RATS AND THEIR EXTERMINATION.*

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I NEED no excuse for drawing the attention of this Society to the public health aspects of the rat problem and the methods of destroying these pests.

There are two main families of rats:—*Mus Rattus*, the common rat of India; it formerly inhabited Europe but has been replaced in England since about 1728 by its stronger cousin the brown or grey rat *Mus Norvegicus* or *Mus Decumanus*, which about that time was conveyed from Persia and India in ships to England and soon practically exterminated the *Mus Rattus*. I have here three stuffed rats which show the differences between the different varieties. The rat in the centre is the common sewer or field rat, the *Mus Decumanus*; the other two are both of the same family *Mus Rattus*, one is black—the usual colour—the other approximates in colour to the *Mus Decumanus*. The essential differences between the two varieties are:—

Mus Decumanus.

Larger and stronger,
Shorter face,
Ears small and narrow,
Tail shorter than body.

Mus Rattus.

More lightly built,
Long pointed face,
Ears large and wide,
Tail longer than body.

The *Mus Rattus* is now found in England in the neighbourhood of docks and wharves only and is conveyed from abroad in merchandise or escapes from foreign going vessels. On Liverpool ships about 90% are of the "black" variety. It is often desirable to ascertain the variety of rat which occupies a certain warehouse; this may be done by examining the entrances to the rat-runs and noting the nature of the rat excreta. In the case of *Mus Rattus* they are smaller, thinner, drier and blacker than in the case of *Mus Decumanus*.

The subject of plague conveyance will be dealt with later, but at this stage we may note that rats in different parts of the world are infested by different varieties of fleas: e.g., the Indian rat has associated with it the *Pulex* or *Xenopsylla Cheopis*, which will bite man readily. Until a few years ago, *Xenopsylla Cheopis* had never been found in England; then a few specimens were found on rats in Plymouth, and more recently a large number has been found on rats examined at Guy's Hospital, London. In Marseilles the *Xenopsylla*

Cheopis is frequently found on rats. The common rat-flea of this country and of North and Central Europe is the *Ceratophylus Fasciatus*, which feeds on man as readily as on a rat. It is by the agency of these two fleas that bubonic plague is conveyed from rats to men. Another variety of flea found on English rats is *Ctenophthalmus Agyrtes*, which does not bite man, and hence plays no part in the transference of plague from rats to human beings. There is a seasonal incidence of fleas on rats, and a close relationship has been found to exist between the maximum prevalence of fleas and the maximum severity of plague. The number of fleas found on rats depends also on the material amongst which the rats live, being relatively few when they live in the open air, as in the Suffolk epizootic, where 504 fleas only were found on the 568 rats examined, approximately one half the total number being *Ctenophthalmus Agyrtes*, which does not bite man. This number, approximately one man-biting flea to two rats, was not found sufficient in India to cause an epidemic amongst men. In Bombay the average number of man-biting fleas per rat is from 3 to 7, and in the Punjab, where plague is very prevalent, from 2 to 12. The general condition of a rat is also a factor in the number of fleas found. I have examined six healthy ships' rats without finding a single flea, and 26 were examined in Glasgow last year with a similar negative result. All these rats had been in traps for a few hours before examination and possibly the fleas had jumped off.

Habits of the Rat.—*Mus Decumanus* shuns mankind and lives mostly in open fields and in sewers, stables, etc. *Mus Rattus*, on the other hand, is domesticated and lives in human habitations. In India nests of black rats have been found in occupied rooms. This variety of rat was prevalent in England during the great epidemics of plague in London in the fourteenth and seventeenth centuries.

Natural Increase.—Rats breed very rapidly; they may have a litter four or five times a year, and the average number in each litter is six. They reach sexual maturity at the age of five months. They carry their young about twenty-four days. It has been estimated that a single pair of rats can, under suitable food conditions, produce 198 descendants in twelve months and 858 in sixteen months. A still larger estimate is made by Drs. Martin and Rowland, who state that, under favourable circumstances, a single pair may have 1,000 descendants at the

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end of twelve months. Hence it is that efforts directed towards rat destruction for a limited period are of little value, because, provided there is sufficient food, the rats can breed up to their original numbers in a few months.

Number of Rats.—This is a very difficult estimate to make, but there is probably a minimum of 40,000,000 in the British Isles. Six hundred have been caught on a single ship in the course of a few days. A rat-catcher at Lime Street Station, Liverpool, caught 200 in one day. On an estate of 2,000 acres near Chichester 37,000 rats were caught during 1904.

