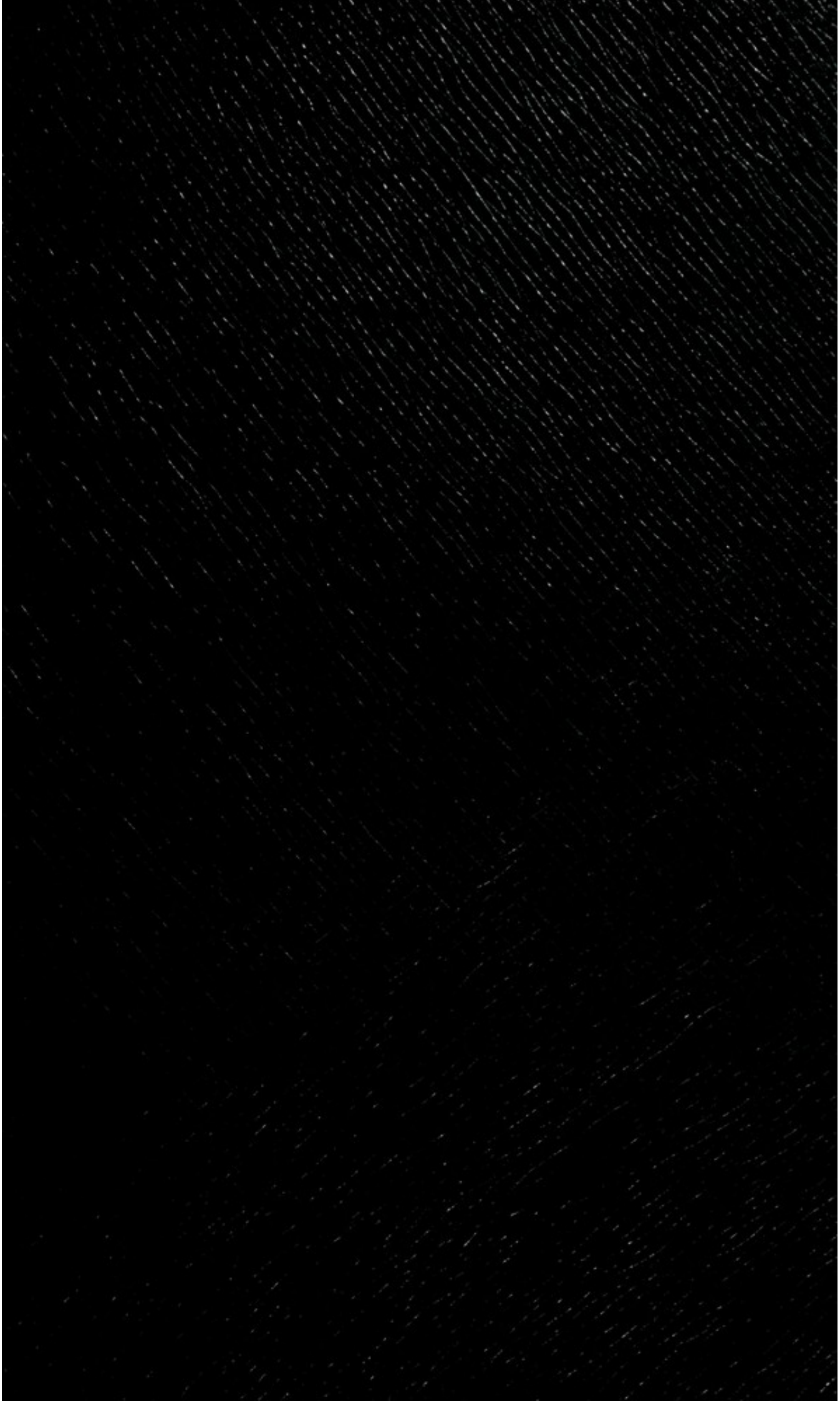
On the effects of volcanic action in the production of epidemic diseases in the animal and in the vegetable creation, and in the production of hurricanes and abnormal atmospheric vicissitudes : the Parkin prize essay of 1901 / by W. G. Aitchison Robertson.



"On the Effects of Volcanic Action in the production of Epidemic Diseases in the Animal and in the Vegetable Creation, and in the production of Hurricanes and abnormal Atmospherical Vicissitudes."

The Parkin Prize Essay of 1901

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"Variæ sunt nempe annorum constitutiones, quæ neque calori, neque frigori, non sicco humidove, ortum suum debent, sed ab occulta potius et inexplicabili quadam alteratione in ipsis terræ visceribus pendent unde aër ejusmodi effluviis contaminatur quæ humana corpora huic aut illi morbo addicunt determinantque."

SYDENHAM: *Observat. Med. circa Morborum Acutorum Hist. et Cur., Cap. II.*

EFFECTS OF VOLCANIC ACTION.

Introductory.

THE questions which we are called upon in this essay to elucidate are of the widest description, and no one has devoted more time or attention to these enquiries than has the late Dr. John Parkin. Any answer to the questions must therefore partake largely of a criticism of this author's theories and deductions.

The investigation includes two distinct and wholly separate inquiries :—

(1.) The effects of volcanic action in producing epidemic diseases in the animal and in the vegetable creation.

(2.) The effects of volcanic action in producing hurricanes and abnormal atmospheric vicissitudes.

The first part of the first question has of course the greatest interest to medical men—the production of disease in man; and it is to this part of the inquiry that we shall devote most of our attention in the following pages.

Aberrations from the normal condition of the atmosphere have from time immemorial been credited with producing the different forms of epidemic disease.

Amongst the ignorant the wrath of God was believed to be manifested against His erring children in various ways, though chiefly in pestilences. The prophets of the Old Testament repeatedly speak of God sending pestilences as well as famine and the sword to destroy certain peoples who had committed some grievous transgression. The very face of the heavens was believed to show the effects of a divine wrath—the sun was red, or red coloured fogs obscured its brightness and cast a constant darkness over the afflicted land; meteors were noted to flash through the sky, or the still more dreadful comet portended some awful catastrophe.

