XIX. ON THE NATURAL OCCURRENCE OF CHRONIC PLAGUE IN RATS.

I. Introduction.

In a previous paper (vol. VI. p. 530) an account was given of seven rats presenting the appearances of chronic plague which were obtained in the Punjab villages, Kasel and Dhand, during the months immediately preceding the epizootic. Since the year devoted to the study of human and rat plague in these villages has now been completed, we are in a position to put on record further observations of chronic plague in rats and to discuss the possible bearing of these observations upon the question of the seasonal recurrence of the infection in an acute form. It will be recalled that the lesions in the seven rats already described were in every instance situated within the abdomen. Further examples of rats with similar lesions are included in the present paper, but in addition reference will be made to certain rats in which the lesion was peripheral, i.e. in the submaxillary, axillary or inguinal regions. We shall refer in future to the former type as "visceral" and to the latter as "peripheral": abscesses in the pelvic lymphatic glands are, for reasons given subsequently (p. 466), to be classed as essentially peripheral. We have in all met with 45 cases, of which 17 were visceral and 28 peripheral. The lesions in every instance consisted of circumscribed caseous nodules or abscesses, and with eight exceptions constituted the only pathological change found. All the rats thus affected were *Mus rattus*, which constitutes practically the entire rat population of the villages examined.

The condition seems to be clearly different from that described by Hunter (*Epidemic and Epizootic Plague*, 1904, pp. 77 and 84), who in Hongkong found a large number of rats suffering from chronic plague. These animals were much emaciated and suffered from chronic diarrhoea: on section necrosed areas of cheesy material were found in the lymphatic glands and viscera, containing few plague bacilli but capable of giving

TABLE I.

Chronic plague rats obtained from Kasel village during the year 29. xi. 05—14. xii. 06.

Chronic plague rats obtained before the first acute plague rat was taken, i.e. on 2. iv. 06.

Serial No.	No. of rat	Date of examination	Where caught	Weight in grs.	Sex	Situation of principal lesion	Microscopical appearances	Cultural tests	Animal tests
1	403	9. xii. 05	House No. 138	—	—	Abscess in spleen	Numerous bacilli like *B. pestis*	Like *B. pestis* on agar	Guinea-pig died in 8 days of plague.
2	754	12. xii. 05	376	—	—	Abscess in spleen	A few plague-like bacilli	All positive*	Guinea-pig recovered after local reaction and buboes.

Rats obtained in the period dating from the first to the last acute plague rat, i.e. from 2. iv. 06 *to* 17. vii. 06.

Note:—Trapping stopped between 24. xii. 05 and 20. ii. 06.

3	4661	6. iv. 06	119	130	F preg.	Necrotic nodule in spleen	Many plague-like bacilli	All positive	Guinea-pig died in 4 days of plague.
4	4739	17. iv. 06	82	155	M	Left axillary abscess	Many plague-like bacilli	——	Guinea-pig chloroformed on 13th day: plague.
5	4765	18. iv. 06	118	140	M	Left submaxillary abscess	Fairly numerous plague-like bacilli	Like *B. pestis* on agar	None made.
6	5470	21. v. 06	31	130	F	Left axillary and right submaxillary abscesses	Submaxillary — abundant plague-like bacilli. Axillary—several clumps plague-like bacilli	——	None made.
7	5485	23. v. 06	109	110	F preg.	Left submaxillary bubo	Abundant plague-like bacilli and involution forms	Like *B. pestis* on agar	None made.
8	5489	23. v. 06	105	165	M	Right and left axillary abscesses	Left axillary—numerous plague-like bacilli. Right axillary—a few plague-like bacilli	Like *B. pestis* on agar	None made.
9	5567	30. v. 06	439	155	M	Right submaxillary bubo	A few plague-like bacilli	Like *B. pestis* on agar	Guinea-pig died in 7 days of plague.
10	5597	31. v. 06	490	95	F	Right inguinal and right pelvic buboes	Inguinal—many plague-like bacilli	(From pelvic bubo). Like *B. pestis* on agar	None made.

