

XXXVII. OBSERVATIONS ON PLAGUE IN POONA.

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PART I.

DESCRIPTION OF POONA CITY AND SUBURBS.

A. *Geographical Position.*

POONA, the most important city of the Deccan, is situated 75 miles S.E. of Bombay on the eastern watershed of the range of Western Ghats, 1850 feet above the sea level. It lies on the Basalt Rock, with a surface layer of Deccan Trap and Black-Cotton Soil.

The name generally includes (see Map I):—

1. A large Native City.
2. The Poona Cantonment.
3. The Suburban Municipality.
4. The Cantonment of Kirkee.

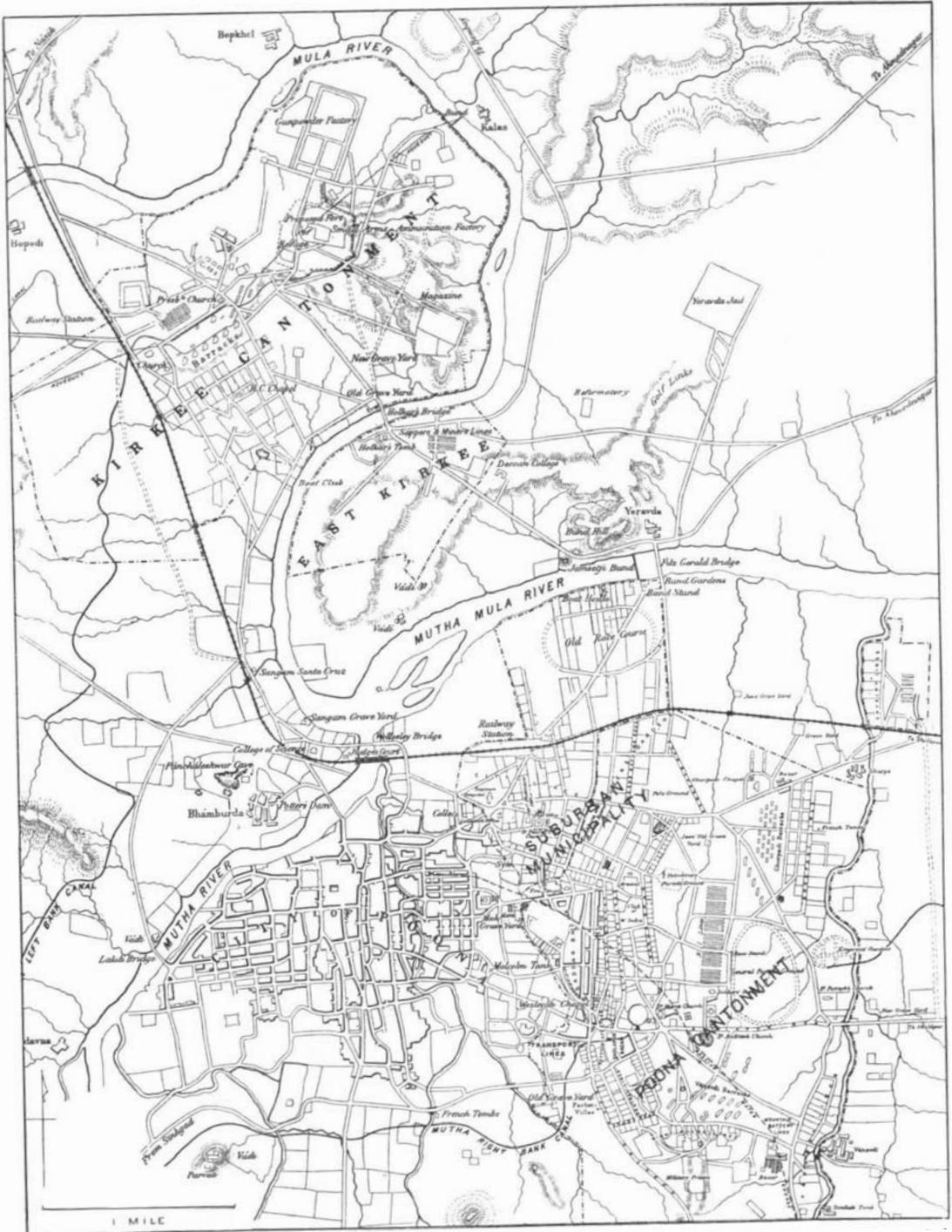
These centres of population cover a very wide area so that at the outset of our observations we determined to limit our operations to the Native City only. Occasional reference has, however, to be made to the area surrounding the city, for extensive and frequent intercourse is maintained between the city and these suburban districts.

1. *The Native City.* This covers a roughly triangular area of about three square miles. The apex of this triangle is directed northwards and approximates, as will be seen on the accompanying map, to the union of the Mula and Mutha rivers (Map II).

On the north-west the Mula with its tributary the Mutha river separates the city from the cantonment of Kirkee. Two small divisions of the city, however, namely the Peths of Bhamburda and Pulachiwadi, lie on the further bank of the river. These Peths are connected with the main portion of the city by three bridges and a stone causeway. On the north-east a comparatively sparsely populated tract of land separates the city from the Poona Cantonment and Suburban Municipality. On the south the city is bounded by extensive gardens and orchards. Population 111,381.

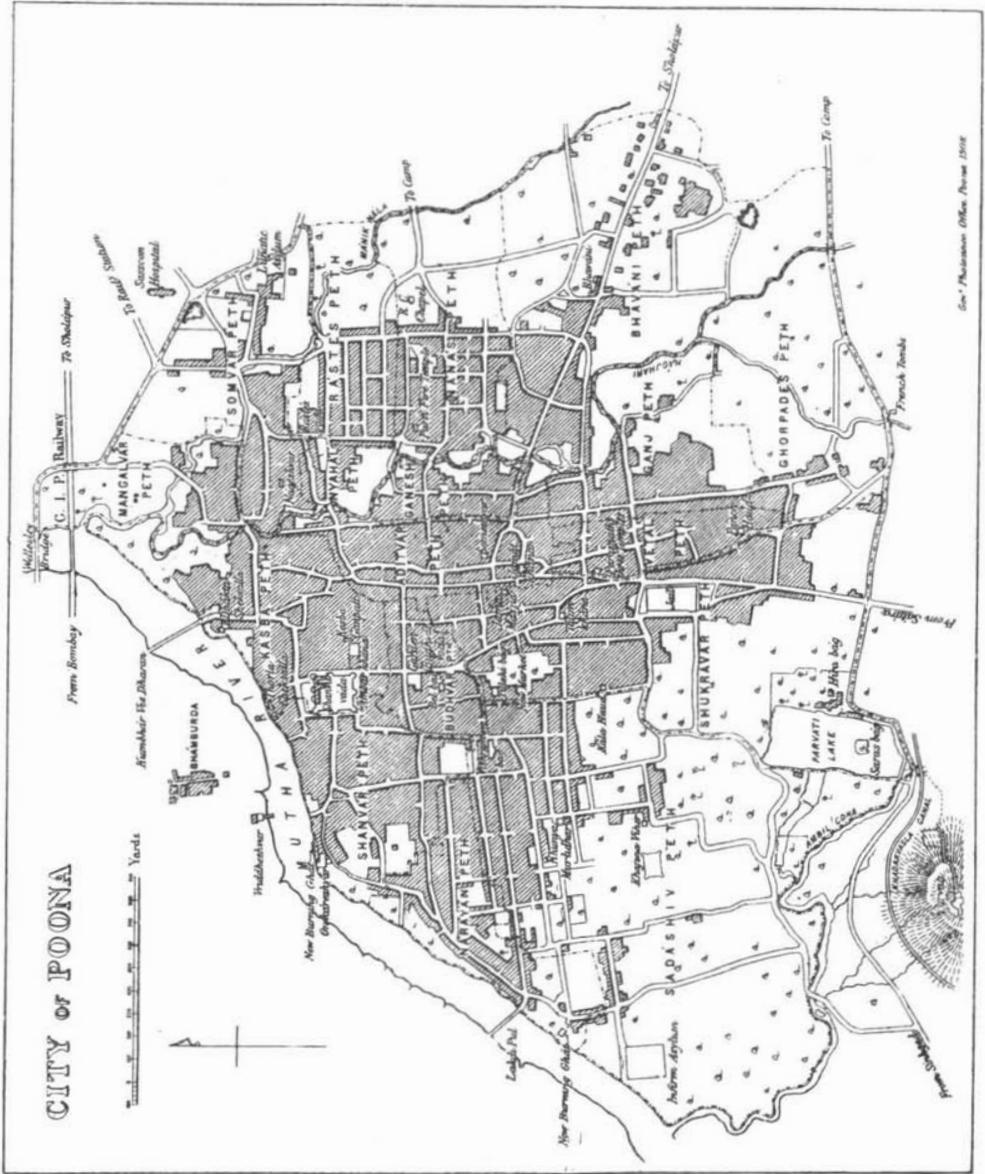
2 and 3. *The Poona Cantonment and the Suburban Municipality.* These areas lie along the north-eastern boundary of the city, the cantonment occupying a position to the south of the Suburban Municipal area. The bungalows of Europeans and wealthy natives are situated in the municipal area while the barracks of the European and native soldiers and the houses of the military officers and other European officials are situated in the cantonment. Here are stationed two

MAP I



POONA

MAP II



British infantry regiments, one native cavalry and three native infantry regiments with a transport corps. The Suddar or cantonment bazaar is situated between the barracks and the native city. This bazaar is made up chiefly of shops and the habitations of the natives who cater for the European and native population detailed above. In structure this bazaar resembles closely the city with which it is coterminous but the buildings and their surroundings are kept in better order, the sanitary arrangements being under the control of the military authorities.

The railway station is situated in the suburban area to the north-east of the city.

The population of the cantonment according to the census of 1901 was 32,777 and that of the suburban municipality 9162.

4. *Cantonment of Kirkee.* The cantonment of Kirkee, separated from the city by the Mutha and Mula rivers, lies to the north-west on the road to Bombay. Here are stationed three batteries of artillery, a company of sappers and miners and a native infantry regiment. There is also a large arsenal and ammunition factory. The factory employs a number of native hands. As in the Poona cantonment there is here also a Suddar bazaar which supplies the population of Kirkee with provisions and other necessaries. This bazaar is distant about three miles from Poona City. The population of this cantonment is 5640.

The district around Poona. Poona City lies in a valley, the surrounding district therefore is more elevated. The country for some miles around the city is rocky and sparsely cultivated, except for a small portion which is irrigated by means of a canal. There are therefore few villages of importance in the immediate neighbourhood of the city.

B. *General description of city—construction of houses, sanitation etc.*

The central portion of the city is the oldest and most densely populated part. The houses are here ill constructed, crowded together, with few open spaces around them. The houses on the east and west of the city are better built, while on the south the buildings are more scattered and are surrounded by large gardens and orchards.

The streets of the city are, for the most part, fairly wide. Compared with the average Indian city there are only a few alleys so that the majority of houses open on to the main streets.

A large market is situated to the south of the centre of the city. Fruit, vegetables and other provisions are brought here daily for sale. Surrounding the market are a number of shops which retail grain, groceries, and stores to the villagers, and others who come to the market for their provisions. The chief grain stores, however, are situated in Nana's Peth in the eastern part of the city. To this wholesale grain market large quantities of grain are brought chiefly from the Ahmednagar and Thana districts but some also from the surrounding country.

It is impossible to describe the houses of the city under any one type as they vary so greatly in size, shape, and construction. One type of house very commonly seen in Poona, however, is built in the form of a square with a court-yard of varying size in the centre. This court-yard or quadrangle is usually well kept, clean and covered with flag-stones or used as a small garden. It may contain a well, but usually the water supply is laid on by pipes. One corner of this quadrangle is often set apart for cattle, but in many cases these animals occupy one of the rooms looking out on it. As a rule half the area of the ground floor is practically an open verandah. The front part of the building is reserved for latrines, stables and stores. Small booths open into the part of the building which faces the street. These booths are like cupboards (often no larger) and are sublet to tradespeople who spend part of the day there, locking up their shops at night; sometimes however they sleep on the premises.

The living rooms are on the ground floor. In some cases these are so dark that food has to be partaken of by the light of a lamp. The sleeping apartments are upstairs (these houses are usually of two stories) and between the apartments and the roof there may be a loft, used as a store-room for grain and much that is apparently rubbish. The contents of these rooms are seldom cleaned out or disturbed. The houses are generally built on a plinth two or three feet high which is faced with stone; the floors are of beaten-down earth covered with a layer of cowdung spread on when moist. The walls are usually made of bricks which are baked, but sometimes only sundried. The roof is covered with two or more layers of tiles upon a framework of bamboo battens. The tiles may be cylindrical, like the Bombay variety, but are usually flat, rough, and spade shaped. Rarely the roofs are made of corrugated iron, or mangalore tiles. The windows are not generally filled in with glass, but can be closed with wooden shutters, which are left open during the day to admit light, and thus, at this time, the houses are well ventilated.



Typical road in Poona showing the peculiar roof.



Grain shop in Poona.

Homes of this description belong generally to the middle class and are probably the commonest type of house in Poona.

The houses of the poorer classes are small, irregularly built, and badly designed; their floors and walls are made of mud with a roof of rough flat Deccan tiles. They are single storied buildings which admit very little light and air through the small holes in the walls which serve the purpose of windows. Nevertheless such houses, especially when occupied by Hindus, are often kept very clean, the floor being frequently plastered with fresh cowdung.

But the houses of the poor are not by any means always ill-ventilated or badly lighted. In some parts, especially in the south of the city, houses occupied by weavers are met with, which consist chiefly of one large room, and this serves alike the purpose of a dwelling room and workshop. This room has no loft, and is so constructed as to admit freely light and air on all sides. Such houses, occupied by the poor, leave little to be desired from a sanitary point of view.

The poorest and humblest class of people, the Mangs, Mahars, sweepers and such like, live in rude huts covered with pieces of tin and rags. Colonies of these people dwell in the north of the city in Mangalwar Peth, in the east in Nana's Peth, and also in Sadashiv and Bhamburda Peths.

The city for municipal purposes has been partitioned into a number of irregular divisions called Peths (literally markets). There are nineteen of these Peths which contain separately from twenty to fifteen hundred houses. In each Peth the houses are numbered consecutively so that generally it is easy to locate a house by its number. In some instances however the numbers on the houses are irregularly distributed with wide intervals between two houses with consecutive numbers. In some cases, too, houses which once existed and were numbered have fallen into a state of ruin or have entirely disappeared. Other houses again are without number plates so that their number had to be guessed by the position they occupied in relation to the adjoining and properly numbered houses. A single number is occasionally applied to a whole group of dwellings; a group of such houses probably arose around a single house at a date subsequent to the time when the numbers were originally given to the houses. These facts have been mentioned in order that the reader may understand some of the difficulties met with in carrying out the observations in Poona City, difficulties which, unfortunately, make some of the records we have compiled not quite as accurate as they might be; any error however from this cause can

generally be overlooked except where attention has particularly been drawn to the matter. The area, population, and number of houses in each Peth are given in Table I.

Sanitation. The sanitary arrangements of the city are very primitive. Latrines are cleaned out by sweepers and their contents removed

TABLE I.

Population of Poona City.

Table showing the population, and the area in square yards, of the different Peths of Poona City, also the castes preponderating in each Peth according to the census of 1901.

