CHAPTER VII.

THE WEATHER AND EPIDEMIC DISEASE, WITH PARTICULAR REFERENCE TO INFLUENZA.

A belief that the states of the weather influence the prevalence of disease is amongst the oldest of popular doctrines, and, in a general way, there can be no doubt of its truth. Not only is it certain that " common colds " are not equally frequent in all seasons of the year, but the same remark., applies to outbreaks of other endemic diseases.

A specific relation between epidemic outbursts of disease and atmospheric changes has also been asserted to exist, and, down to a recent epoch, this doctrine greatly influenced epidemiological thought in general* and the aetiological theory of influenza in particular. Modern physicians have, perhaps, usually derived their inspiration from the teaching of Sydenham or from the writings of those epidemiologists who were influenced by Sydenham's example, but the observations upon which the theory was based belong to Greek medicine, and it will be convenient here to summarise the older teaching, because so much of it has become part and parcel of our half conscious or even wholly unconscious stock of beliefs, and is still influential.

The historical source of our traditions is the collection of writings bearing the name of Hippocrates which are rather *disjecta membra gigantis* than a co-ordinated system; however, from those tractates having the best claim to be regarded as authentic, the following conceptions emerge.

The aetiology of disease involves three prime factors : (1) the character of the individual, his *crasis* or *temperament;* (2) his habits of life in the widest sense, including his diet, occupation, &c. ; (3) the character and variations of the atmosphere, its *kalastastis* or *status,* to which he is exposed.

In the Hippocratic writings, the words " epidemic" and " endemic " are not used quite in the sense of modern writers, and Hippocrates brings under the connotation of an epidemic prevalence of sickness which we, using the term less widely, should not so designate. He studied disease from two sides. On the one hand he linked up the general type of sickness prevailing endemically from year to year and generation to generation in any one place with the enduring and permanent characteristics of its inhabitants and its climatic peculiarities. On the other hand he also studied the diseases of the same locality in different seasons of the same year and in the same seasons of different years, and associated variations of the quantity or quality of prevalent (epidemic) sickness with

* *Cf.* Dr. Ballard's discussion of the subject in his report on the epidemic of pneumonia at Middlesbrough in 1888. (Reports of Med. Off. Local Govt. Bd., 1888, App. A, No. 18, C. 5813.)

variations of atmospheric status. It is this second investigation with which we are principally concerned. It was the model of Sydenham's books on the epidemic constitutions of London in the 17th century.

Hippocrates provided a series of observations covering some years, and these are not welded together by any detailed theory. This may partly be due to the fragmentary character of the surviving books, but a more probable explanation is that the author, evidently a man of rare sagacity, had a vivid sense of the complexity of his task, and felt that—as one of his most famous aphorisms puts it—judgment was difficult and experience deceptive.

In the hands of Galen the observations and provisional theories of the older, and wiser, physician were moulded into a system which has, both for good and evil, largely determined the subsequent development of medical ideas.

From the commentaries of Galen upon the Epidemics of Hippocrates, from his treatise upon Temperaments, and, especially, from his study of Fevers, we can form a tolerably clear idea of the Galenical doctrine, of how Galen elaborated a consistent theory of the three factors of disease.

He assigned the personal or innate character (temperament) to one of nine types, each dependent upon a different blending of four elementary characters, the Hot, the Cold, the Moist, and the Dry. The ideal or eucrasic temperament is that in which these elementary qualities are perfectly harmonised. A discord may arise in eight ways ; four of these are due to simple excess of one quality, four others to linked excess of Hot with Moist or Dry or of Cold with Moist or Dry. This is an exhaustive classification because Hot and Cold, Moist and Dry are taken to be incompatibles, co-existent excess of both members of each pair is deemed impossible, so that no linked excesses of *three* qualities are permissible.

The object of this classification—which is not intrinsically so ridiculous as the naif physical associations of the words themselves make it seem to us—is to explain the varying response of the individual to changes of environment and to what we should now term exposure to infection. A diet or an occupation appropriate to one temperament is harmful to another; the *form* of the injury inflicted upon one temperament by any pathogenic agent will depend upon the temperament, and, as the quantitative range of each class is continuous and there are eight non-physiological groups, the scope of clinical varieties is immense.

The second group of causes, viz., the habits of the individual, is related to the first by a pathological system which we need not expound, since it has long since lost such importance as it possessed, and we pass to the third factor.

Galen posited an extra-corporeal cause of pestilence which he located in the atmosphere. He thought that this might possibly be a mere physical property, such as excessive heat, but indicated that something more tangible, veritable " seeds of pestilence" could never be excluded and might usually be predicated. Whatever the precise origin of these " seeds," their existence depended upon a warm and moist state of the atmosphere. Thus the necessary conditions of a pestilence *{any* disease which, in our usage, is epidemic and produces a great mortality is a pestilence in Galen's usage of the term) are seeds of pestilence existing in a moist and humid atmosphere. But these conditions, although necessary, are not sufficient; they may exist and yet no epidemic may follow, because the " chief factor in the production of a disease is the preparation of the " body to endure it."*

Hence the paramount importance of the temperamental and dietetic, or occupational, factors above discussed; the external invader, the seed of pestilence, excites a change, a " putrefaction " in one or more humours of the body.