Those who were suffering under the terror of a pestilence would very naturally connect such abnormal atmospheric conditions with the cause of the epidemic itself. It is not therefore difficult to understand how the popular prejudice evolved out of this red sun, red or blue mist or fog, the idea that the pestilence itself proceeded from its presence—that this cloud of darkness itself was the *fons et origo mali.*

Brief Historical Review.

It would be as futile, as it is absolutely unnecessary, to go over the historical part of this inquiry—the relation of epidemic disease to alterations in atmospheric conditions.

The causation of epidemic disease has formed a theme for discussion since the earliest writers have left their records. We may very briefly, however, state that Hippocrates, Galen, Aristotle, and Seneca all believed in there being a "pestilential state of the atmosphere," while Livy, Thucydides, Herodotus, Virgil and others refer either to the coincidence of comets with pestilences, or to some other atmospheric change, such as tempests, extreme darkness, remarkable clouds, etc.

Coming to later and more precise statements, we find that a Dutch physician, named *Diemerbroeck*, describing the plague of 1636 in Nimeguen, approaches very nearly to Dr. Parkin's theory. He cites amongst other causes of the pestilence, one—"that it may be a most malignant, poisonous, and deadly pestilent germ, like a subtle fermentum of leaven sent from heaven in a very small quantity, diffusing itself through the air like a subtle gas, and rendering it impure." [1]

About a century previously, however, an Italian [2] observer had stated that frequent earthquakes announce a future pestilence, and by means of exhalations tend to produce it.

Van Helmont [3] also states that "the pestis is not sent down from heaven, but that plagues draw their first occasional matter from an earthquake and from the consequences of camps and sieges; that the cause of pestilence is a gas or air which has putrified by continuance or stagnation."

Sydenham,[4] writing in 1676, believes that the influence of the air is of the greatest importance as regards epidemics, and that this depends on conjunction of heavenly bodies.

Dr. Nath. Hodges,[5] writing of the plague of London in 1665, says that the air suffers some essential alteration which is necessary to favour the propagation of pestilence. The power thus produced proves injurious to trees and cattle as well as to man. It exhales from the bowels of the earth as a subtle aura or vapour which, from too much heat and humidity, has lost its wholesome qualities.

Van Swieten [6] states that it is probable that exhalations in earthquakes may increase or diminish the deleterious quality of the air in pestilences.

Noah Webster,[7] who wrote the first clear and accurate account of pestilential diseases, was fully convinced that pestilence had an intimate

[1] Diemerbroeck (J.): "Tractatus de Peste." Amst., 1665, p. 30.
[2] Frascatori: "De Contagione et contagiosis morbis." Venet, 1546, p. 136.
[3] Van Helmont: "Oriatrike; or physick refined." The common errors therein refuted and the whole art reformed and rectified. Faithfully rendered into English by J. C., London, 1662, p. 1125.
[4] Sydenham: "Tractatus de Podagra" (Syden. Soc.), p. 428.
[5] Hodges; "Loimologia; or an Historical Account of the Plague in London in 1665, with an Essay on the Causes of Pestilential Disease," by John Quincy, M.D., 1721.
[6] Van Swieten: "Concerning the Knowledge and Cure of Disease," 1776.
[7] Webster: "Brief History of Epidemic and Pestilential Diseases," 2 vols., 1800.

connection with the subterranean heat or principle or fire (p. 169). "I have my suspicions that, while the central fires expel immense quantities of burning lava from volcanoes, they may force through the earth in adjoining continents a subtle vapour that is invisible until it is collected and condensed in the higher regions of the atmosphere" (p. 228).

Dr. Thomas Forster[1] thought that epidemic diseases were not due to heat, cold or dampness of the air, but to some peculiarities in its impregnations combined with its electric state (p. 2); that volcanoes and also earthquakes were capable of causing unwonted movements in the air, but many also threw up foul air of a specific character which, by diffusion, might become the exciting causes of disorder (p. 14). He definitely states that plague and other pestilential fevers are known to originate in atmospheric causes (p. 33).

Many other causes are of course affirmed by other contemporary writers, such as that of *J. A. Begg*, who says that the pestilence is sent because we have not advanced in the path which the reformers had opened up, and because we have ceased to follow their example.[2]

Dr. Bascombe[3] in his work states that the grand phenomena of nature exhibited in the commotions of our physical world supply us with abundant materials for the explanation of all epidemic or pestilential diseases (atmospheric vicissitudes).

This brings us down at last to *Dr. Parkin's* theory. The chief conclusion which he arrived at was that the cause of the production of epidemic diseases is the same as that which gives rise to the eruption of the volcano and the shock of the earthquake.[4] "That they are common effects of a common cause, and that cause is volcanic action."[5] He distinctly states that as yet no direct evidence has been adduced to show that an epidemic has broken out at the same time as a volcano has erupted (p. 36),[6] but on this he lays no stress. For long periods antecedent and subsequent to the actual eruption of the volcano, large volumes of different gases escape into the atmosphere, and he believes that some of these gases are lethal.

This brief summary has shown us that the idea of a connection between terrestrial emanations and the production of pestilences is a theory at least as old as the time of Frascatori, and that Dr. Parkin did not originate the idea, although he has done much to elaborate it. Noah Webster even enunciated the same belief in very similar terms.[7]

Relation between Pestilences and Volcanic Eruption or Earthquake Shock.

It would be wearisome in the extreme to recapitulate all the epidemics which have been thought worthy of record by historians during the

[1] Forster: "Illustrations of the Atmospherical Origin of Epidemic Diseases," 2nd Edit., 1829.

[2] Begg: "The True Cause of the Prevalence of Pestilence and other Judgments of God, with the divinely appointed means of Deliverance and Safety," 1832, p. 11.

[3] Bascombe: "History of Epidemic Pestilences from the Earliest Times," 1851, p. 189.

[4] Parkin: "The Remote Cause of Epidemic Disease," 1841, p. 152.

[5] "Volcanic Origin of Epidemic Diseases," 1887, p. 68.

[6] "Remote Cause of Epidemic Disease," p. 36.

