

Yellow fever in the Gambia. I, Historical / by G.M. Findlay and T.H. Davey.

Contributors

Findlay, G. M.

Davey, T. H. 1899-1978.

Publication/Creation

London : Royal Society of Tropical Medicine and Hygiene, 1936.

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ZONAE TORREDAE TUTAMEN

Reprinted from the
Transactions of the Royal Society
of Tropical Medicine and Hygiene.

Vol. XXIX. No. 6. pp. 667-678

(Issued April, 1936)

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I. HISTORICAL.

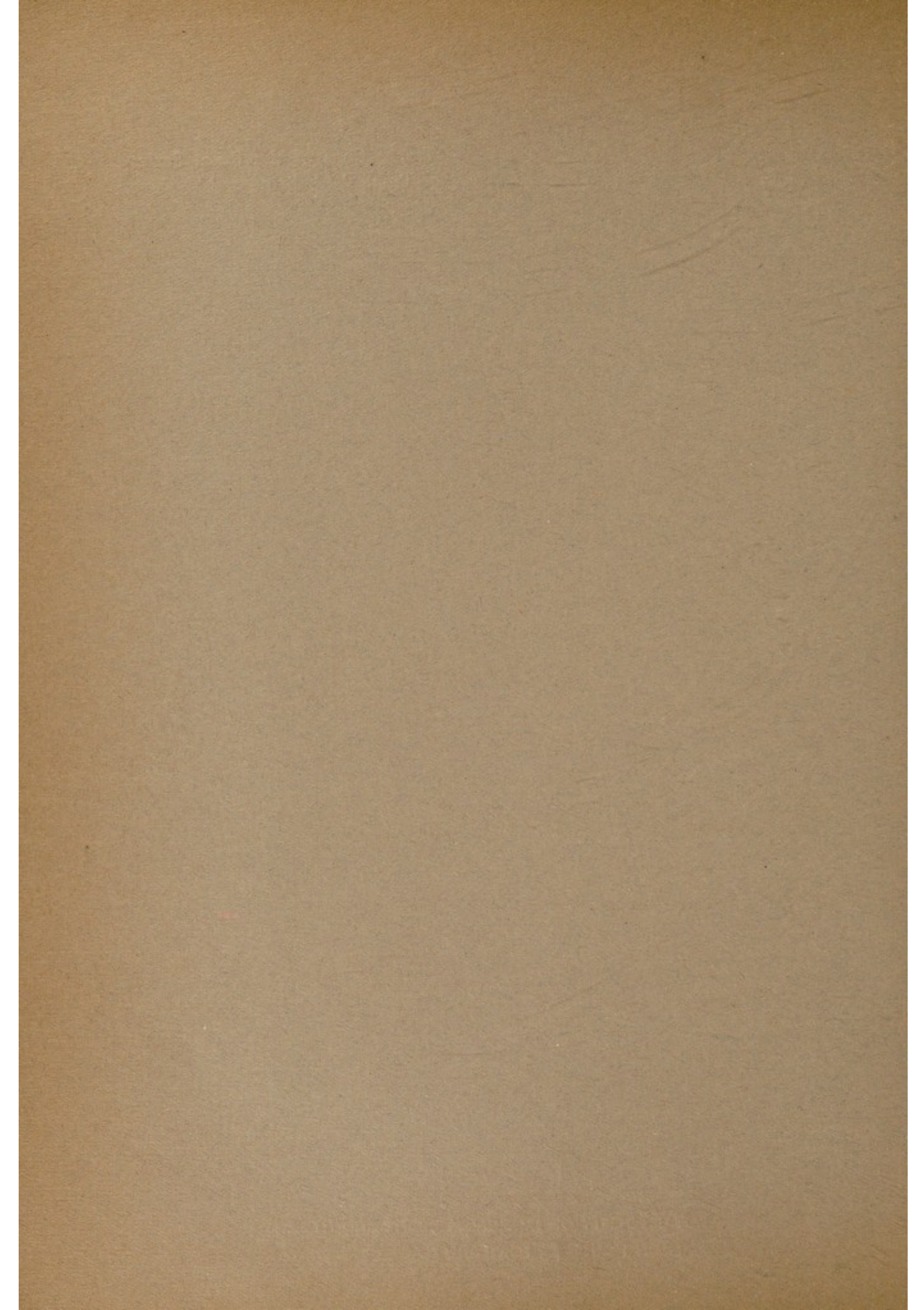
BY

G. M. FINDLAY

AND

T. H. DAVEY,

*Wellcome Bureau of Scientific Research, London; and Sir Alfred Jones Laboratory,
Liverpool School of Tropical Medicine, Freetown, Sierra Leone.*



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During the last three months of 1934 an outbreak of yellow fever occurred in Bathurst, the capital of the Gambia. As a preliminary to a description of the investigations made on this outbreak, a brief account is here given of previous epidemics that have occurred in the Gambia, either of yellow fever itself or of diseases closely resembling yellow fever.

Yellow fever was first accurately described on the Atlantic coast of America during the seventeenth century ; there is, however, no recorded outbreak in West Africa that can, with certainty, be regarded as yellow fever till that reported

by SCHOTTE (1782) as having occurred at St. Louis de Senegal in 1778, a year in which the Gambia also was infected. SCHOTTE, though calling the disease "synochus atrabiliosa," regarded it as a severe form of malarial fever and for many years this was the generally accepted view of its nature. To determine whether a particular outbreak was yellow fever or malaria is by no means easy, more especially when it is remembered that the whole nomenclature of fevers was chaotic till well into the nineteenth century. AUGUSTIN (1909), for instance, gives 105 synonyms for yellow fever and his list can easily be augmented. BRYSON (1847) was the first to introduce some sort of order, so far as the ships of H.M. Navy were concerned, by allowing only three headings for fever in the naval returns—intermittent, remittent and yellow. As DUDLEY (1932) has pointed out, the first must have comprised chiefly benign tertian and quartan malaria and relapsing fever, the second largely subtertian malaria, with a variable amount of enteric fever and missed yellow fever cases. Blackwater fever also probably fell into this second group, together with occasional cases of