The extent of the mischief done will depend upon the state of these humours (which will be affected by habits, &c.) and their original disposition (which will depend upon temperament). " Let us suppose that the atmosphere is bearing certain seeds " of pestilence and that some of the bodies exposed to this " atmosphere are full of waste products apt to putrify and other " bodies are pure .. . . that some have lived in sloth, sexual " excess, and gluttony, others have taken exercise and eaten " in moderation. . . . Judge then which class is the more " likely to be affected by the inspiration of the putrid air, . " So often as the status of the air deviates from its proper norm " into the hot and humid, pestilential diseases must needs " arise, but the victims will be mainly such as were beforehand " full of impurities, while those who labour moderately and are " temperate in diet remain refractory."†

Such was the teaching of the Greek physicians. Part of it was of great value, viz., the emphasis put upon individual predisposition and habit in modifying the corporeal response to infection ; we have seen that an adequate theory of influenza must take full note of this. On the other hand, although an enthusiastic Galenist might make out a case for regarding the Pergamite as a pioneer of the bacteriological school with his seeds of pestilence, there can be little doubt that he had nothing of the sort in mind and even less that the notion of

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* *De Differentiis Febrium,* Bk. I., Cap. "VI. (The text with Latin translation is printed in Vol. VII. of Kuehn's edition of Galen's works, pp. 289 *et seq.)*

† *Ibid.* The first seven chapters of this work and the commentaries on Hippocrates' epidemics contain the more important epidemiological observations of Galen. The latter are printed in Vol. XVII. (a) of Kuehn, *see* especially p. 2 *et seq.,* p. 30, pp. 43-4, pp. 96-7, and p. 667, Vol. XV., p. 121, *et seq.,* are also of some interest.

putrefaction due to an atmospheric something fostered vague speculation and hypotheses which discouraged useful experimental and observational research. So far as the specific object of this chapter is concerned, that of meteorological influences, Galen added little of importance to the teaching of Hippocrates ; he merely formulated in precise language the opinion that a moist and humid atmosphere forebodes pestilence. But even if this opinion were solidly based upon observation, it is hot very illuminating, because the facts were derived from a study of diseases observed in south-eastern Europe and Asia Minor (Galen provides no exact epidemiological observations of Rome). Littre* pointed out that the clinical characters of the cases detailed by Hippocrates were unlike those of current diseases at Paris, but very like the accounts of practitioners in tropical and semi-tropical lands. Consequently, even were the doctrine of a moist and warm pestilential status or constitution appropriate to the general aetiology of "fevers" in tropical or subtropical lands, it does not follow that a warm moist constitution is noxious in other climes.

The error of applying literally the results of the ancients to wholly different conditions is one reason why little profit has been drawn from a study of their writings. It is the spirit, not the letter, which refreshes.

The remarks just made of course apply to the post-classical writers whose observations were not made in these latitudes ; the details of their results, or alleged results, do not concern us; the only question is whether they improved upon the general theory. They did not do so. Avicenna † in his account of the subject incorporates the whole substance of the passage from Galen to which we have referred; the only additions are an amplification of the theory of a putrefaction due to the moist warm air, and some remarks upon forebodings of pestilence to be derived from the appearance on the surface of animals which usually lurk in holes (here we have the famous reference to the deaths of rats in plague times).

Finally, we reach Sydenham, who abandoned the superficially attractive system of Galen and reverted to the iess formally systematic but more philosophical method of Hippocrates. Sydenham asserted roundly that it was impossible to
" describe specific forms of epidemics as arising out of specific
" changes in the atmosphere; easy as such a proceeding may
" appear to those who can theorise about fevers and christen
" the disease accordingly, speculating laxly upon those altera-
" tions which can take place in our blood and humours through
" the degeneration of this or that principle."‡

Yet Sydenham did not abandon the belief that the atmosphere was ultimately responsible for epidemic disease; he

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* *CEuvres d'Hippocrate,* Vol. 2 (introd.).
† *Liber Canonis,* Bk. IV., tract. 4.
‡ *Obs; Med.,* I. 2, 22.

rejected perceptible atmospheric influences, but accepted occult atmospheric influences *(nisi in quantum secr etae aeris influentiae illa deberetur).* His quarrel, in fact, is rather with the Galenists than with Galen, because, as remarked above, it is hardly fair to attribute to Galen the quite crude conceptions of hot and cold moist and dry which the actual words suggest; put otherwise, we may doubt whether Galen himself really supposed that a moist and warm katastasis, status, or constitution meant no more than that the weather was warm and rainy.

We have thought ourselves authorised to devote some pages to the exploration of this ancient history, because the theories in question, whatever may be said against them, have had much influence, and their exposition displays some of the difficulties of the inquiry and why little progress has been made.

There have been several reasons for a failure to advance. One was literal acceptance of the dogma of a pestilential constitution tending to warm and moist. Since this did not seem to correspond to experience, but yet *must* be true, being classical, it followed that the whole doctrine was esoteric and of no practical value. This, no doubt, accounts for an absence of records in early modern times. After the decline of the Galenical tradition as an influential code, the epidemiological and meteorological observations of such writers as Sydenham and Huxham made it appear, not that the weather was of no importance to the epidemiologists, but that its influence was neither direct nor apt to be revealed without the application of methods and the collection of data which even now are incomplete and a century ago were almost non-existent. Hence it is that down to nearly our own time no important progress was achieved.