Serial No.	Name of Peth	No. of houses	Area in sq. yds	Popula- tion	No. of inmates per house	Density per 1000 sq. yds	Castes (chiefly)
*1	Shukurawar	1,638	955,000	14,707	9·0	15	Almost all castes.
2	Kasba	1,510	575,000	12,965	8·6	23	Poor working class.
3	Rawiwar or Aditwar	1,435	325,000	9,254	6·5	28	Jains & Merchants.
*4	Sadashiv	823	2,275,000	8,959	10·9	4	Brahmins.
*5	Bhawani	1,072	1,235,000	8,451	7·9	7	Mahomedans & Merchants.
6	Shanwar	608	445,000	8,140	13·4	18	Brahmins.
*7	Nana	772	525,000	7,069	9·2	13	Mangs & Mahars.
8	Budhwar	545	185,000	5,951	10·9	32	All castes.
*9	Gunj	864	428,000	4,894	5·7	11	Jains & Kumbhars.
*10	Somwar	417	545,000	4,629	11·1	8	Gosavee & others.
11	Vetal	664	195,000	4,625	7·0	24	Gujratee & others.
12	Ganesh	457	155,000	4,168	9·1	27	Poor working class.
*13	Rasta	512	365,000	4,122	8·1	11	Madrasi & others.
14	Narayen	486	375,000	3,997	8·2	11	Brahmins & Marathas.
*15	Bhamburda	500	2,906,220	3,645	7·3	1	Marathas.
*16	Mangalwar	351	485,000	2,904	8·3	6	Mahar & Sweeper.
17	Nyhal	101	105,000	1,243	12·3	12	Rich people.
*18	Ghorpadi	302	655,000	1,230	4·1	2	Mahomedans & Shoe makers.
*19	Gultekdi	21	2,447,300	428	?	0·17	Chiefly Marathas.
*20	Pulachiwadi	156	Part of Bhamburda.	Included in Bhamburda.			
Total			15,181,520	111,381		7·3	

Note.—In those marked with a star the density of population is misleading; being situated on the outskirts of the city a large part of each peth consists of open fields and orchards, the remaining part being often very densely populated.

It will be noticed that the part most densely populated is in the centre of the city, viz. Budhwar, Rawiwar, Ganesh, Vetal and Kasba.

by means of carts. Waste water, running into gutters, is sometimes used to irrigate a small garden, often it is allowed to stagnate and evaporate in the sun. A large under-ground drain runs down one or two of the main thoroughfares and into it a certain amount of sullage and storm water finds its way. The storm water as a rule is carried away in open gutters by the side of the road. In parts of the city, where the traffic is greatest, these roadside gutters are covered over with flat slabs of stone.

There are many wells scattered throughout the city. They are used chiefly for washing purposes, for a good supply of water is laid on in pipes to almost every house.

People. The population of Poona City according to the census of 1901 was 111,381, but it is probable that owing to the ravages of plague the population at the present time is about 100,000.

The following are the different castes amongst the people of Poona City according to the census of 1901 :—

Hindus	97,298
Mahomedans	11,332
Jains	1,133
Christians	952
Jews	483
Parsis	168
Others	15
Total	<hr/> 111,381

The people inhabiting the city are generally poor. Their industries and trades are few in number and of little importance; namely: brass work, silk and cotton weaving, the manufacture of gold and silver threads, and of glass bangles. Of recent years, paper, sugar and spinning factories have been started on modern lines: these, as well as the government small-arm ammunition factory at Kirkee, employ a considerable amount of native labour. These works are all situated outside the city, although most of the workmen live within its boundaries.

Communication by road and rail. Poona lies on the main line of the Great Indian Peninsular Railway between Bombay and Madras. A branch railway also leaves the main line here for Belgaum and the Southern Maratha country. Many excellent roads round Poona afford communication with every part of the surrounding district. Large quantities of agricultural produce are brought for sale to the city daily by road and rail.

C. *Climate.*

Owing to its elevation and comparative proximity to the sea-coast, the climate of Poona is temperate for most of the year. For purposes of description the year may be divided into four equal seasons.

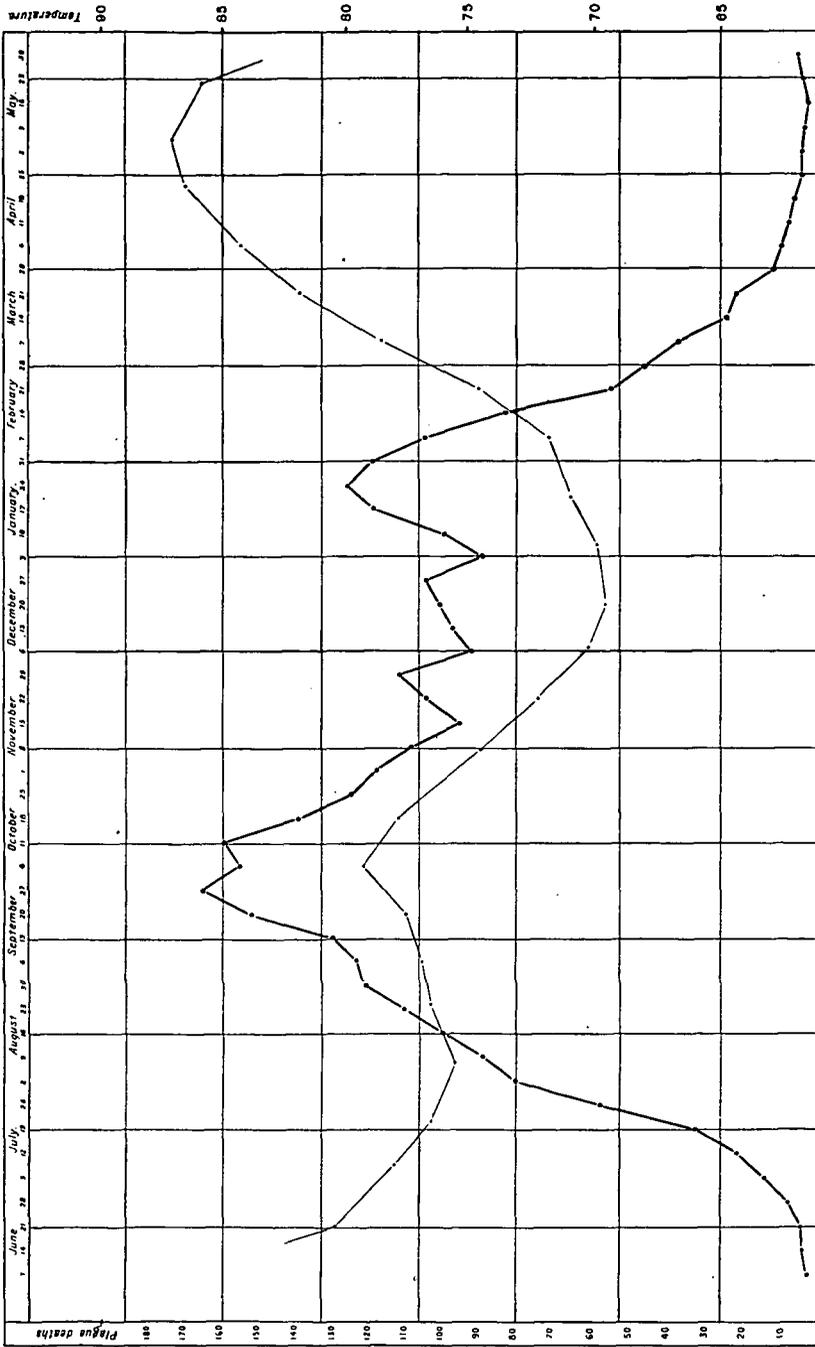
- (1) June, July and August: the rains proper.
- (2) September, October and November: a period succeeding the rains.
- (3) December, January and February: the cold weather.
- (4) March, April and May: the hot weather.

1. The rains:—During this period by far the largest part of the total rainfall is precipitated. The rain begins to fall early in June, at first in the form of showers with considerable intervals of sunshine and clear weather, but during July and August rain falls almost daily. Towards the end of August the interval between each precipitation again lengthens, and a few clear rainless days occur at this time. The temperature in the beginning of June, with a mean of over 80° F. and a diurnal variation of about fifteen degrees, rapidly falls through June and July to a mean slightly over 75° F., the diurnal variation meanwhile being reduced to less than ten degrees. The atmospheric humidity in the beginning of June rises rapidly from a mean of about 60% to over 80% in July and August.

2. The period after the rains:—During the latter part of September a few showers of rain fall; the intervals between the showers become more and more prolonged till the month of October is practically free from rain. The temperature which had fallen with the development of the rains in July and August begins to rise again in September to a mean of nearly 80° F., but at the end of October, the temperature again falls rapidly to a mean of about 70° F. in the end of November. The diurnal variation in the temperature during this period also gradually increases from approximately ten degrees in the beginning of September to as many as thirty-five degrees in the end of November. The humidity during this period falls rapidly from 80% in September to about 60% at the end of November.

3. The cold weather:—As a rule very little if any rain falls during this season of the year, but an occasional shower may occur, especially in January. The climate at this time of the year is delightfully cool, the mean daily temperature seldom rises above 75° F. except

CHART I



POONA

— Average weekly number of plague deaths in Poona City 1897—1909
 - - - Average half-monthly temperature 1897—1906

for a few days towards the end of February. The diurnal variation in the temperature remains considerable, a difference of 35 degrees being often noticed between the maximum and minimum readings. The humidity at this time of the year remains fairly constant between 50 and 60%, but falls slightly towards the end of February when 45% is often registered.

TABLE II.

Table showing the average half-monthly mean temperature for 10 years, 1897—1906 inclusive.

Half-monthly periods		Average
January	1	69·9
January	2	70·8
February	1	71·6
February	2	74·5
March	1	78·6
March	2	81·8
April	1	84·3
April	2	86·3
May	1	87·0
May	2	85·8
June	1	83·6
June	2	80·6
July	1	77·9
July	2	76·5
August	1	75·7
August	2	76·3
September	1	76·6
September	2	77·3
October	1	79·5
October	2	77·7
November	1	74·6
November	2	72·1
December	1	70·2
December	2	69·5

TABLE III.

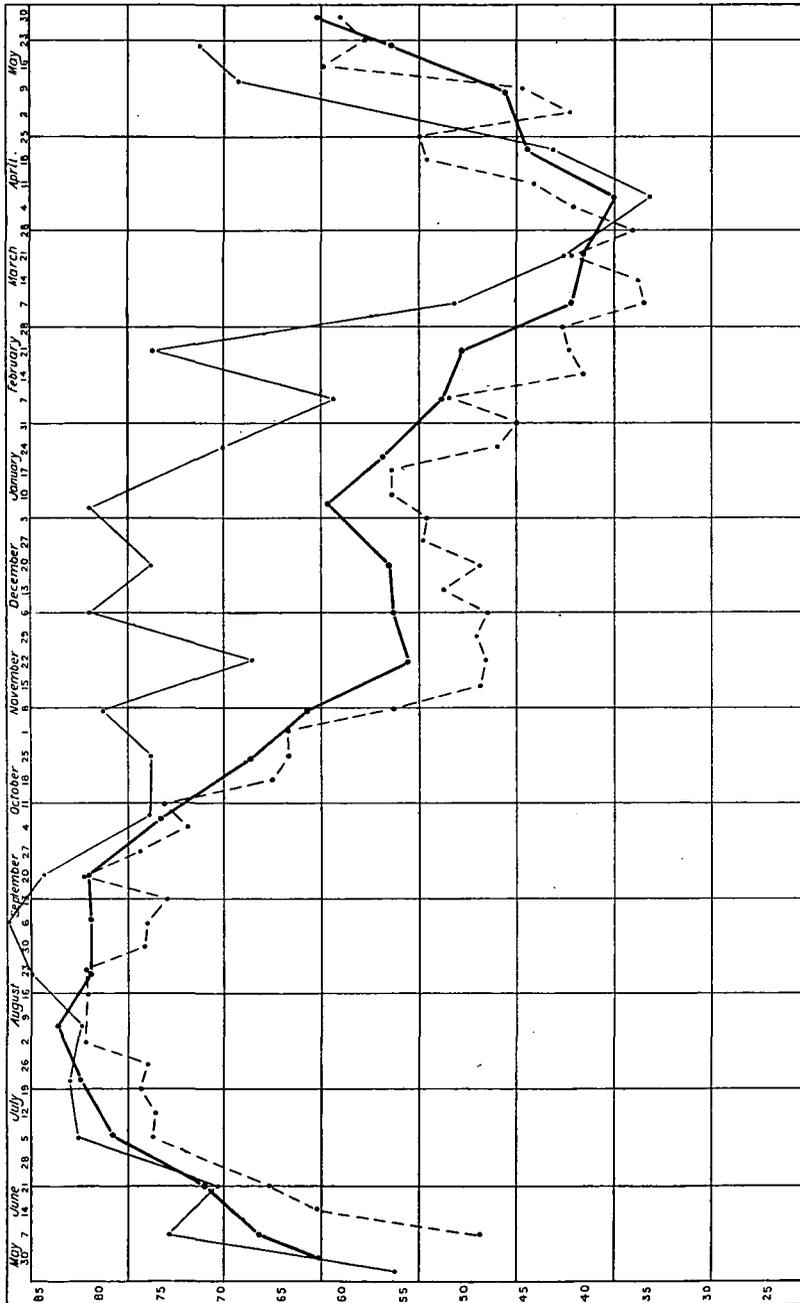
Average humidity in half-monthly periods for 10 years from 1897 to 1906.

Half-monthly periods		Average
January	1	61·4
January	2	57·5
February	1	51·9
February	2	50·5
March	1	41·4
March	2	40·7
April	1	38·0
April	2	45·2
May	1	47·0
May	2	56·4
June	1	67·2
June	2	71·8
July	1	79·5
July	2	83·4
August	1	83·8
August	2	81·1
September	1	81·0
September	2	81·1
October	1	73·3
October	2	67·7
November	1	63·3
November	2	54·7
December	1	56·4
December	2	56·5

The figures represent the percentage of saturation.

4. The hot weather :—This period is almost always rainless but an occasional shower may occur in May. The temperature, which had already begun to rise in the end of February, continues to rise rapidly till a mean daily temperature of 87° F. or higher is registered in the beginning of May. The diurnal variation also still remains considerable,

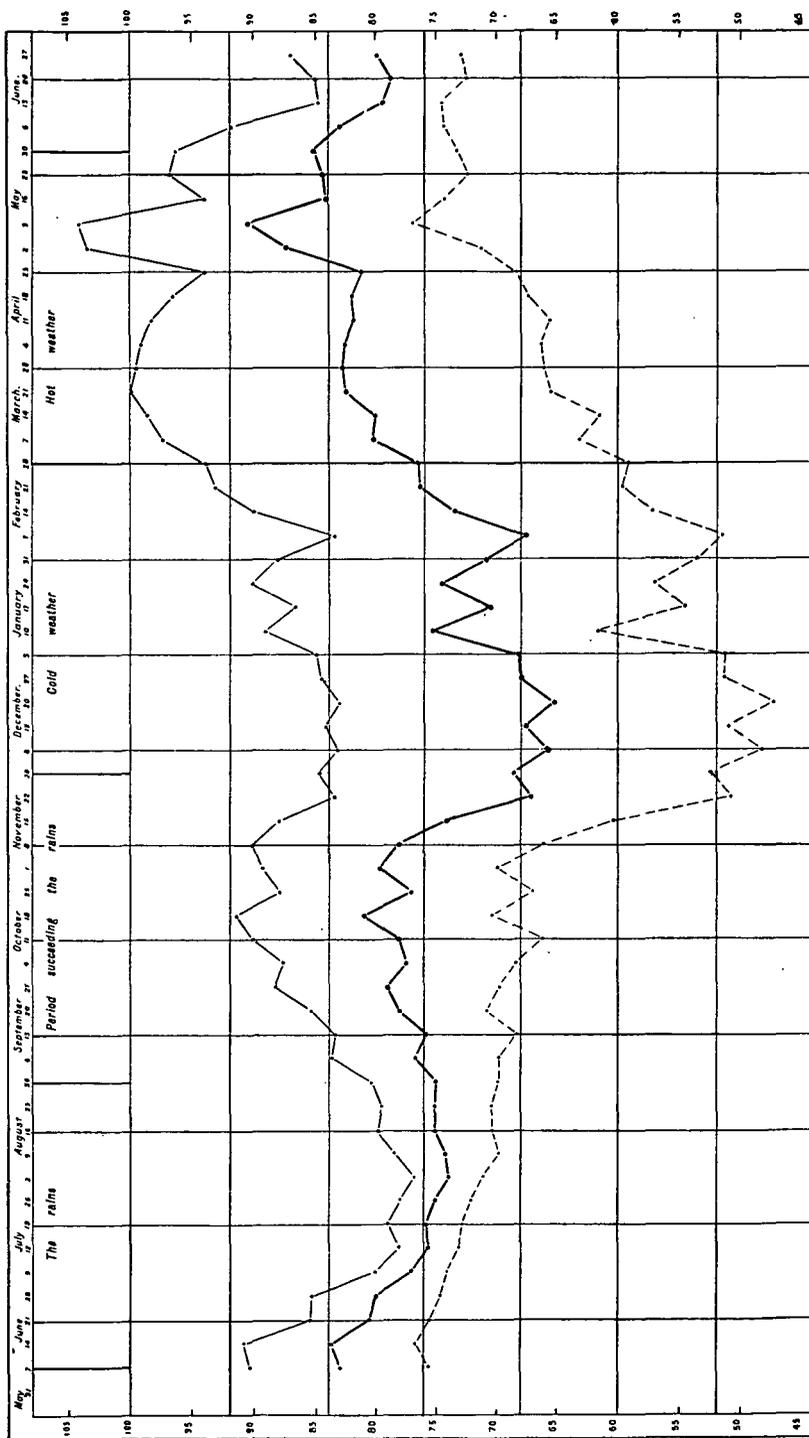
CHART II



POONA

- Average humidity in Poona for a period of 10 years 1896—1907
- - - - Average humidity in Poona for the years 1908—1909
- · · · Average humidity in Poona for the years 1902—1903. 5th epidemic

CHART III



POONA

Maximum, minimum and mean temperatures for 1908—1909. Poona City

TABLE IV.