[7] Webster: "Epidemic and Pestilential Diseases," vol. ii. p. 45.

progress of the world. Almost every one of the great plagues has been accompanied either by great terrestrial or atmospherical disturbances, according to the recorder. The earthquake is, however, the phenomenon *par excellence* which we most constantly find as a concomitant to the epidemic, and next in frequency comes the volcanic eruption. Even Seneca asserts that earthquakes and pestilences are closely related. The constancy with which either of these phenomena is noted as occurring nearly at the same time as a pestilence, compels one's attention to this association. Were we to find these synchronisms mentioned only occasionally, then we might well suppose them to be mere coincidences. The regularity of their association, however, almost prohibits such a view, and it will, later on, be our duty to endeavour to show whether there is any valid reason for supposing that the two (volcanic action and pestilence) are correlated.

It is useless for the purpose of accurate research to note the records of the earlier pestilences, as they are either very imperfectly told, or so ambiguously that little reliance can be placed upon their interpretation. In nearly every one of these pestilences, atmospheric disturbances, etc., are noted; *e.g.*, excessive and long continued heat; prodigious cold; eruption of some well known volcano; earthquake shock; appearance of comets (Livy; Orosius; Seneca).

We may therefore pass over without comment those descriptions of pestilences and earthquake disturbances described by Thucydides, Aristotle, Strabo, Seneca, Pliny, and Livy, because, though their accounts are very interesting, no conclusions could be drawn from their statements.

We frequently find the historian stating that a volcanic eruption or earthquake took place subsequent to the epidemic.[1] According to the theory to be stated later on, this is of no account, and does not in the least invalidate it.

Dr. Parkin's Theories.

He believes that the intense heat which exists in the interior of our globe causes a melting of the constituents. This melted matter forms subterranean rivers, which run underneath large portions of our globe, as from the pole to the equator, or even from pole to pole.[2]

He *summarises his conclusions* as follows:—If epidemic diseases be due to some deleterious substance in the air; if substances evolved from the bowels of the earth be usually present in the atmosphere at epidemic periods; and if there be proof that gaseous matter inimical to animal life is given out from volcanic foci, while all the great pestilences have prevailed in well known volcanic regions, we can hardly fail to infer that they are directly produced by the operation of a poison generated in subterranean reservoirs.

As to the validity of these arguments—Firstly: the *condition of the earth's contents*, and as to the molten rivers and reservoirs which Dr. Parkin believes run underneath the earth's crust.

Authorities differ greatly as to the condition of the earth's contents, some holding that they are in a liquid condition. The greater number

[1] Tacitus: An. Lib. XV., p. 47; Lib. XVI., p. 13.
[2] Parkin, Dr. J.: "Volcanic Origin of Epidemics," p. 93-100.

of physicists on the whole, however, agree in stating that the enormous pressure which is exerted on the earth's contents keeps it as a whole as solid as steel; liquefaction is prevented, and the nucleus remains solid though at a temperature at which, but for the pressure, it would be like so much molten iron.[1]

The above paragraph, if true, does away in a moment with the whole grounds of Dr. Parkin's theory of subterranean laval streams. There is, however, no question of its truth, which is recognised by every scientist.

It is but right, however, to state, that even now many geologists adhere to the hypothesis that the contents of the earth's interior are liquid by reason of the immense pressure to which the earth's contents is subjected, and that the molten matter breaks through the[2] contracting crust. The earth's crust is in a condition of both exterior thrust and interior tension. A fracture of the crust with extrusion in the form of dykes or volcanic vents may occur. This accounts for the numerous dykes of trap by which some volcanic districts are intersected, —for example, the north of Ireland or the centre of Scotland.

The idea of liquid laval subterranean streams was at first a Wernerian theory, and was directly opposed to the Huttonian school, and is, in my opinion, quite untenable. In the first place, even were the earth's contents liquid, the idea of laval streams is incapable of proof. It is merely a theoretical deduction, based on entirely insufficient data and quite unsupported by any evidence.

The elucidation of the direction of earthquake travel is too difficult a matter to decide from a few observations only, and the hearing of noises and subterranean rumblings might quite as easily result from the cracking of deep lying strata as reverberations in underground cavities.

I look upon earthquakes and volcanoes as entirely distinct and separate phenomena. Each may be and probably is due to similar causes, but neither of these are related to one another as cause and effect.

The volcano, if one may so express it, taps only a relatively superficial area of the earth's crust, and certainly never reaches nearly to where molten material might exist were the pressure relieved. The distance from the surface of the earth to where the earth content might be fluid has frequently been calculated—and the figure of 8000 to 10,000 miles has been arrived at. It has never been pretended that any volcano extends to anything like this depth.

Causes of Earthquake Shock and Volcanic Eruption.

We have already seen that Dr. Parkin believes that both of these phenomena result from the evolution of immense volumes of steam generated by the contact of water with the molten matter. The steam then either causes an eruption of lava, mud, water or gas through a volcanic vent, or else it heaves and rends the earth's crust as an earthquake, so allowing these gases to escape through the fissures. This ("steam") theory certainly was one which for

[1] Geikie, Sir Arch.: "Ancient Volcanoes of Gt. Britain," vol. i. p. 11.
[2] Hull, Edw.: "Volcanoes, Past and Present," 1892, p. 231.

long was accepted by geologists, and a recent writer states that the greater number of earthquakes are due to explosive efforts at volcanic foci, and by far the largest number of these explosions occur beneath the ocean and are due to the admission of water through fissures to the heated rocks beneath.[1]

Even at the present day, however, very little is really known as to the exact causation of earthquakes. Probably there is not one but several causes at work.

A view still held by a few geologists is that waves set up in the molten interior of the earth strike on the thin crust of the earth's surface, and so an earthquake results. This theory was first propounded by the Rev. John Mitchell in 1760.[2] It gains few adherents now. You cannot have waves set up in a liquid without some impelling force, and were that present, it of itself would produce the earthquake without the intervention of any liquid medium.

