt, in certain unhealthy situations and near the ground. This conviction agrees well with the realization by physiologists and by public health departments of the general rule that epidemics exist through the action of man and not of the atmosphere. "It is in the power of man," in Pasteur's opinion, "to cause the parasitic maladies to disappear from the face of the globe if, as I am convinced, the doctrine of spontaneous generation is a chimera."

The effect (1) of temperature and (2) of moisture in promoting the growth of various kinds of mold, fungi, saccharomycetes, and plant parasites. Ordinary mold seems to grow well at a low temperature, if the moisture be sufficient.

The influence of dry air in weakening various kinds of microbes or fungi in relation to plant and animal diseases. Their growth on various fomites in relation to qualities of the air and to light.

The relation of weather to diseases, not only to those apparently caused by microorganisms, but to a variety of other maladies. A certain climate or a certain kind of weather may give rise to an excess or maximum of a spreading disease by direct influence on the outside growth of a microbe, or by helping to spread the spores or germs, or by increasing the supply of some pabulum, or by effects on wells and water supply, or by affecting the human constitution so as to lay it open to attack, or by producing effects on human conduct which favor the spread of the disease. The contributory factors may be many, remote, or concealed, but such thorough investigation as is possible could hardly fail to give valuable results.

There is generally a main cause in each disease by attacking which much progress is made. The soil temperature in diarrhea and cholera, the dried sputum in consumption, the close air in typhus, have already been thus marked out.

The lesions, or quasi-lesions, by cold and chill, are exceedingly effective in disarming the resistent powers of the body, so as to give opportunity to such diseases as bronchitis, pneumonia, liver and kidney diseases, dysentery, malaria, and many others. The manner in which by clothing and otherwise these consequences of atmospheric variations may be guarded against might well form a subject for research. The rate of cooling of vessels at the blood temperature surrounded by various fabrics would give useful information. Some experiments of Mr. Garrod[1] showed that in a room at about the average annual temperature of the exterior air, when clothes are removed from the human body, the temperature very quickly rises in the axilla to a point 2° higher than before. The blood vessels are of course congested, and colds, etc., are then easily caught. The rise does not take place when the temperature of the room is above 70° F., and increases as the temperature of the air is less.

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[1] Proc. Roy. Soc., 1869, No. 112.

A temperature between 30° and 42° seems to be very favorable to chills, etc., possibly owing to the humidity and conductivity of the air being greater than at lower temperatures, to the absence of the sharp, bracing action of frost, and to the greater number and vitality of microbes in the air than at lower temperatures. Dry, cold winds may have a chilling effect equal to a calm, damp air of the same temperature.

With regard to all these matters of air and health, or season and health, a great deal might be done for the prevention of disease by the public issue of forecasts, or monitions, at appropriate times, showing the character of the maladies common at the season, or to be expected, and giving some plain directions. If this were done weekly, it is probable that the number of lives saved would be larger than those saved by the weather forecasts for coast purposes.

EXPLORATION OF THE ATMOSPHERE IN CONNECTION WITH WEATHER FORECASTS AND A MORE EXACT KNOWLEDGE OF ATMOSPHERIC CONDITIONS.

Captive balloons regularly used, weather permitting, at a number of well-distributed stations, would give valuable information in addition to the ordinary items furnished for the purposes of governmental forecasting. Mountain observatories have already been long enough established to give results which show a different distribution of temperature and pressure before different types of weather. But balloons might be fitted with instruments which would show the pressure and temperature at several heights in succession during ascent and descent, and this information would very probably be important in forecasts, if the height attained were sufficient. Balloon ascents have shown the atmosphere to be frequently arranged in blocks or masses of air of very different temperatures within a short distance of each other, and occasionally in an inverse order to that which might be expected from the law of diminution with height. Thus, on July 17, 1862, the thermometer on the earth was 59; at 10,000 feet, 26; at 15,000 feet, 31; at 19,500 feet, 42; but on descent a little below this height, the temperature fell with extraordinary rapidity to 16. Strata much below the freezing point may have a few hundred or thousand feet above them, currents of air at 40 or 42. The variations are often very large and rapid. The greater the height, within the limits of the cirrus cloud at least, the greater apparently are the differences between adjacent strata or masses of air. Irregularity of temperature and humidity distribution must have a considerable influence on the consequent weather, and a series of balloon observations for a term of years at a good number of stations would probably be of very considerable service both for theoretical and practical purposes.