Table showing the number of plague deaths in Poona City in periods of seven days for the years 1897 to 1907 inclusive.

Week ending	1897	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	Total
Jan. 3	—	41	2	0	16	288	283	142	239	Nil	Nil	42	21	1074
10	—	99	0	0	3	340	357	169	176	1	2	16	26	1189
17	—	77	0	1	1	304	630	205	155	1	0	33	21	1428
24	—	57	0	1	3	292	787	171	149	0	1	27	27	1515
31	—	33	1	4	2	220	871	147	114	2	0	17	17	1428
Feb. 7	—	37	1	0	2	172	818	130	92	0	0	0	9	1261
14	—	26	4	1	2	118	595	132	93	4	0	0	2	977
21	—	8	17	0	2	76	456	76	47	9	0	0	6	697
28	—	12	43	0	1	59	301	95	38	9	1	0	4	563
Mar. 7	—	2	71	2	3	38	208	89	40	4	0	1	0	458
14	—	3	64	0	1	14	107	81	20	4	1	0	0	295
21	—	3	90	0	0	8	78	65	18	4	0	3	2	271
28	—	2	89	1	0	3	23	28	7	6	1	0	0	160
April 4	—	2	74	0	0	3	15	30	9	4	1	0	1	139
11	—	2	74	1	0	1	10	5	7	2	0	0	1	103
18	—	1	74	1	1	0	8	1	1	5	0	0	0	92
25	—	0	60	0	1	0	1	2	1	3	0	0	0	68
May 2	—	2	64	0	0	0	0	0	2	2	0	0	1	71
9	—	0	60	1	0	0	0	0	0	0	0	0	1	62
16	—	0	41	0	1	0	0	0	0	2	0	0	0	44
23	—	1	57	0	1	0	0	0	0	0	0	0	0	59
30	—	0	71	0	2	0	0	0	0	1	0	0	0	74
June 7	7	0	44	0	0	0	0	0	0	1	0	0	0	52
14	7	0	56	0	0	0	0	0	0	0	0	0	0	63
21	7	0	56	0	0	0	0	0	0	1	0	0	0	64
28	3	1	94	0	0	1	0	0	0	0	0	0	0	99
July 5	5	0	181	0	0	0	0	0	0	1	0	1	0	188
12	12	0	253	0	0	0	0	0	0	3	0	0	—	268
19	5	0	372	0	0	0	0	0	0	19	0	0	—	396
26	0	0	651	1	0	0	0	0	0	48	0	0	—	700
Aug. 2	2	0	886	5	0	1	0	4	1	64	0	3	—	966
9	7	0	894	18	0	0	0	1	0	140	0	2	—	1062
16	8	0	908	25	0	0	0	3	0	245	1	4	—	1194
23	3	0	985	28	1	1	1	2	0	303	1	0	—	1325
30	8	2	992	62	0	1	0	2	0	394	0	1	—	1462
Sept. 6	10	2	813	75	1	4	0	3	0	556	7	15	—	1486
13	18	0	598	161	1	13	6	3	0	736	11	20	—	1567
20	38	0	495	325	2	6	6	8	4	897	26	26	—	1833
27	62	0	348	421	7	7	7	32	1	1013	35	50	—	1983
Oct. 4	75	0	250	541	9	3	5	69	2	813	63	38	—	1868
11	108	1	183	583	18	11	24	100	1	726	71	89	—	1915
18	185	0	84	543	18	9	26	111	2	465	84	144	—	1671
25	263	0	60	398	31	1	51	173	0	281	102	137	—	1497
Nov. 1	359	0	24	337	41	11	80	180	1	168	126	96	—	1423
8	326	0	19	231	80	22	82	270	0	71	96	102	—	1299
15	287	0	6	139	85	25	121	241	0	62	87	92	—	1145
22	336	0	4	134	117	30	108	306	1	27	94	91	—	1248
29	343	1	2	89	212	65	116	361	0	11	79	62	—	1341
Dec. 6	266	0	1	50	157	65	123	309	0	10	65	49	—	1104
13	229	1	2	35	219	89	172	307	0	2	65	50	—	1171
20	230	0	0	39	227	180	122	321	2	0	47	42	—	1210
27	164	0	0	38	269	306	141	273	0	0	39	42	—	1272
Total	3373	416	10218	4291	1537	2787	6739	4647	1223	7120	1106	1295	139	41781

the maximum and minimum temperatures differing from one another in from 25 to 30 degrees. The humidity during this period reaches a minimum in April of approximately 35%. The moisture in the air however increases with the onset of the S. W. monsoon breezes so that at the end of May as much as 60% or more of moisture may be recorded.

These variations in the climatic features of Poona can be readily followed in Charts I, II and III as well as in Tables II and III.

D. *Former Epidemics* (Chart VIII).

From the time plague first appeared in Poona City some eleven years before the commencement of the present observations the disease has continued to prevail to some extent at least every year. The disease has occurred generally in well marked epidemics, but between each epidemic sporadic cases have been registered. Those persons who

TABLE V.

Serial no. of epidemic	Epidemic began in week ending	Epidemic ended	Maximum attained week ending	Total deaths from plague during epidemic
First	Probably Feb. or Mar. accurate figs. not available	30th April 1898	1st Nov. 1897	3778*
Second	31st Jan. 1899	13th Dec. 1899	30th Aug. 1899	10216
Third	26th July 1900	14th Mar. 1901	11th Oct. 1900	4314
Fourth	1st Sept. 1901	11th April 1902	10th Jan. 1902	3430
Fifth	23rd Aug. 1902	25th April 1903	31st Jan. 1903	6496
Sixth	13th Sept. 1903	25th April 1904	17th Jan. 1904	2758
Seventh	2nd Aug. 1904	2nd May 1905	29th Nov. 1904	4287
Eighth	10th Jan. 1906	18th Dec. 1906	27th Sept. 1906	7120
Ninth	1st Sept. 1907	31st Jan. 1908	1st Nov. 1907	1232
Tenth	30th Aug. 1908	28th Feb. 1909	18th Oct. 1908	1289

* The figures for the first epidemic are not complete, accurate figures for the City are available from June only.

have died between the epidemic periods, we have reason to believe, obtained their infection outside the city, many of them in Bombay. This is a matter not to be wondered at when it is borne in mind that Poona is within easy reach of Bombay by a four hour railway journey, and that the epidemic period in Bombay coincides almost exactly with the healthy period in Poona. Moreover, except during the early epidemics, no restrictions have been placed on persons coming from infected houses. Apart from these imported cases of plague, there have

been ten well marked epidemics of the disease in Poona City during the past twelve years. The severity of these epidemics has varied considerably, and they have occurred at different periods of the year as will be seen from the Tables IV and V and from Chart VIII. The explanation we have to offer for the variation in the intensity of the epidemics will be postponed till we have detailed our experience of the tenth epidemic which we have been enabled to study in detail.

E. *Preventive Measures.*

A few remarks remain to be made regarding the measures which have been carried out to prevent the spread of the disease in past years. Till the year 1907 the chief measures adopted had been the disinfection of infected houses with perchloride of mercury; evacuation of infected houses when they were not disinfected; isolation of the sick in hospital when possible. Inoculation with anti-plague vaccine had been resorted to, but few people availed themselves of this measure.

In 1907 Government appointed a committee of influential Indian gentlemen and placed in their hands funds to be used for measures against plague. This enlightened committee carried out an extensive scheme of operations which resolved itself in instructing the people by holding public meetings and circulating popular pamphlets on the most recent views of the manner in which plague is spread, and urging and encouraging the people by pecuniary assistance and otherwise (*a*) to resort to evacuation of their houses as soon as rats were observed to be dying, and before cases of the disease occurred among the household, (*b*) to be inoculated with anti-plague vaccine if evacuation was not possible, (*c*) to destroy rats.

As a result of these measures, during the past two years there has been a considerable decrease in the number of plague deaths. The extent to which these measures were adopted can be gauged from the following figures. The municipal authorities estimate that during the epidemic of 1908—09 four thousand nine hundred persons occupied municipal huts in the plague camps, and that five thousand persons lived in private huts in the fields; they also estimate that between fifteen and twenty thousand persons left the city for the surrounding towns and villages. By this rough estimate it would appear that approximately one quarter of the population of Poona City evacuated their houses during the recent epidemic. Records showing the numbers who were inoculated with anti-plague vaccine from year to year are

much more accurate. The following figures were obtained from the municipal authorities:—

Year	Numbers inoculated
1901—02	92
1902—03	384
1903—04	716
1904—05	468
1905—06	516
1906—07	6,000
1907—08	11,593
1908—09	16,998

PART II.

METHOD ADOPTED FOR STUDYING THE CONDITIONS PREVAILING IN POONA AND THE DATA OBTAINED.

A. *Plan of operations.*

As has been detailed in the introduction to this report, one of the main objects of this enquiry was to determine whether the factors, which influence the seasonal prevalence of plague and which were put forward in one of our previous reports (*Journ. of Hygiene*, vol. VIII. No. 2, p. 273), after a study of the facts elicited from our experiments and observations in Bombay and in the Punjab, held good for Poona, which city, although so adjacent to Bombay (75 miles), presented an entirely different seasonal prevalence of the disease. In conducting this enquiry therefore we had to make arrangements to determine:

- I. The onset, course, and termination of the epizootic and epidemic.
- II. To collect data bearing on each of the factors which we believed had an influence in determining the seasonal prevalence of plague, *i.e.*
 - (a) climatic conditions,
 - (b) variations in the virulence of the bacillus,
 - (c) variations in the total number of rats and variations in the proportion of immune to susceptible rats,
 - (d) variations in the number of fleas.

To this end we made arrangements with the municipal authorities to assist us in collecting daily a fair sample of the rats of the city, and to furnish us with information, as early as possible, regarding any plague cases or deaths that came to the knowledge of their Health Officer. At the same time we improvised a temporary laboratory in a convenient position where the rats which were collected could be examined,

and the various data mentioned above could be registered. The details of these arrangements can most conveniently be considered under the heads

- (1) Arrangements in connection with work in the City.
- (2) Arrangements in connection with work in the laboratory.

(1) *Work in the city.*

(a) *To obtain a good daily sample of rats.*

(b) *To obtain information regarding the onset of the epidemic or epizootic.*

(a) *To obtain a good daily sample of rats.* A campaign against rats had been in force in the city during recent years. The rat catching staff was under the control of the Health Officer of the Municipality and consisted in a "Rat Inspector" and ten coolies. These men were provided with rat traps which they set in no systematic manner nor were the rats which were caught submitted to post mortem examination before being destroyed. By agreement with the municipal authorities this scheme was expanded and modified and the services of the rat catching staff were handed over to the Commission. Three additional "Rat Inspectors" were engaged by the Commission together with twenty-two coolies.

It was considered desirable to obtain from 150 to 200 rats daily, sufficient, on the one hand, to obtain accurate weekly statistics of the flea prevalence and breeding season of rats, and of the presence and the extent of an epizootic amongst them, and not too many, on the other hand, to interfere appreciably with the actual rat infestation of the city, nor with the careful and thorough examination of those caught throughout the year.

In these circumstances it was important that an even sample of rats should be obtained daily from every part of the city, and to attain this object the city was divided up by us into four wards, each having approximately an equal number of houses. Each ward was handed over to an inspector with a certain number of coolies and traps, and in each ward a room was hired to serve as a *dépôt* in which the property in charge of the inspector was kept and where the traps were checked, washed, and oiled once a week.

Each of these wards was subsequently subdivided into two sections, making eight in all. These were then put in charge of eight *muc-cadums* or overseers who could read and write, and the inspectors were

reduced to two, whose duty it was to keep these muccadums at their work, and to see that it was done accurately.

About 100 traps were set in each of the eight sections. The houses were visited consecutively every afternoon, the traps having been previously baited with a small piece of ordinary bread dipped in sweet-oil.

The following morning these traps were all collected, and those containing rats were at once put into flea-proof canvas bags and conveyed to the laboratory, each cage having attached to it a label showing the number of rats and the address where they were caught, etc. This being written in vernacular on the back of the card, was subsequently translated into English by a clerk at the laboratory.

Every effort was made to induce the people to send dead rats to the laboratory for examination. Advertisements were inserted in vernacular papers, and the municipal authorities exerted their influence on the people. Rewards—increased at one time to as much as eight annas per rat early in the epidemic—were offered for dead rats if proved afterwards to be plague infected. Nevertheless dead rats were obtained only at very irregular intervals and not systematically from every part of the city; yet we were aware from our own experience in the city that from time to time during the epizootic large numbers of them were dying. At one time indeed it would scarcely have been possible to pass once through the city without seeing one or more lying dead in some gutter or dust-bin at the side of the road.

It was necessary that we should have some means for estimating as accurately as possible the rat infestation of the houses through the period of our observations. The only method that suggested itself to us to attain this end was to systematically trap the houses and estimate their rat infestation by recording the number of rats caught for every one hundred traps set. This method has of course many obvious fallacies; every effort was therefore made, from the outset, to keep this record as carefully as possible and to exclude every avoidable source of error; for example the work of the coolies in the city was frequently inspected and checked; the same kind of baits was always used in the traps, and heavy penalties were imposed on the coolies for setting traps without proper bait or using them when they were unserviceable or allowed the rats which were trapped to escape. Moreover, a most important precaution, as we were able to demonstrate later, was also adopted, namely, the use of one particular type of trap. We were able to show that with very slight modifications in the type of trap used

very different estimates of the rat infestation of houses as calculated by this method could be obtained; these variations depended apparently on the efficiency or otherwise of the trap used in each case. From Table VI it will be seen that our so-called "Commission" trap was more than six times as efficient as a type of trap we obtained from England and three times as efficient as a very similar trap which had a spring trap door in place of a weighted and balanced one.

TABLE VI.

Table showing the comparative value of different kinds of traps, set uniformly distributed in Poona City.