11	5725	11. vi. 06	1206	55	F	Right axillary bubo, 2 abscesses in spleen	Bubo: many involution forms like *B. pestis*	From bubo—like *B. pestis* on agar	Guinea-pig died in 5 days of plague.
12	5774	15. vi. 06	138	135	F preg.	Right submaxillary bubo	A few plague-like bacilli	Like *B. pestis* on agar	Guinea-pig died in 5 days of plague.
13	5781	16. vi. 06	272	125	F	Left axillary abscess	No bacilli seen	Contaminated	Guinea-pig chloroformed in 7 days: plague.
14	5827	21. vi. 06	552	140	M	Left submaxillary abscess	Fairly numerous bacilli-like involution forms of *B. pestis*	Like *B. pestis* on agar	Guinea-pig died in 3 days of plague.
15	5831	21. vi. 06	508	40	M	Right inguinal abscess	Many bacilli, none like typical *B. pestis*	Contaminated	Guinea-pig died in 5 days of plague.
16	5924	29. vi. 06	715	45	M	Necrotic nodule in spleen, abscess in abdominal wall	Abscess: some plague-like bacilli	Like *B. pestis* on agar	Guinea-pig died in 3 days of plague.
17	6159	13. vii. 06	208	140	F preg.	Mesenteric abscess	No bacilli seen	All positive	Guinea-pig died in 5 days of plague.

Rats obtained in the period dating from the last acute plague rat to the end of the year's investigation on 14. xii. 06.

18	6927	23. viii. 06	525	145	M	Necrotic nodule in spleen	No bacilli seen	Sterile on agar	Guinea-pig chloroformed in 4 days, cultures proved to be plague *.
19	7097	6. ix. 06	1063	130	F preg.	Left inguinal and left pelvic abscesses	Inguinal — no bacilli seen. Pelvic—very numerous like *B. pestis* & some involution forms	Pelvic—all positive	Guinea-pig died in 6 days of plague.
	7667	6. x. 06	899	135	F preg.	Abscess in spleen	No bacilli seen	Like *B. pestis* on agar	Guinea-pig died in 11 days of plague, cultures proved to be plague.
	8279	28. x. 06	138	150	M	Abscess in spleen	A few bacilli unlike plague	All positive	Guinea-pig died in 3 days of plague.
	8580	5. xi. 06	422	145	F	Left pelvic abscess	A few clumps of plague-like bacilli and involution forms	All positive	Guinea-pig died in 3 days of plague.
	8834	13. xi. 06	673	140	F	Abscess in spleen	Very few plague-like bacilli	All positive	Guinea-pig died in 3 days of plague.
	9713	5. xii. 06	564 or 576	190	M	3 mesenteric abscesses	A few bacilli but not typical of plague	All positive	Guinea-pig died in 3 days of plague.

Note:—The first human case was attacked on 9. iii. 06 and the last on 6. vii. 06.

In the animal tests in this Table and in Tables II and III the guinea-pigs were inoculated by the cutaneous method.

* I.e. (1) growth-characteristics on agar, (2) stalactite test, (3) pathogenicity to guinea-pig with characteristic post-mortem appearances.

TABLE II.

Chronic plague rats obtained from Dhand village during the year 4. xii. 05—3. xii. 06.

Chronic plague rats obtained before the first acute plague rat was taken on 27. i. 06.

Serial No.	No. of rat	Date of examination	Where caught	Weight in grs.	Sex	Situation of principal lesion	Microscopical appearances	Cultural tests	Animal tests
1	1255	18. xii. 05	House No. 378	110	F	Multiple abscesses in liver and mesentery	No bacilli seen	All positive	None made.
2	1235	18. xii. 05	407	—	—	Pelvic abscess	A few plague-like bacilli	,, ,,	Guinea-pig died in 5 days of plague.
3	1779	24. xii. 05	623	105	M	Mesenteric abscess	No bacilli seen	,, ,,	,, ,, 6 ,, ,,
4	2356	11. i. 06	192	—	—	Pelvic abscess	,, ,,	,, ,,	,, ,, 9 ,, ,,

Rats obtained in the period dating from the first to the last acute plague rat, i.e. from 27. i. 06 *to* 21. iv. 06.