The most probable cause of earthquake or volcanic eruption is that some shifting of the underlying strata takes place. The heat thus generated by friction is so great as to melt the rocks, producing gases and vapours, and so leads to the earthquake or to the volcanic vent. Mr. Mallet[3] first enunciated this view, which is now almost universally accepted by seismologists. Owing to gradual contraction of the earth's crust, the result of cooling (secular contraction), a shifting of certain strata takes place, as is seen in the flexing and fracture of the strata. The wave movement thus initiated is transmitted in a definite direction through the strata, and not in a centrifugal direction as would result from a beating on the inner surface of the earth's crust from molten waves. Owing to the enormous tangential pressure, the earth's crust yields either by cracking or wrinkling up, and it is through these cracks or fissures that the molten matters and vapour escape to the surface. These matters become liquefied, owing to the relief of pressure afforded to the earth content at these points where the crust crackles up or fissures. Such lines of relief are not distributed uniformly over the whole surface of the planet, but seem to have followed certain lines, which lines are fairly constantly the axes of the continents. Sir Archibald Geikie[4] thinks that the land areas of the globe may owe their continued existence above the sea level to the result of this terrestrial contraction.

Wherever in the earth's crust bending is taking place, there earthquakes occur, and if this process is going on in proximity to an ocean, both earthquakes and volcanoes are present. Though volcanic action may cause the ground to shake, the greater number of disturbances are due either to rock-fracturing or to equilibrium adjustments of a subterranean quasi rigid magma.[5]

We must remember, also, how very frequently earthquake shocks occur. Those which are associated with immense destruction of life and property are fortunately very rare. The slighter forms of earthquake (earth tremor) are constantly occurring. Humbolt stated that the

[1] Milne: "Earthquakes and other Earth Movements," 1886, p. 295.
[2] Mitchell: "Cause and Phenomena of Earthquakes," Philos. Trans., 1760.
[3] Mallet: "Dynamics of Earthquakes," Proceed. Roy. Irish Acad., 1846.
[4] Geikie: "Ancient Volcanoes of Gt. Britain," vol. i. pp. 11, 12.
[5] Milne: "Seismology," 1898, p. 37.

earth's surface is nearly always being shaken at some point or other. Professor Milne[1] says that in Japan one earthquake occurs each day, and that over the whole of the earth's surface, from 20 to 50 shocks take place each day.

Then as regards volcanoes, it is estimated that there are at present 300 actively erupting mountains, constantly pouring out gases at least.

Nature of Gases evolved from Volcanic Vents, Earthquake Fissures, Geysers, Hot Springs, etc.

From active volcanoes, semi-liquefied rocks, lava, mud, smoke, watery vapour, and gases of a more or less acid nature are poured out. The lava is highly charged with steam or water gas[2] and other vapours, and has thus a low specific gravity. Sometimes immense quantities of steam are ejected, and, condensing higher up in the atmosphere, this frequently falls as heavy showers of rain in the vicinity of the volcano.

Fine ashes are also often thrown upwards to an immense height, and in the eruption of Krakatoa it was estimated that these ashes reached an altitude of seventeen miles. It is interesting to remember the beautiful coloured skies seen at sunrise and sunset in our own island, after this great eruption in 1883. These were seen during several months. Similar solar effects were noted at this time over almost the whole world. These effects were attributed to the presence of fine ultra-microscopic dust in the atmosphere.

One might cite many other examples to show what immense quantities of *solid* materials are thrown out, and how rapidly they are carried over great distances, and in directions contrary to the prevailing winds. If solid materials are cast out in such quantity, we may very properly assume that watery vapour and gases will be thrown out in relatively much greater amounts, and will spread through the atmosphere yet more rapidly. If rains and snowstorms were unable to wash the atmosphere free from the dust of Krakatoa for several months, how much less likely that the gases evolved from the ground will be got rid of easily? These must spread over the whole surface of the globe, and must modify the constitution of the atmosphere to a greater or lesser extent. A very detailed inquiry[3] regarding the eruption of Krakatoa and the spread of volcanic dust has been furnished by a Commission appointed by the Royal Society of London.

As to the nature of the gases which are evolved, many analyses have been given; but these are either not very full or unreliable. Prodigious quantities of watery vapour are ejected from every volcanic vent or fissure. Then hydrogen, nitrogen, sulphurous and carbonic acid gases are almost invariably present; while boracic acid and hydrochloric acid, or, on the other hand, ammonia gas are very frequently present. The heavy metals are nearly all volatilised; thus we find arsenic, antimony, mercury, etc,[4] as well as many other substances not usually volatilised.

[1] Milne: "Seismology," 1898, p. 37.

[2] Of course not "water-gas" as chemists now describe the mixture of hydrogen and carbon monoxide.

[3] Report of Special Commission to enquire into the Eruption of Krakatoa, and to find its relation to the Meteorological conditions, 1888.

[4] Judd: "Volcanoes: What they are, and what they teach," 1881, p. 40.

Many of the ejected matters react chemically on one another, as, for example, sulphuretted hydrogen on sulphurous acid, giving a precipitate of sulphur which clothes the sides of the crater frequently, and thus new compounds are formed. The hydrochloric acid resulting from a union of the elements acts energetically on the rocks around the vents, forming the yellow ferric chloride so often mistaken for deposits of sulphur. The gases escaping are often spontaneously inflammable, no doubt from the presence of phosphorus.

Some of these gases are lethal when inhaled in a certain and relatively large proportion, but diffused as they so soon would be in the atmosphere we must look upon them as innocuous to human beings. There is certainly no evidence to show that any truly poisonous material is poured out either from volcanoes or from earthquake fissures, as Dr. Parkin [1] believes. The examples which he gives are, in my opinion, inconclusive, and the mortality after earthquakes or volcanic eruptions can easily be accounted for in other ways than by that of the evolution of poisonous gases from the ground.

Nature of Infectious Diseases.

Everyone now agrees that Infectious Diseases are caused by micro-organisms, and that each specific infection is carried by, and is due to, a special organism.

Something more than this is, however, necessary to explain the *epidemic*, and occasionally, *pandemic* spread of these diseases. Were each of the infectious diseases to spread merely by the passage of a special organism from a diseased to a healthy individual, then everyone would, in the course of time, take that specific disease.