Period between which traps set	Kind of trap	Number of traps set	Number of rats caught	Number of rats per 100 traps set
Sept. 1 to Dec. 13 '08	Commission	43753	15623	35·7
Do. do.	English	13222	700	5·3
Dec. 14 to Mar. 14 '09	Commission	30386	6582	21·6
Do. do.	Spring flap	16051	1132	7·1
Aug. 15 to Sept. 19 '09	Commission	12399	4498	36·3
Do. do.	Tophole	1621	326	20·1

(b) *To obtain early information regarding the onset of the epidemic or epizootic.* In order to obtain the earliest possible information of plague we addressed the private practitioners of the city asking them to inform us at once of all suspected cases of the disease and to acquaint us of any rat mortality that came to their notice. The Health Officer was also good enough to forward to us any information of this nature he might acquire either indirectly or in his official capacity. It may be well here to give a brief description of the system of registration of deaths, which, as in most other Indian cities, is somewhat unreliable, and the precautions we took to remedy these defects as far as possible in compiling our figures. In Poona no corpse can be removed for burial or cremation without a pass which is supplied by the city Health Office to the friends or relations of the deceased. Opportunity is taken by the Health authorities when issuing this pass to obtain information regarding the cause of death. In a few instances only the patient has been attended during his last illness by a qualified medical practitioner. In the majority of instances, especially during the prevalence of an epidemic, the friends of the deceased merely detail a few of the main symptoms from which the patient has suffered and the duration of his disease to the health authorities who, on this information, arrive

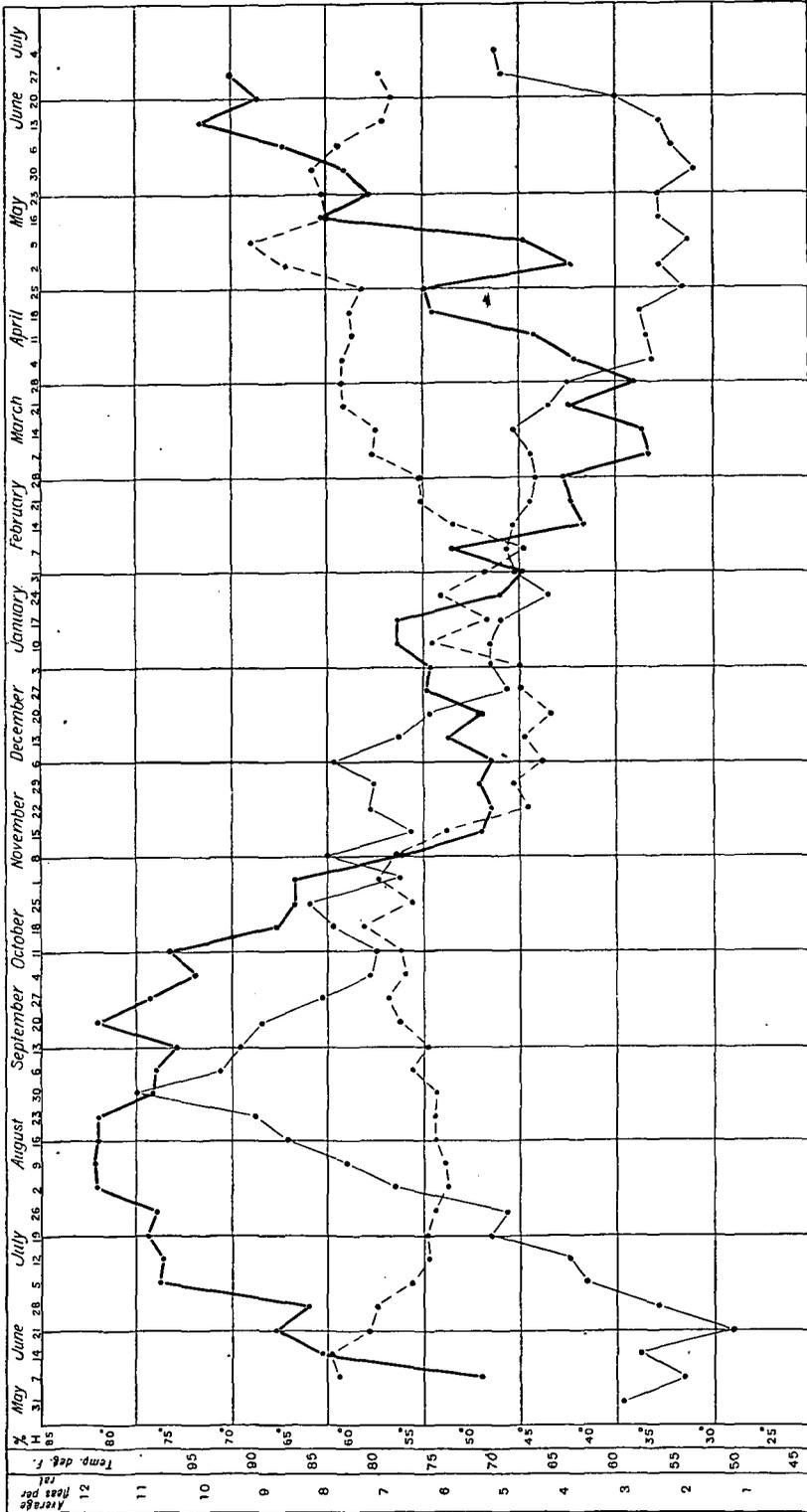
at a diagnosis, and register the case accordingly. All the earlier cases of plague therefore were visited by us to obtain more accurate information and to ascertain any possible source of infection by inquiring into the habits and recent movements of the patient or his friends, and the presence or otherwise of other suspicious cases in the neighbourhood. Inquiry was also made as to whether dead rats had been observed and the opportunity was taken of offering a substantial reward for any that might be found subsequently and sent to the laboratory for examination. These measures were all the more essential in that the notification of plague cases is not compulsory in Poona City. These methods were carefully carried out in investigating the majority of the first hundred cases of plague, the few exceptions being those cases which could not be located or which occurred in an area already known to be infected. Twenty or thirty rat traps were set for a period of a week or ten days in the houses¹ in any suspected locality with a view to detecting plague among these rodents; any rats caught were kept for a few days so that the infected ones might fully develop the disease before being killed and examined. When possible also, *i.e.* when the room could be closed up so as to prevent the access of cats and dogs, or when the room had not been cleaned out, a guinea-pig was allowed to run about the room to act as a flea trap. Generally, however, information regarding plague cases was not received early enough to ensure success for this method, for the patient was often dead before information reached us or the house had been cleared out and evacuated. In some cases a guinea-pig could only be left in a room for an hour or two because the access of dogs and cats could not be prevented. For these reasons therefore our endeavours to obtain evidence of local infection by this method were not very successful.

(2) *Work in the laboratory.*

The work in the laboratory was conducted much on the lines already described in our previous reports. The rat traps, containing rats enclosed within a canvas bag, to which a label was attached giving particulars as to where the rats had been caught, were collected daily at the laboratory. Records were kept here of all houses in which traps were set; the number of traps set daily was also noted, as well as the number of rats caught. Each trap in turn together with its bag was placed in an air tight tin box which was furnished with a shallow tray

¹ These traps were not included in calculating the number of rats per 100 traps set.

CHART IV



POONA

- The average weekly humidity (6 hourly readings) Poona City 1908—1909
- - - The average weekly temperature in degrees F. 1908—1909
- · · The average number of fleas per rat 1908—1909

to facilitate the removal and enumeration of the rats and their fleas. Chloroform¹ was poured into the box which was then closed. By this means the rats and their fleas were killed. The total number of fleas found on the rats was recorded. The rats were then weighed, a card being attached to each giving particulars as to where it was caught and its weight. Each rat was then pinned out on a board for dissection: thereafter details were added on the card as to sex, pregnancy, number of foetuses and any pathological features observed. Any rat which presented the least suspicion of plague infection, either in an acute or chronic form, was subsequently submitted to a more detailed examination with a view to substantiating or refuting these suspicions. The cards having been collected at the close of the day's work, the matter written on these was entered into a register. Daily, weekly and monthly summaries of the work were compiled from this register; these summaries materially facilitated the labour involved in studying the large mass of facts collected in this way.

A certain number of dead rats were brought to the laboratory where they were examined, the result of this examination being also recorded. An experiment was also started to test, if possible, the extent to which immunity was developed among the rats during the course of the epizootic. The details of this experiment are recorded in a separate paper; incidentally it may be remarked that, although the experiment led to no definite conclusion as to the progressive development of immunity among the rats with the advance of the epizootic, yet it showed at least that some local strains of the plague bacillus were highly virulent.

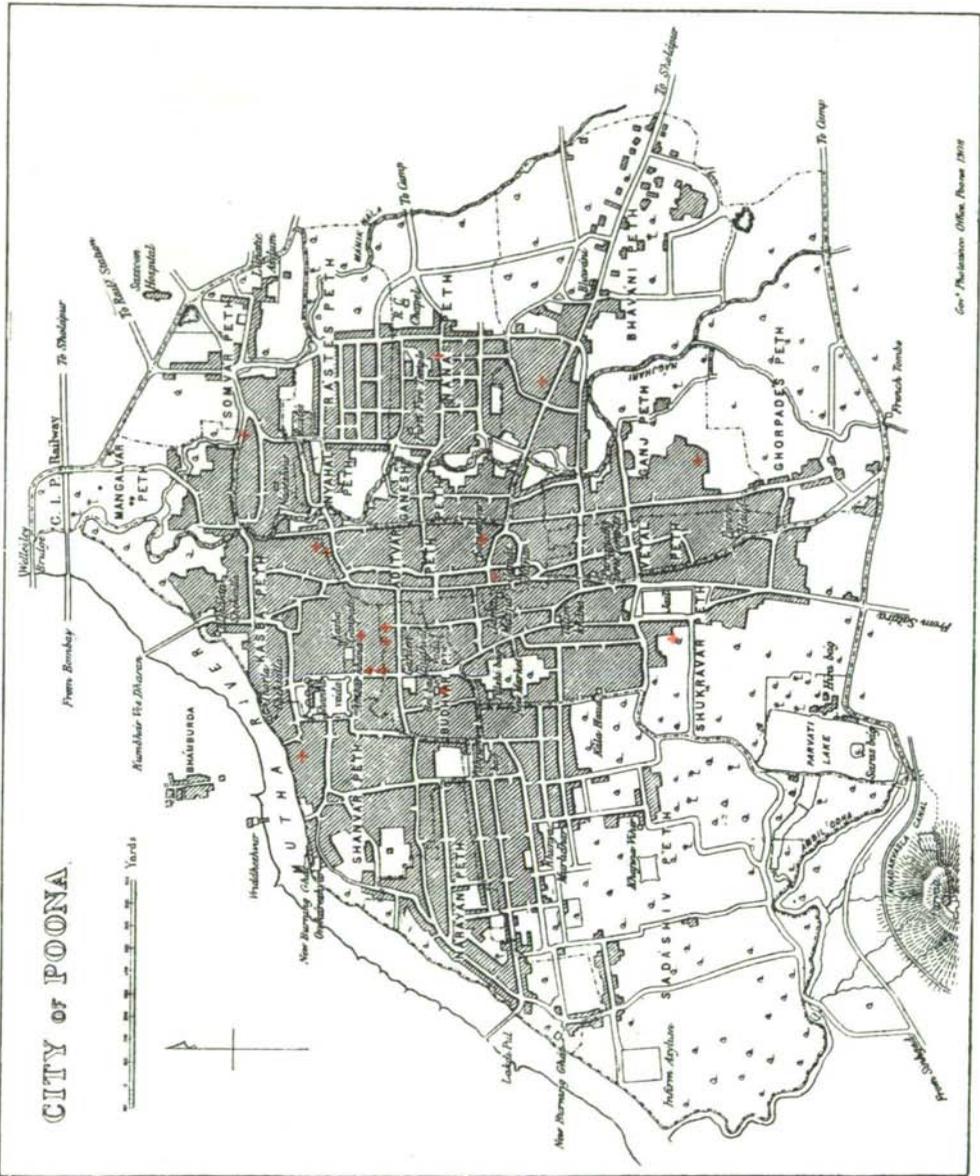
Lastly, records were kept throughout the year in the laboratory by means of a self-registering thermometer and hygrometer of variations in the temperature and humidity of the climate of Poona.

B. *The plague epidemic and epizootic of 1908—09.*

The arrangements for conducting our inquiry had scarcely been completed when already certain cases of plague came to our notice. Although, as has been remarked, on account of the extensive area covered by Poona (including in this term its suburbs) we had determined to limit our observations as far as possible to the native city, it seemed to us to be necessary to keep as close a watch as possible on the suburban districts in order to detect the first case of plague and the

¹ Petrol, especially the "Shell Brand," does equally well.

MAP IV



Plague cases reported during week ending Sept. 6, 1908.

progress of the epidemic there, at least until the disease had established itself in the city. We knew that frequent and intimate communication was continually maintained between the inhabitants of the city and the suburbs; infection, therefore, might at any time be imported from the suburbs into the city which, as our early observations showed us, was quite free from the disease, the last indigenous case having occurred in the end of January, 1908. It will be convenient to consider first the plague cases which occurred in the Suburban Municipal area. We saw that it was in this area that the railway station was situated and it was here that the first cases of plague came under our observation.

(1) *Plague in the Suburban Municipal area.* Before the beginning of June four plague cases had been imported into this area from Bombay.

May 18. 08 The history of importation was definite, for two of the cases, taken from the train, were removed to the General Plague Hospital suffering from the disease. Two other cases had quite recently come from infected areas in Bombay.

The first probably indigenous case that came to our notice occurred in the sweeper's chawl, railway servants' quarters, Poona station. A

June 7 woman, about 25 years of age, the wife of a sweeper, was taken ill on the 7th June. She had a right inguinal bubo and fever and was undoubtedly suffering from plague when seen by us on the 10th June. A dead rat was said to have been found in an adjoining room in which a cow was kept, together with grass and rubbish; the rat had unfortunately been thrown away. The woman died on 12th June. A guinea-pig, put down for some hours in the room in which the rat was said to have been found, harboured one rat flea. The guinea-pig (the flea having been replaced upon it) was removed to the laboratory where it remained healthy. The only information obtainable at the time that

threw any light on the source of infection in this case was that a wedding ceremony had taken place in the house a fortnight previously, and several friends from Bombay had attended it. Later on, two more plague cases occurred almost simultaneously in the same family, a

July 4 woman of 21, and a boy of 10 years of age; they were both admitted to the plague hospital on 4th July, 1908. Sometime afterwards, on inquiring at the railway station, it transpired that, before the above cases occurred, dead rats had been found in the refreshment room of the station, and also in the signallers' quarters.

On July 6th, a man was admitted into the General Plague Hospital suffering from plague: he came from the servants' quarters of the Raj Mahal Hotel which is about 100 yards distant from the railway station;

he had returned from Bombay on 17th June, 1908, and took ill on 4th July, 1908; he had a left femoral bubo and marked aphasia. A guinea-pig was put down as a flea trap on 6th July, 1908, and 12 *L. cheopis* were caught on it; the guinea-pig remained uninfected.

Further evidence of infection in this neighbourhood was obtained whilst investigating City Plague Case No. 3. In this case the history pointed to infection having been derived from a dharmsala (a native hotel or resting house) which is adjacent to the Raj Mahal Hotel, and which is also about 100 yards distant from the railway station. The mother of the patient, a boy, who always accompanied her, used to work through the day at the dharmsala while they both slept at 719 Nana's Peth in the city. The boy was taken ill on the 24th July and was admitted to hospital on the 28th. No evidence pointing to local infection could be obtained at 719 Nana's Peth.

City Plague Case No. 11 also possibly derived her infection at this dharmsala. She was a woman of sixty years of age, a resident of Malavadi. Passing through Poona on her way from Alandi she put up at the dharmsala adjoining the station. She was removed from the dharmsala to 235 Budhwar Peth where she died on 14th August. It is a point of some doubt whether this patient acquired her infection at the dharmsala or at Alandi; the latter place we knew to be infected for another case imported into the city acquired infection there. It may be mentioned that Alandi is a place about fourteen miles north of Poona, greatly frequented at all times by pilgrims from every part of the surrounding district.

A visit to the dharmsala showed that it was frequented by a poor class of people generally passing through Poona. Only a vague history of dead rats was obtained; the manager, unwilling to bring disrepute on his establishment or fearing to cause a panic amongst his clients, was very reticent nor would he allow us to apply the guinea-pig test for infection.

On August 29th, some dead and partially mummified squirrels were found in the roof of the office of the Inspector-General of Police which was about $\frac{1}{4}$ mile to the south-west of the station. The place was evacuated. A guinea-pig was put down but no fleas were found on it and it remained healthy.

On September 4th three dead rats were found in the goods sheds of the G.I.P. Railway about $\frac{1}{4}$ mile to the west of the station. These were proved to be plague infected and subsequently others were found in this neighbourhood.

On September 21st two dead rats were sent from the Lunatic
September 21 Asylum which is just within the city boundary. The
asylum is about $\frac{1}{4}$ of a mile south-west of the Inspector-
General's office mentioned above. These rats were also proved to be
plague infected.