5	3053	14. ii. 06	492	130	M	Pelvic bubo	Numerous small bacilli	All positive	Guinea-pig remained healthy.
6	3424	27. ii. 06	364	165	M	Submaxillary abscess	Many clumps of plague-like organisms	——	Guinea-pig died in 9 days of plague.
7	4022	12. iii. 06	321	110	M	Right axillary bubo	One group of plague-like bacilli	——	,, ,, 9 ,, ,,
8	4116	14. iii. 06	439	55	F	Necrotic nodule in spleen	No bacilli seen	——	,, ,, 4 ,, ,,
9	4639	6. iv. 06	186	35	F	Right submaxillary abscess	Many plague-like bacilli	Like *B. pestis* on agar	,, ,, 5 ,, ,,
10	4696	12. iv. 06	371	110	M	Right submaxillary bubo	No bacilli seen	——	,, ,, 4 ,, ,,

Rats obtained in the period dating from the last acute rat to the end of the year's investigation on 3. xii. 06.

Note:—Trapping stopped between 12. iv. 06 and 22. v. 06.

11	5695	8. vi. 06	262 A	155	M	Left submaxillary abscess	Several clumps of plague-like bacilli	Like *B. pestis* on agar	Guinea-pig died in 4 days of plague.

Note:—Trapping stopped between 25. vi. 06 and 14. ix. 06.

The first human case was attacked on 6. ii. 06 and the last on 2. v. 06.

TABLE III.

Chronic plague rats obtained from Mianpur, Basirki and Dhaul.

I. *Rats obtained in Mianpur.*

Serial No.	No. of rat	Date of examination	Weight in grs.	Sex	Situation of principal lesion	Microscopical appearances	Cultural tests	Animal tests
1	5872	27. vi. 06	70	F	Left submaxillary abscess	Numerous plague-like bacilli and some involution forms	——	Guinea-pig died in 6 days of plague.
2	5916	29. vi. 06	55	M	Submaxillary abscess	No bacilli seen	All positive	,, ,, 4 ,, ,,
3	5936	30. vi. 06	115	F	Right axillary abscess	,, ,,	,, ,,	Guinea-pig chloroformed in 8 days.
4	5937	30. vi. 06	130	M	Right submaxillary abscess	Fairly numerous plague-like bacilli with involution forms	,, ,,	Guinea-pig died in 3 days of plague.
5	5979	3. vii. 06	165	M	Abscess in spleen	Fairly numerous plague-like bacilli	Like *B. pestis* on agar	,, ,, 6 ,, ,,
6	6014	4. vii. 06	110	M	Right submaxillary abscess	Some plague-like bacilli	Like *B. pestis* on agar	,, ,, 5 ,, ,,
7	6171	13. vii. 06	120	F	Right axillary abscess	No bacilli seen	Sterile on agar	,, ,, 2 ,, ,, Culture from second guinea-pig proved to be plague.

II. *Rats obtained in Basirki.*

8	8076	21. x. 06	170	F	Sternal abscesses	No bacilli seen	All positive	Guinea-pig chloroformed in 10 days. Culture inoculated into rat. Culture from rat proved to be plague.
9	8890	16. xi. 06	110	M	Abscesses in spleen and mesentery	A few plague-like bacilli	,, ,,	Guinea-pig died in 3 days of plague.

III. *Rat obtained from Dhaul.*

10	1832	21. xii. 05	—	—	Mesenteric abscess	No bacilli seen	All positive	Rat died in 2 days after subcutaneous inoculation of culture from abscess.

Note:—(1) In Mianpur trapping was commenced on 25. vi. 06 and stopped on 12. ix. 06. 309 rats were trapped during this period. No acute plague rats were obtained.
The village was again trapped on 4. xii. 06 and 5. xii. 06, 10 rats were secured.
The first human plague death occurred on 7. v. 06 and the last on 23. v. 06.