leptospiral jaundice and epidemic catarrhal (common infective hepatic) jaundice. The last three diseases are hardly likely to have caused fulminating outbreaks with a high mortality, while the mildness of the enteric group of fevers in West Africa is well known. Epidemics with a heavy death rate either on shore or on board ship were therefore almost certainly due either to yellow fever or to malaria and even before the days of treatment by "the bark" the latter as compared with the former must have been a negligible cause of death. Moreover, deaths from cerebral malaria were, it appears, often entered as apoplexy or sunstroke.

The good example of the naval authorities in insisting on a standardized nomenclature was not, however, followed by the medical authorities ashore, and throughout the nineteenth and even into the present century deaths are said to have been due to "bilious haematuric" and "bilious remittent" fever.

Although therefore the earliest febrile epidemics with high mortality cannot with certainty be ascribed to yellow fever, there is a strong probability that they were due to this infection.

The Gambia was first visited by the Portuguese in 1455 when ALVICE DA CADAMOSTO entered the mouth of the river. In the following year at the instigation of HENRY THE NAVIGATOR he returned. While proceeding to the country of Battimansa, 60 miles up stream, fever broke out and one man was buried on a small island. At the end of the 11th day of his stay with Battimansa, CADAMOSTO decided to return to the mouth of the river as many of the crew had begun to suffer with a hot fever which was acute and continuous (RAMUSIO, 1563-83 and PRESTAGE, 1933). It is implied that if the sickness had not been so severe as to affect further progress it would not have been noted.

The next Portuguese expedition to reach the Gambia was also unfortunate. Either in 1456 or 1458 DIOGO GOMES ascended the river, accompanied by two caravels. One of these he left at Ollimansa, the other 50 leagues nearer the ocean, while he went further up to Cantor (the modern Kuntaur). Here his

men became worn out with the heat. He therefore returned in search of the other two caravels. In that which had remained at Ollimansa nine men had died, the captain, Gonçalo, was very ill and all the rest of the crew except three, were sick. In the other caravel five men had died. Unfortunately, information is lacking as to the total number comprising the crews of the two caravels, so that the death rate cannot be determined (PRESTAGE, 1935).

