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A REPORT ON PLAGUE INVESTIGATIONS IN EGYPT.

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(With 1 Map and 2 Charts.)

CONTENTS.

A SURVEY OF THE HISTORY OF PLAGUE IN EGYPT.

The Physiographical Features and the Population of Egypt.

THE two generally recognized divisions of the country are the Delta (Lower Egypt), extending from the Mediterranean littoral to Cairo; and Upper Egypt, the narrow strip of alluvial soil in the Nile Valley from Cairo to Wadi Halfa. The valley of the Nile is a rift valley formed by the subsidence of a narrow belt in the neighbourhood of a line of fracture on the earth's surface; from Cairo to Aswân town its length is 880 kilometres (547 miles), and its width varies from 3 to 21 kilometres (2 to 13 miles). The province of the Faiyûm is a depression which is irrigated from the Nile by the Bahr Yûsef Canal, one of the old natural drainage channels of the valley.

There are three climatic regions in Egypt: (1) the northern coast and the Delta; (2) northern Upper Egypt from Cairo to Asyût; and (3) southern Upper Egypt from Asyût to Wadi Halfa. The climate of the first region is determined by conditions existing over the Mediterranean; that of the third is independent of these conditions; and the second forms a transition region, which is governed to some extent by Mediterranean influences but chiefly by its proximity to the desert. Upper Egypt has a hot dry climate tempered by the prevailing wind, which blows from the north. The *khamsin* lasting for a few days in spring

[1] The account that follows has been abridged from the authors' original report of work which they carried out from November, 1911, to November, 1913, on behalf of the Department of Public Health of the Egyptian Government (*Report No. 5 of the Public Health Laboratories, Cairo.* Govt. Press, 1923). Therein will be found the full protocols of the experiments. For the purpose of this inquiry the services of Dr G. F. Petrie were lent by the governing body of the Lister Institute.

is a warm, oppressive, sand-laden wind from the south. With the exception of a belt near the Mediterranean the country is almost rainless. The Nile flood reaches Egypt in the month of July, and is furnished mainly by the monsoon rainfall on the tableland of Abyssinia.

The report of the Census taken in 1907 gives the total population of the cultivated areas (excluding nomad Arabs) as 11,189,978, of which Upper Egypt contributed about five millions. The density of population was 939 persons per square mile (362 per square kilometre); Aswân District had the highest density, namely, 640 per square kilometre. There were 3581 villages, most of them with less than 10,000 inhabitants; the greater part of the population is aggregated within these villages.

The History of Plague in Egypt previous to 1899, *the Year of its Reintroduction.*

Egypt has been frequently represented in the literature as one of the nurseries of plague in the world. There is little doubt that formerly it was often attacked by the disease, and that the old epidemics were of far greater intensity than those of the present day. Scattered throughout the chronicles to the year 1844, there are references to at least 121 years of plague prevalence. Cairo is singled out as suffering from disastrous epidemics; twenty-five notable outbreaks from 1142, the date of the first recorded epidemic in the city, to the year 1841, have been described. The figures for some of them betoken an appalling mortality; for example, it is said that there were 860,000 deaths in the years 1574–6 (Sticker) and 500,000 deaths in the epidemic of 1581 (Prosper Alpinus). The older estimates must, however, be taken with much reserve. Patrick Russel (1791) was sceptical of the accuracy of the contemporary Egyptian figures, and Aubert-Roche (1843) drew attention to the manipulation of the statistics that were compiled for the plague epidemics of the years 1834–5 in Alexandria. One source of fallacy, besides the tendency to Oriental exaggeration, is the concomitance of plague and of famine due to exceptionally low Nile floods; the deaths from these causes must often have been wrongly assigned. The most convincing records that we have seen are those of Gaetani, which give the number of deaths for each day in the Cairo epidemic of 1835; the total is 33,751 for six months. But even if statistical over-statement be admitted it is none the less certain that Cairo was wont to be severely smitten by plague; and its present complete immunity is the more remarkable.

Apart from numerical data the old literature of plague in Egypt consists largely of speculations on the origin and predisposing causes of the disease. We have failed to discover in the early writings specific reference to an associated mortality amongst rats or any evidence that pneumonic plague was recognized as a distinct variety of the disease.

The history of plague in Egypt may be conveniently divided into three periods. The first ends in the year 1798, when the modern study of the disease began with the observations

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of the medical officers who served under Napoleon with the French Expeditionary Force. The second period extends from 1798 to 1899, the year of the reintroduction of plague into the country. The third is concerned with the recent epidemics.

Prior to the seventh century the records are scanty and of little value. The manuscripts of a number of Arabic scholars, who described plague epidemics that occurred in Egypt from the seventh to the close of the fifteenth century, were examined and abstracted by von Kremer (1880), the Viennese orientalist, in his monograph "On the Great Epidemics of the East collated from Arabic Sources." The principal author whom he cites is Sojuty; his rare treatise deals exclusively with plague, and was discovered by von Kremer in Cairo. Sojuty brings together the great epidemics from the beginning of Islam (622 A.D.) to the year 1492, the date of his treatise. Abd Allatif, the celebrated Baghdad physician, observed the devastating plague and famine of the year 1200, and has left a graphic account of the widespread distress that ensued. The Arabic traveller from Tangier, Ibn Batuta, experienced an outbreak of plague in India on his return from China, fell ill with the disease in 1332 at Muttra near Agra, and encountered an offshoot of the Black Death pandemic (1346–52) in the summer of 1348 in Cairo. The epidemic of 1581 was described by Prosper Alpinus, the physician to the Venetian Embassy in Cairo; he specially noted the regular seasonal recurrence and decline of the disease.

The first sustained and concerted efforts to investigate the problems of plague were made early in the nineteenth century in Egypt. The French and Russian Commissions, which worked at intervals between the years 1828 and 1843, had the distinction of being the first to be expressly appointed for this purpose. In 1828 the French Government sent a Commission to study the disease, and in 1835 the better known Commission headed by Clot Bey—the other members being Gaetani Bey, Lachèze, and Bulard—worked for seven months in Cairo and Alexandria, and excited a lively controversy on the question whether plague is or is not contagious; except Bulard they were firmly persuaded that it is not transferable. Clot Bey considered the possibility of a causal microbe, for he mentions the belief of Father Kircher (1658) that in the course of an epidemic at Rome he had seen the infecting agent of plague with the aid of a microscope. Further evidence of Clot's acquaintance with the scanty references to this aspect of the subject is shown by his quoting from Manget (1721) an account of observations, which appear to us to be a forecast of later knowledge, because they indicate a connexion between the prevalence of insects and plague, and even recall the method in use at the present day for establishing the correlation. Manget states that during an epidemic in 1712 at Copenhagen an observer noted that the injurious effects of a plant disease, which was caused by a minute insect, became worse as plague spread over the city; he had discovered the insects by means of a microscope, and he actually demonstrated the increase in their numbers by collecting them on sheets of white paper, which were exposed overnight in the open air. Clot Bey was apparently not content with the information available to him, since he tested the infectivity of plague materials on his own person. He inoculated himself on two occasions, with the blood of a patient and again with pus from a bubo; he also inoculated various animals. All his experiments were negative, and it is perhaps not to be wondered at that he rejected the hypothesis of a microbic origin of the disease.

In February 1843 a Russian Commission (Uraticheo and Ischernikoff) experimented in the Qasr el 'Aini hospital in Cairo on the disinfection by heat of infected articles of clothing. They took the clothing and bedding of patients, and heated them at a temperature of 62° C. to 75° C. for 48 hours. The clothing was given to natives, who wore it for fourteen days and took no harm; some of the heated clothes were sent to Odessa, and were worn there by twenty persons; they, too, remained healthy. Forty-nine persons, including doctors and hospital attendants, who nursed the patients or slept in the wards or carried the clothing to the disinfection stoves in Cairo, escaped ill effects.

The experiments of this period, although inconclusive, are interesting, for they anticipate the accurate observations that were made possible by the discovery in 1894 of the *B. pestis*. In the year 1844 plague disappeared from the country (Prus); the free period lasted for fifty-five years, until the reappearance of the disease in 1899 in Alexandria.

The Origin, Diffusion, and Significant Features of the Series of Epidemics, 1899–1911.

In April 1899 plague broke out in Alexandria. The exact mode of its importation is unknown, and is of little consequence; for it is indisputable that Egypt became infected in the expansion of the current pandemic, which spread from Hong Kong in 1894 and entered India in August 1896 through the port of Bombay. In 1897 Jeddah, on the coast of the Red Sea, was officially declared to be infected; a second outbreak occurred here in 1898, and a third in February 1899. This town may have been a stage on the route of infection from India to Egypt.

The outbreak in 1899 in Alexandria numbered ninety-three cases and lasted from April until November; the rest of the country remained free. In 1900, 127 cases were notified, and the disease was confined to Port Said, Alexandria, and Damietta, the ports of the Delta. In 1901, 200 cases were reported altogether from Alexandria, Port Said, and several provinces of the Delta; and in this year also the first appearance of the disease in Upper Egypt was signalized by two small outbreaks in Minya District. In 1902 plague became widespread in the Delta, and exhibited a definite infiltration of Upper Egypt, where it settled upon the provinces of Minya, Asyût, and Qena. The subsequent history is one of a generalized dispersion of the infection throughout the country. From the date of the introduction of plague in 1899 up to the end of the year 1912, 10,007 cases were notified; the total number to the end of the year 1919, a period of twenty years, is 14,783 cases; all the clinical forms of the disease are included in these figures. There has been no apparent change in the character of the epidemics since the close of our work.

When we began our work several unexplained features of plague in Egypt presented themselves. There is, as in most places, a definite seasonal prevalence, but the disease does not conform to a single epidemic wave flowing and receding over the country; because the epidemic months fall in the first quarter of the year in Upper Egypt and during the summer months in the Delta. The singular tendency for outbreaks of pneumonic plague to appear in certain of the Upper Egyptian provinces, although well known to the Health authorities, had defied explanation and had escaped the notice of commentators on plague. Again, the local circumstances that accounted for the exceptional severity of the Kôm Ombo outbreak in 1911 were not wholly understood. Lastly, it was noteworthy that the infection had failed to take root in Cairo. This city, placed at the apex of the Delta where it joins Upper Egypt, necessarily receives the streams of traffic which pass constantly to and from these regions; and it is, therefore, not surprising that Cairo has incurred the risk of the importation into it of bubonic plague.