It was to be expected that after the establishment of the General Register Office Dr. Farr would devote attention to this matter of weather and disease, and he did so as early as in the Third Annual Report. This first note on the subject only deals with temperature and disease in London during the years 1838-41, but brings out the effect of cold upon " the pulmonary " class and the cerebral diseases of the aged." Farr asked, *inter alia,* how long the effects of excessive cold persisted, and found that the mortality rose at once and continued to be above the normal for so long as 30 or 40 days.

In the 28th Annual Report Farr made a remark which is an appropriate criticism of much statistical work (including that contained in this chapter). He observed that averages taken over extended periods might give very incomplete information as to the state of weather experienced. " The tempera-
" ture, weight, humidity of the atmosphere, and other physical
" forces should not be masked under mean values, but
" laboriously traced throughout their course from day to day,
" and if it were possible, from morning to night and from

night to morning, and observed in connection with, the contemporaneous facts that relate to human life, as these also are successively recorded, if the sway which they exercise is to be appreciated in its full significance."*

In one of the weekly returns (No. 51, 1874) Farr made an assessment of the excess mortality due to cold in the severe winters of 1855 and 1874. He found that the excess mortality increased with age in geometrical progression. Thus, subtracting from the deaths at ages the corrected average number, the excesses were such that, starting from the age group 20-40, the rate doubled every 9. 21 years of life in 1855, and every 8.77 years of life in 1874. It will be noticed that Farr envisaged the subject of weather and disease from a lower altitude than did the ancients. He did not attempt to connect the *ultimate* origin of epidemic or endemic disease with particular atmospheric constitutions, but contented himself with associating quantitative alterations of the variables. Herein he displayed the true modern spirit. Aiming at too much our ancestors failed to reach what was attainable; Farr and his successors with humbler aims arrived at valuable ends. In the happy phrase of Macaulay, " Plato drew a good bow, but, like " Acestes in Virgil, he aimed at the stars, and therefore, though " there was no want of strength or skill, the shot was thrown " away. . . . Bacon fixed his eye on a mark which was " placed on the earth, and within bowshot, and hit it in the " white." Farr's successors were of his school, and discovered many important relations between weather and disease. We may instance Ballard's work on the correlation of summer diarrhoea and the earth temperature,† and Newsholme's work on diphtheria and deficiency of rainfal. ‡

In the interpretation of the results obtained by these methods some difficulty is experienced when we have to do with epidemic diseases owing to the fact that many such diseases exhibit a periodicity which may have nothing to do with variations of weather. For instance, if we associate the weekly or monthly variations of, say, temperature throughout the year with the corresponding weekly or monthly death or morbidity rates, a close correspondence of the graphs may not be due to the high or low temperature determining the incidence of the disease, but merely express a seasonal periodicity; the curve of average temperature throughout the year is regular. This, however, has been the usual plan.§

If on the other hand we ignore the cyclical position of the months and associate months from a series of years, the mean

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* 28th. Annual Report, Registrar Gen., p. xix., also reprinted in *Vital Statistics* (Farr Memorial Vol. pub. by Sanitary Institute in 1885), p. 415.

† On Epidemic Diarrhoea, *Rep. Med. Off. L.G.B.,* 1887.

‡ The Origin and Spread of Pandemic Diphtheria, *Lancet,* I., 1898.

§ See Jessen, *Zeits. f. Hygiene,* 1896, XXI., 287.

temperatures of which fall within certain limits, with the corresponding disease rates* we commit another error, or at least, make another assumption. It is unreasonable to attribute the same weight to the same absolute temperature in March and January. Again, we do not really avoid the before-mentioned difficulty, because on the average the same months are likely to fall into the same groups of temperature limits.

It appears that the simplest method of securing an unexceptional comparison is to confine the scrutiny to meteorological variations of the same, or approximately the same, element in the seasonal cycle, *e.g.*, to compare the temperature and the incidence of disease within the same month over a series of years, the plan adopted by Greenwood and Theodore Thompson in their paper upon the influence of weather upon the incidence of rheumatic fever.†

The application of this method to the problem of respiratory disease will presently be shown. Before passing to this we must refer to the few attempts made to explain the actual origin of epidemic sickness in terms of meteorology. Influenza, as we mentioned in an earlier chapter, is the one great pestilence which a modern writer of genius has referred to meteorological, or more properly speaking, telluric influences.

Dr. Charles Creighton devoted a section of his classical treatise to this subject. He began by pointing out that influenza almost alone of epidemic diseases has conserved its type. "To " have lasted unchanged through so many mutations of things, " from mediaeval to modern, and from modern to ultra-modern, " and to have become more inveterate or protracted at the end " of the 19th century than it had ever been is unique in this " history. Influenza appears to correspond with something broadly the same in human life at all times."‡

Creighton notices with approval the work of Noah Webster (the lexicographer) who " saw that influenza was the crux of epidemiology." In Creighton's opinion, " From Boyle we may " take the great principle of a progressive infection through " regions of air (or leagues of ground). . . . From " Arbuthnot we may take the organic source and nature of the " influenzal miasmata, and the association with changes in " the level of the water in the soil. From Webster we may " take the idea that the historic influenzas, having been sudden, " occasional, or phenomenal, must have had phenomenal causes " somewhere in either hemisphere."§

* *See* Behrens, *Arch. f. Hygiene,* 1901, XL., †.
† *Journ. Hygiene,* 1907, VII., 171.
‡ *History of Epidemics in Britain,* II., 399.
§ *Ibid.,* p. 408.