Free balloons for exploration, such as have given good results in France, might be contrived to ascend to some desired height, and then rapidly to descend, so as to be again available. The hydrogen balloon might, for instance, carry a small vessel containing a substance which would combine with the oxygen and with the vapor of the air at an approximately known and arranged rate; the increased weight of the contents would reverse the ascent at a roughly calculated height, and, except with strong winds, the balloon would descend at no great distance. In calm weather its motion could be watched with a telescope and its approximate height noted. Intelligent persons in towns and villages should previously be instructed to secure the descended balloon and to take readings. Schoolmasters in France have received such instructions.

It is probable that the condition of air immediately preceding tornadoes, cyclones, and blizzards, and thunderstorms or heavy rains would frequently be of sufficiently remarkable character to give ground for generalizations from balloon records by which the advent of these phenomena could be foretold.

ELECTRICITY, CLOUDS, AND RAIN.

The connection of electricity with the formation of rain, snow, and hail requires much fuller investigation than it has yet received, and research in this field is sure to yield interesting results. The upper air is positive, the lower often negative, and the almost invariable necessity for two or more layers of clouds for the production of anything more than misty rain over level ground seems to point to an almost invariable coexistence of oppositely electrified clouds in the formation of heavy rain. Heavy showers and snowstorms always show a large development of free electricity, but of course this may be merely a *consequence* of the agglomeration of the drops, and in no important degree a *cause* of the precipitation. In the heavy clouds of showers there seem to be generally several zones or areas of opposite electricities. The observations on Pikes Peak show the large development of free electricity in the rain, and hail, and snow formed at great altitudes. Howard deduced from Reed's observations that snow and hail unmixed with rain are positive almost without exception. Probably if the snow and hail could have been intercepted in the upper air, it might have been said "without exception." On one occasion, when "a most awful darkness filled the atmosphere" and some rain fell mixed with hail, the positive charge became "as strong as it could possibly be."[1]

Experiment on the electricity of clouds, showers, etc., does not seem to have been continued in recent years, though much might be learned from it in connection with the other conditions of weather. On the other hand, laboratory experiment on the electrification of steam, of smoke, and of small drops has led to most interesting results. An electrified rod, at a few thousand volts, with brush discharge, in a

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[1] Phil. Trans., Vols. XXXI, XXXII.

vessel filled with smoke, widened the "dust-free coat" enormously, and the whole box was cleared of smoke. A discharge from a Voss or Wimshurst machine through smoke causes a very rapid aggregation in masses or flakes along the lines of force, and the soot is left on the sides and floor of the vessel. The most effect is produced when the air itself is electrified, but a knob acts less quickly than a point.

A piece of rubbed sealing wax held about a yard distant from a falling water jet broken into small drops causes the drops at once to cease to scatter, and unites them into large drops as of a thunder shower. A cloud of steam turns into "Scotch mist;" a spherule of water amalgamates with a large mass at the first opportunity; if there be the slightest difference in size or in electrification, the repulsion is exchanged for attraction before actual contact. The opposed surfaces come into collision with considerable violence, even when the relative motion of the centers of the masses is small. Surface tension is overcome, and thus violence of contact promotes the coalescence of drops.

The whole subject is of deep interest, not only in connection with the causes of rain and conditions of cloud formation, but with the physics of the atmosphere generally.

OVERCOOLING, ETC.

Other matters deserving fuller investigation than they have yet received, although they have been the subject of valuable memoirs by Dufour, Von Bezold, and others, are the capability of vapor existing in the atmosphere beyond the normal degree of saturation, "overcooling," as it has been termed; and, secondly, the degree of temperature and other conditions in which small drops of water and cloud globules can exist unfrozen. These questions are of great interest both meteorologically and in relation to physics in general.