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THE SPECIES OF RODENTS TRAPPED IN THE HOUSES, FELUCCAS, AND CULTIVATED AREAS OF UPPER EGYPT.

The Rodent Infestation of Houses, Feluccas and Cultivated Areas.

The general results obtained by trapping various localities are summarized in Table I, which shows the regional distribution and relative frequency of 67,000 rodents captured from houses by setting 233,601 traps. *R. rattus* heads the list (nearly 40,000), *Acomys cahirinus*, the so-called Cairo spiny mouse, taking second place (25,000). *Arvicanthis niloticus*, the common field rat, and *R. norvegicus* only occasionally frequent houses. The kind of trap used was not suitable for catching mice, but there was little evidence that they inhabited buildings. Five shrews (*Crocidura olivieri*), three jerboas (*Gerbillus pyramidum*) and seven weasels (*Mustela africana*) were also captured.

Table I.

(*Reduced from the original table*) *showing species and numbers of rodents trapped from houses in various localities in Upper Egypt.*

Locality		Species and numbers of rodents trapped							
Towns and villages	Province	*R. rattus*	*Acomys cahirinus*	*Arvicanthis niloticus*	*R. norvegicus*	Mouse	Weasel	Shrew	Jerboa
Cairo	—	88	129	—	—	1	7	—	—
2 villages	Minia	21	6	—	—	—	—	—	—
Asyût town... ...	Asyût	25231	19328	634	566	—	—	1	—
17 villages or towns	,,	12320	1942	32	62	3	—	1	—
2 villages	Girga	315	1058	41	—	1	—	3	—
Qûs town and 5 neighbouring villages	Qena	1944	2743	79	—	19	—	—	—
Ibrahim Aly's hut near Sharany	,,	—	—	3	54	—	—	—	—
Kôm Ombo... ...	Aswân	—	—	243	37	92	—	—	3
	Totals:	39919	25206	1032	719	116	7	5	3

R. rattus. The breeding of *R. rattus* in Asyût town is at its height in the summer months, when plague prevails in the district; at this time of the year 40–50 per cent. of the adult females were pregnant. The average number of foetuses in 2226 pregnant rats was 5·8.

In our experience *R. rattus* has a widespread distribution over Upper Egypt. 19 per cent. of the rodents trapped from feluccas (native river-craft) were of this species.

Acomys cahirinus. The wide distribution of this rodent in the houses of Upper Egypt had not been previously recognized, although in some localities it exceeds *R. rattus* in number. It lives in cracks and crannies in the walls of the houses. In Asyût town the breeding season is the same as that of *R. rattus*; 3312 pregnant *Acomys* gave an average of 2·5 foetuses. In the summer months 80–90 per cent. of the trapped females were pregnant, from which it is clear that the species is very prolific. 8 per cent. of the rodents trapped from feluccas were *Acomys.*

R. norvegicus. During two years 682 *R. norvegicus* were caught; 566 were from Asyût town, and 343 of these were captured in corn-mills. The invasion of the town by this species is correlated with the fact that it is the principal rodent inhabiting the feluccas. The following experience indicates that, in places remote from towns and villages, scattered colonies exist, and that they are founded by migrants from feluccas. 54 *R. norvegicus* were caught in and around a single-roomed *boos* (dried millet stalks) hut, which stood alone on cultivated ground quite close to the Nile and half a mile from the village of Sharany (Qena Province). The interior arrangements of the hut were such as to provide food and shelter for rats. There were rat holes at the base of the dried mud grain receptacles (*somâs*) and beneath the straw palisades that formed the walls of the hut.

Observations on the rodent infestation of the Delta collected by Dr C. Todd prove that in the Delta *R. norvegicus* is more widely spread and forms a larger part of the rat population than in Upper Egypt. Feluccas ply along the two branches of the Nile from Rosetta and Damietta to Cairo and thence to Aswân, and they doubtless help to distribute this species throughout Upper Egypt; the railways are also a likely means of conveyance. 72 per cent. of the rodents caught in feluccas were *R. norvegicus.* Excepting the Kôm Ombo estate this rat was never trapped in cultivated fields.

Arvicanthis niloticus. Apart from the figures for the Kôm Ombo estate 789 were caught in houses, and of these 634 were from Asyût town. Here the majority were trapped in about equal numbers from corn-mills and living-places. This rat is seen everywhere in the open country. After the crops are harvested it lives in the deep cracks in the sun-baked soil, from which it is driven out when irrigation commences.

The Flea Infestation of Egyptian Rodents.

X. cheopis contributed from 90–100 per cent. of the fleas from *R. rattus*, *R. norvegicus*, *Acomys*, and *Arvicanthis* trapped in houses.

R. rattus, *R. norvegicus*, and *Acomys*, when trapped from the feluccas during the cool season, harboured *Leptopsylla musculi* in addition to *X. cheopis*; the former species was sometimes the predominating one. Three specimens of *Ceratophyllus fasciatus* were taken from *R. norvegicus* trapped on feluccas at Asyût town. *Acomys* from Cairo had a marked infestation of *X. chephrenis*; a specimen of *Gerbillus pyramidum* from Kôm Ombo gave a high percentage of *X. cleopatrae*; on a hedgehog (*Hemiechinus auritus*) most of the fleas were *Ctenocephalus felis*; and a weasel (*Mustela africana*) carried *Echidnophaga gallinaceus.*

The figures for Asyût town exhibit a definite seasonal wave for both *R. rattus* and *Acomys* with a maximum for each species in March (1912); in this month the average number of fleas was 11·1 on *R. rattus* and 1·2 on *Acomys*. The flea-curves for both years correspond well with the epidemic curve for plague in the district.

Acomys harbours only about one-tenth the number of fleas that are carried by *R. rattus.* For this reason, though susceptible to plague, it is of little importance in spreading the disease; we never discovered a naturally infected *Acomys.*

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OBSERVATIONS IN UPPER EGYPT ON THE RANGE OF EXCURSION OF THE HOUSE RODENTS: *R. RATTUS* AND *ACOMYS CAHIRINUS.*

After several months' experience of plague-infected localities in Upper Egypt, it became evident to us that here, as in other countries, rats, and especially *R. rattus,* are active propagators of the infection. Now the spread of the epizootic and consequently of the epidemic must be influenced by the movements of rats from house to house, and by more distant excursions if they occur. We could not find that any attempt had been made elsewhere to ascertain the normal movements of *R. rattus* living in human habitations, although dubious statements were on record of migrations of this species in considerable numbers from plague-stricken areas in India. Accordingly, having become familiar with the habits and environment of *R. rattus* and *Acomys,* we sought to learn the range of movement that is characteristic of each of those species.

Observations in El Motiâ.

The experiment that we carried out here lasted from March 23 to June 21, 1913, a period corresponding to the local plague season. El Motiâ (Asyût Province) is a typical Upper Egyptian village, and is situated on the Nile bank eight miles south of Asyût town.

Maps of the portion under experiment, indicating each house with its number, were prepared. A constant number of traps (300) were set daily, two traps being set in each house. They were collected next morning, and each animal captured was marked and put back into the house from which it was caught. 450 traps were also set every day in the surrounding squares, and the resulting takes were examined for marked rodents; all the animals caught from this area were returned unmarked to the houses whence they came. Entries of all the rats that were captured, marked, and recaptured were made in a carefully tabulated register. By means of devices used for marking the rats it was possible to identify animals from every one of the 279 houses in the area. At first it was thought sufficient to identify the house from which the rodents were originally captured, but by an extended system of cautery marks made on various regions of the body at each successive capture many individual rats could be recognized.

From the results summarized in Table II we conclude that the movements of *R. rattus* and *Acomys* are limited; most of them are oscillations between contiguous houses, and doubtless represent sorties in quest of food from nests

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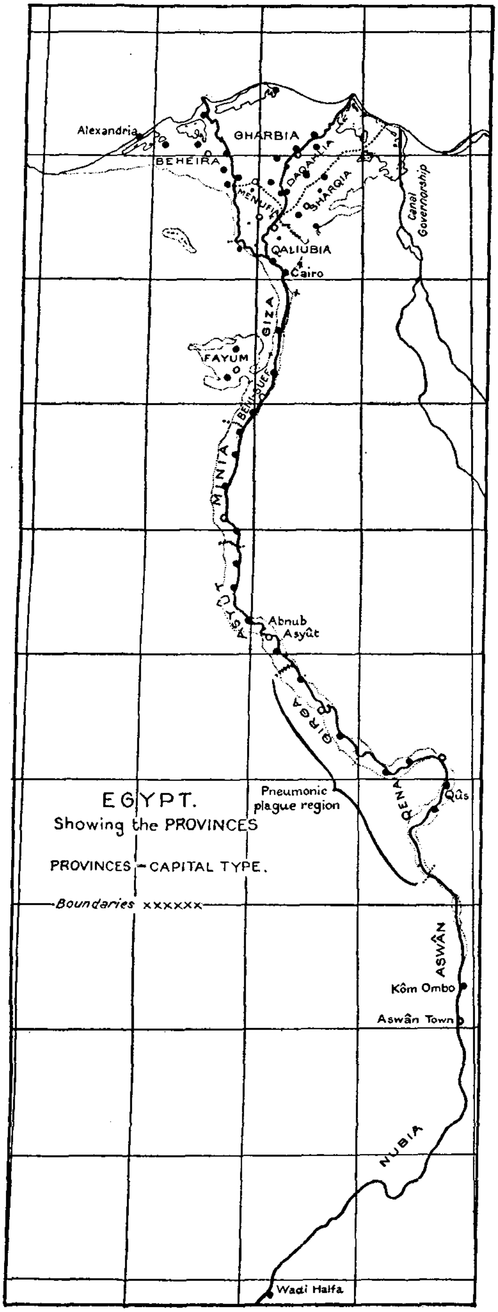

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and burrows situated in the foundation of walls that were common to adjoining houses.

Table II.

Summary of trappings, captures, and movements of marked rodents in the experimental square, El Motiâ.

