

THE OCCURRENCE OF FOOT-AND-MOUTH DISEASE IN THE HEDGEHOG UNDER NATURAL CONDITIONS

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(With Plate 11 and 2 Figures in the Text)

A feature of a series of outbreaks of foot-and-mouth disease at Boughton, Norfolk, during the summer of 1946 was the finding of a number of hedgehogs, *Erinaceus europaeus*, affected with the disease. This is the first record of the discovery of naturally infected hedgehogs showing specific lesions, although in 1933 foot-and-mouth disease virus was isolated from the tissues of an apparently normal hedgehog caught in an orchard on infected premises 14 days after confirmation of the disease in cattle, sheep and pigs (Andrews, Eccles, Hole, Polding, Longley, Hamilton & Graham, 1937). The fact that the hedgehog is susceptible to the virus of foot-and-mouth disease has been known since Minett (1927) reported the successful transmission of the disease by artificial inoculation. Later Gibbs (1931) showed that the disease could be transmitted from hedgehog to hedgehog by contact. Since then the animal has been much used in this country for experimental purposes in foot-and-mouth disease research.

SHORT HISTORY OF THE BOUGHTON OUTBREAKS

The disease was first confirmed on 13 June 1946, affecting forty-four out of sixty-four cattle and seventeen out of 368 pigs, outbreak no. D.F. 7901. The most advanced lesions were estimated to be 8–10 days old and were found in a group of young cattle in a small field along with a few of the pigs. The next outbreak, D.F. 7902, was confirmed on 16 June, three out of twelve cows being affected. These cows were at pasture except when being milked and the disease was almost certainly conveyed from D.F. 7901 to this farm by means of animal movement, the beast with the oldest lesions having broken into a field containing stock on D.F. 7901, 10 days earlier. The third outbreak, D.F. 7904, was confirmed 16 days later on 2 July

three out of forty-six cattle being affected; these animals were also at pasture except when being milked. The fourth outbreak, D.F. 7905, was confirmed on 18 July, two out of thirty-seven cattle being affected; again the animals were at pasture except for milking. These four farms were more or less adjacent to each other, all lying within a circle of 800 yards radius from the village of Boughton (Fig. 1). On 11 August a fifth outbreak, D.F. 7906, was confirmed near Oxborough, about 3 miles from Boughton, affecting thirty-six out of forty grazing bullocks, the lesions on some of these animals being at least 1 week old. No history of direct contact was established between this outbreak and the infected farms at Boughton. It is perhaps unnecessary to stress that while there is no satisfactory evidence to explain the origin of the outbreak at Oxborough there is no apparent reason for dissociating it from the other outbreaks in the area.

No completely satisfactory explanation was found for the origin of the primary outbreak which was the first for 5 months in this county but the following facts were noted: the district had been receiving imported meat for the previous few months; the occupants of a bungalow adjoining the small field containing the stock with the oldest lesions had discarded kitchen waste over the hedge into the field; bones and other household refuse were found at this point which suggests the possibility of the stock having access to the refuse of imported meat products and these, on occasion, have been incriminated as a source of infection (Cabot, 1945).

In accordance with the provisions of the Diseases of Animals Act, 1894, the Foot-and-Mouth Disease Order of 1928 and the Foot-and-Mouth Disease (Infected Area Restrictions) Order of 1938 for the control of foot-and-mouth disease in England, Wales and Scotland, the required infected area and infected place restrictions were enforced, all ruminants and

swine affected, suspected of being affected or exposed to infection were slaughtered and all infected premises were disinfected. Normally an infected area ceases to be such for the purpose of the restrictions imposed by the 1938 Order at the end of 3 weeks from the date of confirmation of the last outbreak, but in this case the restrictions were maintained until 28 days after the finding of the last affected hedgehog on 28 August, thus these area restrictions were in force from 13 June, the date of the first outbreak, to 25 September. Table 1 summarizes some facts relevant to the outbreaks among farm stock.

found with lesions, two on 21 August in the field where the cattle were buried and one on 28 August in the next field, the field where the cattle were grazing at the time the disease was confirmed. The cattle had been moved to this field from an outlying pasture about three-quarters of a mile away 2 days before the disease was confirmed. From the age of some of the lesions on the cattle it was evident that the disease had started in the herd while it was in this outlying field. No affected hedgehogs were found from the neighbourhood of this pasture. The place where each affected hedgehog was found is shown in Figs. 1 and 2.