By the end of the sixteenth century the English were trading in the Gambia but the company founded in 1588 by QUEEN ELIZABETH did not prosper. In 1618 another trading company was incorporated and the *Catherine*, 120 tons, was sent out under Richard Thompson. With the exception of the captain the greater part of the crew of the *Catherine* was massacred. A second ship sailed in 1619, "arrived at an improper season" and lost most of the crew by sickness. At the end of the seventeenth century yet another corporation, "The Royal African Company," was founded and a fort was established on James Island in 1664. In the eighteenth century reports of the unhealthiness of the Gambia increase. STIBBS, on his arrival at Fort James in 1723, was greeted by the news that the Governor and two other Europeans had just died suddenly at Joar, one of the Company's factories. "Mr. Willy was buried on the North Bastion where several other Governors lie." MOORE (1738) himself suffered from an attack of fever while his assistant "died of a fever about the tenth day of his illness." MOORE notes that "while the ships lie in the River the Crews are apt to be sick and consequently not able to guard their slaves. . . . These musquetoos are the greatest plagues to one's person of any other vermin on the River. The musquetoos mind neither wind nor anything else but are always plaguing one, especially in the night."

After the middle of the century the treatment of fevers by quinine, "the bark," became more general, but there was no cessation of febrile epidemics with high mortality. LIND (1777), for instance (p. 172), quotes Mr. MARTIN, surgeon of the *Cataneuch*—a Guinea trader—to the effect that when he was in Gambia River in company with four other ships, "the men in one of those ships was daily taken ill of fevers and fluxes and several of them died delirious. Upon removing that ship about half a league from her first anchorage which was too near some swamps, her men became as healthy as those in the other ships." LIND (p. 196) also relates a very circumstantial account of an outbreak, said to have occurred in August, 1768, on board H.M. Sloop *Merlin*, "which continued six days in the river Gambia being employed in wooding and watering. While there, all the men were in perfect health but in about two days after they put to sea, those who had been employed in wooding were successively taken ill; afterwards those who had been employed in the duty of watering were seized in the same manner. Several of them in a day continued to fall sick for six or seven days afterwards, until at length almost all that had been employed on those services were ill: after them their attendants were seized with the fever and in such numbers as to leave no doubt of the disease being infectious." LIND

fails to mention whether any of these fevers were fatal and unfortunately the surgeon's journals for the period have now been destroyed. An inspection of the original log of H.M. Sloop *Merlin*, preserved in the Record Office, shows that LIND was not entirely correct in his facts. The *Merlin* did not visit the West Coast of Africa in 1768, as stated by LIND, but only arrived off Senegal from England on 1st July, 1769. On 14th July she anchored in the Gambia River and left again on 27th July for Sierra Leone. While off the latter port on 5th August "there departed this life Captain Thomas Male and Thomas Rogerman, surgeon's servant." These were the only fatalities on the voyage and this was the only visit of H.M. Sloop *Merlin* to the Gambia between 1766 and 1773.

A much fuller and more authentic account is given by ROBERTSON (1777) of an outbreak in H.M. Sloop *Weasel* in 1769 following a brief sojourn in the Gambia. "The ingenious Mr. Robertson," as LIND calls him, not only gives a very full account of the outbreak but by printing his daily journal enables the reader to follow accurately the course of the epidemic. The *Weasel* first sighted the Barbary Coast on her voyage from England on 22nd July and on the 28th was off the Gambia River. The next day she "stood in towards the River and spoke H.M. Sloop *Hound* and got a man out of her to pilot us up the River—he had a very sickly complexion"; 30th July was spent in getting up the River. "They anchored p.m." and next day the men were sent ashore to cut wood. "The men were exposed to the rains." On 1st August they continued up the River and ran aground near Fort James, "which occasioned the men's being very much fatigued in the heat of the sun." The following day they got the ship off and "after much trouble anchored in the sun nearly opposite the Fort." On 4th August "the men were employed in watering ship, the watering place being on the north bank at a point where it was very swampy and covered with trees and shrubs. The water was thickish, but had no bad taste. As boats could not get near the shore the men had to swim the casks off." On 7th August "most of the officers and gentlemen were ashore—which was all a marsh—shooting"; 8th August they got under way and began sailing down the river, being clear of it by 10th August.