With regard to the supersaturation of air, this has been proved to be possible in the laboratory to a remarkable degree when dust is absent, but has not yet been proved in the atmosphere. It seems highly probable that occasionally, especially in very moist air, when much rain and cloud has been long continued, or in the intervals between thunder clouds at a great height, there may be spaces of the atmosphere in which dust is so rare and moisture so large that the ordinary point of saturation may be passed. The accumulation upon drops or snowflakes passing through such a space would be heavy.

The latent heat of condensation from vapor upon cold drops of ice has been supposed, owing to its very considerable amount, to make the growth of such drops or hailstones to a large size by deposition from vapor impossible. But rapid passage through cold air may be found to dispose very quickly of the heat thus set free. Experiment is needed on this point.

With regard to the liquidity of droplets below the freezing point, the fact is fully proved, and clouds and fogs often seem to be still liquid at 12° to 20° F. below the ordinary freezing temperature of large drops. But the degree of cooling which may be borne without freezing, and its dependence upon the size of the globules in the free air, has yet to be determined. Observation of the sun and moon and the diffraction effects in clouds at ascertained heights would be the best available means, short of direct observation at great heights, of fixing the relation of size to congelation at various temperatures.

DISTRIBUTION OF VAPOR CLOUDS.

Experiments with kites and with electrometers have shown that transparent vapor is grouped in masses through the air like visible clouds, but less continuous, and astronomical observations seemed to show a distribution of the atmosphere not only into horizontal strata, but into vertically extended compartments differing greatly from each other. Brief perturbations of polarization, occurring at any hour of the day, have been ascribed to "clouds" of cirrus, etc., too faint to be seen. Recent experiments in the foehn and in other hill and valley winds have shown considerable differences of temperature at intervals of a few minutes. Delicate and sensitive thermometers, hygrometers, and electrometers might well be used for the further discovery of the varying states and divisions of the air in respect of temperature, humidity, and electric state and of the causes of differences.

There is much reason to assume that the atmosphere is divided, like the sea, into many large and small masses of unequal temperature. The great reluctance of waters of different temperatures to mingle, as seen in the neighborhood of Newfoundland and of the Gulf Stream, also at the head of the Lake of Geneva where the Rhone enters, and at the junction of the Rhone and Arve below Geneva, has its counterpart in the atmosphere. It is curious to see a large body of water like the Rhone plunge down toward the bottom of the lake, leaving only floating substances on the surface.

The present author believes that since particles of water in the air a little smaller than those of fine blue haze would be quite invisible, owing to their inability to reflect light, like a soap film a millionth of an inch thick, which is quite invisible, there must be a quantity of water in moist, transparent air which is competent to arrest heat waves by absorption, and is not in the state of vapor. He believes that a theoretical and experimental investigation of the various conditions of vapor and water in the air would lead to interesting and important results. The effect of a thin veil of cirrus, and of a slight, equally distributed haze upon the intensity of solar radiation has been recently investigated at Catania and Casa del Bosco (4,725 feet above the sea). The cirrus was found capable of intercepting 30 per cent of the radiant solar energy. The haze intercepted 23 per cent when the sun was 10 degrees above the horizon, and only 4 per cent when the sun was at an altitude of 50 degrees. When the sky was light blue and cloudless the absorption was greater than when it was deep blue.[1] Of course, these experiments refer to the whole thermal solar energy, and there is at present no record of the varying amounts of absorption of dark heat only, or of the varying loss by radiation from an object on the surface of the earth in different conditions of the unclouded sky.

SOUND IN AIR.

Experiment has still to determine the rate of propagation of sound in air at different temperatures in average atmospheric conditions at those temperatures in different countries; the rate of propagation for intense compared with feeble sounds; the rate for notes of widely different pitch, and what sounds may be most effective at long distances to the ear and to recording instruments. It is conceivable that instruments may be constructed which would enable messages to be sent by the voice or otherwise through long distances of air. Converging lenses of gas have been constructed for focusing sounds, and similar ones might perhaps be utilized if made on a large scale.