Table 1. *Summary of information concerning the outbreaks of foot-and-mouth disease in farm stock*

No. of outbreak	Confirmed	Stock affected with estimated age of lesions	Slaughter of stock completed	Disinfection of premises completed	Immunological type of virus isolated
D.F. 7901	13. vi. 46	Cattle 8-10 days, pigs 24 hr.	16. vi. 46	1. vii. 46	Vallée O
D.F. 7902	16. vi. 46	Cattle about 12 hr.	17. vi. 46	30. vi. 46	—
D.F. 7904	2. vii. 46	Cattle about 12 hr.	4. vii. 46	20. vii. 46	—
D.F. 7905	18. vii. 46	Cattle about 12 hr.	20. vii. 46	31. vii. 46	—
D.F. 7906	11. viii. 46	Cattle 8-10 days	14. viii. 46	26. viii. 46	Vallée O

THE FINDING OF HEDGEHOGS WITH LESIONS OF FOOT-AND-MOUTH DISEASE

About noon on 8 July a veterinary inspector of the Ministry of Agriculture's Animal Health Division noticed a sick-looking hedgehog, Hedgehog A, beside a road about a quarter of a mile from D.F. 7901, 7902 and 7904. Examination showed this animal to have small unruptured vesicles on the feet about 1-2 mm. in diameter which ruptured on pressure. It was drowned and the carcass sent to Pirbright where foot-and-mouth disease virus was isolated by guinea-pig inoculation from the epithelium of the feet, the heart-blood clot and the bone marrow. On the next day a dead hedgehog was found outside the buildings of D.F. 7904 with old ruptured lesions on the feet. Trapping of hedgehogs was now attempted and although the help and advice of the Pest Officers of the Norfolk War Agricultural Executive Committee was extremely valuable, it was at no time an easy task. The use of rabbit spring-traps baited with rabbit flesh, rabbit paunches or hens' eggs met with some success when the rabbit bait became tainted. A number of hedgehogs were also caught at dusk without trapping. By the end of July, fifteen adults had been caught or found dead within a radius of three-quarters of a mile of the village. In addition to the two mentioned above, four others were found to be affected with foot-and-mouth disease; two found on 15 July and one on 17 July on or close to infected premises and one, hedgehog F, on 23 July in a field three-quarters of a mile from the infected farms. Later, following the outbreak near Oxborough, D.F. 7906, three more hedgehogs were

Table 2 summarizes the results of the examination of the affected hedgehogs which with Table 1 shows the relation of the finding of each to the outbreaks of the disease in farm stock. A knowledge of the incubation period of the disease in the hedgehog is necessary for a proper appreciation of these tables and fortunately there is a considerable amount of information available on this point as a result of the experimental use of the animal. The records of a series of experiments conducted at Pirbright by Dr J. T. Edwards and his colleagues (unpublished work) in which a total of over 100 susceptible hedgehogs were kept in contact with infected hedgehogs show that an incubation period of 2-14 days is not unlikely. Applying this information to the data in Tables 1 and 2 and, for the moment, leaving out the question of the range of movement of the hedgehog it will be seen that the time factor is such that it is unnecessary to look further than direct or indirect infection from the affected farm stock to account for the presence of the disease in those hedgehogs found with lesions. This point is of some importance as the possibility must be considered of the disease having spread among the hedgehog population.