Creighton collects a large number of instances in which epidemics of influenza have followed more or less closely upon terrestrial disturbances, and concludes in the following terms. " A theory of influenza constructed from such generalities as " those of Boyle, Arbuthnot, and Webster will have attractions for many over the theory that influenza is always present in some remote country and becomes dispersed now and then " over the world by contagion from person to person: it will " have superior attractions, for the reason that influenza is a " phenomenal thing which needs a phenomenal cause to " account for it. But if anyone were to attempt to fit each historic Wave of influenza with its particular earthquake, or " to find the precise locality where clouds of infective matter had arisen, or the particular circumstances in which they " arose, he would certainly find his fragile structure of probabilities pulled to pieces by the professed discouragers and " depravers. I make no such attempt, but I am not the less " persuaded of the direction in which the true theory of " influenza lies."*

In other chapters of this report we have referred to some of the arguments and facts just quoted, and have attempted to associate them by means of a different, although not necessarily better, hypothesis. We have not now to criticise, but merely to record the reasons for devoting attention to the weather and allied phenomena in a report upon the pandemics.

The statistical work of Farr and his successors encourages us to look for some correlation between variations of the meteorological elements and variations of the incidence of epidemic disease, especially of respiratory disease. The well deserved reputation of Creighton requires us to ask whether in the events of 1918 any meteorological happenings were so much out of the common run as to characterise the period and justify the adjective phenomenal.

Our discussion must be confined to the British Isles, and we are deeply indebted to Sir Napier Shaw, F.R.S., Director of the Meteorological Office, for the valuable advice and records which he has placed at our disposal.

The second of the two questions proposed, will not detain us long. No two years are the same and, in that sense, the weather of each is peculiar to itself. But no event of the year 1918 was of such a character that we could fairly bring it into the class of occurrences which would make it a reasonable basis from which to explore further the telluric theories of Boyle, Arbuthnot, Webster, or Creighton. We do not say that this negative result

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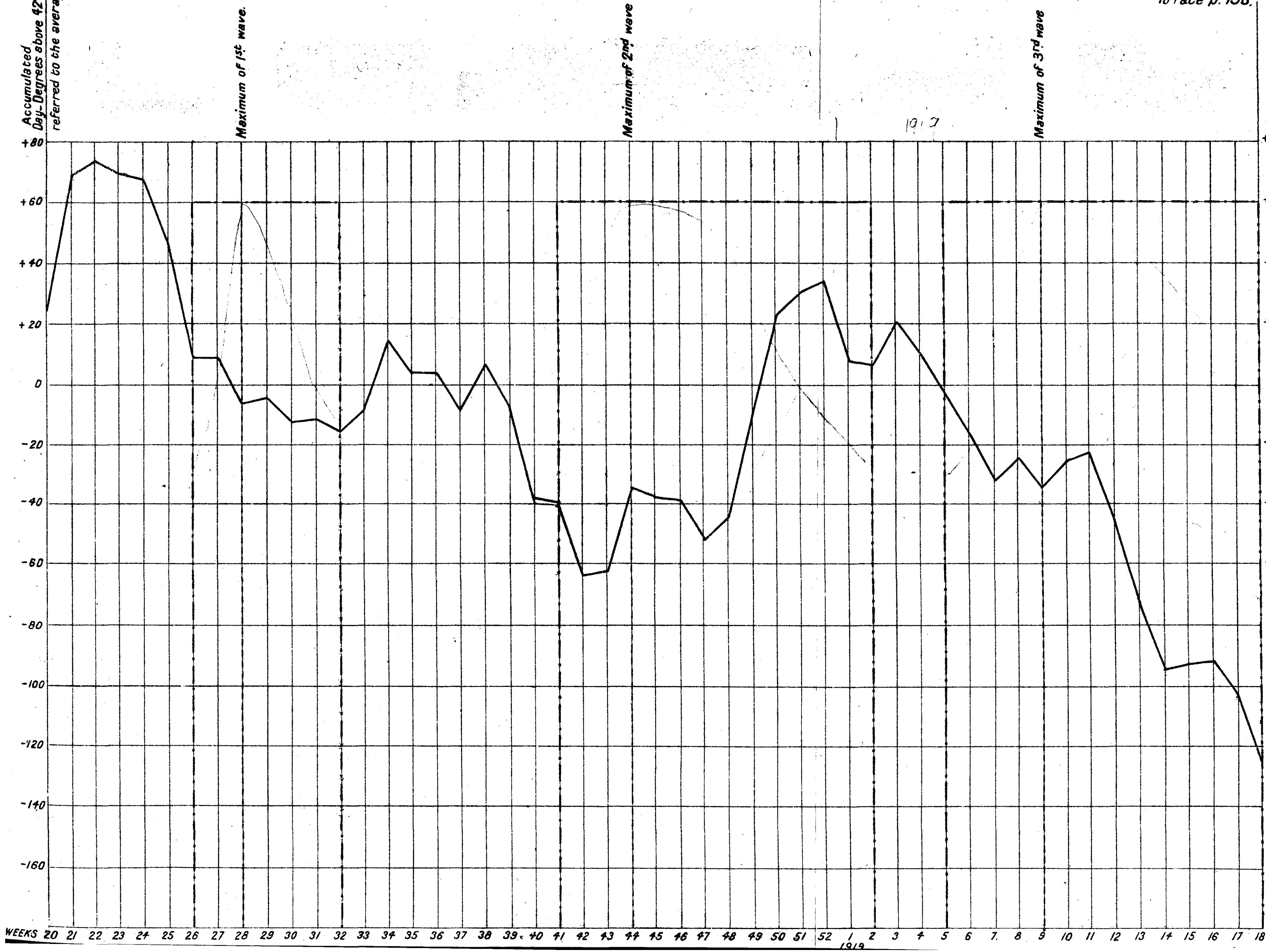
* *Ibid,* p. 425.