Before the arrival of the *Weasel* in the Gambia there was very little sickness on board. On 30th July the *Hound's* man went sick within 24 hours of joining the ship. He suffered from a tertian intermittent fever and went back to duty on 14th August. Between 1st August and 14th August there was one bad case of tertian intermittent and eleven slight fevers which were very mild and easily cured. Some of them were seized with the bad fever afterwards and several died. The first fatal remittent fever was in a boy of 13 years of age who complained of sickness on the 14th August, on which day (6 days after leaving their anchorage) five other remittents were added. The initial symptoms in both mild and severe cases were similar, a continuous pain in the loins, headache, "sickness at their stomachs and great uneasiness." In the malignant cases

the patients complained of severe postorbital pains and were exceedingly dejected during the slight and temporary remission which often occurred about the 3rd or 4th day, to be followed later by delirium. On the 7th day some of their countenances were quite yellow and others looked wild. Vomiting and loose foetid stools were more general; the pulses were irregular. On the 8th day a few, after violent vomitings and purgings, broke out in purple blotches like the stinging of nettles, particularly about the face and neck, which soon disappeared. In one patient the parotid gland became swollen. On the 9th day "one who had purple blotches likewise had an haemorrhage from the nose and mouth at times, his urine too was bloody." In one patient a large ecchymosis-like swelling appeared on the right side of the neck and face a little before death. The majority of those who died had never before been abroad. The following list of fatal cases, *taken from the ship's log*, shows that seven of the ten deaths occurred after an illness of less than 10 days duration. These figures differ slightly from those given in the text by ROBERTSON himself (p. 16) whence

FATAL CASES OF REMITTENT FEVER IN H.M. SLOOP *Weasel*, AUGUST, 1769.

Number of Cases.	Date of Onset.	Date of Death.	Number of Days Sick.
3	14.8.69	21.8.69	7
	20.8.69	27.8.69	7
	24.8.69	31.8.69	7
2	16.8.69	24.8.69	8
	20.8.69	24.8.69	8
2	17.8.69	26.8.69	9
	18.8.69	27.8.69	9
1	18.8.69	28.8.69	10
1	18.8.69	30.8.69	12
1	18.8.69	2.9.69	14

they have been copied (not quite accurately) by LIND (1777) and thence by CARTER (1931). They show that yellow fever cannot be so easily ruled out as a cause of the mortality as suggested by CARTER (p. 256). From 14th August to 27th August inclusive, thirty-three cases of remittent fever were treated, in a crew of ninety, though many of those who were not actually sick are said to have been far from well. On 27th August the ship was "smoked." One further case of fever occurred on 2nd September.

Indications which suggest that the disease may not have been yellow fever are, the fact that vomiting of matter like the grounds of coffee was not observed, and in one case a favourable crisis did not occur till the 18th day. "An eruption appeared about some of their mouths." CARTER (1922) regards herpes labialis

as common in malarial fever but very rare in yellow fever. However, five cases of herpes labialis have been observed among 800 persons immunized against yellow fever, so that its occurrence does not necessarily rule out yellow fever. The high mortality rate, the quick succession of deaths and the tendency to haemorrhage are in favour of yellow fever though almost certainly cases of malaria were also present on board. The fact that the outbreak ceased after fumigation of the ship is, however, highly suggestive evidence that during its stay in the Gambia the *Weasel* had taken on board mosquitoes infected with yellow fever, for if malaria had been the principal cause of sickness the destruction of the mosquitoes would hardly have caused so sudden a cessation of the outbreak.

In 1778 and 1779 cases occurred in the Gambia which were similar in character to those described by SCHOTTE (1780) in Senegal.