	R. rattus	*Acomys cahirinus*
No. caught and marked in the square	341	348
Casualties amongst these	36	79
No. of marked rodents returned to houses	305	269
,, ,, ,, not again captured	159	122
,, ,, ,, recaptured one or more times	146	147
,, ,, ,, caught in more than one house ...	53	46
,, movements to and from contiguous houses separated by a party-wall*	68	40
,, excursions of greater range within the square†	13	12
,, excursions to neighbouring square...	1	0
,, trappings to which recaptured rodents (146 *R. rattus* and 147 *Acomys*) were exposed‡	2458	2685
,, captures of recaptured rodents	436	390
Ratio of captures to trappings of recaptured rodents	1 : 4·1	1 : 5·2
,, movements to captures of recaptured rodents	1 : 6·7	1 : 9·3

* Each oscillation of a to and fro movement has been regarded as a separate movement.
† The stages of these excursions have not been counted separately.
‡ This figure was arrived at as follows: For each rodent captured more than once the number of the last trapping at which it was caught gives the number of its exposures to trapping; hence the total number of exposures to trapping for all the recaptured rodents was obtained by summing the last trapping number of each.

The speculation that, when plague breaks out in a colony of *R. rattus*, some of the rats take fright, desert the colony, and so help to spread the infection, is not borne out by our observations in El Motiâ. Both *R. rattus* and *Acomys* seemed to us to be singularly little impressed by unpleasant experiences, an opinion confirmed by analysing the frequency of captures of individual rodents. There is no ground for the belief that rats are conscious by instinct or reasoning of the risk of contracting a fatal disease from their sick companions or that they are alarmed by an unusual mortality in the colony. Proof of the peculiarities of rodent psychology can with difficulty be conveyed to others apart from actual demonstration; but we are sure that the movements of rats are not increased by motives of fear when an epizootic is in progress. Unfortunately a migration experiment in a town or village where plague is epidemic is not likely to succeed owing to hindrances that may be expected from the heightened suspicions of the people.

Observations on the Relation between Epizootic and Epidemic Plague in Upper Egypt.

We specially observed three localities where human plague was associated with plague in rodents, namely: Abnûb town (Asyût Province), Qûs town (Qena Province), and Kôm Ombo (Aswân Province).

Our investigation of these outbreaks revealed individual differences which were of such a degree as to justify their separation into epidemic types. Thus the outbreak, in both rats and man, in Abnûb town, is representative of plague as it may be observed elsewhere in the northern provinces of Upper Egypt;

it resembled in essentials the town and village epidemics that prevail throughout the East. The epizootic in Qûs town was of the normal type, but the characteristic feature of the epidemic was the interspersion of foci of pneumonic plague amongst bubonic cases; this outbreak may be regarded as a pattern for the southern provinces of Upper Egypt. The large agricultural estate of Kôm Ombo, situated in Southern Upper Egypt, is however an altogether exceptional locality. For the hamlets on this estate do not possess the traditional configuration and structural arrangement of Upper Egyptian villages; and in relation to these differences the circumstances that favoured the spread of plague exhibited peculiarities that concerned both the epizootic and the epidemic.

The Epidemic of Bubonic Plague in Abnûb Town (January to April 1912).

In a population of 16,000 persons 48 cases, all of which were bubonic or septicaemic, were recognized. We made observations in the first infected area, and obtained proof of the general concurrence in time and place of the epizootic and the epidemic. Experiments with rat-fleas caught in this area are as follows:

(1) 295 fleas were caught at 12 noon, January 8, from seven *R. rattus* trapped together; three of the rats were plague-infected. The fleas were transferred to the laboratory at Asyût and were received there at 5 p.m. on January 11. At 7 p.m. on this date, seventy-nine hours after removal from their hosts, 150 fleas were put with a guinea-pig in a flea-proof cage. The guinea-pig died of plague on January 18, and the post-mortem signs included left submaxillary, left axillary, and left inguinal buboes, which contained numerous *B. pestis*.

(2) The rats from which the fleas of the previous experiment were taken had been trapped in a very dirty store-room, which opened into a stable; above the store-room there was a room filled with grain. On January 9, a guinea-pig was allowed to run free in the store-room. Next morning it was searched under chloroform, and thirty-six rat-fleas were taken from it. On January 14, the guinea-pig died of plague, and showed submaxillary and left inguinal buboes in which numerous plague bacilli were found.

(3) About thirty fleas caught at 1.30 p.m. on January 10, from the guinea-pig in the foregoing experiment, were transferred to the Asyût laboratory, where they were received at 5 p.m. on that day. They were kept unfed in a test-tube till January 12, when they were put with a guinea-pig in a flea-proof cage forty-eight hours after their removal from the animal that served as a flea-trap. On January 19, the laboratory guinea-pig was chloroformed to death; it presented right and left submaxillary buboes, which contained the *B. pestis*.

The Epidemic of Bubonic Plague in Qûs Town (January to April 1912).

Of a total of eighty-two cases that were notified from a population of 15,000 persons, fifty-one were bubonic, sixteen had no obvious buboes, and fifteen (18·3 per cent.) were of the pneumonic form. There were in all sixty-one deaths (74·4 per cent.). The distribution of the bubonic cases was so irregular as to suggest the existence of at least four isolated epizootic areas; and a spot map which we prepared shows very well the disorderly arrangement of the outbreak. We are of opinion that the creation of apparently independent foci of rat and human plague in a town like Qûs is attributable to the transportation of infective rat-fleas by persons who inhabit or visit infected areas in the town; these persons may or may not suffer from plague in consequence. In this outbreak some of the patients were suspected of having contracted the infection in a distant quarter of the town.

14,000 traps were set over the whole town from March 13 to June 19, and they captured 1622 *R. rattus* and 2566 *Acomys*. The number of rats with the signs of acute plague (11) that were found was small, chiefly because the people gave us no help in collecting them. Towards the end of the outbreak 11 rats trapped alive had definite or presumed resolving (chronic) plague lesions.

We were fortunate in having been able to make a thorough examination of a badly infected house in Qûs, which had been vacated voluntarily by its owner. The house, which was inhabited by a wealthy Coptic family, was temporarily abandoned early in April on account of plague infection. On April 11 the routine cleansing of the house, including the removal of dead rats, the closure of rat holes, and disinfection with "sublimate" solution, was performed by the Public Health authorities. Our examination was begun on April 21, 1912.

The building is a typical Upper Egyptian dwelling-house of burnt bricks with an upper floor and flat roof; it encloses three sides of a courtyard, which is bounded on the remaining side by the wall of an adjacent house. Five rooms open into the courtyard from the ground-floor; one of them is used as a store-room for fodder and another as a stable for donkeys and domestic animals. The living-rooms on the upper floor are reached by a brick staircase and are entered from balconies built over the courtyard. On the flat roof there are two small rooms. The floors of the upper rooms and balconies consist of a double layer of burnt bricks bound together with clay; these are supported by the lath-like stems of palm-tree leaves, which are laid across stout beams made of split palm-tree trunks. At our first visit, on April 21, we noted the distinctive smell of decomposing rats. A sick *R. rattus*, shown later to be plague-infected, was seen crouching near a wall of the courtyard.

The cesspit shaft was the chief focus of infection; it was discovered as follows. Facing the entrance to the courtyard there was an archway loosely filled with bricks. By their removal a narrow passage little more than the breadth of a man was disclosed; it led round three sides of a rectangular brick shaft, the remaining side of the shaft being formed by the outer wall of the house; a sick rat was observed to retreat through a crack between the bricks of the shaft. The floor of the narrow passage was littered with rubbish and with dead rats, of which thirty were afterwards removed. In a small room on the upper floor immediately above the cesspit there was the usual kind of native privy; a dead infected rat lay near the opening of the privy, and rat burrows tracked into and around the cesspit shaft. The burrows were partly exposed by clearing away the bricks round the privy, and six dead rats were disinterred.

A guinea-pig placed on April 22 in the space at the base of the cesspit shaft and kept there for three days collected 684 rat-fleas, and died of plague on April 25. 559 fleas taken from this animal were transferred to a healthy guinea-pig in a flea-proof cage; the latter died of plague on April 28. We proceeded on June 4 to demolish the cesspit shaft, and in doing so opened up many rat burrows that communicated freely along its whole length. The walls of the shaft were composed of bricks held together loosely with dried clay. Fifty-three dead *R. rattus*, one *Acomys*, and many scorpions were taken from it during its demolition.

A recess underneath the brick staircase that led to the upper floor had been walled off except for a small doorway closed loosely with bricks. The recess was explored, and a dead *R. rattus* was seen on the floor; it was found to be plague-infected.

The loose nature of the flooring was made apparent by dislodging the bricks round several of the rat holes and burrows in the balconies. The clay between the bricks had become pulverized so as to form spaces, which contained many dead rats. The junction of the walls in the rooms showed gaping fissures, some of which ran from floor to roof and afforded good foothold for climbing rodents. Dead rats were picked up from the floor of most of the rooms, having fallen presumably from the beams of the ceilings.

In each of eight rooms a guinea-pig was isolated; five of them died of plague (three in ground-floor rooms and two in upper rooms), two kept healthy, and one was lost. Guinea-pigs placed in the two rooms on the flat roof did not catch any fleas and remained healthy. There was no evidence of rat infestation here, probably because the relative thinness of the walls gave no shelter for rats. Two of our workmen, one of whom unfortunately died, contracted plague in the house during its examination.

Plague on the Kôm Ombo Estate (1911 and 1912).

The Kôm Ombo agricultural estate was founded about the year 1900 and is situated on the Nile bank 836 kilometres (520 miles) south of Cairo and 48 kilometres (30 miles) north of Aswân town. Scattered over the estate there are twenty-nine hamlets (*ezbas*), with a total population in 1912 of 12,831, and an average of 250 persons. The inhabitants are migrants from the southern provinces of Upper Egypt. By providing work all the year round, the Kôm Ombo estate is a centre for casual labour, and on account of its recent origin the settlers do not constitute a fixed population.

In January 1911 plague appeared on the estate for the first time. Many of the hamlets became infected, and the spread of the infection was so rapid that hundreds of the people fled in panic to their native districts, and left some of the villages almost deserted. 357 plague cases with 237 deaths were recorded from January to the end of April, but the figures are certainly an under-estimate.