(2) Basirki was trapped on 20. x. 06 and 21. x. 06, 107 rats were obtained.
The village was retrapped from 14. xi. 06—17. xi. 06, 153 rats were obtained.
No human case was reported in this village during the plague season 1905—06.

(3) Dhaul village was not trapped.
The first human plague death occurred on 22. xi. 05 and the last on 20. ii. 06.

rise to acute plague when administered to healthy rats. He found that such animals were caught more frequently in the interval between than during the epizootics of acute plague. Our rats on the other hand showed no signs of general illness, and in only one instance was emaciation noticed.

The details of all the cases are given in Tables I, II and III in which the rats are arranged according to the village in which they were captured and in order of the date of capture.

II. The Post-mortem Appearances of the Rats[1].

A. *Chronic Plague of the visceral type* (17 *cases*).

1. *Splenic Nodules and Abscesses* (12 *cases*).

Out of 22 rats with lesions in the abdomen the spleen was the seat of the lesion in twelve.

No. 3, *Table I.* The posterior half of the spleen contains a yellowish hard nodule about the size of a pea; the nodule is adherent to the abdominal wall.

No. 18, *Table I.* The spleen contains a small cheesy nodule about 2 mm. in diameter at the junction of the middle and anterior third. The spleen is attached to the abdominal wall by a fibrous band.

No. 8, *Table II.* The anterior end of the spleen contains a necrotic nodule about the size of a small pea adherent to the great omentum: there is a deposit of lymph on the posterior third of the external surface. The liver shows numerous white points.

No. 16, *Table I.* There is a grayish nodule in the posterior third of the spleen. In the abdominal wall opposite to the nodule and attached to it by a fibrous band there is a very small thick-walled abscess. The rat shows some emaciation.

No. 2, *Table I.* A small abscess in the anterior end of the spleen.

No. 1, *Table I.* An abscess in the spleen containing cheesy pus; localised thickening of the capsule.

No. 20, *Table I.* In the anterior third of the spleen there is an abscess about 6 mm. in diameter, projecting from the internal surface and containing cheesy pus.

No. 21, *Table I.* The anterior third of the spleen contains an

[1] With the exception of the lesions described the rats appeared to be healthy.

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abscess 8 or 9 mm. in diameter, with moderately thin walls; it projects from the internal surface of the spleen and contains cheesy pus.

No. 23, *Table I.* An abscess about 20 mm. in diameter is situated in the anterior third of the spleen projecting from the external surface. It has fairly thick walls. The spleen is granular and the kidneys have a pale and mottled appearance.

No. 5, *Table III.* The spleen contains a large bulging abscess at the junction of the posterior and middle third. The abscess has a fairly thick fibrous wall and is partially covered by a thin layer of spleen tissue. A thin fibrous band extends from the spleen in the neighbourhood of the abscess to the abdominal wall; the abscess is connected also by a similar band to the upper and outer surface of the left kidney, the capsule of which has a local thickening. The spleen otherwise appears normal.

No. 11, *Table I.* The posterior end of the spleen contains a small abscess adherent to the stomach. In the anterior third of the spleen there is another small abscess adherent by means of a band of fibrous tissue to the posterior wall of the abdomen. There is a right axillary bubo. The liver shows several white necrotic spots.

No. 9, *Table III.* This rat shows three abscesses, all containing thick pus:—

(1) One the size of a small walnut in the posterior half of the spleen projecting from the internal surface, and adherent to the left kidney: (2) an abscess the size of a large pea in the anterior third of the spleen projecting forwards: (3) an abscess in the liver similar in size to the last.

2. *Mesenteric Abscesses* (5 *cases*).

No. 3, *Table II.* There is an abscess in the mesentery adherent to the spleen.

No. 10, *Table III.* A small abscess containing cheesy pus is situated in the mesentery and is attached to the upper end of the spleen by a band of fibrous tissue.