In the nineteenth century Bathurst becomes the chief centre of interest in regard to the incidence of yellow fever in the Gambia. Bathurst was founded in 1816, the greater part of the population being made up of liberated slaves with a small number of European officials and traders. Even by 1840 the population consisted of only thirty-six whites and 2,825 blacks. The first epidemic, almost certainly of yellow fever, occurred in 1825 when of a detachment of 108 men 74 died of a remittent fever. In 1828, according to BÉRENGER-FÉRAUD (1890) the whole coast from the Bight of Benin to the Gambia suffered from yellow fever but there is no record of cases actually occurring in Bathurst. The conditions in Bathurst in 1835 were very fully described by ALEXANDER (1837). Although many of the Europeans were then suffering from intermittent fever Mr. TEBBS, the surgeon, stated that at that time Europeans rarely died of fever. When he first arrived in 1829 the colonial surgeons had said to him "In bilious fevers you must not be surprised or annoyed if you lose one half of your patients. We consider ourselves lucky if we do not lose three fourths." They bled copiously and used mercurials. TEBBS ascribed his success to purgatives and the bark. Unfortunately, in the next epidemic which took place in 1837, TEBBS himself was one of the earliest victims. This outbreak was fully described by PYM (1848), and is noteworthy as being the first in the Gambia which was definitely described as yellow fever. H.M. Brig *Curlew* left Sierra Leone, where yellow fever was then epidemic, about the middle of May. While on passage the disease broke out among its crew and on arrival at Bathurst on 4th June fifteen men were either dead or dying. One half of the Europeans in the town succumbed, all those infected dying. Five Europeans, including the then Colonial Secretary, escaped to Senegal but all died of the disease, which then proceeded to carry off a large part of the population of Gorée.

Whether the disease was actually carried from Bathurst to Gorée is uncertain. Throughout the nineteenth century it was customary for the authorities of any infected port to accuse other ports of having passed on the infection. According

to BRYSON (1847) a fatal fever was already present in the Gambia in May, 1837, for H.M.S. *Fair Rosamond* in that month had sixteen cases, with five deaths. Details, however, are lacking as the surgeon himself died. Two persons who sailed in the *Rubis* to Gorée at the beginning of August are supposed to have infected that town. In 1842 four cases of yellow fever occurred among the garrison: two of the patients recovered. In August, 1859, what is described as "a lamentable epidemic" occurred. By the end of September only six Europeans were alive and some of these were convalescent. A year later (1860) three medical officers occupying the same dwelling at MacCarthy's Island "yielded to fever of a bad type after five days illness." In 1862 four cases of yellow fever were notified in Bathurst, two of the patients recovered. In 1866 Gorée and Bathurst again indulged in mutual accusations (CÉDONT, 1868). The former town had 249 cases with 110 deaths, the latter 17 deaths in the space of 4 months (July to October). In 1872 the prevailing diseases in Bathurst are said to have been yellow fever and smallpox, though exact details are lacking. BÉRENGER-FÉRAUD (1890) claims that he was instrumental in saving Gorée from infection though Bathurst was decimated at this time. In 1878 the inhabitants of Bathurst congratulated themselves on being not as other men, for whereas yellow fever was known to be raging in French territory 45 miles to the north and again 60 miles to the south, Bathurst itself was only visited by a "malarial fever." This malarial fever, however, was of such extraordinary malignancy and startling fatality that of the European population of between fifty and sixty, thirteen died, ten of them in the last quarter of the year. For the next 22 years there is no recorded epidemic of yellow fever, though occasionally Europeans died from "bilious haematuric fever."