The homogeneity and discrepancy or heterogeneity of the atmosphere have been ascertained to be very important in the transmission and arrest of sound waves; it seems frequently to be impossible, with our present knowledge, to distinguish a good from a bad hearing day. The air is often divided, apparently, into laminæ or divisions of different density, humidity, etc., which stops waves of sound and may even reflect them loudly, though transparent. All these points deserve further elucidation, and are of consequence for maritime and military and naval purposes. They may also serve, with other prognostics, for the forecast of weather. The echoing power of clouds of different kinds is not well made out. The practicability of production of sounds in a dense medium, such as air under pressure or in carbonic acid gas, in order to increase its intensity, is worth investigation.

POSITION OF THE PLANETS, SUN SPOTS, AURORÆ, WEATHER, AND CROPS.

Investigation of the reality of connection between the position of the planets, the number and extent of solar spots and prominences, terrestrial magnetic disturbances and auroræ, cycles of weather, and agricultural crops.

AEROLITES.

The number of aerolites, or shooting stars, which enter the atmosphere daily; their size, weight, and any effect they may have on the upper atmosphere. The possibility of any general sky illumination by the passage of small particles, compared to fine dust.

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[1] Rendiconti del Reale Instituto, Lombardo, 1894.

LIMITS OF THE ATMOSPHERE.

The theoretical limits of the atmosphere; whether any portions are being continually lost into space, and gained from space.

ABSORPTION OF THE SPECTRUM.

The absorption and reflection of various portions of the spectrum of the atmosphere, by air and by vapors, at different heights. The connection of radiation and absorption with states of weather and approaching changes; diathermancy and translucency in connection with forecasting. Absorption of several portions of the visible and invisible spectrum in different states of the air.

COMBINED FORECASTING.

An inquiry into and formulation of a plan for a combined system of weather forecasting. In addition to the present schemes and practice of weather forecast as used in Europe and America, it would seem desirable to employ observation of local instruments and phenomena. Trained observers are often able to make a more correct forecast for their district from the appearance of the sky, etc., than they receive from a central office. The training of observers is a necessary preliminary to a much more extended system of observation. The present writer has proved that a great deal of use may be made of a number of different signs taken in combination. Thus the character of a haze, the superposition of currents, the exact character and appearance of clouds and their edges, the length of trail of steam from a locomotive, the color of the sky and sun, and of morning and evening clouds, the radiation from an exposed thermometer, and the size and manner of fall of raindrops, often give a fair prediction of coming weather. These should be used in combination with the reports of barometric and other instrumental readings from the various stations, and in aid of the established system of data used for weather forecasts. Locally observed phenomena, many of them not at present recognized as significant, might, after a certain number of years' observation, have a definite percentage value assigned to each as a prognostic, and the observer, provided with a table of values, might then add up the percentages of all the signs observed on each occasion, and from the total obtain a very fair estimate of probability of coming weather over a district of moderate area. The following table is intended to furnish an example of such a system of local combined forecast, with imaginary figures:

Station: Haslemere, Surrey, England. Time, 9 a. m.

[Probability of rain in thirty-six hours.]

	Per cent.
Upper clouds, cirrus, cirro-cumulus, from west-northwest. Lower clouds, cumulus, from southwest	16
Edges of cirro-cumulus, hard	27
Edges of cumulus, rounded and hard	31

	Per cent.
Motion of cirrus, fast	23
Motion of cumulus, very slow	8
Vertical height of cumulus compared with breadth, great	73
A few waves or close ripples of well defined hard cirrus strata nearly overhead.	84
Length of steam trail, moderate (estimated 90 yards)	52
Color of clouds at dawn, pale yellow	58
Regular or irregular distribution of clouds	(?)
Regularity or variability of temperature and humidity in adjacent strata, etc.	(?)
[Probability of rain in twenty-four hours.]	
Visibility, great	70
Audibility, great	61
Humidity, difference of bulbs, 4 degrees	46
Humidity (increasing or diminishing), diminishing	29
High clouds, increasing	68
Cirrus (straight or tangled), tangled	81
Stars last night, much twinkling	71
Smoke, tending downward	69
Total	877

Probability, rain.