Damage Caused by Rats.—Enquiries and experiments have shown that each rat destroys on an average, food and material worth $\frac{1}{4}$ d. a day, or 7s. 7 $\frac{1}{4}$ d. a year. Hence, rats cause a total loss each year in the British Isles of at least £12,000,000; this is quite apart from the loss they cause by (1) the introduction of disease, and consequent loss of human life, and (2) loss to trade by quarantine laws. Instances of material damage, as opposed to damage caused by their acting as disease-carriers, are very numerous: at a brewery in Scotland rats gnawed through oak beams supporting a tank, which fell and smashed £2,000 worth of machinery. A manager of a seed farm states that rats destroy and spoil annually at least £1,000 worth of seed and plants belonging to his firm. Poultry farmers, grocers, flour millers, leather manufacturers, drapers, librarians, gamekeepers and estate agents are amongst those who complain bitterly of the great damage done by rats. As an illustration of their sagacity, it may be mentioned that they have been seen to convey eggs by one rat lying on its back, taking an egg between its legs, whilst the other rats pull it by its tail. Lead soilpipes into which rats have eaten holes have not infrequently been found; they also cause damage by making runs under drain pipes, which fall and cause the joints to open. They sometimes gnaw through water mains and cause great damage by the consequent loss of water.

Several cases of rat-bite fever have recently been recorded: after an incubation period of from one to twenty-one days the patient becomes feverish and develops a painful inflammatory reaction at the site of the bite. Death sometimes occurs after a prolonged illness. A protozoon is said to have been found in the blood. It may be mentioned that trypanosomes are not infrequently found in rats.

Serious though these are, yet they are not nearly so important as is the damage done by rats through the dissemination of disease. It is not generally known that trichinosis is largely spread by means of the rat. Rats infected with trichinosis have often been found in Germany, and some time ago 3 per cent. of the rats killed at the Glasgow City Abattoir were found to contain the *Trichina Spiralis*. It is thought that the rats are infected by eating the trimmings of condemned pork; pigs are infected by eating the dejecta of trichinous rats. No sooner has a case of trichinosis been reported to the health authorities in Germany than the wholesale destruction of rats is undertaken as a matter of course.

Investigations are now proceeding which will probably show that rats are concerned in the dissemination of foot and mouth disease and of the influenza of horses.

Rats and Bubonic Plague.—It is only within the past few years that the exact mode of conveyance of plague from rat to man was discovered, but some 3,000 years ago the association between plague and rats (or mice, as they were then named,) was recognised, and in the book of Samuel it is related that "after 50,000 persons had died of plague in Ashdod, the priests directed the people to make an offering to God in the shape of five golden images of the emerods in their secret parts (inguinal buboes) and five golden images of the mice that marred the land." In the famous painting of this subject in the Louvre, rats are depicted in the streets. In the "*Bhavagta Purana*," written in Hindustani some 800 years ago, the people are warned to leave their houses as soon as any dead rats are seen. Thomas Lodge, in his "*Treatise of the Plague*," dated 1603, states that in London, during epidemics of plague, rats and moles, which generally live underground, forsook their holes "owing to the corruption of the soil."

It is now well known that an epidemic of bubonic plague amongst man is almost invariably associated with an epizootic amongst the lower animals. Rats are by far the most important animals in the dissemination of plague, but it has recently been shown that the ground squirrel of California, the marmot and the tarabagan may all suffer from plague and, indirectly, infect man.

Both *Mus Decumanus* and *Mus Rattus* suffer from plague. The troopship "*Antillean*," on which cases of plague occurred, contained *Mus Decumanus* only. Some years ago about 150