In November 1911 we visited Kôm Ombo, which was then free from plague, and made observations on the rodent infestation of the villages and of the cultivated land. In the last week of January plague broke out at El Abbasîya (population 920 in 1912), a hamlet in the south-east corner. The next hamlet to be attacked was Atmour Mistigid (population 364 in 1912), situated in the north-east corner; the first of a total of twenty cases occurred on February 7. Shortly after plague broke out in this village the inhabitants, taking their animals with them, abandoned it at the instance of the Public Health authorities, and were accommodated in a temporary camp of matting huts a little distance away. We were then able to make a complete examination in advantageous circumstances of the plague conditions of Atmour Mistigid.

This hamlet was less than a year old in February 1912, for it had been built since the epidemic in Kôm Ombo of the previous year. It comprises about 100 mud houses, which are arranged in four blocks. Two of the blocks, each consisting of two rows of back-to-back houses, are in alignment, and are separated by an opening for traffic. On the opposite side of the street two rows of "single" houses are similarly arranged. The plague patients had resided in the back-to-back houses, and in these most of our experiments were made.

The huts are of the simplest construction; each consists of a single room six feet square, with mud floor and walls and with a straw roof supported by a wooden pole. Most of the owners had added a small courtyard, in which to stable the larger domestic animals; these were enclosed by straw palisades, which were cleared away when the villagers betook themselves to the temporary camp.

On February 12 the Public Health authorities cleaned the houses and treated them freely with perchloride of mercury solution (1 in 1000); at the same time the straw roofs were removed, and thus the walls and floors were exposed during the day to the brilliant and continuous sunlight. Our experiments were begun three days later.

We first trapped the empty village but did not capture any rats, nor were any dead ones seen. This result was puzzling in view of the considerable number of human plague cases, and the capture of *Arvicanthis niloticus* and *R. norvegicus* in similar but uninfected houses elsewhere on the estate. As the sequel indicates, the absence of rats was due to the heavy mortality amongst them from plague, and perhaps also to the desertion of the survivors owing to the removal of food from the huts.

The next step was to allow a guinea-pig to run free for twenty-four hours in the houses, including those in which the plague patients had lived. The results from twenty-seven houses showed that numerous rat-fleas (*X. cheopis*) were caught on the guinea-pigs that served as traps; the extreme figures were 15 and 1005, and fourteen of the houses yielded 120 or more rat-fleas. Four of the houses that had been occupied by plague-stricken families were proved by the death of the guinea-pigs from the disease to be still infective: experiments were carried out later in these houses to determine the period of infectivity; and from the results obtained we conclude that the infection persisted in them for nearly a month. The extraordinary flea infestation of the houses deserves notice; we have never seen any record of observations at all approaching our experience here.

Attempts were made to rid the houses of fleas by treating them with substances recommended as flea-killing agents, for example, cyllin or other coal-tar derivatives and petroleum emulsions. The primitive construction of the houses permitted a thorough application of these fluids, but the results were invariably disappointing. When we consider the far more complicated structure of Upper Egyptian houses, we find it difficult to believe that substances of the kind used can do more than a minimal amount of good in suppressing or even materially reducing plague infection within them.

Our attention was next directed towards discovering the source of the rat-fleas in the houses. This was not obvious, because we could see no plain signs of rat holes or rat burrows except the cracks at the junctions where four walls of the back-to-back houses meet. The experiments designed to elucidate the point were as follows:

Guinea-pigs remained free from fleas when they were confined to shelves placed along the walls at a height of one foot and upwards above the ground-level. Further, rat-fleas could be partly excluded from the floor of the houses, if the bottom of the walls was sealed with wet mud. Lastly, in a house which had previously yielded 2843 rat-fleas in all on guinea-pigs introduced as traps, a guinea-pig was allowed to run free for twenty-four hours; it caught 208 rat-fleas. Three days later a fresh animal was confined for twenty-four hours in a rat-trap placed at the centre of the floor; it caught only fifteen fleas. Two days later thirty-five Tanglefoot papers were arranged side by side along the junction of the walls and floor, and kept there for twenty-four hours; during this time a guinea-pig was allowed to run free on the floor. 402 fleas were caught in the Tanglefoot and only twenty-eight on the animal let loose on the floor. All the papers except six had one flea or more, and 105 was the largest number on a single paper.

These observations taken together made it apparent that the fleas must have issued from the inconspicuous fissures at the junction of the walls and floor, and from no other part of the house. When the houses had lost their infectivity, two of them were broken down—with difficulty on account of the surprising coherence of dried Nile mud—and the rat burrows were exposed and traced. A regular system of nests and burrows existed at the bottom of the walls with free communication at their junctions, an arrangement that indicated continuity along the whole length of each block of houses. Mummified *R. norvegicus* and *Arvicanthis niloticus* were removed from the nests and burrows; the number of rat-fleas found here was remarkable, and clearly pointed to the nests and burrows as the breeding place and depot of the fleas that infested the houses. The failure of the attempts to rid the houses of fleas by substances that are ordinarily lethal to them through contact for a sufficient length of time is explained by the inaccessible retreat of the fleas in the foundation of the thick mud walls.

Arvicanthis, *R. norvegicus*, and mice infest both stone and mud-built houses and also the cultivated fields. The absence of *R. rattus* and *Acomys* is easily explained, for it is unlikely that those species could compete successfully with *R. norvegicus* and *Arvicanthis* in the kind of houses we have described. The continuous irrigation throughout the year must interfere with the settlement of rat colonies on the land. Certainly the density of rodents was greater in the hamlets, where the conditions gave them every encouragement. The houses serve the double function of dwelling-place and animal stable, a combination frequently to be seen in Upper Egypt. Goats, donkeys, sheep, and fowls share them with their owners; and camels, oxen, and buffaloes are tethered in the enclosures annexed to each house. Grain and other foodstuffs are either stored in receptacles made of dried mud and thus penetrable by rats, or they are wholly unprotected.

The possibility of the carriage from one hamlet to another of infected fleas by human beings is strengthened by the results of examining the clothes of four plague patients from Atmour Mistigid. Only two *P. irritans* were found in the four lots of clothes, and the numbers of *X. cheopis* were 4, 4, 4, and 1; one of the sets of clothes belonged to Ahmed Mohammed Saad who, when detected, had walked five miles in order to escape quarantine. In contrast with these results thirty-two lots of clothing from healthy persons did not contain any rat-fleas; they yielded only three human fleas. And, further, 185 *X. cheopis* were taken from the clothes of three of our rat-catchers after they had dug out nests in houses in Atmour Mistigid.

The exceptional severity of the epidemic in the year 1911 is adequately explained by our observations. Foremost must be placed the quite remarkable

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degree of infestation of the houses with *X. cheopis*. With the exception of a few *P. irritans* this was the only species of flea found. Bugs were never seen. We have never observed and cannot imagine conditions more favourable to the spread of bubonic plague than those which exist in the mud-built villages on this estate. The back-to-back arrangement of mud houses in a continuous row is an ideal one for facilitating the intercommunication of rat colonies, the dispersion of epizootic plague, and the transference of infected rat-fleas to the human occupants.

The Seasonal Prevalence of Bubonic Plague and its Relation to Climate.

Plague in Egypt, as elsewhere, prevails within well-defined time-limits for each infected locality. The monthly figures for plague cases from 1899 to 1912 have been grouped and charted to correspond with four divisions of the country: (1) Southern Upper Egypt; (2) Northern Upper Egypt; (3) the provinces of the Delta; and (4) the northern ports on the Mediterranean, namely, Alexandria, Damietta, and Port Said (Chart I). The chart is composed of a regular succession of epidemic waves associated with an increasing delay in the seasonal prevalence of the disease. Thus the maximum prevalence for Southern Upper Egypt is in March–April; for Northern Upper Egypt in May; for the Delta in June; and for the northern ports in July. The rise of the epidemic in the Delta is roughly synchronous with the decline of the epidemic in Upper Egypt.

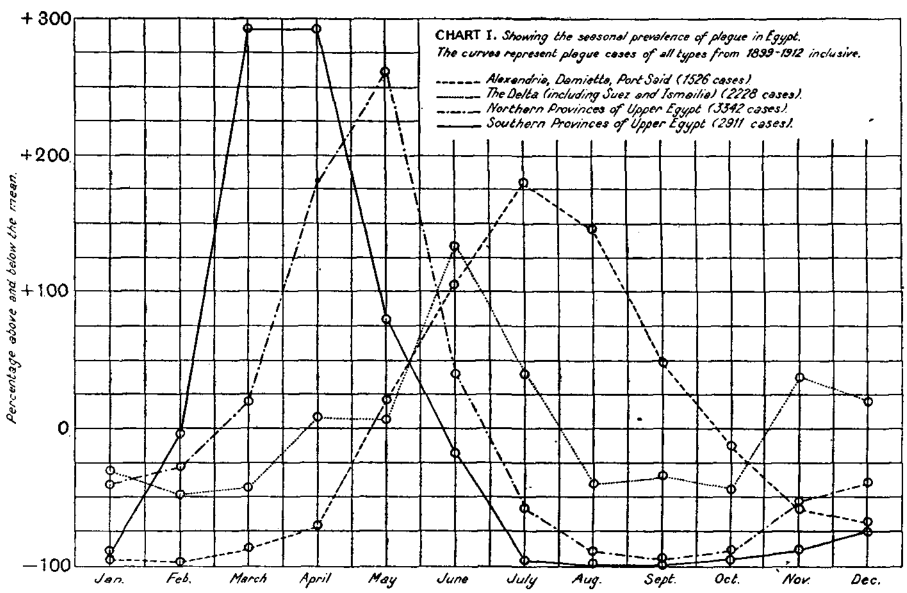

CHART I. *Showing the seasonal prevalence of plague in Egypt. The curves represent plague cases of all types from 1899-1912 inclusive.*

It is a natural supposition that the varying climatic conditions afford a clue to the characteristic delay in the seasonal prevalence from south to north; but when we came to examine the subject, difficulties arose which were due chiefly to the smallness of the plague

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data even when they were massed for the longest available period. Brownlee (1918) has pointed out that the best materials for study are obtainable from populous cities with a continuous plague history of several years that furnish considerable numbers of cases, for example, some hundreds or even thousands annually. The Egyptian statistics being excluded by adopting this standard as a measure of suitability, we decided to postpone their analysis until we had reviewed the problem with the help of ampler data gathered from other countries.

