At the threshold of any inquiry as to the influence of rainfall in yellow fever, one is met by a body of statements seemingly at variance with one another. Creighton lays stress on the fact that the first epidemic in Barbadoes followed a parching drought. For Colin says drought is "most favourable for the development of the miasms of yellow fever." Hirsch, in his exhaustive summary, says epidemics have been observed to begin and to terminate with rain. To this Berenger-Feraud adds, that at the endemic centres of the disease the annual explosion is deferred when the rains are delayed, and vice versa. And finally, Davidson dismisses rainfall as having no influence in yellow fever, except in so far as it affects temperature.

In view of all this, Fig. No. 1 is interesting. It is prepared from data as to Vera Cruz, furnished by Lombard; and as he does not give the rainfall, I introduce it—as shaded columns—from another source. The upper curve is that of temperature; the lower, that of incidence of yellow fever based on the admissions for a series of years into the Vera Cruz hospital.

For the beginning and end of the year there is some parallelism between the curves. But beyond this there is none. For at a
time when the temperature is stationary, important fluctuations occur in the fever curve. When, however, we admit rainfall to consideration, this Figure in itself bears out many of the seemingly contradictory statements made by different observers. Before the explosion we have a season of drought—only 1 in. of rainfall in 120 days. The annual explosion occurs in May and June, i.e. with the initial rains. After this there are two months of heavy rain, namely, July and October, in each of which there is a marked drop in fever; whilst in the intervening period of little rain there is no oscillation in the fever curve. This suggests that rainfall must be admitted as a factor in the problem, and the most obvious effects of rainfall are on the soil.

It is interesting to note, therefore, that some connection has been observed to exist between yellow fever and certain conditions of the soil as to moisture. Observations as to the relative prevalence of malaria and yellow fever have been so frequent and so striking as to invite generalisation. Twice Lombard\(^1\) repeats it, that there appears to be a certain antagonism between these diseases, of such sort that where the one prevails the other occurs but exceptionally. Remembering that up to recently malaria was identified with swamp land,\(^2\) it is not difficult to form some idea as to what it was that so impressed observers. It appears to be that yellow fever rarely established itself in places which, owing to the swampy character of the soil, would be especially regarded as malarious.

The town of Belize is built on partially reclaimed swamp land on the Atlantic seaboard of Central America. It has rarely been visited by yellow fever, and even then the disease has not established itself in the town. Is this coincidence, or is there more than coincident in it? To study this problem I got together all available information as to yellow fever in Belize, and for about four years have taken a series of observations on the ground water level in the place. For ordinary record one reading was taken daily at 10 a.m. The fluctuations in the level attributable to other causes are so slight and occur so rarely that for all practical purposes they may be neglected; and it may be taken that the level of the ground water in Belize is determined solely by local rainfall.

The rainfall in December and January—about 5 in. in each month—is insufficient to sustain the ground water at the level previously attained. It therefore begins sinking. In the next three relatively rainless months it sinks more rapidly, till in May it is about 5 ft. below the surface. At about the middle or end of May the dry season is terminated by the initial summer rains; and if these be continued, the ground water rises pro-

\(^1\) Op. cit., vol. iii. p. 431, and vol. iv. p. 546.

\(^2\) "Si, pour beaucoup d'auteurs, le marais est considéré encore comme la cause indispensable de la fièvre intermittente, c'est," etc. Colin, op. cit., p. 130.
gressively, till in October and November it is barely 1 ft. below the surface, and the soil becomes water-logged with even moderate showers of rain. It is needless to say that any given amount of rainfall will produce widely different effects according to the season. In the early months, with low water level and a parched soil, the effect of even heavy rainfall is but transient; whilst late in the year, with high water level and a damp soil, a relatively trifling shower of rain suffices to saturate the soil.

The town of Belize is about 120 years old. The original grants of land were made on condition that the lots should be properly filled up and reclaimed. But, owing to the dearth of suitable material, this condition has not been complied with. Ships' ballast is suitable material. But the anchorage is so far from shore that the cost of handling and lighterage makes the ordinary use of this material prohibitive. Beyond this ballast nothing is brought to Belize by way of import from places within the "yellow fever zone," and where the disease is active. This accounts for the rareness of invasion of the town by yellow fever.