plague-infected rats found in Glasgow were nearly all *Mus Decumanus*. No black rats were found during the Suffolk epizootic of 1910. The plague-rat found in Bootle last year was a brown rat. The *Mus Rattus* is generally associated with plague epidemics because it lives in and about the habitations of man, whilst *Mus Decumanus* shuns man whenever possible. This explains how it is that several epizootics amongst rats in ports and on ships have been discovered without the occurrence of a single human case. On the other hand, cases of human plague have occurred in Great Britain, *e.g.*, Glasgow (1900 and 1901), Liverpool (1901 and 1908), in which no plague-infected rats were found amongst many hundreds examined; but plague-rats were found in Glasgow in 1902. As only a small proportion of rats, *e.g.*, 6 per cent. in Bombay, suffer from plague during an extensive epizootic, it might easily occur that the few infected rats might not be discovered. A serious epizootic occurred in Cardiff in 1901, and was associated with two human cases. The Suffolk outbreak of 1909 will be fresh in your memories. There, four definite human cases occurred, and plague-stricken rats and hares were found over a wide area. As mentioned above, plague may occur in rats without any human case being discovered, *e.g.*, in Hamburg 350 plague-rats have been found since 1900, but no human cases have occurred. Plague-rats were found on the ss. 'Rembrandt' in 1901 without any associated human case either in the crew or in the seventy-seven Bristol dock labourers who unloaded the cargo of grain. Dr. Thompson, in 1904, gave a list of nine vessels in which plague had occurred in rats but not in man.

Within recent years plague has been found amongst the rats of many home ports, including London, Liverpool, Glasgow, Hull and Cardiff. It is difficult to obtain details of rat epizootics in other European ports, but Marseilles, Calais, Oporto, Odessa and Hamburg are all said to have been infected.

The recent history of plague in Liverpool and Bootle is interesting. The portion which relates to Liverpool is given by the kind permission of our president, Dr. Hope.

On June 19th, 1912, I was informed by the police that several dead rats had been seen in a certain warehouse in Bootle. The warehouse was visited and the information was verified; during the preceding two or three weeks about twenty dead rats had been found and thrown into the street by the warehousemen. No

more dead or dying rats were seen until July 1st, when a dead brown rat was found and sent to Professor Glynn. Microscopical examination showed that it had most probably died of plague, but it was about four weeks before it was conclusively shown that the organism which had been isolated from the animal was the *B. Pestis*. From July 2nd, efforts were made to capture as many rats as possible in that and other warehouses. A large number of rats, both black and brown, was examined, but in no other Bootle rat was any evidence of plague found.

Cargo (including blood and cotton-seed meal from the River Plate, cotton and oil-cake from Alexandria, and rice meal from Rangoon) which had come from infected countries was found in the warehouse.

No matter what precautions are taken it is almost impossible to prevent rats being conveyed ashore in merchandise. Cotton samplers tell me that they know of cases where a hand having been put into a bale of cotton for a second sample a rat was discovered. The Indian Plague Commission state that rats can dive into bags of grain or bran and disappear without leaving any evidence of their presence. They are very liable to be conveyed ashore in crates of goods packed in straw.

After the discovery of the plague-rat every effort was made to discover whether any other case in man or rodent had occurred, but none were found. I was informed that rats had not been particularly numerous. In only one store-shed had any dead or dying rats been seen, and there virus had lately been used.

On August 1st a plague-rat was found in a Liverpool cotton warehouse. Cotton from Alexandria, brought to England in the same ship, was present in both this and the Bootle warehouse. At the time the ship left Alexandria that port was reported to be free from plague, but human cases have occurred there both before that date and since. No dead rats were seen in this building; the plague-rat was caught in a trap. Another plague-rat was discovered in a warehouse adjoining the Liverpool cotton warehouse on August 30th.

In connection with these cases there was a most interesting occurrence. On July 24th a boy aged eight was admitted to the Liverpool Royal Infirmary with acute abdominal pain; it was thought that he had some septic focus in one of the deep inguinal glands, and he was operated upon. Inflamed glands were found, and one was removed for microscopical

examination; this was made the next day and the B. Pestis was found. The boy was removed to a city hospital on July 26th and died on August 23rd. On investigation being made it was discovered that this boy's brother, a youth aged about 17, had been taken ill on June 30th with lumps in his armpit and pneumonia. He died on July 2nd; the death was certified on July 5th to be due to "broncho-pneumonia," but the history of the illness was such that it was not improbably plague from which he died. A striking fact is that this youth who died of so-called "broncho-pneumonia" was a cotton sampler who had been employed in the cotton warehouse in which the plague-rat was caught some few weeks after his death. The disease may have been transferred from the youth to his brother by means of fleas: several flea-bites were found upon the boy.