The Influence of Atmospheric Temperature and Humidity upon the Stages of Development of the Rat-flea (X. cheopis) *and upon the Survival of unfed Adult Fleas.*

Periodic variation in the numbers of fleas infesting rodents is dependent upon climatic conditions. Bacot (1914), working in England with artificially regulated atmospheres, and the Plague Research Commission in Poona (1912), utilizing natural climatic variations, observed the effects produced by temperature and humidity on the phases of development of the rat-flea, and on the survival of unfed adult fleas. The interpretation of these observations is rendered difficult to the reader by the absence of grouping, and by the statement of the hygrometric records in terms of percentage humidity. We, therefore, converted the humidity data into the equivalent vapour pressure deficiencies (millibars), and grouped the individual observations in each set of experiments according to temperature and V.P.D.[1] The V.P.D. has the advantage over the relative humidity figure of giving a more exact measurement of the drying capacity of the air.

The method of grouping adopted by us shows that there is good agreement between the observations of Bacot and those conducted at Poona. Inevitable differences in the experimental methods affected principally the duration of life of unfed adult fleas, the conditions in Bacot's experiments having been more favourable for their survival, but the trend of the results in both sets of experiments is towards the same conclusions. We, too, made observations from January to June 1913 at Asyût on the period of survival of starved rat-fleas. The shortening of life, as the temperature and V.P.D. increased within certain limits, is plainly seen in Table III. The table shows also that the life of the Asyût fleas was prolonged during the hot months of June and July by adding moisture to the jars in which they were kept. Our analysis of the data as a whole leads us to conclude: (1) that for *X. cheopis* temperatures from 20° C. to 25° C. and V.P.D.s from 1 to 10 millibars are most suitable for its development at all stages; and (2) that the higher the temperature and the V.P.D.—a high deficiency indicating excessive dryness of the air—the shorter is the period of survival of adult fleas when they are kept unfed.

The Influence of Atmospheric Temperature and Humidity upon the Seasonal Prevalence of Human Plague.

We next tried to ascertain whether these conclusions fitted with epidemiological information relating to the seasonal prevalence of plague. We used first the data for six cities in India—Bombay, Poona, Belgaum, Lahore, Nagpur, and Rawalpindi—that were published by the Plague Research

[1] The symbol V.P.D. may be conveniently used to signify "vapour pressure deficiency" (saturation deficit).

Commission (1908). These cities were selected for study by the Commission, because they had suffered severely from plague for a number of years, and because they illustrated diverse climatic conditions. In order to eliminate irregularities in individual epidemics due to accidental causes, we thought it best to work out and tabulate for each city the mean or normal figures for human plague deaths, temperature, and V.P.D., grouped according to fortnightly periods and based on all the available years. When this was done, the figures for each period in the epidemic season were examined; the results did not agree well with our conclusions on the optimum conditions of temperature and humidity for the stages of development of the rat-flea; and the discrepancies were chiefly noticeable in the data for the up-country stations. However, the agreement progressively improved when the plague incidence for any fortnightly period in the epidemic season was compared, not with the corresponding temperature and V.P.D. figures, but with those of successive preceding fortnightly periods up to a limit of four to six weeks. And, further, when the results were plotted on charts, it was seen that the graphic correlation improved, for both temperature and V.P.D., by taking account of a lag period; this applied particularly to the data for Bombay.

Table III.

Summary of observations showing the influence of climatic conditions upon the survival of unfed X. cheopis.

Month	Mean temperature of month °C.	Mean V.P.D. of month (mbs.)	Total fleas tested	Total days survival	Average days survival	Longest period of survival (days)
			SERIES A.			
Jan.	11·6	3·9	418	1834	4·4	17
Feb.	12·6	5·5	1014	4442	4·4	16
March	15·1	7·1	1814	6970	3·8	12
April	23·1	13·8	1312	2791	2·1	6
May	25·2	17·8	1716	2829	1·6	6
June	26·3	19·6	1467	1906	1·3	3
			SERIES B. (Moisture added to jars in which fleas were kept.)			
June	26·3	19·6	177	864	4·9	12
July	29·3	22·2	63	395	6·3	14

A study on these lines of other localities in India and of places outside India for which rat-flea counts were available strengthened our belief that the extent of the disease at any moment in the epidemic period is dependent upon atmospheric factors in operation some six weeks before, and not upon the strictly contemporaneous weather conditions. Moreover, since, even in places with diverse climates, the mean temperatures and V.P.D.s that prevailed six weeks before the height of the epidemic fall within a range varying from 20° C. to 25° C. and from 1 to 10 millibars, the conclusion seems to be justified that there is an optimum mean temperature and V.P.D. within these limits for the spread of the disease. The lag is reasonably explicable by the time taken for the complete development of *X. cheopis*.

The authors who have hitherto written on the subject have noted the wide range of temperature within which plague epidemics in different localities reach their maximum intensity, but they have not taken a lag period into consideration.

The graphic correlation for places, such as Lahore, where the diurnal temperature variations are extensive, is not so good as that for Bombay where the range of variation is smaller. We believe that the hourly temperature variations during the day deserve close attention in a study of the problem, because they must exert a constantly changing influence either in the direction of stimulating or curbing flea development. A useful inquiry would be to compare the mean diurnal temperature variations and the human plague data for corresponding weekly or fortnightly periods, with special reference to the lag interval which we have defined. If it were possible to procure the necessary figures—up to the present we have not succeeded in doing so—the number of favourable hours, on the assumption that there is an optimum range from 20° C. to 25° C., could be extracted and compared with the human plague data. We have attempted an approximate analysis for Lahore, and found that the results conformed to the views expressed above.

The Relative Influence upon the Seasonal Prevalence of Human Plague of the Temperature of the Air and of its Dryness as measured by the Vapour Pressure Deficiency.

Maritime cities such as Bombay, Hong Kong, Madras City, Colombo, Surabaya (in Java), Sydney, and Marseilles, possess a humid climate; the V.P.D. is, as a rule, less than 10 millibars. We conclude that in those cities the temperature of the air is the chief factor accounting for the varying flea-rate and the prevalence of rat and human plague. The Plague Research Commission in their later work in India attributed primary importance to the factor of relative humidity in checking plague epidemics in the hotter and drier up-country stations, but we think that the influence of the temperature in these places cannot be ignored. In localities where extreme drought prevails during the fall of the epidemic the influence of the V.P.D. is difficult to estimate, for the reasons that this factor has a temperature component, and that the temperature and V.P.D. usually run parallel. In some places, however, a V.P.D. above 10 millibars is able to restrain the spread of plague when the temperature is favourable; and Poona may be mentioned as a case in point.

The Relation of Departures either in Excess or in Defect of the Optimum Range of Temperature to the Extent of Spread of the Disease in Different Localities.

The degree in which the climate of an infected locality approximates to the optimum is apparently a material factor in determining the normal mildness or severity of plague within it. In maritime cities, where the V.P.D. is low, the prevailing temperature throughout the year may be such as to inhibit the disease. Colombo, with many opportunities for importing the infection, is an example; it has never been badly infected. The mean monthly temperatures are consistently higher than those of Bombay and vary from 26·1° C. to 28·7° C.; the flea average is low. Surabaya, a seaport, is relatively immune from plague, as compared with other localities in Java. The climatic conditions of this town are very like those of Colombo, the mean temperatures varying from 26·0° C. to 28·1° C.; in Surabaya, too, the flea average is low.

The Analysis of the Epidemic Curve throughout the Year.

There are two types of epidemic curve for human plague. The normal figures for Bombay, Calcutta, and Hong Kong give symmetrical curves; in Lahore, Nagpur, Cawnpore, and Lucknow the fall is more rapid than the rise, and the curves are therefore asymmetrical.

Symmetrical Epidemic Curves. In Bombay not only is the epidemic curve symmetrical, but also that of the epizootic (for 1906) and of the flea-variations (for 1907). The portion of the curves representing the epizootic and epidemic periods is explained by the rat-flea variations, which are mainly a function of temperature, since the V.P.D. is rarely unsuitable. The non-epizootic and non-epidemic seasons are accounted for by the high temperatures then prevalent, which diminish the numbers of fleas owing to their unfavourable action on the developmental stages, and which shorten the life of infected fleas whose valve of the proventriculus is inoperative.

Asymmetrical Epidemic Curves: Lahore, Nagpur, Cawnpore, and Lucknow. It is unfortunate that for these cities no epizootic curves are available for comparison, but probably they too would prove to be asymmetrical. We have not met with an asymmetrical flea-curve from a tropical locality; those of Cawnpore, Lucknow, and Asyût, in part associated with high temperatures and V.P.D.S, are symmetrical. The flea-variations are again the principal factor in this class of epidemic curve, but an additional modifying circumstance is present, and we suggest that this may be found to reside in the wide range of diurnal temperature variations appertaining to those localities. We surmise that the temperature of some part of the day rises so far above the optimum as to exert a retarding influence upon the transference of the infection to rats and human beings, by shortening the life of infected fleas in which the proventricular valve is imperfect.

In Bombay, where the amplitude of the diurnal temperature wave is smaller than in the up-country cities, excessive temperatures are also lethal to infected fleas, but the effect begins to appear only towards the close of the epidemic period; in Lahore, on the other hand, the influence of high temperatures appears earlier, namely, at the time of maximum plague prevalence. The difference, then, in the character of the two classes of curve depends upon the time in the course of the epidemic when high temperatures begin to operate effectively. The element, whether temperature, or, as some may think, V.P.D., or a combination of these, that distorts the normal epidemic curve, produces its effect within a brief space of time, for it acts directly on the insect carrier of the infection.

The process of thinning out that goes on in the plots of infection where rat plague exists, as the result of the death of infective fleas within them, may be conceived as operating continuously and in uniformly varying degrees throughout both types of epidemic. This hypothesis implies a superposition of variation curves, one of them referable to the breeding of fleas, and the other to the

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infected part of the flea population; the effects of abnormally high temperatures are seen, however, only during the fall of epidemics of the asymmetrical type. Analysis of the diurnal temperature variations will lead, we think, to a promising line of attack upon this aspect of the problem.