The number of items in the forecast might be much increased with increasing knowledge, and the value of each sign would also increase with continuous exact observation. Moreover, each sign should be studied not as a single item, but as occurring with others, and when considered in relation to others would gain much in value. Thus, visibility is not infrequent in fine dry weather, and also occurs in moist weather, before rain. If observed day after day in fine weather, its value in forecasting is evidently much less than when occurring in somewhat unsettled weather. In fact, each sign has properly a particular value in particular kinds of weather, and the special value has to be ascertained. The length of time during which a certain type of weather has continued is in some proportion to the probability of the ensuing days being of a similar type.

When the total of the various percentages exceeds a certain fixed amount, the probability of bad weather rises to something approaching certainty, and perhaps the probability of fine weather when the amount is minus goes a little further still. When, in addition, the probability announced by the central office from wide data is in the same direction, it becomes justifiable to place reliance on the forecasts for agricultural purposes and general district warnings. It will also eventually be of great use to farmers to have telegraphic information forwarded to districts toward which bad weather is moving, if there is reason to regard the change as more than local when first noticed.

ON SOME POSSIBLE MODIFICATIONS OF CLIMATE BY HUMAN AGENCY.[1]

There can be no doubt that some effect upon climate, shown more by physiological influences upon mankind than by instrumental records,

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[1] This section is derived from MS. written in 1891, but not in any way published.

has been produced by extensive afforesting or disafforesting, substitution of pasture for arable land, drainage of wet land, and irrigation; but certain means still remain untried which, if undertaken on a large scale, would probably bring about more important changes than any hitherto accomplished, with the exception, perhaps, of the drainage of wide marshy areas like the fens of East Anglia, irrigation works in India, and changes in the irrigated area of the basin of the Nile.

The drainage works of the eastern counties put an end to the once prevailing ague of the low levels, and the cessation of irrigation in parts of the Nile Valley seems to have deprived the plague, which was once a dreaded affliction, of its former power. The substitution of pasture for arable land tends to increase the cold of the lowest atmospheric stratum, and ground fogs are favored by the active radiation of grassy surfaces.

The influence of mountain ranges, even of small elevated tracts, upon surrounding districts in a climate such as that of England has long been recognized, and no traveler can be surprised to find fewer fine days and more rain in the hilly country than on the plain, but some of the less striking geographical conditions which tend to increase or diminish the rainfall or cloudiness of neighboring localities have been little noted and appear to deserve investigation. During a visit in September, 1889, to the coast of Donegal adjoining Slieve League, a mountainous cliff about 1,600 feet high, the summit of the cliff was observed by the author to be much more densely clouded than the vicinity; this characteristic is common to high, somewhat isolated mountains on our western coast. Moreover, the beginning of the cloud formation took place at a distance of fully a quarter of a mile or half a mile to windward of Slieve League, so that the modification of the wind blowing from the sea took place long before the strong upward trend caused on actually reaching the cliff. The air was raised and expanded, and its moisture partially condensed by the pressure in advance, due to the opposing mass, and not, as commonly stated in text-books, by the cold tops causing condensation. Now, a similar effect is produced by ranges much lower than the Donegal coast mountains, and when the wind is sufficiently charged with vapor rain would begin to fall on many occasions at a considerable distance to windward, and would always be greater in annual amount near the hills than in the more distant low country. Such instances occur in the west highlands of Scotland, the west of England, and Wales. The excess of rainfall begins at a little distance to windward of the hills, reaches a maximum a little to windward of the highest altitudes, and declines again toward the low country on the other side. The western coasts of Britain, Norway, Ireland, and Spain and Portugal all have a large rainfall, and, on the whole, the number of days on which rain falls decreases continually from west to east, except where mountain ranges or hills demand a fresh tribute of moisture. Thus, in the west of Great Britain, among mountains, the average yearly rainfall is from 45 to 150 inches, and in the west, away from the hills, from 30 to 45 inches, while in the eastern counties it is only from 20 to 28 inches. This very large effect is produced by mountains of moderate extent and of average elevation of 2,000 to 3,000 feet. At Bergen, in Norway, the fall is 89 inches; at Coimbra, in the Spanish Peninsula, 118 inches; at Nantes, 51 inches, and at Bayonne 49 inches. In parts of Sweden and Russia it is as low as 15 inches; in France the average is 30 inches; in the plains of Germany and Russia 20 inches.