Such then is briefly the early history of the epidemic and epizootic
in the Suburban Municipal area. It apparently started in the neigh-
bourhood of the station, the rats acquiring the disease from infection
probably imported by the railway. It spread thence in a westerly and
south-westerly direction towards the city. That the epidemic did not
assume greater proportions with the advent of favourable conditions
may be explained by the fact that in this neighbourhood all the houses
are of the better class, viz. government offices and private bungalows
with extensive compounds surrounding them and widely separating them
from each other. Meanwhile plague cases were reported from the
Kirkee Cantonment; the history of this epidemic and epizootic will
next be considered.

(2) *Plague in Kirkee Cantonment.* Two cases of plague were
May 30 admitted to the Cantonment Hospital on the 30th May,
June 2 while a third case was admitted on the 2nd June. All
three cases lived in separate houses and apparently were in no way
connected with one another, nor was it possible to trace the source
from which they derived infection; certain it is that for eighteen months
prior to these cases none were known to the authorities.

No further cases occurred till the 28th June, when two cases living
June 28 in the same house occurred quickly following one another,
the one on the 28th June and the other on the 1st July.
Thereafter the epidemic became widespread throughout the Kirkee
Cantonment bazaar, 65 deaths from the disease being registered in July
while 128 were recorded in August. In the three succeeding months
the epidemic rapidly declined with 68 deaths in September, 21 in
October, and only two in November. In all there were 288 deaths in
a population of 5640. Bearing in mind that a very large part of this
population consisted in British and Indian troops among whom very few
cases occurred, the epidemic cannot but be regarded as a very severe
one. We shall later offer an explanation for the severity of the
epidemic, meanwhile contenting ourselves by referring the reader to
Table VII which compares the Kirkee epidemic with the epidemics
in Poona City, Poona Cantonment and the Suburban Municipal
area.

Observing that the epidemic raged in Kirkee while it had hardly begun in the city, we determined to collect and examine a certain number of rats from this locality in the same manner as we were examining those collected in the city. These operations were started on the 17th July, and on the 21st July, four days after trapping was begun, a plague infected rat was found among those caught on that day. On the 27th another plague infected rat was captured in No. 2 Battery Lines and thereafter several others.

TABLE VII.

Table showing the number of plague deaths per mille of population in Poona City, Cantonment, Kirkee, and Suburban limits in monthly periods during the year 1908—09.

Month	Poona City Population 1901—111,381		Cantonment Population 1901—32,777		Kirkee Population 1901—5640		Suburban limits Population 1901—9162	
	Deaths	Per mille death rate	Deaths	Per mille death rate	Deaths	Per mille death rate	Deaths	Per mille death rate
June '08	—	—	—	—	4	.71	—	—
July	4	.04	—	—	65	11.11	1	.11
August	9	.08	10	.305	128	22.695	5	.545
September	123	1.10	71	2.17	68	12.06	14	1.53
October	472	4.24	142	4.33	21	3.72	31	3.84
November	370	3.32	116	3.54	2	.355	16	1.75
December	191	1.71	29	.885	—	—	2	.22
January '09	101	.91	4	.12	—	—	1	.11
February	21	.19	1	.03	—	—	—	—
March	3	.03	2	.06	—	—	—	—
April	1	.01	—	—	—	—	—	—
May	2	.02	—	—	—	—	—	—
June	—	—	—	—	—	—	—	—
Total	1297	11.645	375	11.44	288	51.06	70	7.64

An average of about 20 rats were brought in daily—397 in all were examined, of which 364 were alive and 33 dead—of these 10 live rats and 22 dead ones were found to be plague infected.

The observations were discontinued at the end of August, when it was found very difficult to catch any more rats, and when, moreover, our attention had become fully occupied by the city epidemic which had just commenced.

Tables VIII and IX summarise the observations made in Kirkee in respect to (1) the number of fleas found on the rats, and (2) the number of rats caught per 100 traps set, and compare these figures

with similar ones obtained from Poona City during the same periods. It will be seen from these tables (1) that the numbers of fleas found per rat in each place do not materially differ from one another, although the fleas on the rats were slightly more numerous in Kirkee than in Poona; (2) that while, on the one hand, the number of rats caught per 100 traps set in Poona city in the latter half of July was not only higher than the number caught in Kirkee but was increasing each fortnight later, on the other hand, the number of rats caught in Kirkee rapidly dropped each fortnight later, from 32·2 in the latter half of July, when the epizootic was already well started, to approximately only nine, when the observations were discontinued, that is when the epidemic was rapidly declining. The conclusion to be drawn from these observations are better left for consideration later. We may pass on now to briefly outline the course of the epidemic in the Poona Cantonment.

TABLE VIII.

Table comparing the number of fleas per rat in Kirkee and Poona City for corresponding periods.

Period	Poona City			Kirkee		
	Flea counts made on live <i>rattus</i>	Total no. of fleas obtained	Average no. of fleas per rat	Flea counts made on live <i>rattus</i>	Total no. of fleas obtained	Average no. of fleas per rat
July 17 to 31 '08	2304	13100	5·7	215	1337	6·1
Aug. 1 to 31 '08	4700	42871	9·1	129	1355	10·5

TABLE IX.

Table comparing the number of rats per 100 traps set in Poona City and Kirkee Cantonment during July, August, September in fortnightly periods.

Fortnight ending	Poona City			Kirkee Cantonment		
	No. of traps set	No. of rats caught	No. of rats per 100 traps set	No. of traps set	No. of rats caught	No. of rats per 100 traps set
July 26 '08	6614	2449	37·04	371*	123	33·2
Aug. 9 '08	6996	2858	40·9	672	108	16·1
Aug. 23 '08	6558	2733	41·6	672	61	9·1
Sept. 6 '08	6816	2726	40·0	336†	33†	9·8†

* These are figures from 19th to 26th July only.

† These are figures from 24th to 30th Aug. only.

(3) *Plague in Poona Cantonment.* A case of plague occurred in 27th July the Poona Cantonment on the 27th July. This case was August 1st said to have acquired infection in Kirkee. It was soon followed however by one of local origin reported on the 1st August. Ten cases occurred during that month at fairly regular intervals. During the first fortnight of September, 55 were reported. In the first half of November 126 cases were reported, and in the second half only 36. The epidemic then declined till the end of December. We were unable to give much attention to the study of plague in the cantonment, for the epidemic in the city commenced soon afterwards, the first indigenous cases in the city being registered on the 28th August, while the first plague infected rat (apart from a plague infected mouse found on the 18th July) was noted on the 7th Sept.

(4) *Plague in Poona City.* (a) *The epidemic.* While thus the epidemic raged in the suburbs of Poona, especially in Kirkee, not till the end of August could any evidence of indigenous plague be obtained in the city. Large numbers of people meanwhile were flocking into the city from the surrounding infected areas to live there with friends or relatives in uninfected quarters, if haply they might escape the plague. One who is familiar with the habits of Indians can easily picture the flight from the infected suburbs; whole families, carrying with them their household impedimenta and oft times their sick relations, might be seen on the roads leading to the city. In reviewing the course of the epidemic in the city, one would expect to find therefore, first a number of imported cases of the disease, occurring in widely scattered localities: then later a large number of indigenous cases, also widely scattered, arising from numerous infected centres. If, on the one hand, the disease is infectious (using the word infectious in the ordinary acceptation of the term) it would be right to expect that the indigenous cases would occur in direct association with the imported ones; on the other hand, if infection is transmitted indirectly from rat to man and from rat to rat by the agency of the rat flea then it would be reasonable to expect that, in many instances, the indigenous cases would bear no immediate relation to the imported ones; moreover many of the indigenous cases might occur in localities where the source of the infection could not be traced, especially when we bear in mind the fact that rat fleas are readily carried by man, almost unknown to himself, from one place to another, and that the fleas by choice select rats for their hosts rather than man. Centres of epizootic infection arise in this way in areas where a history of the importation of the

infection could only be obtained with the greatest difficulty. The history of the epidemic in the city will be seen to bear out this latter hypothesis.

We have detailed in another part of this report the means we adopted to inquire into the history of the first hundred cases of plague in the city. These careful inquiries enable us to state with some confidence that the first eighteen cases of plague which occurred in the city acquired their infection outside of it. A review of these cases showed that they were attacked by the disease at dates between the 1st July and the 24th August. Fourteen of the cases picked up infection in the suburbs of the city, ten in Kirkee and four in the municipal area. Four other cases acquired infection away from Poona and came by rail to the city, two from Kalyan (a place near Bombay), one from Bombay and one from Alandi, a place already mentioned in connection with the epidemic in the municipal area. Following these imported cases, the first indigenous case took ill on the 24th August; the patient, a man, had never left the city, nor had he been in contact with any plague cases. The nearest imported case occurred in a house two hundred yards distant. This imported case had acquired infection in Kirkee whither he had gone on a visit; returning therefrom on the 27th July, he developed plague the same day and died on the 29th. Two days after the first indigenous case was attacked by the plague (*i.e.* the man attacked on 24th August) his wife fell ill with the disease and died on the 29th August, the day after her husband's death. This woman seldom left her house and without doubt acquired infection there.

On September 5th thirteen cases were reported as having occurred during the previous five days, in various parts of the city, *viz.* at Rawiwar 50, Kasba 40, Kasba 195, Kasba 5, Rawiwar 591, Shukurawar 293, Budhwar 429, Bhawani 951, Rawiwar 1082, Nana 287, Budhwar 426, Somwar 368; with the exception of the first two houses all are rather widely separated from each other.

It is worthy of note here that Kasba Nos. 40 and 5 and the two houses in Budhwar are not very far removed from the house in which a partially decomposed mouse (which was proved to be plague infected) was found on the 18th July. We may also mention here, that on September 7th we obtained further evidence of the presence of an epizootic in this neighbourhood by finding a dead plague infected rat at No. 5 Kasba, while on the 8th a live rat suffering from plague was trapped in house No. 1419 Kasba, this house being about five hundred yards distant from the above mentioned No. 5.

On September the 6th four more cases were reported to us as having occurred during the last few days at Gang 363, Shanwar 27, Budhwar 169, and another case was brought to the General Plague Hospital from an address in Shanwar Peth, which could not be traced.

We may at this stage direct attention to two maps which show the distribution of the early cases of plague. Map III shows the position of the houses in which the first twenty cases occurred; all of these, except two which were infected in the end of August, were imported cases of the disease occurring during the months of July and August. Map IV shows the distribution of the first indigenous cases of plague (save the two above mentioned) which occurred in the first week of September. From these maps it will be gathered that the indigenous cases bore no relation, at least as regards distribution, to the imported ones, and from Map IV the inference can be made that already, early in the epidemic, foci of indigenous plague were widely distributed through the city.

In order that we might be assured that no deaths from plague had been overlooked, the daily death returns of the Health Office were obtained, and a note made of all deaths which occurred during July and August between the ages of three and sixty years, excluding only those returned as deaths from plague. The places where these deaths had occurred were then allocated on a large scale map of the city with a view to selecting those for further inquiry which appeared to be grouped particularly closely together. This inquiry was made by personal visits to the friends of the deceased with the object of eliciting any facts which might point to the deaths as having been due to plague but incorrectly registered under another cause. Two areas only fell under suspicion, viz. Budhwar and Nana's Peths.

Accordingly 23 deaths in Budhwar and 21 deaths in Nana's Peth were investigated. Amongst other details of the case, the history and chief symptoms were noted, viz. the presence of delirium, fever, glandular swellings, etc; also the duration of the illness; presence, at the time, of a rat mortality, or other cases of plague in the neighbourhood, and whether the patient had been treated by a medical man, in which case further inquiries were also made from him. The homes of seven persons who had died in Budhwar Peth could not be traced, of the other deaths fifteen were definitely due to a chronic illness of from a month to a year's duration. The remaining death occurred at 443 Budhwar. This person was taken ill on 26th August with, the friends said, fever and a rigor, followed by diarrhoea and vomiting lasting two

days, the death had been registered as due to diarrhoea, but on inquiring from the medical practitioner who treated the case he describes it now as definitely due to plague. This case occurred at a house not far from the one in which the first plague infected mouse had been found on July 18.

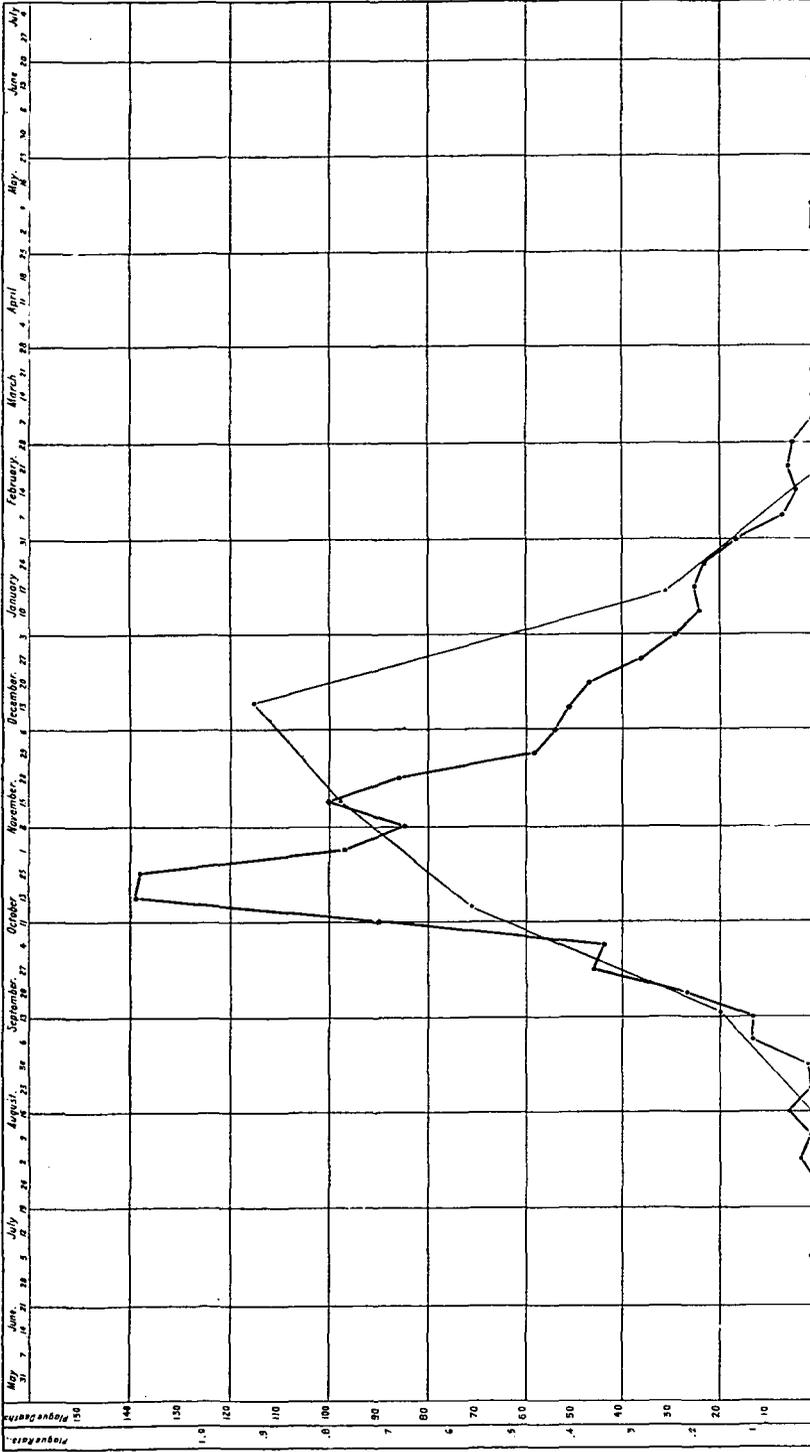
In a similar way twenty-one deaths in Nana's Peth were investigated. The homes of three of the deceased could not be traced. The cause of death in the remaining cases except three was due to chronic illnesses of some kind. Of the three deaths due to acute illnesses, one appeared to have died from cholera, another suffered from an illness of fifteen days' duration following parturition without any history pointing to plague. The remaining case a Mahomedan boy, aged 12, took ill on 19th August at No. 288 Nana's Peth. The illness started with a rigor and fever; no glandular swelling was observed. The boy died on August 25th, 1908. The neighbours, however, described this as definitely a plague case, and remembered noting other cases later in the same locality. The house, since the death occurred in it, has remained unoccupied.