No. 17, *Table I.* There is a thick-walled abscess about the size of a large pea in the mesentery near the rectum; the abscess contains fairly thick pus. The spleen has two thin fibrous adhesions each about 5 mm. long attaching it at two points to the abdominal wall.

No. 24, *Table I.* There are three abscesses in the mesentery. The largest, about the size of a small walnut, lies below the stomach and is adherent to the small intestine and to the coecum. The second is oval

in shape, measuring about 8 × 4 mm. and lies close to the coecum. A third abscess about the same size as the first is situated in the great omentum; it has no adhesions to any of the organs. All these abscesses contain thick cheesy pus.

No. 1, *Table II.* There are numerous abscesses in the liver and mesentery.

B. *Chronic Plague of the peripheral type* (28 *cases*).

Out of 27 rats with peripheral abscesses the lesion was pelvic in 5, submaxillary in 13, axillary in 6, inguinal in 2, and in one there was an abscess in two situations. The details of the pelvic abscesses are as follows:—

No. 2, *Table II.* One of the retroperitoneal pelvic glands is full of cheesy pus.

No. 4, *Table II.* One of the pelvic glands is converted into an abscess.

No. 5, *Table II.* There is a pelvic bubo containing pus. The kidneys are pale and distended with urine; the bladder and ureters are also distended with urine, the result evidently of pressure by the abscess on the neck of the bladder.

No. 19, *Table I.* There is a very small left inguinal bubo containing a drop of pus and a left pelvic abscess about the size of a hazel-nut with cheesy purulent contents.

No. 22, *Table I.* The left pelvic gland is converted into an abscess about the size of a pea adherent to the posterior abdominal muscles and containing thick pus.

In 3 only of the remaining 22 rats was anything abnormal noted beyond the abscess:—

No. 6, *Table I.* Left axillary and right submaxillary purulent buboes; the spleen shows a few yellow nodules.

No. 10, *Table I.* Right inguinal and right pelvic necrotic buboes; the liver shows several small white necrotic nodules.

No. 12, *Table I.* Right submaxillary bubo; the spleen contains a few white nodules.

There remains for description *Rat No.* 8, *Table III.* This rat had an abscess containing thick cheesy pus in the middle of the sternum, connected with the bone. In close relation to it there were 2 subcutaneous abscesses with similar contents.

3. *Microscopical Appearances.*

Plague bacilli were not abundant in the lesions: in 17 cases none were found, while in 10 instances they were noted as being few, and were abundant in 18 only. Cultures were made in 36 instances and plague bacilli recovered in 32.

The heart-blood and normal tissue of the spleen in these animals showed no plague bacilli microscopically, and gave negative results on cultural examination. The heart-blood and spleen of some of them were inoculated into guinea-pigs without result, except in the case of No. 19, Table I. The following are the notes of this case:—There is a very small left inguinal bubo containing a drop of pus and a left pelvic bubo about the size of a hazel-nut with cheesy purulent contents. On microscopical examination, very numerous plague-like bacilli and some involution forms are seen in the pus from the pelvic bubo, while no bacilli can be seen in the pus of the inguinal bubo nor in the heart-blood nor spleen. A guinea-pig inoculated cutaneously with the pus from the pelvic abscess died in 5 days and a guinea-pig inoculated by the same method with the spleen died in 3 days. Judging from the post-mortem appearances we think it probable that this rat was passing from a subacute to the chronic stage of the disease.

4. *Virulence of the Bacilli.*

In the great majority of cases the bacilli in the lesions were virulent. The following table gives the result of the cutaneous inoculation of guinea-pigs with material from the lesions or with cultures from the pus. Of the 38 cases examined in this way, the test animals died of acute plague (5 days or less) in 21 (55 per cent.); the details are shown in the next table.

TABLE IV.

Guinea-pigs which remained healthy ...	1
,, ,, were ill but recovered ...	1
,, ,, died in 2 days	1
,, ,, ,, 3 ,, ...	8
,, ,, ,, 4 ,, ...	5
,, ,, ,, 5 ,, ...	7
,, ,, ,, 6 ,, ...	4
,, ,, ,, 7 ,, ...	1
,, ,, ,, 8 ,, ...	1
,, ,, ,, 9 ,, ...	3
,, ,, died after 9 days	1
,, ,, were killed and showed plague	5
	38

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One rat inoculated with a culture from a mesenteric abscess died of acute plague in 2 days.