In an attempt to gain further information about this possibility it was decided to obtain as many live hedgehogs as possible from this area and determine whether or not they were susceptible to the virus isolated from these outbreaks. If, as a result of such an examination, it was found that a number of apparently normal hedgehogs were immune to this virus strain it would be more suggestive that the disease had occurred in the hedgehog population and

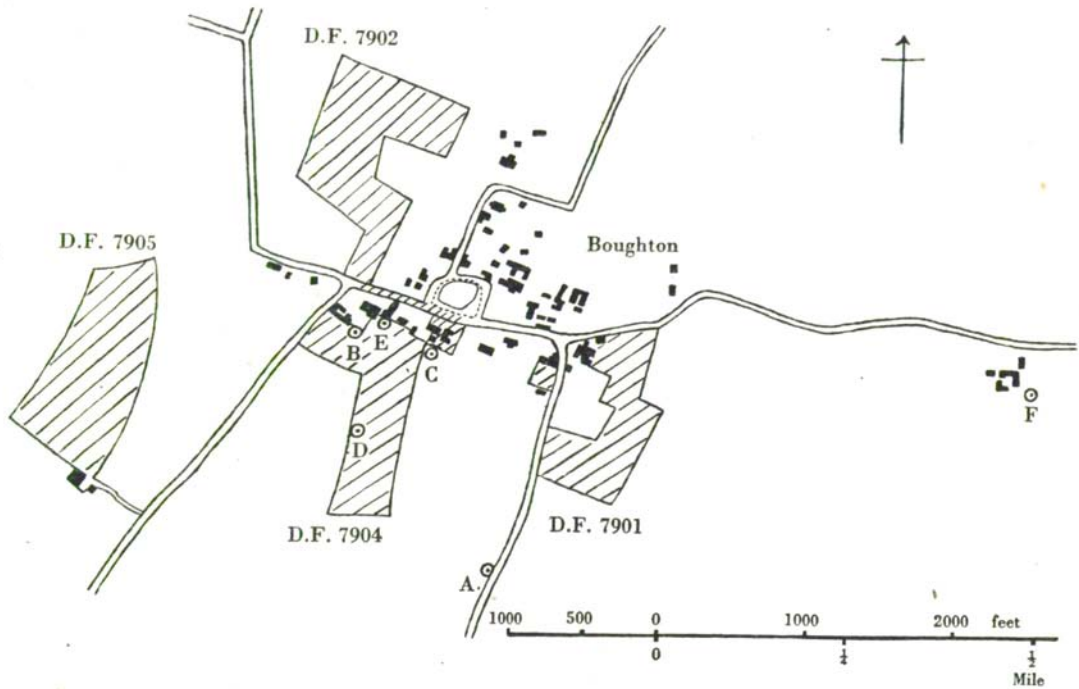


Fig. 1. Map of Boughton village showing the position of the infected premises and the sites where affected hedgehogs, A-F, were found. The shaded areas indicate the ground covered by the diseased farm stock at each outbreak.