The result of this inquiry showed that, on the one hand, we probably did not miss many plague cases during the early part of the epidemic, on the other hand, we might with equal certainty say that one or two cases of plague did occur, which, for various reasons, had been kept hidden from the authorities.

From the 6th September onwards the number of deaths from plague rapidly increased, so that by the end of September there had been 123 deaths from this cause followed by 472 in October. The preventive measures which we have already detailed in another part of this report were meanwhile being actively pushed, so that in November there was already a distinct fall in the mortality from plague in the city, three hundred and seventy deaths being recorded in this month, this, be it noted, in spite of the fact, as will be evident by consulting Table X, that the epizootic among the rats was still on the increase. In December there was a still greater fall in the number of deaths from plague, which in this month registered 191. In January, February, and March the figures were respectively 101, 21 and 3. The epidemic came to an end with four imported cases of the disease, one in March, one in April and two in May.

(b) *The epizootic.* We have seen that the first evidence of plague among the rodents of the city was obtained in the finding of a plague infected mouse on the 18th July. It seems probable that, at least in

CHART V



POONA

— Plague deaths in Poona City per week, 1908—1909

- - - Percentage of live rats plague infected (acute) in each month

the locality where this mouse was found, we succeeded in obtaining evidence of the very commencement of the epizootic, for some time elapsed before further testimony was forthcoming of the presence of the disease in the place either in the return of plague cases (the earliest possible one being the doubtful plague case registered as cholera on the 26th August at 443 Budhwar Peth mentioned above) or in the discovery of plague infected rats, the first one being found on the 7th September; the epizootic however by this latter date appeared to be fairly widely distributed in the neighbourhood, for on the following day (8th Sept.) a plague infected rat was trapped in a house more than a quarter of a mile distant. Thereafter the epizootic rapidly increased.

TABLE X.

Table showing percentage of live rats (Mus rattus) plague infected (acute) in monthly periods, during the year 1908—09.

Period	Number of live <i>Mus rattus</i> examined	Number of live <i>Mus rattus</i> (acute) plague infected	Percentage of live <i>Mus rattus</i> plague infected	Resolving plague	Percentage	Plague deaths in Poona City
Sept. '08	6115	10	0.16	18	.2	123
Oct.	4913	29	0.59	27	.5	472
Nov.	3814	30	0.78	29	.7	370
Dec.	2924	27	0.92	77	2.6	191
Jan. '09	2376	6	0.25	33	1.0	101
Feb.	2284	1	0.04	22	.9	21
March	2906	0	—	18	.6	3

In view of the fact that dead rats were received at the laboratory at very infrequent intervals, we determined to consider only those rats which were trapped alive and found to be infected with plague in measuring the onset, progress, and termination of the epizootic. In adopting this course we no doubt considerably curtailed the actual period during which the epizootic prevailed, for the reasons that (1) the number of rats examined daily, on an average two hundred, a representative sample no doubt as far as distribution was concerned, was only a very small fraction of the whole of the rats in the city, and (2) the chance of capturing a plague sick rat by tempting it into a trap with bait was probably small; yet this method yielded results which appeared to be near the truth. It is apparent from what has been said above, that the capture of the first plague infected rat occurred only about a fortnight

(15 days) after the first indigenous case fell ill with the disease. Considering then only rats caught alive in the city suffering at the time from acute plague we found ten in September, twenty-nine in October, thirty in November, twenty-seven in December, six in January, and one in February; these numbers are detailed in Table X where also the percentage of plague infected rats on the total number examined has also been calculated, and these figures compared with the number of deaths from plague that occurred among the inhabitants of Poona City each month. We think that we have measured the extreme limits of the epizootic rightly when we state that it lasted from the end of August to the end of March and that it reached its acme in the month of December.

It is convenient here to mention certain other features connected with plague among the rats of Poona. In previous reports we detailed at some length the naked eye pathological appearances found in acute plague infected rats, which had died of the disease. In Poona and Belgaum we frequently encountered the disease in living rats; it was natural therefore that we should find all stages of the disease. Some rats, for example, had just acquired infection; the pathological changes in these cases were of course somewhat obscure, sufficient time not having elapsed from the commencement of the disease to allow the lesions to be easily visible to the naked eye; a few of these rats therefore might have escaped detection during dissection had it not been for a microscopical examination of a spleen smear, in which it was possible, even at this early stage, to detect plague bacilli. Again, other rats were met with which had apparently passed the critical stage of the disease, and which, had they not been captured and killed, might well have recovered from the disease. Among this latter group of plague infected rats all stages of recovery from the disease were met with. There were rats, for example, with lesions closely resembling those found in acute plague, but on closer inspection these lesions were observed to be more isolated, and more localised in the tissues. Thus the presence of minute necrotic spots in the liver is a very characteristic pathological finding in rats which have died from acute plague; on close inspection these necrotic spots are found to have an ill-defined margin, the necrotic material fading away imperceptibly into the liver tissue, but in rats which are recovering from the disease these necrotic areas have a more defined outline, are often larger, and less numerous. Then, again, there were rats also belonging to this group, apparently also recovering from

the disease, which presented the lesions of resolving plague described elsewhere (p. 335). Finally, a number of rats were observed, which showed various scars and adhesions between the abdominal viscera, the parietes and mesentery; these rats we believe had suffered from plague, but had recovered. The importance of the existence of these cases of resolving and recovered plague among the rats will be appreciated when we come to discuss the question of immunity among rats as a factor in causing the decline of an epidemic.

TABLE XI.

Name of month	Total live <i>rattus</i> examined	Acute plague		Resolving plague		Adhesions		
		No.	Percentage	No.	Percentage	No.	Percentage	
June 1908	3977	0	—	3	—	Figures not available before November.	—	
July	5351	0	—	4	—		—	
Aug.	5946	0	—	4	—		—	
Sept.	6115	10	·16	18	·2		—	
Oct.	4913	29	·59	27	·5		—	
Nov.	3814	30	·78	29	·7		—	
Dec.	2923	27	·92	77	2·6		26	·88
Jan. 1909	2376	6	·25	33	1·0		43	1·8
Feb.	2284	1	·04	22	·9		57	2·4
Mar.	2906	0	—	18	·6		48	1·6
April	2644	0	—	5	—		28	1
May	2479	0	—	5	—	19	·7	
June	2830	0	—	4	—	22	·7	

C. *Data bearing on the factors which determine the seasonal prevalence of plague collected in Poona 1908—1909.*

(1) *The climatic conditions in Poona 1908—1909.*

Under this head little requires to be added to what has already been said. From a study of Charts I, II and III it will be appreciated that the climatic conditions of the year approximated very closely to the normal. In Charts I and II the mean daily temperature, averaged for weekly periods, for the year 1908—09 may be compared with the mean daily temperature, averaged for half-monthly periods, and calculated for the ten years 1897—1906. In Chart II the relative humidity, expressed in percentage of saturation, calculated on six hourly readings daily and averaged for each week, has been compared with similar figures

expressing the mean result for the ten year period 1897—1906. Chart III shows the maximum, minimum, and mean temperatures, averaged for weekly periods, for the year 1908—09.

(2) *Variations in the virulence of the bacillus.*

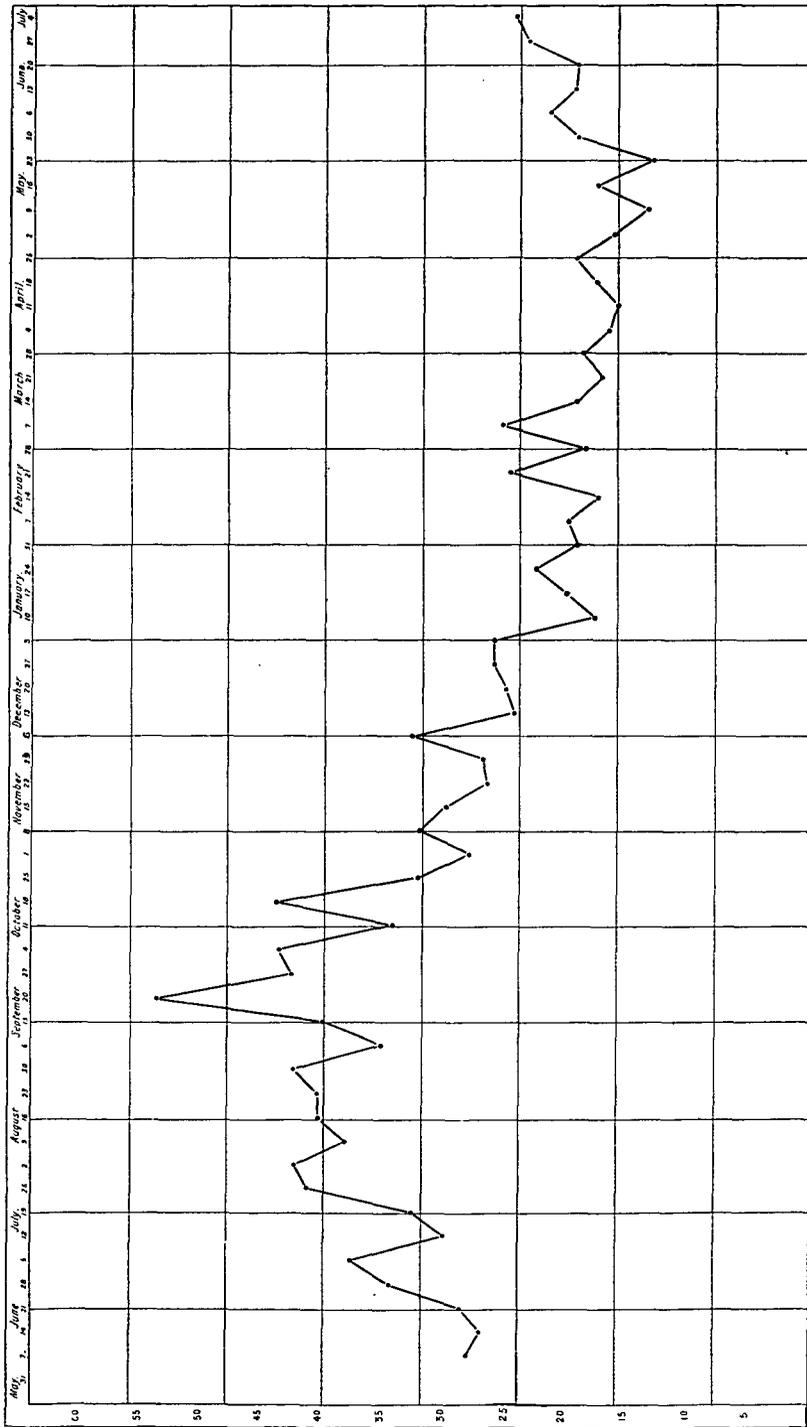
Practically no data have been collected under this head. In the absence of any satisfactory standard for measuring the virulence of the plague bacillus little can be said on this subject; it will suffice to mention, that strains of the plague bacillus were isolated in Poona, during the course of the epidemic, which showed a high degree of virulence.

(3) *Variations in the total number of rats.*

The means by which we hoped to collect data bearing on the infestation of the houses with rats in Poona City have already been discussed. We hoped by setting in rotation a number of rat traps daily in the houses of the city to be able to measure their rat infestation by calculating the number of rats caught for every one hundred traps set. The following table shows the total number of rodents and "musk" rats caught during these operations from May 1908 to June 1909. It will be observed that the number of rats caught amounts to approximately one half of the population of the city. It will also be noted that the species *M. rattus* predominates largely over the other species; we have considered this species only, to the exclusion of the others, in conducting our inquiry.

Bearing in mind the limitations which must be placed on the use of our method for estimating rat infestation, a method open to many fallacies despite our best endeavours to avoid the most obvious sources of error, we think our figures are trustworthy enough to show that there was, during the year, a marked variation in the rat infestation of the houses in the city. The figures we have compiled can be seen in Table XII; it will be noted that the number of rats caught per 100 traps set during the first four months of the operations steadily increased from 30·7 in June to 42·8 in September; meanwhile more than twenty thousand rats had been caught, this considerable destruction of rats having little effect in reducing the rat infestation of the houses when measured by our method. It will be seen from Table XII that breeding among the rats was going on actively during this period,

CHART VI



POONA

Number of rats per 100 traps set in Poona City

TABLE XII.

Table showing the number of rats caught in Poona City per 100 traps set.

Period	Number of traps set	Number of rats caught	Number of rats caught per 100 traps set	Remarks
June 1st to June 28th	11363	3494	30·7	
June 29th to July 26th	13249	4704	35·5	
July 27th to Aug. 30th	16888	6890	40·8	
Aug. 31st to Sept. 27th	12697	5436	42·8	Epizootic begun.
Sept. 28th to Oct. 25th	11620	4508	38·8	
Oct. 26th to Nov. 29th	14862	4283	28·8	
Nov. 30th to Dec. 27th	9036	2471	27·3	Acme of epizootic.
Dec. 28th to Jan. 31st	11178	2370	21·2	
Feb. 1st to Feb. 28th	10479	2116	20·2	
Mar. 1st to Mar. 28th	12907	2562	19·8	Epizootic ended.
Mar. 29th to April 25th	14657	2533	17·2	
April 26th to May 30th	18606	2966	15·9	
May 31st to June 27th	13295	2775	20·8	

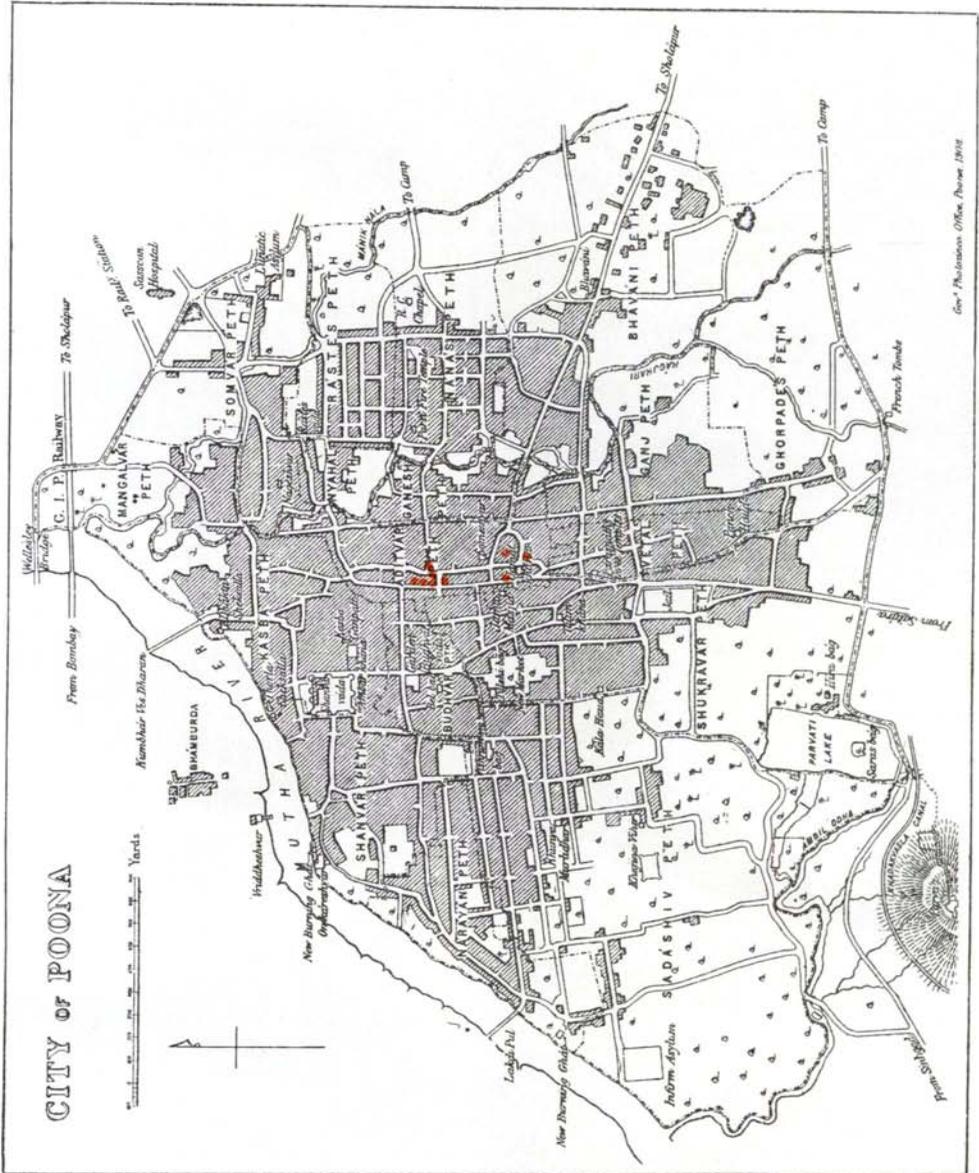
Table showing percentage of young rats on total rats weighed.