The fact, however, is that within certain (epidemic) periods a very large proportion of the population are attacked by a certain zymotic disease, even though that disease may never be entirely absent from the country, but may exist merely in a few sporadic cases. After this period of outbreak the special specific infection may then die away more or less quickly, and may not again recur for many years (*e.g.*, Cholera in Great Britain) or perhaps for ever (Black Plague in our own country).

Various theories have been propounded to explain the reason for the epidemic rise of diseases, and why only certain people are attacked by the infectious disease during its period of prevalence. Thus, for example, we have the theories of acquired immunity, either through heredity or conferred by a previous attack of the same disease; individual power of resistance or non-susceptibility to the infection, and others. No doubt some of these theories may afford valid reasons for the occurrence of epidemic diseases, but they help little to explain the widespread prevalence of the disease when it assumes a pestilential character. In certain epidemics, almost the whole population becomes affected, and the mortality from the disease may undergo an enormous increase; for example, in ordinary epidemics of Scarlatina, the death rate is usually only from 10 to 12 per cent. In other and more aggravated epidemics, the mortality may reach up to 50 or 60 per cent.

Something more is required to explain the rise and spread of

[1] Parkin: "The Volcanic Origin of Epidemics," 1887, p. 109.

epidemics than the mere fact of individual infection, potent though this factor is. Atmospheric alterations have, as we have already seen, for ages been attributed with the spread of infectious diseases. The object of this essay is to try and reconcile these two theories—the atmospheric and the contagious; to try and explain why, under certain conditions, infectious diseases spread so rapidly, and affect such large numbers of the population, with the old idea of the non-contagious nature of these diseases, and the so called epidemic nature of the atmosphere.

Many eminent epidemiologists have been non-contagionists, as well as Dr. Parkin,[1] as Clot-Bey, the eminent Egyptian physician,[2] and Dr. Charles M'Lean,[3] who affirms that the contagion theory constitutes one of the most destructive errors in the whole circle of human opinions.

While we grant the absolute truth of the spread of infectious diseases by contact or infection, it is well known that certain epidemics are much more restricted than others of a similar kind, both in the severity of the attack and in the number of those who are affected.

Individual resistance to the infection cannot be ascribed as the sole cause of this immunity, though doubtless it plays an important part. Why should a particular disease cause a far greater mortality (though not a greater incidence) in one epidemic as contrasted with its ravages at another time? Take, for example, the case of scarlatina where the mortality in certain epidemics reaches twice or thrice that of the ordinary mortality from this disease. Inherited immunity cannot explain this, neither can a greater facility for the diffusion of the poison. Were heredity to have any influence, the immunity gained would have a constant influence in reducing the mortality from the endemic diseases of childhood and infancy—the death rate from year to year would go on diminishing. By those who adopt the latter argument, the disease of scarlatina is frequently cited as a proof that acquired immunity can be transmitted. They say that though the case incidence from scarlet fever has by no means diminished, yet the mortality from this disease has steadily declined. Though this may be as a whole true, yet we often enough find an epidemic of scarlatina with a mortality far above the average death rate from this exanthem. I am afraid that conclusions have been drawn from insufficient data as regards this disease. Even in the time of Sydenham scarlet fever was considered a very benign trouble. In Dublin, according to Graves,[4] it was a mild disease until 1831, when it began to increase in malignity, until in 1834 it was a destructive epidemic. This character of the increasing severity of an epidemic has been frequently observed. Older writers term it "the progressive intensity of a pestilence"—the type of the epidemic disease on its first outbreak is comparatively mild, but its virulence gradually increases and the mortality rises.

Modern statistics, on the other hand, show that *Measles* is gradually but constantly increasing in severity, and causing a greater mortality. Diphtheria is another disease which undergoes marked fluctuations, both in its prevalence and in its malignity during an epidemic.

[1] Parkin: "Are Epidemics contagious?" 1887.
[2] Clot-Bey: "De la Peste observée en Egypte," 1840, p. 369.
[3] M'Lean, Chas.: "Investigation respecting Epidemic and Pestilential Diseases," 1817, vol. i. p. 37.
[4] Graves: "Clinical Lectures," Sydenham Society, 1884.

It is unnecessary to remark on immunity acquired by residence or otherwise in warding off endemic or tropical diseases.

Much might be said regarding *Seasonal Variations*, *Secular Mutations* or *Multiannual Nutations* of infectious diseases and their bearing on this enquiry, but space forbids.

Recognising the fact that infectious diseases are caused by micro-organisms, which may exist outside of the human body and are capable of growth and reproduction in other media than the animal tissues it is not going beyond what is in all probability the truth, to state that at certain seasons this growth and reproduction takes place to a much greater extent than at other times. Thus the infectious disease increases until it reaches its maximum.

The nature of this atmospheric change may be in an increase in the temperature or in the humidity of the air. It may depend on variations in the density of the air, or in alterations in the chemical constitution of the earth's atmosphere inappreciable to chemical methods as at present in use. Any one, or a combination of these changes, may give rise to increased activity and multiplication of certain organisms, and so an epidemic may originate.

My Theory.

Now it seems to me that the only possible source of this extraneous heat, moisture, and abnormal gases is furnished by volcanic vents, earthquake fissures, or the innumerable geysers and grottoes which are constantly pouring these products forth. Where else are we to look for any other powers which can so alter the earth's atmosphere to the same extent? We have already seen how enormous are the amounts of watery vapour and gases which are poured out and distributed over the globe. The excess or abnormality of these products will alter, to a greater or less degree, both the physical and chemical nature of the atmosphere. As the composition of the gases issuing from these vents and fissures is constantly varying, so only at times will an atmosphere result which is entirely suited to a particular organism. It may be only once in one, two, or three centuries that a combination of physical and chemical conditions will occur in the atmosphere, suitable, say, for the pandemic growth of the *Bacillus pestis*.