But in 1849 and 1852, in two reports on quarantine against cholera and yellow fever, the General Board of Health in England put forth the doctrine of an epidemic atmosphere. According to this, the "primary and essential condition" for the occurrence of these diseases was an "epidemic atmosphere," which might exist over thousands of square miles; and during its existence the disease might occur, irrespectively of traffic, in any unsanitary place within the area. This doctrine was implicitly accepted in Belize. Hence its local insanitation could give rise to but one opinion, namely, that if an "epidemic atmosphere" prevailed, Belize would suffer. The year 1853 was "one of the most terrible in the annals of yellow fever. The disease was widely disseminated throughout the Antilles. It occurred from the extreme north to the extreme south; the Greater and Lesser Antilles and the Bermudas were ravaged." North America, South America, and the inter-American continent suffered. In view of the above doctrine, these events must have produced local dread. This soon found expression in the statute book. For early in 1854 an Act was passed to compel owners of property to fill up their lots. The preamble reflected the theory; the penalty, the dread. This penalty was—confiscation of property. Six years later, when yellow fever did appear in Belize, a committee of the Board of Health, in reporting on the matter, referred to this Act as calculated to prevent such an occurrence, and complained that its provisions had been inadequately complied with. But had all the material available in the interval been utilised, the result would have been such that the same language might have been used.

1 Simon, "English Sanitary Institutions," p. 218.
2 Berenger-Feraud, op. cit., p. 123.
3 Repealed as obsolete in 1879.
From Hirsch's tables we know that yellow fever prevailed in certain places at the end of 1859 and in 1860. From the local gazette I find that in the early months of 1860 vessels were arriving "in ballast" from such infected places, notably St. Thomas. In view of the current doctrine, of the above-mentioned drastic Act and the benefits it was supposed to secure, and of the arrival of ships from different places with their tale of yellow fever, it is but reasonable to infer that an "epidemic atmosphere" would be regarded as imminent, and a fresh impetus would be given to the reclamation of lots. In this case the ballast from these ships would be handy. Be this as it may, it is now we have the first definite record of yellow fever in Belize.

First Invasion, 1860.—The contemporary report accounts for the outbreak by the above doctrine. It dismisses transmission of the disease from place to place as but a popular error.

"Sporadic cases" occurred from February to May. In the first week of June the disease became "epidemic," and continued so till October. After this, occasional cases occurred till February 1861, if not till later.

Here the importation was in the dry season, during which sporadic cases occurred. With the initial rains the disease became epidemic, and continued so till October, when soil saturation is reached.

Second Invasion, 1869.—No report is available for this period, and the information is fragmentary. During the end of 1868 several vessels arrived in ballast from Colon with their crews fever-stricken. At first the disease was returned as febris remittens; but on the 17th May 1869, when it was reported, it was termed a virulent type of yellow fever. By this date we know the disease was ashore; for the records of the local Jesuit mission show that a priest was attacked by the disease early in May 1869; and the local gazette announces a death from this affection in the middle of the same month. After this, scraps of contemporary record show the disease to have been about, but to what extent is unknown. One thing is certain at this time, Belize was distinctly infected; for vessels arriving here free from the disease contract it. Thus on the 23rd Oct. 1869, a date when there were at least two cases ashore, the Lady Head arrived in Belize harbour. Nothing of note occurred in connection with her till she had been a month in the place. Then five of her crew fell ill of yellow fever in three days. A fortnight later the disease reappeared on board, attacking the remaining fourteen persons in the course of seventeen days more.

The information for this period is too meagre to admit of any statement as to seasonal influence.

Third Invasion, 1886.—This was brought about by the use for road repairs of ballast taken from an infected ship. This material, "soft stone which crumbles easily," was broken for road metal, mixed with other stone, and "carted to different parts of the town streets." The

1 Trans. Brit. W. Ind. Conf. on Quar., 1888, pp. 52-53.
distribution of cases was what might be expected. Road repairs amount merely to depositing small quantities of stone in the hollows formed by traffic. Thus a little stone goes along way, and within a week or ten days of its being landed portions of stone will be found on the streets. The facts are:

19th June 1886.—The brig Hedwig arrived from Colon with a foul bill of health. On the voyage one of her crew died from “fever.”

19th July 1886.—Released from quarantine. In the interval, two of her crew died from “yellow fever”; and all had had fever.

22nd July 1886.—She had discharged her ballast.

5th August 1886.—The Hedwig left Belize.

9th and 10th August 1886.—The first two cases took ill, the one in the north, the other in the south of the town.

September and October 1886.—Fifteen other cases occurred. This outbreak of invasion was initiated during the rainy season. As in 1860, it terminated in October.

Recurrence of 1887.—From the middle of May to the middle of October, sixteen cases occurred. Again, as in 1860, the onset corresponds with initial rains; the termination with soil saturation.