But the most striking instance of the rain-compelling power of mountains is afforded by the Khasia Hills, situated about 200 miles north of the head of the Bay of Bengal, and only about one-third of the height of the Himalayas. Here the annual rainfall is said to be 600 inches, of which 500 fall in seven months. At 20 miles farther inland, beyond the hills, the annual amount is reduced to 200 inches; at 30 miles to 100 inches; and at Gowahatty, in Assam, to 80 inches. In the more westerly Himalayas, where the southwest monsoon has already been drained of part of its vapor by passing over a tract of dry land and hilly country, the rainfall is only 120 to 140 inches. Similar instances occur in India, e. g., Bombay, on low ground, 75 inches; among the Western Ghauts, at Uttra Mullay, 263 inches; at Poonah, more inland, 24 inches.

In Mauritius, at Cluny, in the vicinity of mountains and exposed to the southeast trade wind blowing from the sea, the rainfall in almost any month is from four to six times greater than at Gros Cailloux, on the northwest coast, only 16 miles distant.

In England the difference between hilly and level districts is well observed in the winter, when the clouds are low, and when precipitation is less due to ascensional currents than to vapor-laden winds. The clouds on rainy days in winter are very frequently between 500 and 1,000 feet above the sea level. The effect of low hills is consequently most marked at this season. Dartmoor, Exmoor, the Chiltern, Cotswold, Derbyshire, Surrey, and Hampshire hills severally raise the observable rainfall above that of the surrounding country. At the head of the valley of Longdendale, near Manchester, nearly 1,000 feet above the sea level, the rainfall in 1859 was 53½ inches; on the west side, and just over the summit on the east side, 58½ inches. At Penistone, a few miles farther east, it was 39 inches, and at Sheffield, still farther east, 25 inches. The height of the hills producing this effect is about 1,400 feet. Similarly, the fall varied from 39.1 inches at Rochdale to 67 inches at Blackstone Edge (1,200 feet), 32.25 at the easterly foot of the ridge, and 20 inches at York in 1848. In 1859 a gauge on the westerly side of Loch Ard gave 92 inches, while another near Glenfinlas, farther east, gave only 48 inches. The instances of Slieve League, of Hoy, and of the South Downs show that it is not only mountainous masses, but also mere barriers against the wind from the rainy qaurter which cause precipitation. The air will be equally lifted to windward whether the obstacle consist of a mountain or of a galvanized iron screen.

SYMONS'S BRITISH RAINFALL.

An examination of the means for fifteen years at a number of stations in England shows that such cases are not isolated. At Saltash, on the southwest side of Dartmoor, the rainfall was 53.87, at Lee Moor (860 feet), on Dartmoor, 68.96, and at Bovey Tracey, east of Dartmoor, on low ground, 46.08. At Clyst Hydon, the mean was only 34.21; at Exeter, 36.61; and at Exmouth, 34.74. Similarly, at Tavistock (316 feet), near the western edge of Dartmoor, the fall was 54.18; while at Tiverton (450 feet), at some distance northeast of Dartmoor, it was 44.35. At Kingsbridge, to the south, where the influence of Dartmoor was not conspicuous, owing to its position with regard to the prevailing winds, only 37.15 was registered. Taunton, protected apparently by the precipitating influence of both Dartmoor and Exmoor, as well as by the nearer Blackdown Hills to the southwest, recorded only 29.75, against Tavistock's 54.18 and Barnstaple's 41.95.

In Sussex we find that the South Downs, mostly 600 to 700 feet high, and the ranges of hills on the southwest border of Surrey, have an appreciable effect, though they do not exceed 800 feet, except at a very few points. Thus, Arundel registered 34.29; the rising ground north of Chichester, 34.90; Petworth, 36.19; Midhurst, 39.65; Fernhurst, 32.19, against 28.41 at Dunsfold, near Godalming, some miles to the northeast of the hills; 26.55 at Weybridge, still farther east, and 26.13 at Greenwich. At Alton, on high ground (496 feet), the fall was 35.58, against 26.73 at Reading. At St. Lawrence, Isle of Wight, and Osborne, the record gave only 31.20 and 29.91, respectively, and the seacoast from the Isle of Wight to Dover has an average of less than 30 inches. On the low ground of the eastern counties, where the air would no longer be forced upward in crossing the land, the amounts diminish to 24.22 at Royston, 23.78 at Peterboro, 22.81 at Cambridge, 22.63 at Ely, and 21.85 at Shoeburyness. But the low hills of Norfolk and Lincoln raise the amount to 28 and 29 inches.