As regards *Endemic* infectious diseases—the local conditions necessary for the growth of one or more particular organisms are already present, and we therefore do not require to bring into action in such cases any of the causes which favour pandemic pestilences. These diseases remain localised, until a general atmospheric condition is brought about over the globe, or at least over a large part of it, suitable for the growth and multiplication of the special organisms.

We may therefore rest assured (and this would almost meet the views of the old non-contagionists) that sporadic cases of a disease would never give rise to an epidemic. They would only do so were the "epidemic nature of the atmosphere" suitable and such as we have above described. The recent outbreak of bubonic plague in Glasgow is a case in point. The number of those who had been in contact with plague patients was large, and yet a very small proportion actually took the disease. In all probability no great epidemic would ever have

arisen. Yet the authorities only did what was right in isolating the patients as well as the "contacts," as they were unable to know whether the atmospheric conditions were favourable to the growth and spread of the organism or not.

Even in the case of epidemic plague, great atmospheric changes decidedly influence its origin and progress. When the air is warm and moist, then its attacks are more frequent and the mortality higher (Larrey [1]). There are a large number of records to show that cases of sporadic plague do not transmit the disease, while the epidemic form is easily transmissible. A large number of reliable observers do not believe in the contagious nature of plague. Dr. Lachese,[2] for example, says that, unless there be a "pestilent constitution of the air," a plague patient can at most infect only a few individuals, but those latter in no instance transmit it to anyone else.

Dr. Adams, writing in 1809, affirms that the epidemics of plague have subsided, not by any human contrivance, but by an alteration in the constitution of the air.[3] Dr. Dall Ingram,[4] surgeon and man-midwife, exposes what he calls the absurdity of thinking that plague is contagious or capable of being transported by merchandise.

My theory gives a much more reasonable explanation of the term "epidemic constitution" of the atmosphere than any I have yet met with.

That a certain alteration in the atmospheric conditions is associated with an enormous increase in a particular organism, and that this may result in a special epidemic, seems to me much nearer the truth than to suppose that an alteration in the atmospheric condition alone will lower the resisting power of the individual, and so make him accessible to the organism.

I do not mean to deny for a moment that certain atmospheric changes may not lessen the power of resistence of an individual. To deny this would be absurd. The breathing of a cold, damp atmosphere may so lower the vitality of the faucial and bronchial mucous membranes as to allow the passage of organisms, and so end in tonsillar or pulmonary diseases. Or again, the ingestion of fruits (often over-ripe) or vegetables in the warm months of summer or autumn may originate diarrhœa, which, by lessening the vital activity of the cells forming the mucous lining of the intestines, allows of the entrance of the *Bacillus typhosus* into the tissues. Typhus fever frequently finds its victims amongst those who have been subjected to long continued over-exertion (camp fever), or who have been debilitated by antecedent famine. In these individuals the resisting power to specific organisms is low.

While admitting that external circumstances play a very important part in predisposing an individual to disease, yet I affirm that epidemics do not, as a rule, arise entirely in this way. If they did, we should in nearly every case be able to trace some slight antecedent disorder. We know that this is not the case, but that the strong and perfectly healthy

[1] Larrey, quoted by Dr. Milroy: "Quarantine and the Plague," 1846.
[2] Lachese: "Mémoire sur la Peste en Perse," 1836.
[3] Adams: "Inquiry into the Laws of Epidemic Diseases," 1809, p. 8.
[4] Ingram: "Historical Account of Plague since 1346," 1755.

fall victims to epidemic disease just as, and perhaps more, easily than do the week and debilitated.

I certainly do not for a moment credit the idea that some poisonous product issues from underground reservoirs or from volcanic vents, and so renders the air poisonous and produces a particular epidemic, but I certainly think that there are good grounds for believing that the large volumes of gases and watery vapours arising as a result of subterranean volcanic action may cause such an alteration in the atmospheric conditions as to lead to an immense increase in the number of certain organisms, either locally or universally.

It is well known that plants react most energetically to such slight variations in the composition of the surrounding air, that we can hardly by hygometric or chemical methods identify the change. If plants are so susceptible to these changes, it is much more reasonable to think that minute micro-organisms will react still more energetically to even slighter atmospheric changes. In this way what was formerly known as the "epidemic constitution of the air" may result.

In the history of nearly all plagues we find mention of excessive and long continued moisture usually associated with great heat. As a rule this gives rise to a great increase in insect life—plagues of locusts are often mentioned. This unpropitious atmospheric condition leads to failure of the crops, with resulting famine. Of such importance was the humidity of the air that we frequently find it noted that a luxuriant growth of the minutest cryptogamic plants was noted during the pestilential periods in water and on damp articles of all kinds.[1] These fungoid growths from their form and colour gave rise to the greatest terror amongst the inhabitants, and if they appeared on the clothes of an individual (*signacula*) they were interpreted to mean that the owner would be immediately attacked by the pestilence (*Lepra vestium*). In 1500-1503 during the prevalence of the plague these spots were noted to be more usually red, brown or yellowish white, and the imaginative traced in them the form of a cross. In Germany and France the populace were thrown into the greatest alarm as the signacula appeared on garments, utensils, or even in closed boxes.

The importance of these fungoid growths to our present inquiry lies in their relation to the atmospheric conditions which were then present —the continued and excessive humidity together with some other gaseous constituents which were present in the atmosphere and derived in all probability from volcanic vents or earthquake fissures. If such a combination of changes in the atmosphere can stir the lower fungi into such activity (and these occasions furnished ocular proof), the still lower unicellar organisms will partake still more actively in this change, and such change must of necessity escape direct observation.

The theory which I promulgate merely presupposes a condition of air very favourable to the growth of micro-organisms. The increased number of these and their functional activity must lead of necessity to a larger number of persons falling victims to the special disease (which each individual organism originates) than happens in normal conditions of the atmosphere. The greater the suitability of the atmospheric conditions to a special organism, the greater will be its activity and

[1] Hecker: "Epidemics of the Middle Ages," Syden. Society, p. 205.

multiplication, and by consequence the more widespread will be the epidemic. The less suitable the atmospheric conditions, the less active will be the organism and the slower its rate of multiplication, consequently the epidemic will be less extensive. In this way I explain the differences in the case incidence in different epidemics.