In May, 1900, however, the "ancient tale of wrong" is continued and in the succeeding 5 months there were eleven cases of yellow fever with nine deaths. The outbreak is noteworthy, as it is for the first time recorded that "perhaps and not improbably in this case mosquitoes were the agents responsible for the yellow fever spreading from its original centre. It is worthy of note that all the cases (except one at the Catholic Mission) occurred in the front street of the town, the street most infested with mosquitoes." Following the report by DUTTON (1902) on conditions in the Gambia, sanitary reforms were instituted; though in 1903 a Catholic father died under somewhat suspicious circumstances from bilious remittent fever, no further epidemic occurred till 1911. In that year there were again eleven cases with nine deaths:—four cases with three deaths in May, six cases and five deaths in July, one case and one death in November. A full account of this outbreak is to be found in the *2nd Report of the Yellow Fever Commission (West Africa)*. Again there was a respite for 11 years, during which time, as a result of the War, the European population of Bathurst was greatly reduced. There was a new outbreak in October, 1922, when a young Moroccan died from yellow fever. Two mild cases were seen in adolescent Africans and two suspected cases also occurred. In November, 1928,

two Europeans and an African died from yellow fever and one African recovered : a month later a second African died and other cases were suspected. The first cases were associated with the premises of a trading firm heavily infected with *Aedes aegypti*. In October, 1934, there began the epidemic which is the subject of the present enquiry.

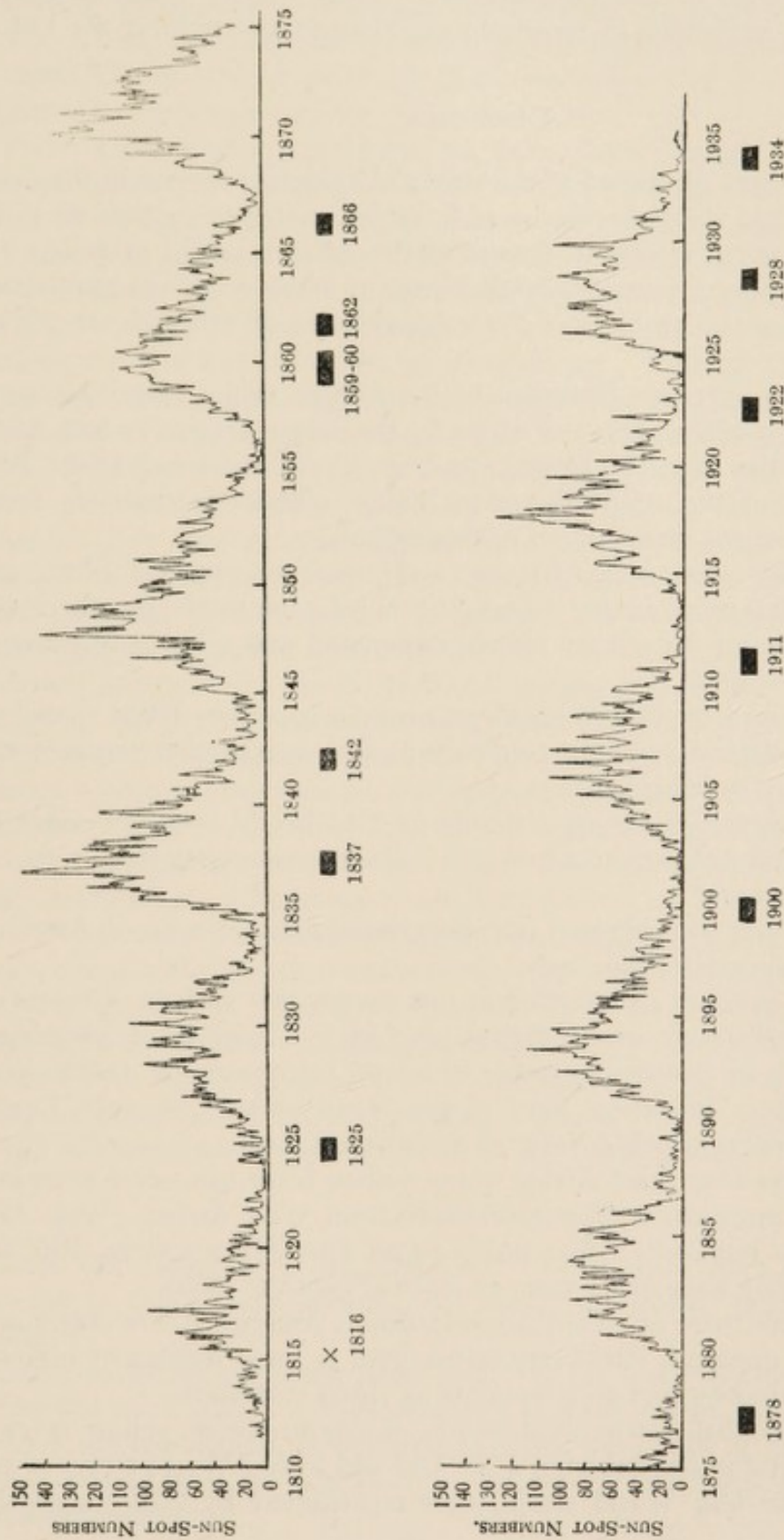
The history of acute and fatal epidemics among Europeans in the Gambia thus extends back for 480 years. Absolute proof that the earlier outbreaks were due to yellow fever is, of course, lacking, but in view of the uncertainty as to whether yellow fever is of African or American origin it is worthy of note that there was no change in the general character of the epidemics (i) either before or after the discovery of America, (ii) either before or after the institution of the slave trade, (iii) either before or after the general introduction of cinchona bark as a routine treatment for tropical fevers.