Temperatures below 20° C. hinder the multiplication of fleas, and accordingly also check plague. In Lahore, the months that immediately precede the epidemic season are characterized by low mean temperatures: 11·2° C. is the lowest normal mean monthly temperature; whereas the non-plague months following the epidemic are marked by high mean temperatures (25° C. to 35° C.). The curves of Tongshan in Manchuria are probably typical of localities with a temperate climate. Here, an increase in the number of fleas runs parallel with temperatures rising to the optimum zone, a decrease in their numbers with temperatures falling to zero.

The Relation of Climate to the Seasonal Prevalence of Plague in Egypt.

Reverting now to the Egyptian data, we find that the normal temperatures and V.P.D.S for the month preceding that of maximum plague prevalence in the four divisions of the country are, from south to north, respectively: 14·9° C., 20·5° C., 22·1° C., 23·8° C., and 7·9, 11·7, 9·8, and 7·9 millibars. These figures are in good agreement with the views we have expressed for optimum plague conditions. We reach the conclusion that the delay in the diffusion of plague in Egypt from south to north is correlated with the climatic variations throughout the country.

Conclusions.

We are conscious that it is not easy to estimate the influence of the climatic factors implicated in the seasonal prevalence of bubonic plague. With due reservations we would summarize our conclusions as follows:

(1) The extent of the disease at any moment in the epidemic period is determined not by the strictly contemporaneous weather conditions, but by those which existed four to six weeks previously. The interval is attributable to the effect of atmospheric conditions on the various stages of development of the rat-flea (*X. cheopis*).

(2) When this lag period is taken into account, there is found to be an optimum range of temperature from 20° C. to 25° C. and of vapour pressure deficiency from 1 to 10 millibars for plague prevalence; these, too, are the optimum limits for flea development.

(3) The degree in which the climate of a locality approximates to the optimum determines to a definite extent the normal character, whether mild or severe, of its plague history.

(4) In maritime localities the atmospheric temperature is a more important factor in regulating the prevalence of the disease than the vapour pressure deficiency. In places with a hot dry climate the rise of the epidemic is correlated with the temperature variations; a high prevailing temperature or excessive dryness of the air (vapour pressure deficiency) or a combination of these hastens its decline by increasing the mortality in the infected part of the rat-flea population, and thus restricting the transference of the infection.

In certain localities, when the temperature is favourable, a dry atmosphere with a vapour pressure deficiency above the optimum limit is able by itself to check the spread of the disease.

(5) In the dissection of the climatic factors associated with plague, the diurnal temperature variations deserve attention.

(6) The gradually increasing delay in the onset of epidemic plague from south to north of Egypt is correlated with the seasonal variations in the climate throughout the country. The analysis leading to this conclusion indicates that, in agreement with the data from India and elsewhere, the seasonal prevalence of human plague in Egypt, as deduced from the massed statistics, is dependent upon the factors governing the prevalence of rat plague, and, in particular, the climatic factors that influence the life history of the rat-flea (*X. cheopis*).

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GENERAL CONSIDERATIONS ON THE EPIDEMIOLOGY OF BUBONIC PLAGUE IN EGYPT.

Plague as observed at the present day in Egypt does not equal in local intensity and widespread diffusibility the older epidemics that overran the country, or the epidemics of recent years in India. The number of cases that were notified in Egypt from 1899 to 1919 inclusive, namely 14,783, has been exceeded in several single years in the city of Bombay alone. This relative exemption does not seem to be due to a scarcity of rats and fleas, the cardinal requisites for epidemic spread; but the Egyptian rat may have a higher average immunity than the Indian rat, inherited from the survivors of the continually recurring epizootics of the seventeenth and eighteenth centuries. Thus plague was scarcely ever absent from Egypt during the period of 243 years dating from the commencement of the seventeenth century; the records we have consulted speak of its presence in nineteen out of the twenty-four decades of this period. The prolonged succession of plague-stricken years was followed by a free interval of fifty-five years: from 1844 until 1899. In India, on the other hand, the two generalized epidemics prior to the year 1896 belong to the seventeenth century: one in 1616 in the time of the Emperor Jehangir, of which it is said that it devastated the country for eight years, and the other in 1688 which lasted for seven or eight years in the reign of Aurungzeb (Creighton).

In November 1913 we made observations on rodents trapped from houses in two native quarters in Cairo, namely, the Musky, the bazaar quarter in the centre of the city, and Bulâq, which is adjacent to the Nile and opposite the island of Gezîra. 5400 traps were set; they caught only 88 *R. rattus* (equal to 1·6 per cent. traps set and 176 per cent. pure takes) and 129 *Acomys* (equal to 2·4 per cent. traps set and 141 per cent. pure takes); seven weasels (*Mustela africana*) and one mouse were also trapped. These results show that the rodent infestation of native houses in Cairo is very small, and they explain the immunity of the city to plague. The fewness of rats is probably associated with the substantial construction in stone of the buildings and with the commonness of weasels in the native houses.

The distribution of the plague cases in the Abnûb and Qûs outbreaks indicates that the spread of infection in these towns was haphazard. If it were possible to ensure that the human agent remained wholly passive, the infection would proceed in a regular manner outwards from a centre, the first focus. The best evidence for this belief that we have found is the experiment related by the Indian Plague Research Commission (1907), in which the human population of an infected and evacuated village near Bombay was represented by guinea-pigs. Here the uniform progression of the epidemic amongst the experimental animals from the first infected house proves indirectly that the excursions of the rats (*R. rattus*), while a severe epizootic was going on, were of short range; our own evidence on the movements of

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the Egyptian *R. rattus* points in the same direction. It is true that some of the scattered nuclei in local outbreaks of rat and human plague may be due to fresh importation of infection from outside the locality, but we think that internal rather than external causes are at work in their formation. We believe that the people themselves are largely responsible for the spread of the infection by their movements to and fro and by the removal to distant parts of the town of relatives who are ill or of bundles of clothing or other articles. And, further, we suspect that measures for disinfection are a means of spreading the disease, not only by leading to concealment of plague patients in an endeavour to evade sanitary interference, but also through the agency of the disinfecting staff.

It is naturally difficult to ascertain by actual observation precisely how the infection is conveyed from one part of a town to another; our experience agrees best with the conclusion arrived at in India that it is conveyed in the rat-flea.

It is an axiom that the spread of plague in a country is directly related to its means of communication, whether by rail, road, or river; and that the scattering of infection is hindered or favoured by the simplicity or complexity of the network.

Egypt has an excellent system of railways, with a total length in 1912 of 1481 miles; in 1911 nearly 28 million and in 1912 nearly 29 million passengers travelled by rail in Egypt. The records give instances of the detection of persons suffering from plague while travelling by train. It has been already shown that the native river-craft ("feluccas") which voyage along the Nile from Aswân town to its mouths at Rosetta and Damietta are rat-ridden. Highways and agricultural roads hardly exist, but there is an immense network of field paths and riding tracks between the towns and villages. The river in its course through the cultivated areas is not a serious barrier to the passage of the infection; the barrages across it serve as bridges; and there are eighty-nine Government ferries in Upper Egypt. Feluccas are means of transit across the Nile at any part of its course.

Markets (agricultural produce and cotton) increase the movements of the people during the epidemic period, and so help to spread the disease. From information supplied to us we learn that 180 *mulids* (fairs of a semi-religious character lasting from one to four weeks) held annually over the whole of Egypt attract at least three-quarters of a million visitors and last altogether for 1300 days.

A scheme was organized in 1913 whereby the clothes of plague patients could be sent to our laboratory at Asyût from towns or villages in other provinces in order that they might be examined for rat-fleas and for infectivity to guinea-pigs. Specially designed flea-proof bags were used for the conveyance of the clothes. On arrival at the laboratory the bag and its contents were transferred to a roomy flea-proof sack, held open by bamboo stakes, into which a guinea-pig was put and kept for at least ten days. The year 1913 was an exceptionally mild plague year, and the seventeen experiments that we made—the results were negative in all—were not convincing, because we were unable to obtain in each case satisfactory evidence of the exact nature of the patient's illness. The clothes were sent from patients who were suspected of having contracted plague, but the bacteriological diagnosis was reported as positive from only one of them. We prefer to trust to observations in plague localities that strongly impressed us with the likelihood of infective rat-fleas being conveyed from place to place and so starting fresh epizootics. The plan that we adopted might, however, prove in more advantageous circumstances a valuable means of estimating the risks of infected fleas being carried in clothing.

Our observations at Asyût on the duration of life of unfed rat-fleas (Table III) showed that, as the weather in the plague season became hotter and drier, their length of life diminished; and we conclude that under natural conditions the diffusion of plague receives a corresponding check.

The rôle of the human flea as a possible plague carrier was investigated by the Plague Research Commission in India (1907). They thought it unlikely that this flea conveys the infection from man to man, because the septicaemia in human beings as compared with that in rodents is so slight that the chance of the flea becoming infected is negligible. We made a number of observations at Asyût on the infestation by human fleas of clothes taken from unselected patients who had been admitted to the adjoining Government Hospital but were not suffering from plague (Tables IV and V). The results are interesting apart from the question of the ability of the human flea to convey plague infection. They indicate that the numbers are greatest in February, March, and April, and that they diminish as the weather becomes hotter. Fleas (*P. irritans*) and lice were present in 89 per cent. of the lots of clothing. The number of fleas was sometimes startling; thus, from the rather superior clothes of an old man, more than 1000 fleas and innumerable lice were removed, as well as a considerable number of bugs (between forty and fifty) and a variety of other insects; 538 of the fleas were examined, and all of them were found to be *P. irritans*.

Table IV.

Showing average number of human fleas in clothes of plague-free hospital patients at different seasons of the year. (*Asyût town*, 1913.)

Period	No. of patients	Fleas	Average per patient
Feb., March, April	127	4002	31·5
May, June, July	58	382	6·6
Aug., Oct., Nov.	28	52	1·9
Totals:	213	4436	20·8

Table V.

Showing distribution of human fleas and lice in clothes of plague-free hospital patients at different seasons of the year. (*Asyût town*, 1913.)