In the Midlands and northern counties the distribution of rain is similar. Thus, while at Sedbergh, Penistone, and Dunford Bridge, the amounts were 55.26, 56.76, and 55.75, stations at a moderate distance eastward of the hills registered as follows: York, 26.93; Doncaster, 27.33; Leeds, 27.70; Sheffield, 35.02; Stockwith, 23.66; Lincoln, 23.83. The rainfall of Carlisle is remarkable, only 30.07, owing to its position to the northeast of the mountains in the same county, where the amounts reach 80 and 100 inches. In the neighborhood of Sheffield the fall varies from 43.26 at 1,100 feet at Redmires to 33.03 at Broomhall, not many miles distant. Buxton, at 989 feet, has 57.14 inches, and Chatsworth, about 20 miles distant, 36.66. Tunstall, a little eastward of the mountains of the North Riding of Yorkshire, has only 28 inches against 55.26 at Sedbergh on their western side.

In Scotland the rainfall of the northern part of Elgin and Nairn, protected by the mountains intervening between it and the west coast, is less than half that of western Sutherland, Inverness-shire, and Skye. Portree, in Skye, has 81.75 against 25.87 at Inverness. The east coast of Scotland, generally, is very much drier than the west, although the large precipitation during east winds tends to counteract the effect which the mountains westward have in reducing its rainfall during the prevalence of the equatorial currents. Great differences in rainfall may exist within a small area; for instance, the rainfall at Perth is only 32.10 and at Ochtertyre 44.17 against 50 at Lochearnhead, and the rainfall at Bothwell Castle is only 29.98 against 115.46 at Ardlui. At Braemar, at the height of 1,114 feet, the rainfall is only 36.50, owing to the great mass of high mountains toward the south and west.

In Ireland the greatest amounts are registered on the southwest and west coasts, and the fall diminishes inland eastward of the mountains, until in the northeast corner the average is only about 30 inches against 60 to 80 in the west.

Among the above instances the most instructive, perhaps, for the present purpose are the records of Midhurst, Petworth, and Arundel, compared with those a little south and north of these stations. It is plain that the action of the long, wall like ridge of the South Downs, not exceeding 600 feet in average height, is sufficient to cause from 5 to 10 inches excess of rain in its immediate neighborhood, the rainfall 20 miles westward and 8 miles southward, being only about five sixths of that which occurs in close proximity to this ridge. Part of the deficiency on the coast must be attributed to the frequent exemption from heavy showers which form over the land, but not over the sea, in summer. The present author has observed this, especially on days with a light westerly or southerly breeze, and has also noted the preference of thunderstorms for the low ground between the hills and the downs. The greatest fall takes place at Midhurst, which lies about 5 miles north of the South Downs, and at the foot of the southern slope of a second ridge, Henley Hill, about 600 feet high, which stretches from east to west. Compared with Dunsfold, about 17 miles to the northeast, the amount is in the proportion of 4 to 3. Dunsfold is probably deprived of a good deal of rain by the mass of Blackdown (900 feet) 8 miles to the south. Fernhurst, near a cleft or dale in some high hills on its northern side and 2 miles north of Henley Hill, has, roughly, 7½ inches less than Midhurst. That even lower hills (400 feet) in a flat country may raise the rainfall of their climate by 5 or 6 inches is shown by the records of the high ground of Norfolk and Lincolnshire.

Now, the practical inference from these statistics is that it may be possible where desirable to imitate natural barriers on a small scale and to increase rainfall in their proximity in order to diminish it elsewhere. Thus, if between Chichester and Arundel the natural height of the Downs were to be raised by 300 feet, the rainfall would be increased a mile or so southward and perhaps a few miles northward, but would be diminished over the northern half of Sussex, and probably in Surrey, to an appreciable degree.