Period	Number of rats weighed	Number of young rats	Percentage of young rats under 70 gms.	Remarks
June 1st to June 28th	3479	1916	55·1	
June 29th to July 26th	4640	2481	53·4	
July 27th to Aug. 30th	6740	3398	50·4	
Aug. 31st to Sept. 27th	5736	2895	50·5	Epizootic begun.
Sept. 28th to Oct. 25th	4782	2557	53·4	
Oct. 26th to Nov. 29th	4525	2211	48·8	
Nov. 30th to Dec. 27th	2697	1054	39·0	Acme of epizootic.
Dec. 28th to Jan. 31st	2797	1082	38·6	
Feb. 1st to Feb. 28th	2301	1090	47·3	
Mar. 1st to Mar. 28th	2613	1485	56·8	Epizootic ended.
Mar. 29th to April 25th	2422	1451	59·9	
April 26th to May 30th	2890	1670	57·7	
May 31st to June 27th	2728	1443	52·8	

Table showing percentage of pregnant females.

Period	Adult female <i>rattus</i>	Female <i>rattus</i> pregnant	Percentage of adult females pregnant	Remarks
June 1st to June 28th	937	366	39·1	
June 29th to July 26th	1282	551	42·9	
July 27th to Aug. 30th	2149	870	40·4	
Aug. 31st to Sept. 27th	1702	653	38·3	Epizootic begun.
Sept. 28th to Oct. 25th	1302	384	29·4	
Oct. 26th to Nov. 29th	1271	304	23·9	
Nov. 30th to Dec. 27th	833	184	22·1	Acme of epizootic.
Dec. 28th to Jan. 31st	929	307	33·0	
Feb. 1st to Feb. 28th	668	236	35·3	
Mar. 1st to Mar. 28th	632	248	39·2	Epizootic ended.
Mar. 29th to April 25th	562	214	38·1	
April 26th to May 30th	696	283	40·6	
May 31st to June 27th	730	297	40·6	

MAP V



Map showing location of "M. rattus alexandrinus" caught alive between June, 1908 and July, 1909.

TABLE XII (continued).

Table showing total rodents caught.

<i>Mus Rattus</i>	...	...	...	49,678
Mice	...	...	...	686
Musk Rats	...	...	...	37
<i>Gunomys varius</i> or <i>Nesokia bengalensis</i>	...	...	...	1
			Total	50,402

In addition to the animals mentioned above sixteen mongooses were caught in the rat traps; the mongooses had apparently entered the traps in order to kill the rats caught in them, and were chiefly taken during the rainy season. We may here also mention two facts of subsidiary importance, viz. (1) no bandicoots (*N. bandicota*) were seen or captured in Poona, but intelligent citizens declare that, before plague visited Poona, rats answering this description were commonly seen there; (2) no *M. decumanus* were caught in Poona, contrasting markedly in this respect with Bombay, and this in spite of the fact of the proximity of Bombay to Poona, and that there exists in this city a system of underground drains or closed gutters suited to the habits of *decumanus*; we would infer therefore that this species of rat is not very commonly transferred from one place to another in merchandise. The local distribution of the variety *alexandrinus* is shown in Map V.

about 40% of all females captured being pregnant. The number of young rats among the total number of rats caught at this time was also considerable; from Table XII it will be seen that more than 50% of all the rats captured weighed less than 70 grams.

From the end of September to the end of January there was a very rapid decrease in the number of rats caught per 100 traps set. It is possible that a number of factors contributed to bring about this decrease. First among these we must mention the plague epizootic which came to our notice, be it remembered, in the discovery of plague infected rats in the beginning of September, and which thereafter rapidly developed, reaching its acme in December. During this period, September to the end of December, there was a very marked drop in the number of rats caught per 100 traps set, from 42·8 to 27·3, a difference of 15·5 rats per 100 traps set. With the decline in the epizootic a considerable, though diminished, fall was still maintained, especially during the first month of the decline, the number of rats caught decreasing then from 27·3 to 21·2 per 100 traps set; later, a more gradual decline took place to the close of the epizootic in March, when 19·8 rats were caught. There can be little doubt, therefore, that the epizootic had a considerable effect in reducing the rat infestation of the houses. We saw that in Kirkee, where the epizootic was much more severe than it was in the city, an even greater reduction in rat infestation took place from this cause

during the short period of one and a half months, viz. from 33 rats per 100 traps set to approximately nine.

We must not however overlook the fact that during the epizootic period, at least from the end of August to the end of December, there was a very considerable curtailment in breeding among the rats, and this must also have had some effect in bringing about the fall in the number of rats caught recorded above. The percentage of females found to be pregnant fell during this period from 40·4% in the end of August to 22% in the end of December. Whether this decrease in the number of pregnant females was directly due to the epizootic or not, we cannot at present say; future observations, during a year when plague is absent from the city, may shed some light on the matter. After the month of December, however, which, curiously enough, corresponded exactly with the acme of the epizootic, the breeding again increased. Following the slack breeding period in September to November, there was a reduction in the percentage of young rats among the total rats captured, the figures falling, as will be seen in the table referring to this matter, from 53·4% in October to 38·6% in January; thereafter, the percentage of young rats among the total rats again increased.

By the end of January, therefore, conditions again seemed to be favourable for an increase in the rat infestation of the houses, the epidemic was on the decline, more females were pregnant, and more young ones were being added to the rat population, but our figures do not show any increase in the number of rats caught per 100 traps set. There is rather a decline, for, after remaining at a fairly constant, though declining level, during January, February and March, when 21·2, 20·2 and 19·8 rats respectively were caught for every 100 traps set, a still further and rather greater drop in the figures occurred during April and May when, so far as we were aware, no epizootic existed, and when only 17·2 and 15·9 rats were caught.

To account for this persistent fall in the number of rats caught in spite of circumstances favouring their increase, such as active breeding and the absence of epizootic disease, we must presume that either (1) the reduction in the number of rats brought about through the combination of factors mentioned above had been so great, that now our trapping operations (being still maintained nearly as actively as at the commencement, when we saw they had little effect on the rat infestation), were causing the destruction of a number of rats as great, if not greater than, the number which was being added to the rat forces

by breeding, or (2) some other factor, which we have not yet considered, was playing a part, directly or indirectly, in reducing the number of rats captured. In seeking for this other factor we cannot help being struck by the fact that the rat infestation of the houses was maintained at a high level during the rainy season, and gradually declined from the termination of the rains to the close of the hot weather, when again, with the advent of the rains, an increase in the number of rats captured was immediately registered. On the one hand, it is reasonable to suppose that the inclement weather conditions during the rains might tend either to drive rats which lived outside of houses to find shelter in them during this season or that it tended to cause rats, which habitually lived in the houses but sought for food outside, to look for it now within their sheltered homes, and so cause them more frequently to be caught in our traps at this season, the traps, of course, being always set within the houses. On the other hand, it seems equally reasonable to suppose, in view of the fact that the rainy weather almost abruptly terminates in the end of September, that the tendency for the rats to leave the houses would occur almost as abruptly; nevertheless, in place of an abrupt egress, our figures show that a long, slowly drawn out migration from the houses to the surrounding compounds must be supposed to take place. If there is such a seasonal migration of the rats into the houses during the rains and out again during the dry weather it must be considered as a factor favouring the prevalence of plague during the rainy season in Poona, for then the rats, which are known to play so important a part in conveying the disease to man, would on this hypothesis be more intimately associated with him than at any other time of the year.

(4) *Variations in the proportion of immune to susceptible rats.*

An experiment was carried out in Poona during the course of these observations to test the immunity of rats during the progress of the epizootic. From 70 to 100 rats every week throughout the year were inoculated with as constant a dose as possible of a virulent strain of plague bacillus to ascertain the proportion that died of plague, and in this way to get a measure of the immunity of the rats to plague infection. For the purpose we had in view the experiment entirely miscarried, chiefly for the following reasons. (1) During the damp rainy season it was difficult to keep dry the cages in which the rats were kept,

so that many rats died from causes other than plague. (2) During the cold weather, especially in November and December when the minimum temperature during the night frequently fell to below 50° F., many rats were found in the early morning to be in a moribund condition; some of these died and were found to be suffering from plague, others however revived when the temperature rose later in the day. The lowering of the temperature during the night was apparently so important a factor in increasing the liability of the rats to death after inoculation with plague, in the artificial surroundings in which the rats had to be kept, as to obscure any increased immunity they might have acquired in having passed through an epizootic of plague. It was found impossible to avoid this source of error in conducting this experiment, for the rats had to be kept in cages in an open corrugated iron shed which occupied a somewhat exposed position; moreover the full significance of this source of error was not at the time recognised. The experiment however suggests that the cold weather may be a factor in increasing the death rate among plague infected rats.

We have therefore to fall back on indirect evidence as to whether during the progress of an epizootic of plague, especially towards its close, a large number of rats acquire immunity to the disease. The evidence of this sort which we were able to collect in Poona may be seen in Table XI, where we give the number of rats found each month during the epizootic suffering from "resolving plague," *i.e.* an attack of plague from which the rats were evidently recovering; in this table, it will be seen that as many as 2·6, 1·0 and ·9% of the rats caught alive in the city during the months of December, January and February respectively presented this form of the disease.

(5) *Variations in the number of fleas found on rats.*

Loemopsylla cheopis was practically the only flea found on the rats of Poona. Amongst 240,433 fleas caught throughout the year, only two cat fleas and four human fleas were seen. The average number of fleas found on *Mus rattus* was noted from week to week (Table XIII). When observations were commenced in May 1908, and until the week ending June 21st, their number appeared to be still on the decline. In that week they reached the minimum for the year of 1·3 fleas per rat. A rapid and very constant rise then took place, until the week ending August 30th, when the maximum for the year, *i.e.* 11·2 per rat, was

TABLE XIII.

Table showing the average number of fleas per rat (*M. rattus*) in weekly periods.

Week ending	Number of <i>rattus</i> on which fleas were counted	Number of fleas counted	Average number of fleas per rat
June 7, 1908	640	1370	2.1
14	663	1826	2.8
21	886	1194	1.3
28	1115	2789	2.5
July 5	1181	4317	3.7
12	951	3761	4.0
19	1063	5622	5.3
26	1152	5725	5.0
Aug. 2	1030	7117	6.9
9	1026	7902	7.7
16	1010	8836	8.7
23	1112	10274	9.2
30	1168	13052	11.2
Sept. 6	1031	10053	9.8
13	1056	9986	9.5
20	1376	12499	9.1
27	1033	8324	8.1
Oct. 4	1040	7587	7.3
11	790	5676	7.2
18	991	7831	7.9
25	754	6245	8.3
Nov. 1	753	5129	6.8
8	848	6810	8.0
15	712	4665	6.6
22	678	4958	7.3
29	692	4969	7.2
Dec. 6	726	5727	7.9
13	507	3450	6.8
20	591	3745	6.3
27	379	1895	5.0
Jan. 3, 1909	562	2973	5.3
10	361	1924	5.3
17	506	2605	5.1
24	604	2617	4.3
31	548	2697	4.9
Feb. 7	560	2791	5.0
14	580	2843	4.9
21	552	2548	4.6
28	555	2501	4.5
Mar. 7	766	3542	4.6
14	516	2459	4.9
21	652	2835	4.3
28	613	2447	4.0
April 4	603	1551	2.6
11	523	1437	2.7
18	531	1470	2.8
25	717	1513	2.1
May 2	590	1487	2.5
9	482	981	2.0
16	614	1525	2.5
23	455	1154	2.5
30	662	1240	1.9
June 6	681	1540	2.3
13	613	1508	2.5
20	609	1950	3.2
27	759	3878	5.1

observed. It is noteworthy that this increase coincided exactly with the commencement of the rainy season, and consequently also with the rise in humidity and with the fall in temperature. After August 30th there was again a rapid fall during the month of September to 8·1 fleas per rat in the last week of that month. In October, November and the first week of December an average of about 7·5 fleas per rat was maintained. During January, February, and March an average of about 4·5 fleas per rat was recorded. In the beginning of April a sudden drop in the number of fleas was noted to about 2·5 per rat, and this figure was maintained throughout the remainder of the hot weather and first half of June¹.

The rainy season of 1909 commenced rather earlier than usual, a few heavy thunder showers occurred towards the end of May associated with a considerable fall in the temperature. The onset of the rains therefore occurred three weeks earlier in this year than in 1908 when the monsoon was somewhat delayed. It is interesting to note that the rise in the number of fleas commenced in 1909 after the week ending May 31st, when the average number of fleas reached its lowest point, *i.e.* 1·9 per rat, while in the year 1908 the lowest figure recorded, *viz.* 1·3 per rat, was in the week ending June 21st, that is, three weeks later, corresponding exactly with the later onset of the rains in that year.

Other hosts of L. cheopis. Not many animals other than rats were examined for fleas. On about 22 squirrels which were chloroformed no *L. cheopis* were found. It is noteworthy, however, that on one of these brought in on 6th October 1908, 19 fleas closely resembling *Ceratophyllus fasciatus* were found. Although a certain number of this species were found on the rats examined by us in the Punjab, none were ever noticed amongst the rat fleas of Poona. No fleas other than *Loemopsylla cheopis* were found on mice, and of these they harboured only very few as compared with *Mus rattus*. As an example we may give the figures obtained in the month of July, when the average number of fleas per *M. rattus* was 4·4, whereas the average number per mouse (eighty-two examined) was only 0·26².

¹ These observations have been repeated in Poona for the year 1909—1910 (when there was no epidemic plague) and very similar results have been obtained.

² A rat of 100—150 grammes has nearly three times the skin area of a mouse of 20—30 grammes.

PART III.

DEDUCTIONS DRAWN FROM THE DATA COLLECTED, ESPECIALLY AS TO
THE SEASONAL PREVALENCE OF PLAGUE IN POONA.

A. *The significance of imported infection.*

It is an axiom to state that there can be no plague without the plague bacillus. The factors suggested by the Commission which influence the seasonal prevalence of plague can only do so in the presence of plague infection. The introduction of infection into a place is thus a matter of prime importance, and the first deductions to be made from our observations in Poona have reference to this important point.

First, the evidence we have collected shows that a plague case, imported into a place, is not necessarily associated with other cases. Thus we saw that during July and August eighteen cases of plague were imported into the city, yet the subsequent cases were not directly associated with these. Any evidence we were able to collect regarding the infectivity of plague is in conformity with the view put forward in our previous reports, that man generally acquires infection from the rat, that, in short, the epidemic is dependent on the epizootic.

Secondly, the fact that the first indigenous cases of plague in the city bore no relation to, but were usually widely separated from, the first imported cases of the disease, suggests the possibility that infection can be brought into a place apart from persons suffering from the disease. A reasonable hypothesis to explain the carriage of infection in this way is to suppose that infected rat fleas are carried by human agency from infected to uninfected places independently of persons suffering from the disease.