In eight cases rats were fed with the lesions, and in two instances died of acute plague. It is moreover to be noted that the material used contained few or no plague bacilli on microscopical examination.

TABLE V.

Feeding experiments with the lesions of chronic plague rats.

No.	Lesion	Microscopical examination	Result	Remarks
9713	Mesenteric abscess	1 or 2 bacilli not typical	Died in 4 days	Mesenteric bubo; plague
9713	,, ,,	1 or 2 bacilli not typical	Chloroformed in 8 days	P.-M., nothing seen
8834	Spleen and splenic abscess	Very few plague-like bacilli	Died in 3 days	P.-M. plague, left submaxillary bubo acute plague
7097	Very small inguinal bubo	No bacilli seen	Died in 9 days	Nothing P.-M.
7667	Spleen and splenic abscess	No bacilli seen	Chloroformed in 15 days	P.-M., nothing seen
8279	Spleen and splenic abscess	A few bacilli not like *B. pestis*	Chloroformed in 21 days	,, ,, ,,
8890	Abscesses in spleen and liver	A few plague-like bacilli	Chloroformed in 20 days	,, ,, ,,
5695	Submaxillary abscess	Several clumps of *B. pestis*-like bacilli	Chloroformed in 33 days	,, ,, ,,
2356	Pelvic abscess	No bacilli seen	Killed in 14 days	,, ,, ,,

5. *Origin of the Lesions in Chronic Plague Rats.*

(1) *Peripheral abscesses.* These were invariably in the situation of the peripheral lymphatic glands and undoubtedly originated from buboes. In 14 animals out of 22 (64 per cent.) the abscesses were in the submaxillary region. This corresponds with the distribution of the primary buboes of acute rat plague (see above, p. 382), and indicates that the infection takes place by the same route in the two classes; reasons have been already given which suggest that the route in question is by the skin through the agency of rat fleas.

(2) *The pelvic abscesses.* We think that these abscesses originate from an infection of the skin of the hind limbs or of the lower part of the body. The reasons for this conclusion are (1) that the lymphatics of this area drain into the pelvic glands, and (2) that we have repeatedly observed instances of implication of the pelvic glands following experimental inoculation of plague bacilli in the hind limbs of rats.

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Moreover, not a few instances of pelvic buboes have been observed in rats dead of plague as the result of the transmission of the disease by infected rat fleas, i.e. by a skin infection. In this connection a rat cited above (vol. VI. p. 533) as an instance of chronic plague produced by experimental flea transmission is of interest. All the organs in this case were healthy but there was a bubo in the right pelvis containing virulent plague bacilli.

(3) *The splenic and mesenteric abscesses.* The origin of the splenic and mesenteric abscesses is obscure, and susceptible of several explanations.

The theory to which we incline is that the bacilli in the first instance find a lodgement in the spleen, either in the course of a septicaemia or as an embolus from, e.g., a bubo. They here give rise to a local necrosis which, owing to the prolonged life of the rat, is followed by a local inflammatory reaction. In this way an encapsuled abscess and a localised perisplenitis are produced. Subsequently there is an extension by direct contiguity to the mesentery, the connecting inflammatory links being later reduced to fibrous bands which may in their turn altogether disappear. The points in the morbid anatomy which especially favour this version are the facts that of 17 abscesses among the abdominal viscera, the spleen was involved in 12, and in 3 out of 5 cases of mesenteric abscesses the lesion was connected to the spleen by a definite adhesion.

It is, however, possible that these splenic and mesenteric abscesses are the few remaining representatives of multiple localised foci of plague bacilli, and that their distribution is an expression of individual peculiarities in infection and resistance by the different viscera. It is also possible that the mesenteric abscesses represent encapsuled remains of a generalised infection of the peritoneum, arising in the first instance from e.g. the spleen or bowel.