		Fleas, no. of lots of clothing with							Lice, no.	
Period	No. of lots of clothing	0	1–5	6–20	21–50	51–100	101–200	201 and over	infested with lice	no lice
Feb., March, April	128	1	15	56	31	17	6	2	113	15
May, June, July	58	10	28	15	5	0	0	0	55	3
Aug., Oct., Nov.	28	13	13	2	0	0	0	0	22	6
Totals:	214	24	56	73	36	17	6	2	190	24

Bubonic plague may become extinct without any obvious cause in a country where it has been rife; for example, it disappeared from Egypt in the year 1844 and from India in the seventeenth century. The chief reasons for its virtual extinction in Europe are, first, the supplanting of *R. rattus*, the house rat, by *R. norvegicus*, the outdoor rat; and secondly, the improved housing conditions, which have accompanied the general advance in the

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standard of living. The diversion of trade routes, by lessening the chances of reimporting the virus, has helped in the past to keep the disease within bounds; thus the decrease in the intercoastal trade between the countries bordering on the Eastern Mediterranean which is said to have taken place near the middle of the nineteenth century has been assigned as one of the reasons for the cessation of plague at that time in Egypt. The fundamental causes are, however, doubtless traceable to the rat and the rat-flea. It is impossible with our present knowledge to predict the future course of the disease in a country like Egypt where the conditions seem to be favourable for its continuance; nor can we even explain satisfactorily the fluctuations in its prevalence from year to year. But since there are only a few references in the literature to the behaviour of plague during epidemic cycles, we may note briefly some unfamiliar aspects of the subject.

A long succession of plague epidemics in a city or district has the effect of increasing the resistance of the rat population, not only by eliminating susceptible individuals but by the transmission of immunity to the progeny of the survivors. (Plague Research Commission, 1912.) This factor operates slowly and, if it were the sole cause, we should expect it to lead to a gradual disappearance of the disease.

The relative abundance of the fleas infesting rats has also to be considered. A diminution in their number below a critical point, if it were maintained during the plague season, would soon result in the infection either ceasing to spread or spreading at a slow rate. Our observations in Asyût on the prevalence of rat-fleas are significant here. The monthly averages for *R. rattus* and *Acomys cahirinus* were uniformly higher throughout the year 1912 than in the following year; the incidence of human plague, too, was greater in 1912, for there were 687 cases in this year in Upper Egypt as compared with 335 cases in 1913. The weather, as we have seen, has an influence upon the breeding of rat-fleas, but the climatic variations during those two years do not appear to us to be such as to account wholly for the differences in the flea prevalence; and it is quite conceivable that other factors were at work.

We devoted attention to the natural enemies of rat-fleas and their larvae, and collected various insects from houses at Kôm Ombo and Asyût, which we submitted to Mr Bacot for identification and for his opinion regarding their ability to act as a check to the breeding of fleas. He thought that the larval stage of the flea is the one at which such a check is brought about, for the flea larvae are subject to attack by other insects and their larvae; and that among the insects in our collections certain small beetles belonging to the group "Staphylinidae" and minute yellowish ants of the group "Leptothorax" are likely to be of importance. It had occurred to us that the exceptionally heavy rat-flea infestation at Kôm Ombo might have been in part associated with the recent foundation of this estate; we supposed that there had not been enough time for insect enemies of the fleas to become established in the nests and burrows of the rats. Mr Bacot, to whom we referred the point, wrote to us: "Your suggestion is very probably an explanation of the flea prevalence, and fits in with the known facts concerning insects in a new environment."

There are scattered publications which deal with the parasitic invasion of rat-fleas by bacteria, protozoa and helminths, but systematic observations have not yet been made in countries where plague is endemic with a view to discover whether internal parasites adversely influence the flea population in any important degree. Investigations in plague-infected districts on the enemies and parasites of the rat-flea are desirable, and might help to make clear unaccountable fluctuations in the prevalence of bubonic plague from year to year, both locally and over extensive tracts of country, as well as the causes that lie at the root of the natural decline and termination of a recurring series of epidemics.

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THE EPIDEMIOLOGY OF PNEUMONIC PLAGUE IN EGYPT.

When we survey the cumulative experience of the great epidemics of pneumonic plague in recent years throughout the world, certain features are seen to be common to all. First, the disease prevailed amongst peoples who were entirely ignorant of the means of self-protection, and who were unassisted by any sanitary organization capable of arresting its course. Secondly, the housing conditions were characterized by gross overcrowding and by the absence of any provision for ventilation. The inferences may be drawn that popular ignorance, administrative deficiencies, overcrowding, and bad ventilation are the essential factors that contribute to the spread of pneumonic plague; and that the extent of spread in an outbreak, in whatever country it may occur, is determined by its particular set of co-operating factors and by the degree in which each is present.

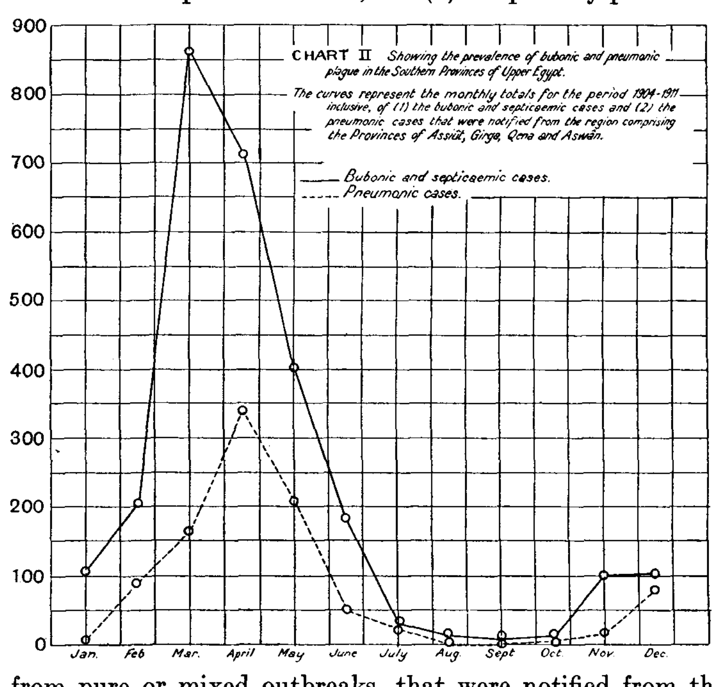
The incidence of pneumonic plague has been fortunately low—1 to 5 per cent.—in localities that have suffered severely from bubonic plague during the present pandemic, for example India, Hong Kong, and Java. In contrast with these localities Upper Egypt—particularly its southern provinces, Qena and Girga—manifests a decided inclination to kindle pneumonic plague foci. In the period from 1899 to 1913 there were altogether eighty-eight pure outbreaks of pneumonic plague in Egypt. Viewing the outbreaks as a whole we find that the number of cases in each is small, and that the majority remained isolated. When the escape of contacts from the primary outbreak led to the introduction of the disease into neighbouring villages, there were seldom more than three or four secondary offshoots. It is clear then that, although in the affected districts foci are apt to flare up, the outbreaks that follow are characterized by low diffusibility.

In Egypt the ignorance of the people and their habit of clinging to traditional customs and prejudices encourage direct transference of the infection. The practice of crowding round and kissing the sick, the assemblage of men and women at funeral ceremonies, and the attempts that are made to conceal deaths and to evade the measures for controlling the disease, add greatly to the difficulties of the Sanitary Administration. Fortunately not all the main elements of spread are present, and this accounts for the low diffusibility.

Although overcrowding takes place on special occasions in the manner indicated, it is not a normal feature of Egyptian domestic life. Further, owing to the hot weather in Qena and Girga during the pneumonic plague season the people keep their houses sufficiently well ventilated, and, moreover, live a good deal in the open air. Again, the restricted regional distribution of pneumonic plague in Egypt makes it possible to strengthen the defences against its spread. The smallness of the individual foci, as contrasted with the extensive epidemics within recent years in China, is not due to any enfeeblement of contagious quality; clinical and bacteriological evidence revealed no difference in the character of the disease from that observed elsewhere; the cases without exception were fatal. We attribute the small scale of the outbreaks to the alertness and active intervention of the Sanitary authorities, to ample ventilation of the houses, and to the absence under normal conditions of domestic overcrowding.

Seasonal Prevalence.

Chart II represents the monthly totals for the period 1904–11 inclusive, of (1) the bubonic and septicaemic cases, and (2) the primary pneumonic cases,



whether from pure or mixed outbreaks, that were notified from the region comprising the provinces of Asyût, Girga, Qena, and Aswân. The close correspondence between the epidemic curves makes it practically certain that pneumonic plague in this region originates locally from bubonic or septicaemic plague. We are indebted to Mr J. I. Craig for working out the coefficient of correlation of the figures from which the curves were plotted; $r = +0{\cdot}857$ for bubonic and septicaemic cases correlated with pneumonic cases of the same month, $+0{\cdot}880$ with one month's lag, and $+0{\cdot}291$ with two months' lag: the best fit was obtained for a lag varying between a fortnight and a month[1]. Although it can scarcely be doubted that the majority of the pneu-

[1] r lies between 0 and ± 1, ± 1 indicating complete association.

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monic cases arise locally, and prevail within fairly narrow limits contemporaneously with bubonic cases, pure outbreaks in the southern provinces sometimes originate in the local non-plague season. We had experience of three of these off-season outbreaks, namely, at Khattara (Qena Province), Zarâbi (Girga Province), and Damanhûr (Asyût Province). Of eighty-eight pure outbreaks in Egypt during the years 1904–13 inclusive 76 fell within the local plague season and the remaining twelve within the local non-plague season; all of the latter group broke out in villages in the southern provinces of Upper Egypt, and 72 out of 76 in the former group attacked the provinces of Qena, Girga, and Asyût. This analysis includes sixteen instances in which only one case of pneumonic plague was found; but we have judged it right to regard them as potential outbreaks, for we believe that those cases remained single on account of the vigilance of the Public Health staff. The off-season outbreaks are derived from patients suffering from bubonic plague who travel from the Delta when the disease is prevalent there. A good deal of the casual labour of the Delta is undertaken by temporary migrants—mostly males—from the southern provinces of Upper Egypt, especially Qena and Girga; and it is known that, when attacked by illness, they seek to return at once to their homes. The high mortality amongst the plague-stricken travellers is associated with the strain of the journey, and is probably often due to a septicaemia or a secondary plague pneumonia.