is fatal to their theories, but it absolves us from their discussion. For the same reason we have no basis whatever for the reconstitution of a doctrine of pestilential katastasis which would explain any of the epidemiological facts. Such connection between the influenzas and the weather as our study has helped to elucidate is of a lower order of importance and to it we now turn.

We shall first and more particularly consider the meteorological conditions of the London district. The three waves of the pandemic were experienced in the metropolis between the 26th and 32nd week of 1918 (first wave), from the 41st week of 1918 to the 2nd week of 1919 (second wave), and from the 5th to 18th week of 1919 (third wave). The maximum weeks of mortality were the 28th of 1918, the 44th of 1918, and the 9th of 1919. An examination of rainfall and of sunshine records does not bring out any variation from the normal which is in the same sense in each period, but there is a certain similarity between all in the matter of temperature.

It is the practice of the Meteorological Office to tabulate accumulated temperature, a base being an air temperature of 42° F. For instance, the report for the 28th week of 1919 notes that in S. E. England the accumulated number of day-degrees above 42 was 1,344, and that this was 134 below normal; in the 29th week the return is 1,460, 155 below normal. This is to say, that down to the 28th week the balance of warmth above 42 was below the average (the normal standard is the mean of the years 1881-1915), and that in the 29th week the adverse balance was increased, that week being below the standard. If now we plot the weekly variations from the standard for a series of weeks, the heights of its ordinates will measure the general situation, while the slope from point to point measures the change of position. Diagram 1 shows the deviations of accumulated temperature from the standard from the 20th week of 1918 to the 18th week of 1919 (Kew readings) and the positions of the waves of influenza in London are indicated. The broken lines correspond to the week of maximum mortality in each wave. In the 20th week of 1918 a credit balance of day-degrees over 42 F. had been amassed, and this was increased up to the 22nd week, and but slightly diminished by the 24th. Then a sharp fall began and by the 26th week nearly the whole of the credit balance of more than 70 degrees had been spent. This sharp fall immediately preceeded the manifestation of the epidemic in our mortality returns and occurred during the first stage of the pandemic in London. A similar phenomenon will be observed before the second wave ; from the 38th to 40th week there is a steep decline. We see the same course before the third wave, temperature is lost steeply from the 3rd week of 1919 to the 7th, *i.e.*, until well into the period of epidemic prevalence.

To face p. 158.


Accumulated Day-Degrees above 42° F referred to the average.
Maximum of 1st wave.
Maximum of 2nd wave
Maximum of 3rd wave
+80
+60
+40
+20
0
-20
-40
-60
-80
-100
-120
-140
-160
WEEKS 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
1919