It might appear at first sight that the mesenteric abscesses originated from an intestinal infection resulting from feeding on plague-infected material. As against this view, however, the lesions were not the same as those in certain rats with chronic plague induced by experimental feeding on plague-infected material, and the appearances presented by the abscess did not support the view that they originated in lymphatic glands, though this origin cannot of course be altogether excluded. The buboes in the rats infected by feeding were always in the sites of known lymphatic glands, while the abscesses in the present

series of animals occurred in places where no lymphatic glands could be demonstrated in normal animals.

6. *Chronic Rat Plague in Bombay.*

It is a remarkable circumstance that chronic plague rats, either with abdominal or peripheral abscesses, seem scarcely to exist in Bombay. Among more than one hundred thousand live and dead rats (*M. decumanus* and *M. rattus*) examined by us, only one has been found with lesions corresponding to those under discussion. The details of this rat are briefly as follows.

Mus decumanus: 27. VIII. 06—weight 310 grammes—trapped alive. The spleen contains a small abscess about the size of a large pea with semi-liquid purulent contents. The spleen is attached by a fibrous band to an abscess which is adherent to the abdominal wall above the left kidney and to the mesentery. A third abscess is situated between the spleen and the left kidney and is adherent to both these organs. A fourth abscess is situated below the left kidney and in close relation to the coecum. Microscopically the abscesses show a very large number of organisms, both coccal and bacillary forms. A guinea-pig inoculated cutaneously with the pus of one of the abscesses remained healthy, but cultures on Conradi-Drigalski medium of the pus from the splenic abscess furnished a pure growth of *B. pestis.*

We can put forward no adequate explanation of the reason for the relative frequency of chronic rat plague in the Punjab villages and for its rarity in Bombay.

7. *The Relation of Chronic Rat Plague to acute Epizootic Plague.*

The relation in time between the cases of chronic plague and the prevalence of acute epizootic plague is shown in the following table (Table VI) as far as the two villages chiefly investigated are concerned.

It seems fairly clear from these figures that the peripheral type occurs especially during the progress of the acute epizootic, and chiefly during its decline, while the visceral type is found more commonly in the intervals between the epizootics. Thus four-fifths of the peripheral type and only one-half of the visceral cases occurred during the prevalence of the epizootic.

We have little evidence which might bear on the aetiology of this interesting condition; and still less to explain the varying seasonal incidence of the two types. A diminution of the virulence

of the bacilli would appear to be excluded by the experiments with the organisms in the abscesses already detailed (p. 465). *If observations on the rats of Bombay may with propriety be transferred to Punjab rats,* an increase in the immunity of the rats may be excluded. There are reasons for thinking that the mode of infection of the peripheral group of cases is the same as that which operates in acute plague, and for these a diminution of the quantity of bacilli inoculated is a suggestion which receives support from the observed diminution in the

TABLE VI.

	Kasel			Dhand		
Date	Acute	Chronic peripheral	Chronic visceral	Acute	Chronic peripheral	Chronic visceral
Dec. 1905	—	—	2	—	1	2
Jan. 1—20, 1906	—	—	—	—	1	—
,, 21—27	—	—	—	1	—	—
,, 28—Feb. 3	—	—	—	3	—	—
Feb. 4—10	—	—	—	2	—	—
,, 11—17	—	—	—	—	1	—
,, 18—24	—	—	—	1	—	—
,, 25—Mar. 3	—	—	—	3	1	—
Mar. 4—10	—	—	—	3	—	—
,, 11—17	—	—	—	1	1	1
,, 18—24	—	—	—	3	—	—
,, 25—31	—	—	—	3	—	—
April 1—7	5	—	1	6	1	—
,, 8—14	5	—	—	—	1	—
,, 15—21	15	2	—	2	—	—
,, 22—28	22	—	—	—	—	—
,, 29—May 5	44	—	—	—	—	—
May 6—12	48	—	—	—	—	—
,, 13—19	42	—	—	—	—	—
,, 20—26	23	3	—	—	—	—
,, 27—June 2	12	2	—	—	—	—
June 3—9	5	—	—	—	1	—
,, 10—16	9	2	1	—	—	—
,, 17—23	2	2	—	—	—	—
,, 24—30	3	—	1	—	—	—
July 1—7	1	—	—	—	—	—
,, 8—14	1	—	1	—	—	—
,, 15—21	1	—	—	—	—	—
,, 22—31	—	—	—	—	—	—
August	—	—	1	—	—	—
September	—	1	—	—	—	—
October	—	—	2	—	—	—
November	—	1	1	—	—	—
Dec. 1—14	—	—	1	—	—	—