Regional Distribution.

The heavy incidence of pneumonic plague upon the provinces of Qena and Girga and the lessening incidence towards the north are difficult to explain. In order to compare the climatic conditions in localities which have suffered from pneumonic plague, we obtained the data for temperature and vapour pressure deficiency relating to the epidemic periods in Southern Upper Egypt, Johannesburg, Srinagar (Kashmir), and Changchun and Mukden (Manchuria). The figures show that the weather in Qena and Girga during the prevalence of pneumonic plague is exceptionally hot and dry. This result does not fit in with the view of Teague and Barber that the extent of spread of the Chinese epidemics is associated with the low water deficit of the air due to the cold weather when these outbreaks prevailed; they think that the moist atmosphere protects the bacilli in the droplets of sputum from desiccation. The Egyptian experience confirms our belief that the primary factors concerned in the widespread dissemination of pneumonic plague in countries where the disease spreads during cold weather are those we have already mentioned, and that the influence of atmospheric conditions upon infected sputum particles is less important.

We sought for any significant circumstances peculiar to the Qena-Girga district. The southern part of Upper Egypt from Asyût to Aswân is the only region in the country where perennial irrigation does not exist, so that there is no summer cultivation and the ground during the plague season is dry and parched. It has occurred to us that by increasing local drought the lack of irrigation and cultivation during the plague season in Qena and Girga may be a factor predisposing to the onset of a secondary pneumonia in bubonic and septicaemic cases. Excessive evaporation of moisture from the pulmonary mucous membrane due to a high saturation deficit of the air may conduce to the production of patches of secondary pneumonia; this is more likely to occur if the mucosa is congested as in those plague patients in whom there is a blood infection.

We looked, too, for indications of varying susceptibility to plague infection amongst the Egyptian natives. Direct evidence was not obtainable from the plague statistics, but evidence of ethnological variations was found in Craig's study of the anthropometry of modern Egyptians. The Qena-Girga district forms from this point of view a well-defined unit, and indeed the racial grouping worked out by Craig corresponds fairly well with the distribution of pneumonic plague over the country. It may be that the ethnological differences connote variations in susceptibility to pulmonary plague infection.

Table VI.

Showing the regional distribution of pneumonic plague in the provinces of Egypt; the figures represent the total notified cases of each type for each locality summed for the period 1904–12 *inclusive.*

Region	Bubonic and septicaemic cases	Pneumonic cases	Percentage of pneumonic to total cases
Aswân province	535	7	1·3
Qena province	1192	586	33·0
Girga province	312	218	41·1
Asyût province	1071	150	12·3
Minia province	964	62	6·0
Beni Suef province	401	13	3·1
Fayûm province	502	44	8·1
Gîza province	18	—	—
Delta provinces	1603	58	3·5
Suez and Ismailia	98	11	10·1
Alexandria, Damietta and Port Said	912	24	2·5

The Clinical Forms of Pneumonic Plague and their Epidemiological Relations.

The two clinical forms are: (1) primary pneumonic plague arising from direct infection of the respiratory tract, and (2) secondary plague pneumonia coming on as a complication in a bubonic case or in one without obvious buboes (septicaemic plague); whether buboes are present or not a blood infection may be assumed. If exceptional cases such as laboratory infections are left out of account the primary form of the disease, in whatever country it is found, may be traced to a plague patient with a secondary pneumonia.

In endemic centres a rapidly and invariably fatal disease attacking several members of a family should at once suggest a diagnosis of primary pneumonic plague; but in Egypt confusion may arise from the concurrence of typhus fever, which is common in the plague season. Here, typhus fever is often difficult to diagnose clinically, for in general it runs a mild course and the rash may not be characteristic. In Upper Egypt the season for relapsing fever is also coincident with plague, but the differential diagnosis is much easier and can be confirmed by examination of the blood. A simple, rapid, and certain means of post-mortem diagnosis consists in the preparation of smears of material taken with a needle and syringe from the apex and base of each lung and from the heart. In our notes of lung and heart-blood smears from twenty-seven cases of pneumonic plague the bacilli are stated to be on the average most numerous in smears from the right apex, diminishing in the order: the right base, the left apex, the left base, and the heart-blood. The preparations often resembled those made from a pure culture. The conditions under which we worked were not suitable for withdrawing material from the lungs during life, but we sometimes used this method, and we believe that it will prove to be a valuable diagnostic aid where it can be conveniently employed.

We were able to obtain evidence that a secondary pneumonia is apt to supervene in persons who travel while they are suffering from plague. Apart from a natural desire to return home when they fall ill, these patients may be urged on by the impulse to wander, which is one of the symptoms of plague; some are able to get about fairly well, even when the disease is far advanced. The liability of ambulant plague patients to a secondary pneumonia may be explained as follows. The walls of the blood-vessels of the bubo tend to rupture as the result of softening brought about by the inflammatory process. Infective thrombi form in the vessels; and if they become detached the bacilli may be swept into the circulation and may reach the lungs. Muscular efforts made by the patient must greatly increase the risk of a pulmonary complication.

Gotschlich (1899) affirmed that virulent plague bacilli can be found in the sputum obtained from patients in the convalescent stage of a plague pneumonia, even after several weeks have elapsed from the onset of the disease. This observation, which was based on the examination of one case of primary and two cases of secondary pneumonia, has been often cited, but, so far as we are aware, it remains uncorroborated. He stated that the plague bacillus was isolated by inoculating guinea-pigs intraperitoneally with the sputum, but no mention is made of any tests used for identifying the plague-like bacteria that were recovered. We have never met with such a carrier, nor with a pneumonic plague patient who was thus infected. Moreover, we have been unable to find in the Egyptian records any suggestion of such a mode of origin of pneumonic plague. When evidence on this important question is brought forward, the details that are given should be as full and unequivocal as possible.

Types of Outbreak.

In Egypt, two types occur: (1) mixed outbreaks, and (2) pure pneumonic foci. The former is the normal type in the provinces of Qena and Girga. Thus, in a mixed outbreak, previously described, of eighty-two cases of all forms at Qûs town, there were fifteen cases of primary pneumonic plague, which were distributed in five groups, each with a different originator. Pure outbreaks originate either from a primary pneumonic case or from a bubonic patient with a secondary plague pneumonia who has come from another locality. They are not accompanied by any bubonic plague, and are not directly related to rat infection.

A guinea-pig was kept for three days in each of eight houses of patients in Edfa village, and was examined daily for fleas. On five of the guinea-pigs no fleas were caught, and the total counts on the others were 2, 8, and 16; all the animals remained healthy. The fewness of the rat-fleas contrasts with the results obtained elsewhere in houses in which there were plague-infected rats.

Inter-local Movements of the People that promote the Dispersion of the Disease.

Temporary migrations associated with local economic and labour conditions are particularly noticeable in the provinces of Qena and Girga, and are due to the gap in the succession of the agricultural seasons caused by the partial

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irrigation system. The introduction of the system of perennial irrigation into the southern provinces may be expected to act indirectly as an effective plague measure by increasing their fertility and so stabilizing the population.

General Conclusions on the Origin, Spread, and Decline of Pneumonic Plague.

(1) Outbreaks of pneumonic plague take their immediate origin from patients with bubonic or septicaemic plague in whom a secondary pneumonia has supervened; they may assume the form of scattered foci in localities in which a bubonic epidemic is proceeding (mixed outbreaks); or they may occur as pure epidemics.

(2) Ignorance of the means of self-protection, deficiencies in the Sanitary Administration, overcrowding, and the absence of proper ventilation are the primary circumstances that encourage the spread of the disease.

(3) The decline and cessation of epidemics are associated with a return to healthier conditions of life, in particular, a free circulation of air within the houses and a diminution of overcrowding.

(4) The range of contagion in pneumonic plague is so close that direct transference of the infection must often occur. Mediate infection from a high concentration of sputum particles in the air doubtless happens when the ventilation is inadequate. The influence of atmospheric conditions upon infected sputum droplets is of secondary importance. An essential requisite for its spread is the close contact between the sick and the healthy that results from overcrowding or from the habits of those exposed to risk.

(5) The prevention of pneumonic plague in man depends in the last resort upon the extinction of plague in rodents.

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The Prevention of Plague in Egypt.

The subjects usually discussed under the head of plague prevention are: (1) the exclusion of rats from houses; (2) the reduction in numbers or the extermination of rats infesting houses; (3) the removal of the infection within buildings when plague has appeared; and (4) the prophylactic use of a plague vaccine. In principle, these measures need no defence, but it is necessary to inquire whether the success to be expected under the most favourable conditions may not be modified in practice by circumstances peculiar to the country in which it is proposed to apply them.

The work at Asyût during two years showed that persistent trapping had the effect of appreciably reducing the numbers of rats infesting the houses. The reduction was due solely to trapping and not to any discoverable epizootic disease; the rats remained free from plague throughout the period of observation. Four small villages were trapped as thoroughly as possible by setting traps daily in the houses for several weeks. The results are similar in all, and indicate a near approach to extinction of the rodent population. They suggest that the Egyptian people themselves could virtually abolish the risk from plague if, instead of a surprising tolerance, they were possessed by such a dislike for rats as would call forth persistent efforts to exterminate them.

In theory plague is one of the easiest as it is also in practice one of the most difficult diseases to combat. The communities of Western Europe have successfully solved the problem—not of set design but in consequence of the gradual progress, both social and material, during the last two centuries. The risk of a widespread epidemic of bubonic plague in these countries is, we believe, negligible, and even if plague should become epizootic amongst the field rats, a considerable epidemic of human plague is unlikely to break out, so long as the modes and standards of living do not change for the worse. An adequate idea of the distance which must be travelled before Egypt enjoys a similar security can be got only by observation at close quarters in the country. Improvement in the housing conditions is desirable, but is scarcely feasible on a large scale. The ignorance of the mass of the people, confirmed by age-long prejudices, effectually hinders them from understanding and willingly submitting to logical methods of dealing with epidemic diseases. In our judgment the outlook may be indicated in the statement that progress in plague prevention will be found to keep pace with the course of national development.

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