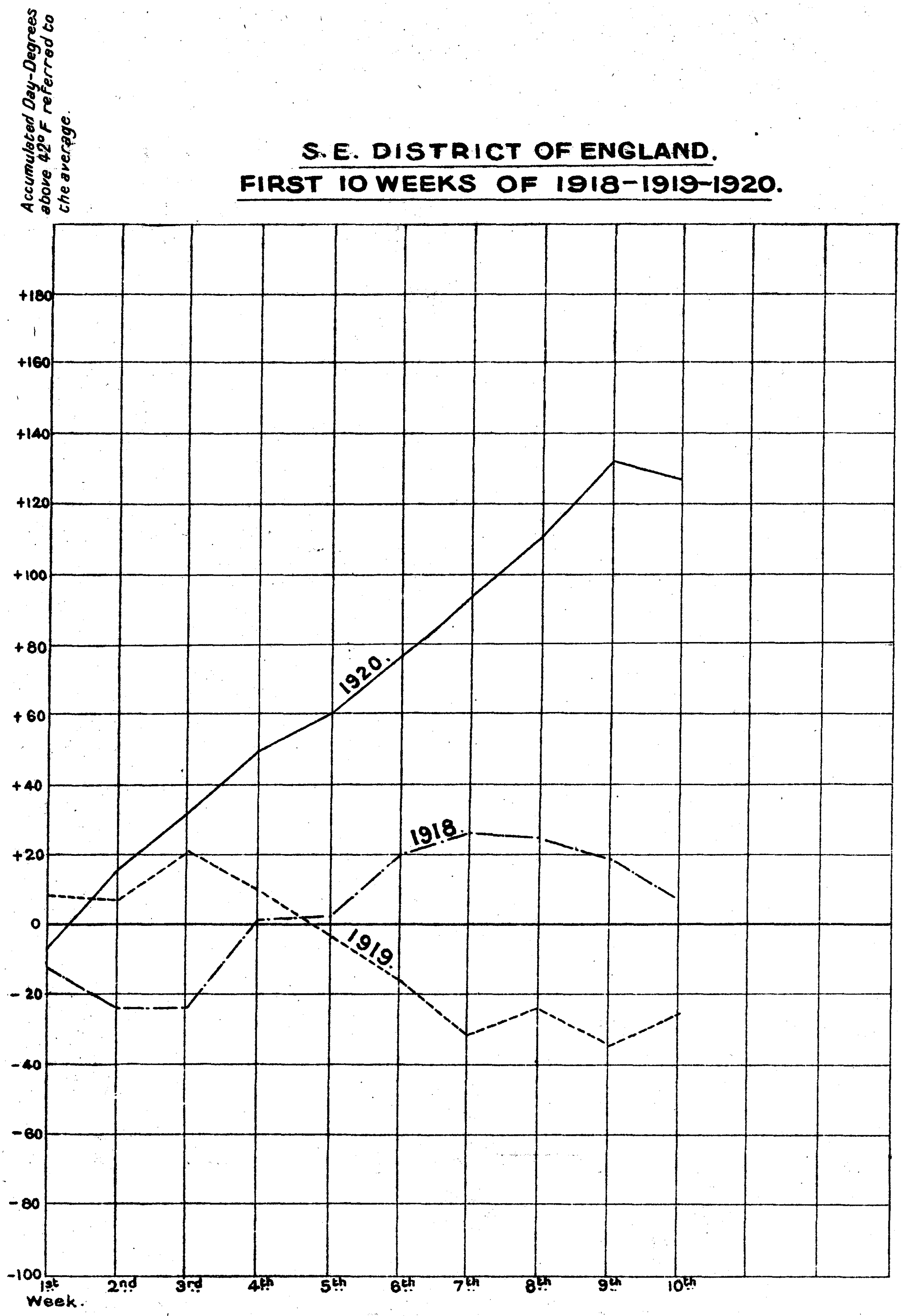


DIAGRAM 2.

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Turning to the general facts of the situation, we find that in the 25th week of 1918 the mean temperature in all stations was below normal, and strong south-westerly to westerly winds were experienced. In the following week warmth was " very deficient " in 10 districts, and " deficient" in the remaining two. In the 39th week, eight districts reported " deficient," and four " moderate " warmth. In the 40th week, S.E. England reported "very deficient" warmth, 10 others " deficient," and only one (East Scotland) "moderate" warmth. It may be mentioned that " very deficient" warmth is such a departure beneath the average as is likely to occur once in 12 years, while " deficient" warmth will occur on the average three times in 12.

In the 4th week of 1919, six districts were " deficient," and six "moderate"; in the 5th week, S.E. England was "very deficient," and all the others "deficient"; in the 6th week, S.E. England was still " very deficient," and all other districts, except Ireland, " deficient." In the 7th week, the Midlands were "very deficient," and all the others, again excepting Ireland, " deficient."

We see then that the state of affairs in London was fairly typical of conditions prevailing over most of the British Isles.

This uniformity of deficient temperature before and in the first stage of each outburst of influenza may be contrasted with the diversity of the rainfall conditions. Prior to the summer wave, the weather was exceptionally dry. The report for the 25 th week of 1918 refers to the almost continuous deficiency through seven weeks, S.E. England having but 39 mm. as compared with a normal of 77 mm. In the 38th week, the rainfall was " very heavy" in 10 districts, and " heavy " in the remaining two. In the 40th week it was " very heavy" in three districts, " heavy" in seven districts, and "moderate" in only two. Thus there is agreement in the matter of deficient warmth; flat disagreement with respect to moisture.

In diagram 2 a further comparison is instituted. We give the differences of accumulated temperatures above 42° F. for the whole S.E. District of England in the first 10 weeks of the three years 1918, 1919, and 1920. In 1918, influenza was not epidemic in the first 10 weeks of the year ; in 1919 there was a great outbreak, the third wave of the pandemic; in 1920 influenza was epidemic, but the epidemic was of minor importance. Only in 1919, the year of great mortality, is there a long continued downward trend, the curve from the 3rd to the 7th week was almost a straight line and more than 40 day degrees were lost in the period.

Somewhat similar observations were made in Paris, and in the report issued by the Direction d'Hygiene* the following remarks occur:—

> " Without pre-judging the relation which may exist between meteorological phenomena and the invasion of influenza, we observe that the mortality in 1918 was at first low in the course of a period of remarkable dryness from May to the end of June coincidently with a lowering of the temperature prolonged for live or six weeks. From this point the mortality began to rise slowly, and then diminished as the temperature rose and more than the average rain fell.
>
> " August was characterised by a period of four weeks' dryness and ended with a sensible increase of deaths seeming to prepare the way for the critical period from mid-September to mid-October, in the course of a phase of drought which endured for six weeks during which great deviations were noted. A lowering of the temperature, which was below normal for live weeks, coincided with this exceptional dryness. It was during this period that the percentage of deaths from influenza were most numerous ; 32 • 66, 45• 27, 49 • 22, 46 • 59.
>
> " In November, the temperature became normal again and rain fell in abundance, the rain gauge showing a considerable positive deviation ; the deaths from influenza decreased, falling from 1,263 to 629, and then to 309 (absolute numbers) or to 42 • 22, 39 • 84, 26 • 45 per cent.
>
> "The curve of mortality rose again coincidently with a new fall of temperature. It reached 25 per cent. During this period, rain fell in abundance, then at the first increase of temperature, influenza declined ; this outburst lasted, with a slight inflection, three weeks.
>
> " Is there correlation between the increase of mortality from influenza, and a fall of temperature coinciding with a period of drought ? Or is influenza favoured by one only of these meteorological phenomena, low temperature or absence of rain ? "