† Thirdly, it follows from the two deductions above that the importation of plague cases to a place is only an imperfect measure of the extent to which potential infection is being brought to it. The arrival of infected persons indicates that possibly other persons are coming from infected areas and are perhaps carrying with them infection in the form of infected rat fleas. The enormous extent to which migration from infected to healthy places takes place in India was well illustrated during our experience in Poona. We have seen that shortly after work was commenced there four cases of the disease were imported into the

municipal area from Bombay, two of the cases were actually taken out of the train ill and removed to hospital, while two others developed the disease immediately after arrival in Poona. Infection, about this time, also seems to have been carried to Kirkee, for three cases of plague were reported there in the end of May and beginning of June; previous to these cases none had occurred for more than eighteen months. The rats in the neighbourhood of the railway station were already infected before our inquiry started, or at least became infected shortly after. An epidemic and epizootic originating in this way extended rapidly, especially in Kirkee, affording a favourable opportunity for extensive importation of infection into Poona City, which, at this time, appeared to be free from infection, for the last indigenous case of plague had occurred in the end of January, and the examination of more than twenty thousand rats caught in the city failed to reveal the presence of the disease among them. The extent to which infection was imported into the city is apparent in the fact that during July and August eighteen cases of the disease were brought to it, fourteen of these coming from the suburbs, while four were from places more distant and were carried thither by rail. With the development of the epidemic in Poona City in the month of November infection must have been disseminated far and wide, for the municipal authorities estimate (and we had no reason to doubt this estimate) that from fifteen to twenty thousand people left the city for the surrounding towns and villages. Fortunately the conditions for the development of the disease had by this time become to some extent unfavourable, but, had this emigration and evacuation of the city occurred at an earlier period of the year, opportunities for the conveyance and propagation of infection would have been more favourable and a widespread epidemic might easily have occurred.

Fourthly, since the importation of infection is largely a matter of chance and may occur at any time of the year, the successful implanting of it will largely depend on whether the factors which influence the development of the disease are favourable or otherwise. The importation of infection at a season of the year when these factors are week by week becoming more favourable will not only assure a more successful implantation of it, but will also occasion a severer epidemic than had the infection been brought at a time when the favourable influences are on the wane. In Kirkee, for example, infection was successfully implanted there in June, and the epidemic, developing with a rising flea prevalence, was therefore very severe; while in Poona infection only took

root towards the end of August, when already the number of fleas was about to decline, so that the epidemic here was comparatively mild. Further evidence bearing on this point will be discussed when the influence of the number of fleas on the course of the epidemic is considered.

B. *The influence of climate on plague in Poona.*

In our paper on the seasonal prevalence of plague (*Journ. of Hygiene*, vol. VIII. No. 2, page 287) in discussing the influence of climate, we concluded from the evidence we had collected that a high temperature, especially when it reaches a daily mean of 85 or 90° F., or a low temperature, that is a mean below 50° F., was very unfavourable to plague. Our experience in Poona (see Chart I) showed that the influence of climate, in these directions at all events, could play only a small part in checking the plague. It was indeed for this reason that Poona was selected as a place worthy of observation, for, unlike Bombay and the Punjab villages where we had worked, epidemics came to an end here apart from the influence of temperature on them. But in the paper referred to above (p. 273) we considered that climate might influence the seasonal prevalence of plague in so far as it reacted on the life history and habits of the flea. We have shown, in the present report, that in Poona climate, especially the atmospheric humidity, plays an important rôle in causing a variation in the number of fleas found at different seasons of the year. In Chart IV the figures representing mean temperature and humidity for weekly periods during the year of our observation have been plotted against those which show the average number of fleas per rat for each week. It will there be seen how close is the relation between the percentage humidity and the flea prevalence, and how little this latter is affected by temperature. The influence of climate then on the seasonal prevalence of plague in Poona is largely exerted through its effects on the prevalence of fleas.

C. *The influence of the virulence of the bacillus on plague in Poona.*

No evidence was obtained in Poona to show that the virulence of the plague bacillus played any part in influencing the seasonal prevalence of plague there.

D. *The influence of (a) variations in the number of rats and (b) variations in the proportion of immune to susceptible rats on plague in Poona.*

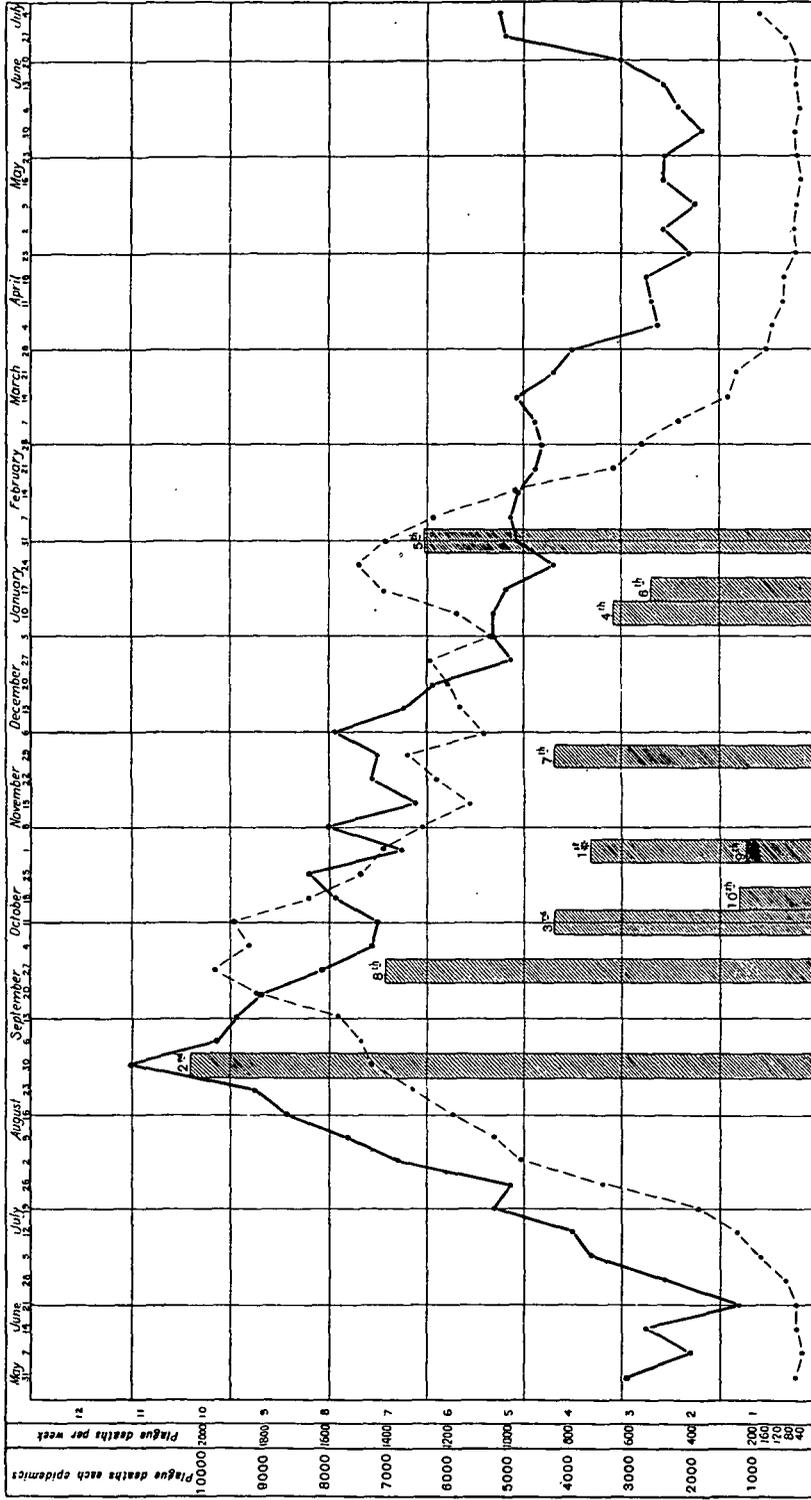
(a) Our observations showed that when plague broke out in Poona City the number of rats per house was at its maximum for the year; with the progress of the epizootic the number decreased rapidly. This diminution in the number of rats caught, however, continued after the epizootic had ceased, in spite of active breeding among the rats, possibly because the capture of rats on a considerable scale was still continued, eight thousand rats being killed in the course of the three months following the close of the epizootic. There can be little doubt that the decrease in the number of rats in Poona City with the progress of the epizootic played some part in bringing it to a close; an increase in the number of immune individuals and a decrease in the number of fleas per rat contributed to this end¹. The influence of a reduction in the number of rats, as the main, if not the only, cause leading to the termination of an epizootic, was especially well illustrated in Kirkee. Here the disease began to die out when it was springing to life in the city. We have shown that, save in respect to the number of rats present in each place, the other conditions necessary for the development of plague were favourable; thus with the decline of the epidemic in Kirkee the rats caught per 100 traps set fell from thirty-three to only nine, though at the same time the number of fleas per rat rose from approximately six to ten: the influence of climate need not be considered, for it was the same in both, the places being adjacent to one another. (b) There can be little doubt that an increase in the proportion of immune to susceptible rats as an epizootic progresses assists to some extent in bringing it to a close. In Poona no very direct evidence however was obtained in favour of this contention other than that, at the close of the epizootic in the city, an increasing number of rats were found which were either recovering or had actually recovered from the disease.

¹ The possibility must be considered that a large mortality among the rats might to some extent concentrate the fleas upon the survivors and so bring about an increase of fleas per rat. As a matter of fact in Poona fleas and rats appeared to be most abundant about the same time.

E. *The influence of variation in the number of fleas per rat on plague in Poona.*

The importance of this factor in influencing the seasonal prevalence and severity of the disease was well marked in Poona and has already been referred to above. We there drew attention to the fact that in Kirkee the epidemic, developing with a rising flea prevalence, was much more severe than the epidemic in Poona, which developed during a declining flea prevalence. On Chart VII we have plotted out in weekly figures the average number of fleas per rat. We have already noted the important bearing climate, especially the humidity, has on the prevalence of rat fleas in Poona and we have shown that the climatic conditions of the year under observation closely approximated to the mean for the ten year period 1897—1906, so that we may conclude that the variations in the flea prevalence found during the year 1908—1909 approximated very closely to the normal. On the same chart we have plotted out the figures obtained by adding together all deaths from plague which occurred within the city during each of the same weekly periods since June 1898 (the figures available for the early part of the first epidemic being somewhat inaccurate have been excluded). These figures show the extent to which plague has prevailed in each week of the year calculated on the experience of twelve years, that is, of ten epidemics. The curve obtained by plotting these figures on the chart will be seen to correspond very closely with the curve representing the flea prevalence, except for a period in January and February when the two curves slightly diverge: an explanation however for this divergence will be offered presently. In the same Chart VII each of the epidemics which have occurred in Poona City during the past twelve years has been represented in a series of shaded columns. The columns have been drawn to scale, so that each represents in height the severity of a particular epidemic as estimated by the total number of deaths from plague which have occurred during that epidemic (see Table IV p. 495). In addition the columns have been placed in the chart in the weekly period in which each epidemic reached its acme, that is, the week in each epidemic in which the maximum number of deaths was recorded. Taking for granted that the flea prevalence during each of the epidemics conformed to the experience of the year 1908—09, we may formulate the rule that the severity of the several epidemics bears a direct ratio

CHART VII



POONA

— The average number of fleas for *Mus rattus* in Poona City, 31.5.08 to 4.7.09
 - - - Total deaths from plague each week for 12 years, June 1897 to May 1908
 ■ Total deaths from plague in each epidemic, 1st to 10th

* Figures incomplete for first epidemic

to the number of fleas per rat found at the time when each epidemic reached its acme; thus, the severest epidemic, the second, reached its acme in the last week of August, a period corresponding with the greatest flea prevalence of the year 1908—09. The second epidemic in point of severity was the eighth in numerical sequence. This epidemic reached its acme in the last week of September when the number of fleas, judging from our experience in 1908—09, was somewhat less than the number in the last week of August, but greater than the number found at the time of year when any other epidemic, except the first, reached its acme.

Certain exceptions to this rule however are to be noted, namely, the fifth epidemic as well as the ninth and tenth. Good reasons we believe can be given to explain these exceptions. Considering, first, the fifth epidemic which occurred in the year 1902—03 and which, it will be noticed, is the third epidemic in point of severity, we find that the climatic conditions at the time when this epidemic prevailed were quite exceptional and conformed in respect to humidity (and thus presumably also in respect to flea prevalence) to the conditions usually found during September, October, and November, *i.e.* the period succeeding the rains, and not to the usual conditions found in January and February, the months in which this epidemic was at its height. In Chart II the mean half monthly humidity of the year 1902—03, the year of this exceptional epidemic, is compared with the mean for the ten years 1897—1906 and with that of the year 1908—09. How materially the year 1902—03 differed from the normal, and the year of our observation, is therein manifest; attention, especially, may be drawn to the records of December and January, the figures 81 and 76, 71 and 70% humidity for each half of these two months of the year 1902—03, contrasting with 55 and 56, 57 and 61% as a mean record for the same half monthly periods during ten years. It is evident, that in December and January 1902—03, the climatic conditions in point of humidity approximated to that found during the period immediately succeeding the rains, and it is reasonable to suppose that the flea prevalence too in this year approximated to that usually found at this season. If this were the case the unusual severity of the fifth epidemic would be explained, and it would naturally be placed between the eighth and the third in numerical sequence, making it thus the third in point of severity. In the advent of this unusual epidemic we have also an explanation for the want of correlation between the flea prevalence curve and the plague curve above referred to in January and February.

Passing to the exceptions noted in the ninth and tenth epidemics we have already drawn attention to the elaborate arrangements for the suppression of plague which were adopted by the committee appointed by Government during the ninth and tenth epidemics; especially noteworthy figures have been given to show the larger extent to which preventive inoculation was practised during these years, and the estimate of the municipal authorities has been quoted to show the enormous extent to which evacuation was resorted to in the tenth epidemic (see p. 497). Moreover our experience during this epidemic showed that these measures had a marked effect in checking the epidemic, for, contrary to our past experience in Bombay and in the Punjab, the epidemic of 1908—09 reached its acme before the epizootic¹: had these measures not been in force, we have reason to think that the epidemic might have increased in severity till the month of December, when the epizootic was at its acme, in place of declining, as it did, early in November.

Having thus disposed of the exceptions to the rule formulated above (exceptions which may be said to prove the rule), that the severity of the several epidemics in Poona bear a direct relation to the number of fleas present on rats at the time each epidemic reaches its acme, we have established the fact that, in Poona, the factor which has the greatest influence on the seasonal prevalence of plague is the flea infestation of the rats, and this, again, is largely influenced by the climatic conditions, especially the atmospheric humidity.

PART IV.

CONCLUSIONS.

1. Plague may occur in Poona at any time of the year, but the disease generally prevails in well-marked epidemics.
2. The period of the year at which an epidemic may occur depends largely on the time at which infection is successfully implanted.
3. When infection takes root immediately before the flea season or with a rising flea prevalence a severe epidemic follows.
4. When infection takes root immediately after the flea season or with a declining flea prevalence a less severe epidemic results.

¹ The failure to obtain dead rats in any quantity in Poona may have given an erroneous picture of the intensity of the epizootic at different times.

5. The severity of an epidemic in Poona thus bears a direct ratio to the flea prevalence at the time it reaches its acme.

6. The flea prevalence in Poona is intimately connected with the climatic conditions, especially with atmospheric humidity.

7. Other conditions being favourable, an epidemic may come to an end on account of the scarcity of rats.

8. The epidemics in Poona City, however, generally terminate owing to a combination of adverse factors, viz. a decrease in the number of fleas, a decrease in the number of rats, and an increase in the proportion of immune to susceptible rats.

9. Which of these three factors will exercise the preponderating influence in terminating an epidemic will depend on the season of the year at which the epidemic occurs, the two latter probably exercising the greater influence during the rains and the period immediately succeeding the rains, when the flea prevalence is high, while the former will have the greater effect during the cold and hot weather when the flea prevalence is low.

10. The climatic conditions in Poona affect the course of plague mainly through their effect on flea multiplication.

11. No evidence could be obtained to show that the virulence of the bacillus plays any part in terminating an epidemic.

12. The preventive measures adopted in the last two epidemics seem to have materially decreased the mortality from plague.