Recrudescence, 1889–90.—The year 1888 was free. But at the end of 1889, in the coolest months of the year, yellow fever reappeared. And this is interesting in view of the rainfall for the preceding twelve months.

| Month    | Rain. | Average. | Month    | Rain. | Average. |
|----------|-------|----------|----------|-------|----------|
| 1888. December | 1.95  | 5.53     | 1889. June | 5.45  | 7.70     |
| 1889. January   | 1.54  | 5.32     | ,, July    | 14.45 | 7.33     |
| ,, February     | 2.52  | 3.09     | ,, August  | 4.45  | 7.63     |
| ,, March        | 2.94  | 2.11     | ,, September | 2.44 | 8.58     |
| ,, April        | 0.70  | 2.51     | ,, October | 6.68  | 11.11    |
| ,, May          | 0.42  | 5.23     | ,, November | 21.47 | 11.03    |

So far as soil conditions go, this was practically a prolonged dry season, effectually terminated in November and December. Then there occurred an unusually severe outburst of malaria, and with it yellow fever reappeared. There was no “epidemic”; but up to the end of 1890, cases continued to crop up at intervals of from two to five weeks, there rarely being more than one case under treatment at the same time. In 1891 there were three cases, after which the town has been free.

The health of the town previously to the recrudescence was spoken of as “phenomenally good.” This, in Belize, means that malarial and rheumatic affections were conspicuously absent, and testifies to the

1 This date is from the books of the firm to which she was consigned; the rest are from published records.
dryness of the year. Further, having before me the daily record of rainfall for this period, and guided by my observations on the water level, I constructed a hypothetical chart of the ground water level for the entire period. By the end of June this must have sunk as low as 9 ft. The July rain was so distributed that, under the circumstances, it could not have sustained the water level at a greater height than 4 ft., and after this the water would sink again. The soil condition, therefore, was one of prolonged dryness.

Such, then, has been the history of yellow fever in Belize. It points to soil conditions rather than air temperature as influencing outbreaks of yellow fever. It shows that soil moisture following soil dryness is favourable to outbreaks of yellow fever; that soil saturation is unfavourable thereto. Another interesting point in this history is the want of persistence of the disease after importation. This can receive no explanation in the sanitary state of the town. From the collateral testimony of the Army Medical Reports, it is seen that in the years following the first two invasions there was no break in the local conditions that make for malaria. The disease did not persist. On the last occasion, shortly after the importation, there was a marked break in the conditions of soil usually existent; then followed a recrudescence, a revivification of virus as it were; and the marked manner in which the disease was localised around a place where, in 1887, a case occurred under conditions and surroundings that make soil pollution a certainty, was indeed very suggestive of soil influence. The want of persistence, and the recrudescence after suspension of normal soil conditions, lend countenance to the observations that were made as to the relative prevalence of malaria and yellow fever.

Whether the subject is dealt with from a clinical, a hygienic, or epidemiological point of view, one point is always insisted upon, namely, that yellow fever is a disease of summer-time. This was certainly so in New Orleans, where the annual range of temperature was such that, by examining the records of prevalence of yellow fever, some useful conclusions were arrived at as to ranges of temperature favourable and unfavourable to outbreaks. But when we turn to places where the favouring range of temperature is always existent, we still find a selection made: it is still a disease of summer-time. To accentuate this, it is usual to cite the data as to Vera Cruz in the north and Rio de Janeiro in the south, and to point out that, though the summer in these places is in different months of the year, yet the disease occurs in summer. This done, it is usual to state or imply that the governing influence is air temperature. I have already cited the data as to Vera Cruz. Borrowing from the same sources, I now give the

1 Æstas sicca Romae saluberrima.
2 Lombard, op. cit., tome i. tab. viii., and tome iii. p. 477; and Davidson, “Geographical Pathology,” p. 941.
data as to Rio de Janeiro in graphic form. Viewed as a matter of temperature, this figure is the reverse of that of Vera Cruz. The dotted curve is that of temperature; the other that of deaths from yellow fever during nine years; the shaded columns represent the rainfall. It will be observed that for the first six months there is no correspondence between the curves; then, when the fever curve does rise, it lags behind the temperature, and attains its maximum after the latter has declined; whereas in the Vera Cruz figure the fever declines though the temperature is sustained at a maximum. In face of these facts it cannot be conceded that temperature is the predominant and governing influence.

Yellow fever is undoubtedly a disease of summer-time. Summer-time in the Tropics is one of both elevated temperature and rainfall; and since temperature alone does not explain the behaviour of the disease during the summer months, we must consult the rainfall. But it would be idle to regard rainfall as an isolated item of the meteorological register: as merely so many inches of rain; for the effects of rainfall are most obviously on the soil, and here they are purely relative. For, as I have already observed, any given amount of rainfall will produce widely different effects according to the season, i.e. according to the amount of water already contained in the soil. Viewed, then, from the standpoint of the soil as affected by rainfall, summer-time in the Tropics is a season when the soil, previously parched and dry, is first moistened, and then gradually made more and more wet; and yellow fever is a disease of this season. And that this subject should be so regarded appears to be supported by the oft-repeated observation, that when the rains are delayed the annual explosion is deferred.