These results suffice to establish a *prima facie* case in favour of the view that an unseasonable deviation of weather towards the side of coldness played some part in the mortality of the epidemics. They not less clearly testify against any claim that weather conditions rank among the primary factors of the pandemic or epidemic prevalences. Diagram 2 makes this clear, for, were deficient temperature primary, we should expect that 1920 would have less fatal influenza than 1918, since it

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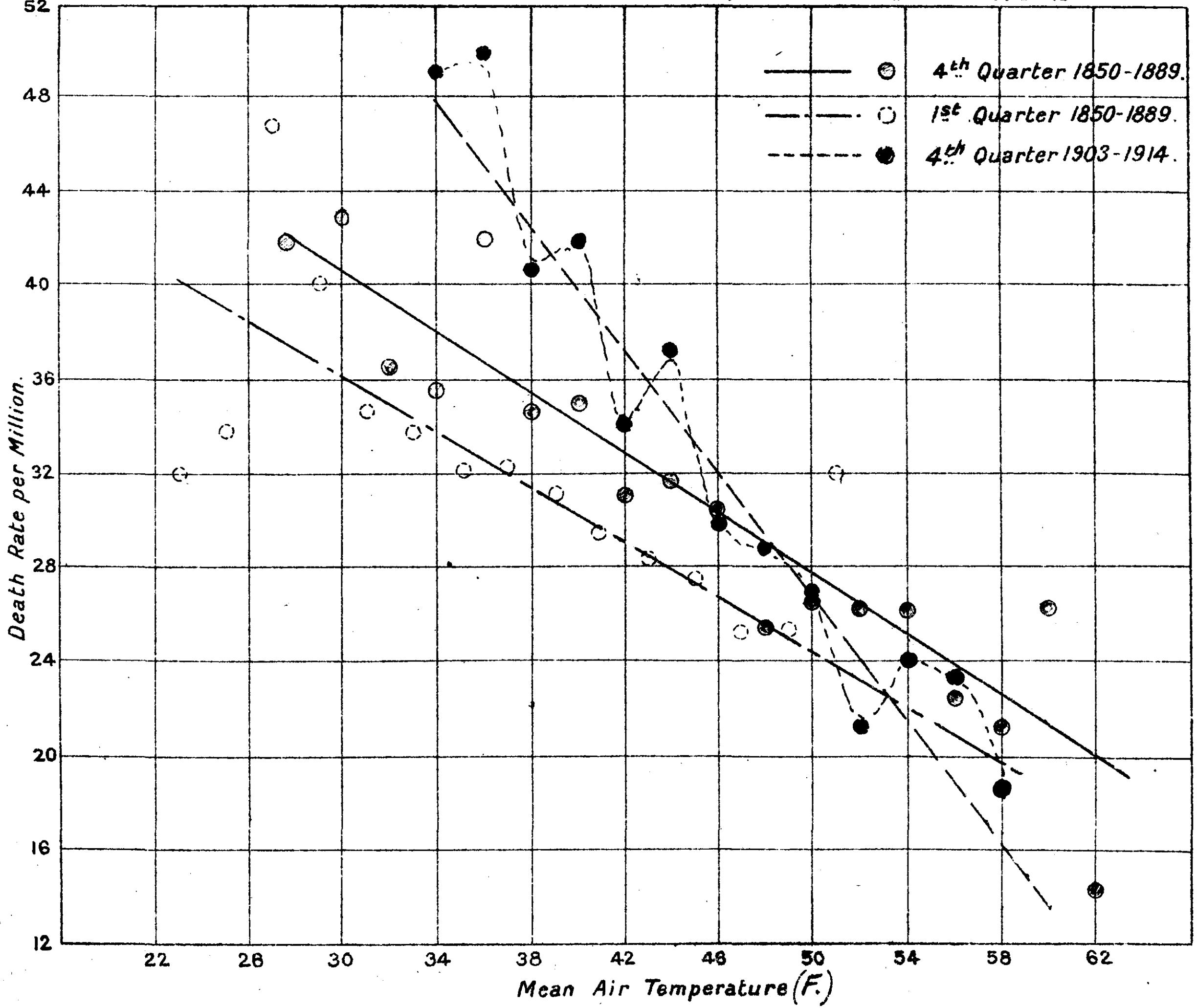
* *Epidemie de Grippe a Paris,* Recueil de Statistique de la Ville de Paris et du Department de la Seine. 1919, p. 13.

DIAGRAM 3.
MEAN DEATH-RATE FROM PNEUMONIA, AND AIR TEMPERATURE.



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accumulated steadily for weeks a credit balance of warm days. Actually there was more influenza in 1920 than in 1918 within the periods compared. But it is hardly necessary to labour the point, since it is not here contended that deficiency of temperature was more than an accessory cause. Yet such a subordinate role is not without importance. We may in fact suppose that, given the necessary conditions of epidemic prevalence—the nature of these has been the subject of discussion in other chapters of the report—those climatic conditions which are the sport of chance but yet capable of moderately accurate prediction over short periods, do appreciably modify the price in terms of mortality which the epidemic will exact

Some interest therefore attaches to an investigation of the quantitative relation between temperature changes and the mortality rate from respiratory diseases, especially pneumonia, and we have therefore analysed certain data.