It is imposssble to believe that the gases evolved from such underground sources as I have mentioned can *appreciably* affect the chemical constitution of the atmosphere except perhaps in the immediate vicinity of some great source. As yet we have no trustworthy account of any epidemic arising directly as the result of a volcanic eruption. My proposition would indeed be negatived if such were to happen. The enormous volumes of hydrogen, carbonic dioxide, ammonia, and sulphuretted hydrogen escaping from a vent or fissure would render the air in the immediate neighbourhood anything but suitable for the free multiplication of organisms.

These gases or vapours must be dilated to an immense extent before the *optimum* atmosphere for the special organism is arrived at. This of necessity must be at a distance from the point of origin of these emanations. My theory would require that the epidemic should arise at some considerable distance from the source both as regards space and time. This also is borne out by a consideration of the epidemics which have arisen.

Even in the neighbourhood of the famous Grotta del Cane near Naples the air is perfectly pure and harmless (as I have myself proved), although immense quantities of ammonia and carbonic acid gas are constantly being evolved. It is only in the grottoes themselves where the gases are confined and but slightly diluted with ordinary air that dangerous symptoms ensue on breathing the air.

In considering epidemic diseases, it is of the greatest importance to remember the fact that an organism may change both its morphological and biological characters (polymorphism). Such a change is well exemplified in the three simultaneous epidemics of 1528, which destroyed (1) the French army of 30,000 men within seven weeks, at Naples (either typhus or plague); (2) the Tousse-Galant, which carried off its victims within a few hours (petechial fever). This disease, together with famine, is estimated to have reduced the population of France by one quarter; (3) The Sweating Sickness of England ("The Great Mortality"). The air seemed to be specially suited to the growth and propagation of infectious organisms during this year. To show that the virus resides chiefly in the air during pestilences, I may state that in nearly all the epidemics of plague the greatest mortality takes place amongst those who are first affected. "When an epidemic commences, almost all who are attacked by it perish," [1] while as the epidemic is disappearing almost all those affected recover.

If this polymorphism of bacteria be kept in mind, we do not require that a new species of organism should arise. If the surroundings undergo change, then the organism itself may change also, and so may the results of its growth.

As I have already stated, I do not consider that the alterations in the physical and chemical constituents of the atmosphere, brought

[1] Clot-Bey (Antoiné B.): "De la Peste observée en Egypte," 1840.

about by volcanic emanations, have much effect in themselves in lowering the vital resistance of individuals. Such a lessening of the resisting power is much more likely, in my opinion, to be due to what we may call grosser meteorological variations—want of sunshine, persistence of rain or fog, excess of sunshine causing sultriness, prevalence of hot or cold, or cold and damp winds, may be taken as examples. None of these are necessarily due to the effects of volcanic action, yet if any of these depressing conditions of the atmosphere exist, they depreciate the health of the community and *a fortiori* increase the tendency to the spread of a specific epidemic.

It must be clearly understood, however, that I do not lay any great stress on a lowered resisting power as being due to the products of volcanic action in the atmosphere. I lay great stress, however, on the optimum atmospheric condition as leading to an immense reproduction of micro-organisms. I affirm that this suitable atmospheric condition very probably results from volcanic emanations, and that there is an optimum condition of air for each specific organism.

The theory which is now propounded does not require the presence of clouds, fogs, red sunsets, or any other sensible effects. These may be present along with an epidemic as mere meteorological conditions; but, in my opinion, they have absolutely no significance from a epidemiological point of view.

Nor does this theory require that there should be actual volcanic eruption or earthquake shock. The gases may be given off rapidly from these, or, on the other hand, may escape more gradually and insensibly from fissures, etc. In this way, the normal composition of the atmosphere undergoes alteration. In Mr. Mallet's catalogue,[1] we find an enormous list of recorded earthquakes, and this bears out my contention that there is an enormous and constant escape of gases from underground into the atmosphere. Only a certain proportion and kind of these gases will furnish the *optimum* conditions necessary for the growth of a special organism, and so it is only at comparatively rare intervals that certain epidemics arise.

My argument is that emanations (gaseous and water vapour) escaping from the ground modify the atmosphere to an extent only appreciable to the vital activity of unicellular organisms. To such, however, each minute change is all-important, either in the way of favouring or retarding their growth. On occasions, some particular organism finds every condition present for its luxuriant growth, and thus we have an immense multiplication of this specific germ, with, in all probability, an epidemic outbreak of disease in either the animal or vegetable world. At another time, some other slight atmosperic alteration takes place, and another micro-organism finds its optimum conditions, and so on.

Such an argument makes it easy to understand how epidemics arise and spread. In widespread epidemics, the optimum atmospheric conditions cannot possibly be confined to certain small limits, but must extend over wide areas. Winds or insects may readily carry certain organisms from one locality to another, and if the optimum conditions for their growth be present there also, they will flourish and spread the

[1] Mallet: "Catalogue of recorded Earthquakes from 1606 B.C. to 1850," British Assoc. Reports, 1852-4.

disease. We have already seen that epidemics may travel against the prevailing local winds, or may even break out in far-distant localities, entirely cut off from communication with infected districts. In such cases, the specific organism may have lain dormant for years until suitable conditions have again brought it into activity. On the other hand, and specially when the distance from infected areas has not been very great, it is much more probable that the infection has been carried by animals, birds, or insects. Once the organism has reached its new site, climatic and meteorological conditions being suitable, it will spread rapidly and produce the epidemic.

Any sudden change in the meteorological conditions may bring an epidemic to a sudden cessation. This it does by altering the conditions necessary for the easy growth and reproduction of the organism; as, for example, the sudden onset of cold weather during an epidemic of yellow fever.