Since the foundation of Bathurst in 1816 it is noticeable that there is no history of any outbreak of yellow fever affecting the Africans in the Protectorate and no death in this area among Europeans except in 1860, when three medical officers are said to have died at MacCarthy Island. The Protectorate, in fact, might be regarded as " a silent area " for yellow fever.

So far as Bathurst is concerned, there is a very faint suggestion that epidemics of yellow fever tend to recur at intervals of either from 5 to 6 or from 11 to 12 years. The data, however, are of insufficient statistical value to establish any definite periodicity. DUTROULAU (1868), it may be added, found in the lesser Antilles a periodicity of either 6 or 10 years, while various authorities have suggested an 11 or 12 years periodicity for malaria epidemics. GILL (1936), as MELDRUM (1881) and others had done, has attempted to associate these malaria epidemics with variations in the sun-spot cycle, major epidemics occurring at periods of sun-spot minima, minor epidemics at sun-spot maxima, the average duration of the sun-spot cycle being just over 11 years.

The Chart on page 675 shows that from 1825 to 1935 there have occurred eleven periods of sun-spot minima. Eight of these periods have been associated with outbreaks of yellow fever in the Gambia. Of the four other yellow fever outbreaks in these 110 years, three occurred at or near periods of sun-spot maxima, while the outbreak of 1862 was probably merely a continuation of the 1859-60 epidemic.

It must not, however, be assumed that the sun-spot cycle and outbreaks of yellow fever are directly correlated. The sun-spot cycle is one of the twelve or more regular periodicities which together make up the cycle of solar variation. All the periodicities in solar variation are integral submultiples of 23 years ; as ABBOT (1935) has shown, the weather contains features which tend to repeat themselves at intervals of 23 years. Various phenomena depending on weather thus show the influence of the 23-year cycle—the level of the Nile, the levels of the Great Lakes, the rainfall of New England, the width of tree rings and the



SUN-SPOTS (AFTER ABBOT, 1935) IN RELATION TO OUTBREAKS OF YELLOW FEVER IN BATHURST, GAMBIA.

■ = Years when yellow fever was epidemic.

X = Year in which Bathurst was founded.

abundance in the sea of cod and mackerel. Only further research can show whether periodic variations in mosquito populations also exhibit the influence of this cycle.

DISCUSSION.

The history here recounted of outbreaks of epidemic disease in the Gambia would seem at first sight merely to add further evidence to that so skilfully marshalled by CARTER (1932) in favour of the African origin of yellow fever. Since the publication of CARTER'S book, however, many new facts have accumulated which render the problem of the original home of yellow fever still more complicated.