These cases illustrate the necessity for being always on the watch for cases of plague in a seaport, and the occurrence of the disease in rats is one of the first danger-signals. It is desirable in every seaport to diffuse information amongst ship and warehouse owners as to the possible significance of disease amongst rats, and to ask their co-operation in efforts to diminish their number. It is probably unnecessary to examine all rats caught, but it is essential to make a post-mortem examination of all diseased or unhealthy rats and of all found dead, and also to examine a considerable *proportion* of all the rats which are caught, for it must be remembered that the susceptibility of rats to plague may vary considerably: they may even become almost immune to it. If there is any suspicion of plague, the rats should be immersed in petrol in order to kill the fleas.

The Indian Advisory Committee state that microscopic examination was, in their opinion, quite sufficient to establish or reject the diagnosis of plague, but the experience of the Suffolk outbreak shows that in England post-mortem examination, followed by microscopical and cultural tests, does *not* ordinarily suffice to establish a definite diagnosis: for that purpose inoculation tests in animals are necessary.

The points to be observed in the post-mortem examination of a rat are, in order of importance:—

1. A bubo—in about 75 per cent. of cases this is cervical, in 15 per cent. in the axilla, and in 6 per cent. in the groin. The gland when cut has a grey or yellowish cheesy spot in the centre.
2. Pleural effusion.

3. Subcutaneous congestion and hæmorrhages and a peculiar purplish-red appearance of the muscles.

4. A firm enlarged mottled liver with necrotic foci in it.

5. Enlarged spleen.

A plague-stricken rat is not necessarily emaciated.

Smears from the bubo, spleen and heart blood when stained with carbol-thionin blue should show bipolar rods.

To confirm the diagnosis, isolation of the B. Pestis is necessary. In the Bootle case, it was particularly difficult to make quite sure that the organism obtained was B. Pestis and not the B. pseudo-tuberculosis rodentium. It was eventually shown by inability to act upon isodulcite, glycerine, litmus milk and malachite green, and by its great virulence for rats that it was the B. Pestis.

Having shown the great need for rat-destruction, we must now consider the various methods of doing this. The first essential in conducting an anti-rat campaign is concerted action, for rats breed with such rapidity that they soon regain their former numbers by recruiting from neighbouring districts. If an endeavour is being made to clear a considerable area, a combined effort should be made at the periphery, and the rat-catchers should gradually work towards the centre where poisoned food, virus, and traps may be used. To prevent plague attacking a community, rats should be kept out of houses and places where food is stored, by every possible means. It is probably well known that rats, when deprived of food, eat their weaker brethren, and a most effective method of dealing with them is to prevent their access to food supplies, especially corn-stacks. Incidentally, I may mention a method which has been tried on ship-board: the method is to trap a dozen rats and kill the females: after starving the males for a few days feed them on the females, and then liberate them; they have a decided liking for rat-flesh and are said to clear a ship in a very short time; but eventually they kill each other and the experiment has to be started again.

In accordance with the Rat Laws of Barbadoes, dated 1745 and 1748, and of Antigua, dated 1880, a fee of 1d. or, in the earlier Acts, 2d. is paid for each rat caught. The Rat Ordinance 1902 of Hong Kong authorizes the Governor to make regulations for the destruction of rats and imposes a penalty of 100 dollars for any breach of them.

The Rat Law of Denmark was passed in 1907. It provides for a small payment of 3d. or 1d. for each rat caught, and for a State grant of £1,600 per annum; one-third in aid of research on the subject of rat extermination, and two-thirds for the purchase of preparations for destroying rats. It is now replaced by the Rat Law of 1910. Though the amount paid for each rat has been increased, the number caught in Copenhagen is gradually diminishing: the figures being 255,797 for the year ending June 30th, 1908, and 143,029 for that ending June 30th, 1912. In these Danish laws, heavy penalties are imposed on those who breed or import rats.

In November, 1910, the English Local Government Board made regulations, under the Public Health Acts, which make compulsory the destruction of rats and the taking of steps to prevent their access to buildings and other premises, in any district where a representation is made to the Local Authority that the rats in the district are infected or threatened with plague, or that there is unusual mortality amongst rats.

In country districts various animals are used to destroy rats, especially female ferrets and the mongoose; the weasel, kestrel and pine-marten are all good "ratters." The value of cats and terriers for keeping down rats must not be forgotten.

Baits containing poisons have been used for rat-destruction; the poisons generally used are strychnine, phosphorus, arsenical preparations, barium carbonate (recommended by the United States Department of Agriculture), and plaster of paris, which hardens in the stomach and is a particularly cruel method of destroying the animals. It has been stated that phosphorus causes the animals to dry up without smell, but this is not the case. Barium carbonate is said to make them come into the open to die. It may here be noted that rats are not found in those sewers of London (Soho) which are connected with the large garages, the smell of petrol which is washed into the sewers is said to drive them away.