The epidemic, as a rule, fades gradually down until it disappears entirely, or in those which are endemic until it reaches its normal in non-epidemic times. This gradual disappearance takes place in proportion as the atmospheric conditions suitable to the particular organism become less and less so. Sydenham's [1] words on this subject are worth repeating. He says that if the pestilential virus, unmodified by atmospheric conditions, were transmitted from man to man by a continual series of propagations, it would follow that, if the plague entered any populous town, death would succeed death in one continuous and indefinite series, until at last no one would be left upon whom the murderous miasma might fasten itself.

My proposition does not demand anything out of the usual—it merely takes account of phenomena which are constantly going on. Germs of disease are always present somewhere or other, though quiescent. They only require a certain stimulus (suitable nidus, favourable surroundings) to stir them into active life, and when these organisms are pathogenic, an epidemic ensues. This stimulus, I venture to think, is of telluric origin, which by modifying the constitution of the atmosphere, and making it suitable for the growth of the micro-parasite, favours the production of epidemics.

The theory does not ask much of faith—to me it seems eminently reasonable and, so far as history can prove, reliable. It does not, in the least, interfere with the "contagion theory," *i.e.*, the direct transference of a particular disease from one person to another by means of the breath or excretions. It, however, amplifies this, and explains many otherwise inexplicable cases, and gives a new and intelligible meaning to "the epidemic constitution of the atmosphere."

The effect of Volcanic Action in the production of Epidemic Disease in the Vegetable Creation.

It is unnecessary for me to enter into any detail regarding the diseases which affect the vegetable kingdom. It is, however, subject to an immense number of micro-parasitic diseases.

[1] Sydenham's Works, Greenhill's Edition: "Pestil. Fever," chap. ii.

"Mildew" is a familiar example, and gives the gardener much trouble by "damping off" his seedlings and his cuttings. This affection is due to the growth of the *Peronospora Viticola*, the spores of which germinate on damp ground. It thus gains a ready access to the young plant, and the hyphæ which are soon produced secrete a ferment which dissolves the cell walls of the seedling. The stem therefore soon becomes almost liquefied where the ferment has acted, and the plant drops over. This organism can live as a saprophyte, and thus we see how difficult it must be to eradicate the disease from a greenhouse.

Potato Disease depends on a similar cause. Weather conditions have, however, the greatest influence on the growth of the fungus. A continuation of damp weather causes the organism to flourish luxuriantly, and to attack the leaves of the plants over a wide area. Thus in one or two days we may see whole potato fields withered, and the leaves shrivelled. Dryness of the air on the other hand arrests the growth of the fungus.

Dry Rot is caused by the growth of the *Merulius lacrymans*, which, penetrating in tiny canals, sets up a chemical action in the wood and renders it very brittle.

There are many other fungoid diseases of trees, wood, bulbs, etc.

Ordinary meteorological conditions have the greatest influence on the growth of these fungi. In greenhouses, vineries, or even in cold frames, the condition of the air has to be carefully attended to, else not only do the plants suffer in health, but (what is of far greater importance) the growth of fungi is encouraged, and the grapes, plums, seedlings, etc. may succumb to their ravages.

I have already fully stated how the prevalence of micro-parasites depends on atmospheric conditions, and how diseases in animals result from their too free growth.

The theory which I have been bold enough to formulate covers the causes of blight and pestilence in the vegetable kingdom in the same manner as it applies to the diseases which affect the animal kingdom.

All the diseases which are epidemically fatal to plants are of a fungoid nature. My argument applies to these diseases equally well, and consequently it is unnecessary to recapitulate the reasons already given.

It also accounts for the simultaneous diseases which affect both plants and animals at epidemic periods.

The Effects of Volcanic Action in the Production of Hurricanes and Abnormal Atmospheric Vicissitudes.

Our historical survey has also shown that coincident with earthquake shocks and volcanic eruptions, hurricanes of wind, excessive heat or torrential rains, causing great inundations, are noted.

The frequency with which these phenomena are mentioned makes clear the fact that these two sets of manifestations are correlated. Were this stated merely once or twice, we might well deem them to be mere coincidences, but when we find the concomitancy stated over and over again, the relation becomes a certainty.

Nor is it difficult to see why intense heat, hurricanes, or excessive

rains should follow volcanic eruptions. When we consider that all air movements are caused by differences of pressure, and that these again are due to rarefaction or condensation of the air by heat or cold, it is easy to understand the effect of volcanic action. We have seen how immense are the quantities of heated gases which escape not only from an active volcano, but from old vents and fissures, as also the huge amounts of water vapour which are poured out. These escaping products must have an equally powerful effect in modifying the meteorological conditions. We know that escaping steam puts into motion a volume of air 217 times its own bulk. We can thus imagine how powerful must be the "upcast" from a volcano of any size. This heated air is relatively very light compared to the surrounding air, as it contains so large an amount of moisture, and will therefore rise far above the relatively cold air on the earth's surface. From this elevation it will flow in definite directions over the underlying cold air, which of necessity will rush in to replace the heated air. The greater the heat from the volcano, the larger the amount of escaping gas, and the greater the humidity of this gas, so there will be a greater rush of cold air to replace this which has ascended. This inrushing air must, therefore, partake of the nature of a hurricane, and it will be all the greater if it falls in line with some of the more ordinary causes of hurricanes. The amount of heat thrown into the atmosphere from many active volcanoes must also materially modify the meteorological conditions, and may to a certain extent account for the excessive heat which has been so often noted in connection with volcanic eruptions.

On the other hand, where immense quantities of watery vapour have been ejected, the humidity of the air must be altered, and so the excessive rainfall or persistent fog can be explained.

I have already alluded to the influence of volcanic dust on meteorological conditions, and shown how it may give rise to many atmospheric effects.

From the disturbances which may result from volcanic action we can therefore see how many may be the atmospheric vicissitudes and even hurricanes (cyclonic or anti-cyclonic) which may and do result. The subject might lend itself to prolonged discussion, and one might criticise many of the views which are held.

As I have, however, entered rather fully into the relation of volcanic action to epidemic disease, so must my remarks on this division of the inquiry be brief. I regret this the less, as the statements which I have made on the relation of volcanic action to abnormal atmospheric effects are self-evident, and conclusively prove that volcanic action has an intimate and immediate relation to meteorological phenomena.

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