The following facts are in favour of the African origin of yellow fever :—

(i) As a result of the survey of Africa by the mouse protection test, Africans with immune bodies to yellow fever have been found as far east as the Bahr el Ghazal Province of the Anglo-Egyptian Sudan. There is evidence that the disease is not of recent introduction in this region.

(ii) The mild reaction of Africans to yellow fever suggests a long period of exposure to infection during which the more susceptible members of the indigenous population have been slowly eliminated and a racial resistance has been gradually acquired.

(iii) The failure of African monkeys to react to yellow fever virus by the development of clinical symptoms or pathological lesions also suggests a long period of exposure to infection.

(iv) *Aedes aegypti* is almost certainly an Old World mosquito since there are many parts of South America to which it has not yet penetrated.

On the other hand :

(i) Yellow fever has occurred in mountainous regions in South America far removed from the eastern seaboard.

(ii) A mild reaction to infection is not always met with in Africans since in certain outbreaks their mortality has been high. Inapparent infections are by no means rare in South Americans of mixed European and Indian descent while, as laboratory infections have shown, even persons of pure European descent may suffer from yellow fever in a very mild form.

(iii) Monkeys from East Africa where yellow fever has never been known to occur are no more susceptible than those from West Africa. West African monkeys are also relatively insusceptible to an East African virus, Rift Valley fever, to which they have never been exposed (FINDLAY, 1933).

(iv) Although there are many areas in South America where *Aedes aegypti* is absent yet the disease is effectively transmitted in these regions by indigenous South American mosquitoes such possibly as *Aedes scapularis*.

It is possible that a true explanation of the origin of yellow fever may eventually be found in the existence of an Old and a New World strain of yellow fever virus. The Old World strain, that transmitted by *Aedes aegypti*, has

undoubtedly crossed and recrossed the Atlantic on countless occasions in historical times, infecting and reinfecting the eastern seaboard of America. The New World strain would be that transmitted by non-domestic *Aedes* mosquitoes in the jungle regions of South America.

There is now growing evidence that yellow fever may persist in the absence of susceptible human beings while both in South America and in Africa (SOPER, 1935 ; and FINDLAY, STÉFANOPOULO, DAVEY and MAHAFFY, 1936) monkeys have been found with immune bodies to yellow fever. It is thus possible that yellow fever was present in Africa and in South America at a time long before the appearance of man. There is considerable evidence that at some remote period or periods the Old and New Worlds were united. Though WEGENER's theory of continental drift, which suggests that West Africa and Brazil were connected as late as the cretaceous period, has not met with universal acceptance since, as WATTS (1935) has pointed out, the resemblances between the tertiary floras of America and Europe actually increased at the time when, on the theory of continental drift, the Atlantic should have been widening, nevertheless the possibility of migration across polar lands or seas when terrestrial climates differed from the present cannot be ignored. SMITH WOODWARD (1935) for instance, suggests that the little Mesosaurian reptiles of the Permian rocks of both South America and South Africa, descendants of those found in the coal measures of North America and Europe, wandered south in parallel ways down the African and American continents. The ancestors of the primates and of the aedine mosquitoes may similarly have travelled south in two separate streams.

Evidence that two strains of virus may exist in a continuous land area is now forthcoming in the case of the virus of equine encephalomyelitis which in North America has differentiated into two strains, an eastern and a western form. The clinical symptoms and pathological changes produced by these two strains are practically identical while serologically the differences are quantitative rather than qualitative. The western strain, however, is readily transmitted by *Aedes aegypti*, the eastern with the greatest difficulty, if at all. Highly suggestive evidence of the existence of a New World strain of yellow fever virus might possibly be obtained by an examination of the bloods of Amazonian Indians from the still unexplored forests that lie to the north of Matto Grosso.

CONCLUSION.

Since the discovery of the Gambia in 1455, there have occurred among Europeans in this region periodic outbreaks of disease, attended by a high mortality.

These outbreaks occurred before and after the discovery of America, before and after the introduction of cinchona bark as a routine treatment of fever.

Since the foundation of Bathurst in 1816, outbreaks of yellow fever have occurred periodically in this town: they have not been recorded in the Gambia Protectorate.

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