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prevalence of fleas in the Punjab coincident with the decline of acute plague[1]. The remarkable difference between the prevalence of chronic plague in Bombay and in the Punjab villages cannot be explained. In Bombay the intervals between the acute epidemics are filled in with a small but continuous prevalence of acute plague in rats and men, while in the Punjab they are occupied by scattered instances of chronic rat plague without any human plague. As far as can be ascertained, the bacilli and the fleas in the two places show no suggestive difference in any respect.

We may next proceed to consider whether rats affected with chronic plague, such as we have described, possess any significance as a source of bacilli in the recrudescence of acute epizootic plague. The bacilli in these lesions seem strictly localised, and it would appear that they could only become available for other animals in one of two ways:—(1) the chronic lesion lights up into an acute condition, or (2) rats become infected with acute plague by eating animals with chronic plague.

Considerations based upon the morbid anatomy of the lesions in chronic plague appear to us to bear against the view that the condition may become acute, e.g. by an abscess rupturing into the peritoneum or into a vein. Adhesions seem to form readily so as to limit the lesion, and most of the abscesses had thick fibrous walls. There is too no direct evidence of any such "lighting up": no rats have been found with lesions suggestive of such an occurrence, which would, however, not be without parallels in human pathology.

We have no reason to think that rats contract acute plague in nature by feeding on the carcases of chronic plague rats. Rats infected by feeding show mesenteric buboes (p. 373), and neither in Bombay nor the Punjab have these been found in any rat dead of acute plague.

It is therefore not easy to see how these chronic abdominal abscesses can afford a source of origin for an acute epizootic. The fact, however, remains that they are the only place where plague bacilli are known to occur in the intervals between the epidemics of acute rat and human plague in the Punjab, and direct experiment has demonstrated that the abscesses may give rise to acute plague when fed to healthy rats.

The evidence at present available although suggestive justifies no positive conclusion as to the epidemiological importance of these rats.

[1] This will be fully described in a later paper.

8. *Summary and Conclusions.*

(1) The characteristic feature of chronic rat plague as described in the foregoing account is the presence of circumscribed abscesses containing plague bacilli in rats caught alive, the animals usually showing no other lesions nor signs of ill-health. No bacilli were seen on microscopical examination of the heart-blood and of the spleen tissue in any of the rats. The bacilli in the great majority of the cases were virulent.

(2) We have grouped the 45 rats conforming to this description which were found during the year's investigation in the Punjab into two classes, one group including those in which the lesions were situated in the abdominal viscera, and the other group including those in which the abscesses were found in regions occupied by peripheral lymphatic glands.

(3) Lesions of the viscera were found principally in the spleen and in the mesentery, while the submaxillary group are most frequently affected among the lymphatic glands.

(4) The peripheral type was observed chiefly during the decline of the epizootic, while the visceral type predominated in the off-season.

(5) In Bombay, only one chronic plague rat was met with out of 17,000 plague-infected rats. In Kasel, 9 % of all the rats which were proved plague infected had the chronic disease, while in Dhand the proportion was as high as 28%. With our present knowledge we can advance no adequate explanation of these facts.

(6) We have no direct evidence that chronic plague, as it occurs in the Punjab villages, possesses any significance in the seasonal recurrence amongst the rats of the infection in an acute form, nor is any evidence available which excludes this possibility.