Similarly, a wall of 400 feet in height between Yes Tor and Hartland Point, in Devonshire, would increase precipitation along a band parallel with the wall, but would give a drier climate to the more easterly portions of the county, and probably also to Somersetshire. In England, not only does the greatest quantity of rain reach us from the southwesterly quarter, but the clouds are lowest in the rains from that quarter, so that the greatest effect of a barrier is produced on rains coming from south and southwest.

The method of construction is a question for engineers. Would it be possible to construct a screen several hundred feet high, of iron, as used in the large gasometers which we see in the neighborhood of our large towns? Or is masonry necessary in order to withstand the extreme possible pressure of strong winds?

The desirability of forming any such artificial barrier would, of course, depend on the calculated probable benefit to be conferred on any county or district, and it would very likely be only in rare cases that the increased geniality of climate would repay the outlay. Possibly it is only worth considering in the case of very wet climates, or of places where little rain falls and more is needed. In England, supposing for a moment that its erection is desirable, the line to be taken for a wall must be such that there would be very little disturbance of natural features of interest or beauty; in fact, it should either be across barren moors or wastes, or else parallel to the cliffs on a desolate coast. The line above suggested from Yes Tor, near Okehampton, toward Hartland Point, appears in all respects a favorable one for the purpose, as the country to be crossed is dreary and almost uninhabited. The wall would have an additional advantage of permitting trees to be planted on its northeast side in a broad belt, so as to make the beginning of a forest, where the winds are now too severe for vegetation. Another favorable stretch of country lies along the ridge of the South Downs between Swanage and Bridport. A high barrier here would give to a large part of Dorsetshire and southeast Wiltshire a climate not unlike that of Bournemouth, which owes its dryness to the hilly promontory of the Isle of Purbeck.

Portsdown Hill, which runs east and west for nearly 7 miles, and is over 400 feet high, would be another highly favorable ridge for an experimental wall, say 400 feet in height. The practicability of works of this kind can hardly be questioned when we hear of structures like the reservoir embankment at Bombay, a stone barrier 118 feet thick, over 100 feet high, and 2 miles long. A less amount of material would have gone toward a wind wall 30 feet thick at the base, 300 feet high, and 3 or 4 miles long.

A wall 300 or 400 feet in height and 5 or 6 miles in length, extending from near the Thames a few miles east of London in a northwest direction, would probably have the effect of stopping a considerable amount of fog, which often moves from the Essex marshes toward the metropolis. It would somewhat increase the annual rainfall on its westerly side. A wall stretching from northwest to southeast across some of the heaths in the neighborhood of Woking would reduce the rainfall of northeast Surrey and of London.

The effect of a wall, like that of a perpendicular cliff, would be to drive the impinging air vertically upward, so that the increased rainfall would take place near the wall and a little to leeward.

Experimental barriers might be first erected across the mouths of valleys open toward the west or southwest, for in many such situations a wall 1 or 2 miles long and 500 or 600 feet high would cause increased precipitation near the ocean, and a considerably drier climate in nearly the whole of the remainder of the valley. For example, a wall across the valley, a little to the north of the town of Neath, would reduce the rainfall of the Vale of Neath for a long distance, and many of the Welsh valleys opening westward to Cardigan Bay might be equally protected from excessive winter rains.

With regard to other countries, there are localities where a structure a few miles long based on rocks or ridges already some hundred feet above the sea would prove very beneficial in reducing rainfall farther inland. In other exceptional cases, where precipitation is deficient, it might be promoted on the windward side by similar means.

In parts of Australia, local rainfall might be appreciably increased by raising the height of ridges. Wherever water is scarce and valuable and the climatic conditions favorable, experimental barriers would give interesting results.

Some American cities are very liable to be attacked and partially destroyed by violent tornadoes or whirlwinds. These storms usually proceed from about the same direction, and it might possibly be an experiment worth making to set up a wall, say 300 feet high and 2 miles long, on the dangerous quarter, with the object of breaking their force. The clearing of forests seems to favor the development and progress of American tornadoes by allowing the surface of the earth to become more highly heated and by reducing friction, for they are caused chiefly by the breaking of unstable equilibrium when the lowest strata are highly heated and a cold current prevails within a few miles of the earth's surface.

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