Allied to poisons is the use of certain kinds of virus; these are cultures of organisms, generally of the Gærtner group, which produce an infectious disease in rats and are harmless to other animals.

The reports indicate that different strains of virus differ somewhat in efficacy. A disadvantage of these preparations is that the rats eventually become immune to them. An

advantage is that the dead bodies cause little or no odour.

A most interesting account is given by Dr. Melville-Davison of the use of a virus in vessels of the Booth Line. The virus was more successful in the older than in the newer ships; the explanation given is that by in-breeding, the rats on the older vessels are not so resistant as those on the newer boats. A virus was used in which the virulence had been increased by passage through "black" rats. The most remarkable fact, however, was that months after the virus had ceased to be administered on certain vessels, the rats in these ships steadily decreased in number owing, it was thought, to some of the rats acting as "carriers" and gradually infecting the others as their immunity diminished.

A disadvantage of all poisons and of virus in port-work is that the presence of a dead or dying rat is regarded as of no importance by ship and warehouse workers: if no poison or virus has been used, a dead or dying rat ought to cause one to think *immediately* of plague and have a careful examination made.

The use of traps is very commonly adopted: spring traps are probably the best.

In a seaport the method usually employed is to retain the services of a skilled rat-catcher, who traps the rats and submits a certain proportion of the presumably healthy, and *all* the unhealthy, ones for examination, and burns the others in a furnace. It is probably better to pay a fixed sum per annum than a certain amount for each rat caught.

A rat-catcher has been employed in Bootle since the beginning of 1911. He comes of a "rat-catching" family, his father and grandfather both having been in this business; his services are often requisitioned by property owners, tradesmen, and others. He regularly works in the sewers, the schools, the parks, and at the refuse destructor. An index of the work done is shown by the fact that in December, 1910, 340 rats were trapped in the course of a fortnight in the sewers of the borough; in the same places, and under exactly similar circumstances, 68 were caught in October, 1912.

Various methods have been proposed for killing rats on ships. Incidentally it may be stated that it is practically impossible to prevent rats reaching the shore from ships, as funnels, etc., on the hawsers are not successful, and the rats come ashore in merchandise. As has been mentioned, virus is used in certain

vessels, but most firms employ professional rat-catchers, who sometimes obtain hundreds of rats from a single ship.

Routine fumigation of ships is not now considered necessary. But disinfection is sometimes required, and "deratization" by fumigation or otherwise is essential when plague in man or rats has been discovered on a ship. Clayton Gas, containing 10 per cent. of SO_2 is very useful in empty vessels, but is unsuitable for full holds and seriously damages many kinds of cargo, e.g., flour. Some recommend Clayton Gas mixed with 10 per cent. producer gas, which contains carbon monoxide. In empty vessels it often suffices to burn $1\frac{1}{2}$ lbs. of sulphur for each 1,000 cubic feet of air space. The use of liquid SO_2 is expensive. One-half per cent. of SO_2 will kill rats and insects in two hours. Producer gas is generally used when disinfection of a full hold is required: it is very fatal to rats, but unfortunately has no action on insects. By reason of the fact that it is odourless, it is necessary, in order to prevent risk of poisoning human beings, to mix some odorous gas, such as carbon bisulphide, with it.

I think I have said enough to convince you of the great importance of this subject, and I hope that in the near future an effort will be made to deal with rat destruction on a large scale and in a comprehensive manner.

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REVIEW.

LONDON PUBLIC HEALTH ADMINISTRATION. By W. McC. Wanklyn, B.A. Cantab., M.R.C.S., L.R.C.P., D.P.H., etc. Longmans, Green and Co. 2s. 6d. net.

A small work on this subject has just been published which will be of considerable value to those engaged in the practice of the law in public health in London, and will no doubt be found useful to those who desire to have information concerning the particular duties which devolve on the numerous local authorities engaged in London administration. The work is from the pen of Dr. W. McC. Wanklyn, who has set out, mostly in tabular form, the several duties, the authorities on which they devolve, and the powers under which they act. The work also contains, in chronological order, a list of the Acts of Parliament relating to a variety of subjects of municipal concern.