The death rate per million from all forms of pneumonia in each of the last 12 weeks of the first quarter of the year was computed for each of the 40 years, 1850-1889. in London, and each death rate was associated with the mean) temperature of the air in the immediately preceding week. From the resulting 480 pairs of observations a correlation table was formed (the units of grouping were 2° for temperature and 4 per million for death rates). The same course was followed with the observations relating to the last 12 weeks of each year.

It was found that temperatures and death rates were quite definitely correlated (Tables 1, 2, and 3, and Diagram 3), and although the regression cannot be truly linear it will be seen that a straight line is a quite reasonable representation of the general trend. A drop of 1° Fahrenheit in the temperature corresponds to a rise in the pneumonia death rate per week of about 6 per 10 million living.

The absolute magnitude of the effect is small, and in this analysis no attempt has been made to correct for seasonal trend. However, when this is done—by a method it is needless to to describe—correlation is still observed.

The same process was then applied to the London data for the 12 years from 1903-1914, and for the last 12 weeks of the year (135 observations were available; meteorological observations were not published after the third week of the last quarter in 1914, and for the purposes of this trial it was not necessary to consult the unpublished data).

The interesting result emerged that in the recent period the correlation between the pneumonia death rate and the temperature of the previous week was much higher than in the pre-influenzal period. It will be noticed that the slope of the representative line is much steeper than in the previous trials, and the difference is greater than to be expected as a result of chance fluctuation, The absolute magnitude of the variation of death rate with temperature is indeed still small, and the irregularity of the trend considerable, but it is hard to escape the suspicion that the pneumonia of recent years has varied more closely with temperature changes than was the case in the pre-influenzal period. The limitation of the analysis to the last quarter of the year which, prior to the great pandemic, has not, in the present generation, been much affected by epidemic influenza avoids an obvious source of fallacy.

The object of the present remarks is not to expose the general relation between weather and respiratory diseases—a problem which it is intended to examine in detail in another report—but to illustrate the fact that inferences drawn from one period cannot be safely transferred to another. A further inference is that, although the measurable fluctuations of mortality from pneumonia and of such a criterion as air temperature have been much too small to warrant any certain inferences from the peculiarities of 1918-19 noticed above, there is still room for further study of the problem.

We may, indeed, have complete confidence that the cruder generalisations of the old hypotheses are unsound, and that the part played by the meteorological peculiarities of the pandemic years was a minor one ; it is not, however, improbable that some importance attaches to the features to which we have directed attention.

TABLE 1.

Relation between the Weekly Death-rate from Pneumonia in London and the Average Temperature of the previous Week.

—	1st Quarter, 1850–89.	4th Quarter, 1850–89.	4th Quarter, 1903–14.
Mean temperature (x) - -	39·57	44·49	46·15
Mean death-rate (y) - - -	30·48	30·77	31·69
Standard deviation of temperature.	5·13	6·26	5·51
Standard deviation of death-rate	8·08	9·37	10·11
Coefficient of correlation - -	—·371	—·458	—·707
Regression equation - - -	$y=53{\cdot}59-{\cdot}584x$.	$y=61{\cdot}27-{\cdot}686x$.	$y=91{\cdot}57-1{\cdot}298x$.
No. of observations - - -	480	480	135

Difference of regression coefficients in the two samples of 4th quarters, •612 ± •086.

TABLE 2.

A Comparison of the observed Mean Death-rates for particular Ranges of Temperature with the Values assigned by the Equations for4th Quarters.

Mean Temperature (F.).	1850-89.			1903-14.		
	No. of Observations.	Mean of observed Death-rates.	Calculated Death-rate.	No. of Observations.	Mean of observed Death-rates.	Calculated Death-rate.
28	4	41·5	42·1	—	—	—
30	3	42·5	40·7	—	—	—
32	14	36·6	39·3	—	—	—
34	12	35·7	38·0	3	49·2	47·5
36	18	41·8	36·6	3·5	49·9	44·9
38	42·5	34·7	35·2	5	40·5	42·3
40	45	35·2	33·8	13	41·9	39·7
42	58	31·3	32·5	19	34·1	37·1
44	57	31·5	31·1	14·5	37·3	34·5
46	58·5	30·8	29·7	13	29·9	31·9
48	47·5	25·6	28·4	25·5	28·7	29·3
50	48	26·8	27·0	11·5	26·8	26·7
52	29	26·2	25·6	12·5	21·2	24·1
54	22·5	26·2	24·3	5·5	24·0	21·5
56	13	22·5	22·9	5	23·3	18·9
58	6	21·2	21·5	4	18·5	16·3
60	1	26·5	20·1	—	—	—
62	1	14·5	18·8	—	—	—

TABLE 3.

A Comparison of the observed Mean Death-rates for particular Ranges of Temperature with the Values assigned by the Equation for 1st Quarters (1850-89).

Mean Temperature (F.).	No. of Observations.	Mean of observed Death-rates.	Calculated Death-rate.
23	1	32·0	40·1
25	3·5	34·3	39·0
27	4	46·5	37·8
29	10·5	40·0	36·6
31	22	34·5	35·5
33	26	33·9	34·3
35	51	32·1	33·1
37	63	32·4	32·0
39	58·5	31·1	30·8
41	63·5	29·6	29·6
43	80·5	28·4	28·5
45	49·5	27·8	27·3
47	35·5	25·2	26·1
49	10·5	25·5	25·0
51	1	32·0	23·8