But the effects of rain differ not only according to season, but, in different localities, according to the structure and composition of the soil and subsoil. Hence, unless the rainfall is distributed

---

1 "Dans la zone tropicale, c'est la saison chaude, qui est en même temps la saison pluvieuse."—Berenger-Feraud, op. cit., p. 443.
in a markedly irregular manner, the mere record of total rainfall will not help the observer, unless he has intimate and minute acquaintance with the effects of rain on the soil of the locality concerned. This is shown in the two Figures presented in this paper. In the case of Rio de Janeiro, 27 in. of rain are distributed throughout the twelve months in such manner that, without actual observations on the ground water, it would be difficult to form any clear idea as to the results. But in the case of Vera Cruz, 39 in. of rain are so distributed that two months alone, July and October, receive more than half, namely, 21 in.; and during four consecutive months, January to April, there is only 1 in. Here we can form some conception as to the alterations produced; and when we appeal to the Figure, it bears out not only the limited experience of Belize, but also the seemingly contradictory conclusions of several observers.

"Les choses les plus contradictoires, en apparence, ont été dites au sujet de l'action de la pluie," says Berenger-Feraud. But as these observations were made by competent persons, we must accept them as observed facts in nature—as truths. To do this is to admit a paradox. "But we must remember that so-called paradoxes are merely facts as yet unexplained." In this instance it appears to me that the solution will be found when we interpret the observations as to rainfall into terms representing the soil conditions produced by this rainfall. Apart from my own observations, the Vera Cruz Figure itself reflects the truth of many of these seemingly contradictory observations. It goes to show that we should not regard these observations as contradictory and mutually destructive, but as truths and facts capable of being welded together into one harmonious whole.

Tentatively, then, we may conclude that—(1) A dry state of the soil furnishes conditions that are favourable as antecedents to yellow fever; (2) that when this dryness is terminated by rain, the explosion occurs, and continues with a moderate amount of moisture; (3) that soil wetness, well pronounced, favours the decline of fever; (4) habitual wetness or moisture of the soil is unfavourable to yellow fever. All this means that yellow fever is a disease of the summer season in the Tropics, because this is a season when marked alterations in the soil are produced by rainfall; and hence when the rains are delayed, the explosion is deferred. As to temperature, so long as that is maintained above a certain point, that is all that is needed; and in the Tropics that minimum is more or less always existent.

In connection with this subject, it is impossible to avoid making some reference to two places noted for the prevalence of both malaria and yellow fever, namely, New Orleans and Rio de Janeiro. From the literature of twenty years ago it would be easy to cite opinions as to the endemicity of yellow fever in

1 Op cit., p. 426.
New Orleans exactly opposed to one another. But the marked immunity of that town since its authorities have taken detailed precautions against importation, forces the conclusion that the prolonged history of yellow fever in New Orleans is resolvable into a history of repeated importations, and that the disease did not succeed in establishing itself there as an endemic. The same order of facts that used to be relied upon by those who denied that yellow fever was endemic in New Orleans, are now relied upon by those who deny its endemcity at Rio. But as the history of the place is now being played out, it would be premature to express an opinion on the subject, particularly as, from the point of view of this paper, important modifications appear to have occurred in the climate of Rio—modifications that cannot but result in producing marked alterations in the soil conditions of the place, as shown by the following passage from Lombard 1: "Depuis le siècle dernier où, d'après le naturaliste Dorta cité par Sigaud, la quantité des pluies a notablement diminué, de 1782 à 1787 l'on avait compté 1454 mm, tandis que de 1851 à 1867 il n'en est plus tombé que 1096 mm. Les mois extrêmes sont, pour le maximum, décembre avec 148 mm, pour le minimum, juin avec 43 mm. En même temp que les pluies, le nombre des orages a diminué de fréquence et d'intensité, en conséquence du défrichement des forêts environnantes. Les mêmes causes sont invoquées pour expliquer l'abaissement des moyennes pluviométriques. Les orages étaient autrefois quotidiens: ils éclataient vers trois heures de l'apremidi et s'accompagnaient de larges averses; les affaires cessaient vers cette heure de la journée et l'on se donnait rendez-vous après l'orage."

THE CLINICAL ASPECTS OF ARTERIAL PRESSURE: SOME PHYSIOLOGICAL DATA BEARING ON THE CLINICAL OBSERVATION OF THE BLOOD PRESSURE

By George Oliver, M.D., F.R.C.P.Lond.

(Concluded from page 239.)

II. PHYSIOLOGICAL CAUSES OF VARIATION IN THE BLOOD PRESSURE (ARTERIAL AND VENOUS).

7. Respiration—The respiratory Pump Effort.—The influence of ordinary inspiration and expiration on the blood pressure is so transitory and insignificant that in practice it may be disregarded. It is quite otherwise, however, when the respiration is stimulated to increased activity. During the past four years I have repeatedly observed that when in the vertical position of the body there is evidence of gravitation of blood into the splanchnic

1 Op. cit., tome iii. pp. 451-452.