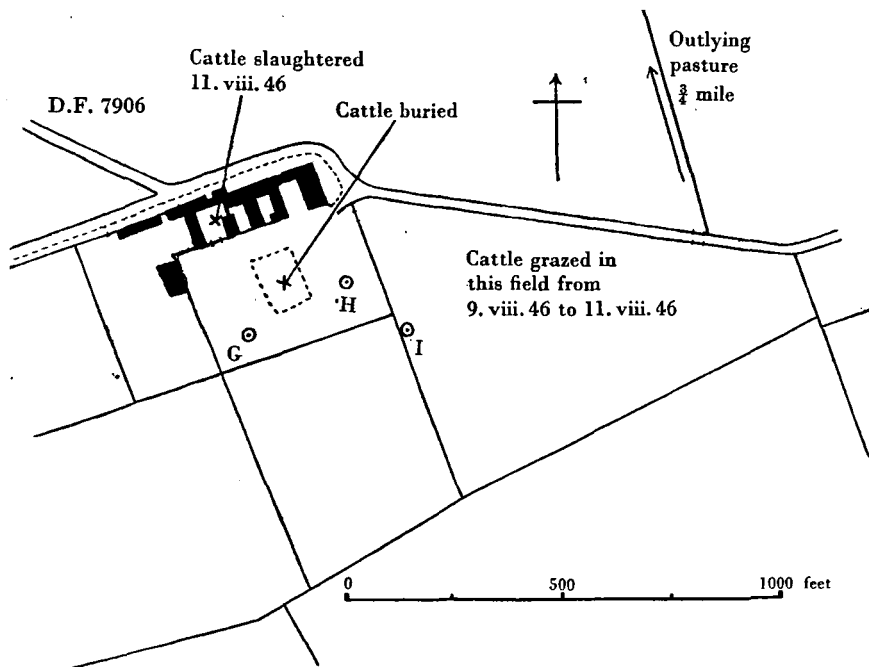


Fig. 2. Map of the infected farm near Oxborough showing the ground covered by the diseased farm stock and the sites where affected hedgehogs, G-I, were found.

not that the affected ones found were purely the outcome of fortuitous contact with the virus on the infected premises. A member of the Animal Health Division staff supervised the catching and feeding of these hedgehogs; they were kept in wooden cages supplied by the Research Station and were fed on kitchen waste consisting of meat scraps, bread and milk. Eventually five apparently normal animals were brought to Pirbright for test.

Samples of 3-5 c.c. of blood were obtained by cardiac puncture under A.C.E. mixture anaesthesia. Pooled serum from these samples was tested for the presence of foot-and-mouth disease virus and antibody with negative results. The test for the presence of virus consisted of the intradermal inoculation of the plantar pads of nine guinea-pigs; no reaction was

FOOT-AND-MOUTH DISEASE AS IT AFFECTS HEDGEHOGS

A detailed description of the lesions found following the infection of hedgehogs with foot-and-mouth disease virus has been given by Edwards (1931). It need only be stated briefly that in most cases the whole of the hairless skin of the feet becomes involved in a vesicular lesion, the epithelial covering of which can be readily stripped off; in addition vesicular or abraded lesions may be found on the snout, margins of the lips, tongue and in the perineal region. Pl. 11 illustrates typical lesions, those found on hedgehog G. There is also some systemic disturbance and it is not uncommon in the laboratory for death to occur about a week after the development of the

Table 2. Summary of information concerning the finding of hedgehogs with lesions of foot-and-mouth disease

Identity of hedgehog	Date of finding	Estimated age of lesions	Result of examination for presence of virus	Immunological type of virus isolated
A	8. vii. 46	5-8 days	Positive	Vallée O
B	9. vii. 46	7-10 days	Negative	—
C	15. vii. 46	2-3 days	Positive	Vallée O
D	15. vii. 46	Unknown	Not examined	—
E	17. vii. 46	3-8 days	Positive	Not examined
F	23. vii. 46	2-6 days	Positive	Vallée O
G	21. viii. 46	3-4 days	Positive	Vallée O
H	21. viii. 46	Unknown	Not examined	—
I	28. viii. 46	Lesions first observed 29. viii. 46	Negative	—

produced. The antibody test consisted of the simultaneous inoculation of three guinea-pigs with 2 c.c. of serum subcutaneously and with a virus suspension intradermally on one plantar pad using the strain of virus isolated from the primary outbreak in cattle, strain no. 644, Vallée O type. No evidence of protection was observed. The quantity of serum available was insufficient for a more elaborate test. These five hedgehogs were later inoculated intramuscularly with strain no. 644 and all proved to be susceptible.

At different times during this period the carcasses of apparently normal hedgehogs were sent to the laboratory but no virus or antibody was recovered from the small number that could be tested.

In all, from 9 July to 23 September, fifty-six adult hedgehogs were examined for the presence of vesicular lesions on the tongue, snout and feet; such lesions were found in nine animals and the virus of foot-and-mouth disease was isolated from the tissues of five of them. The strains isolated from the hedgehogs were of the same immunological type as the strain responsible for the outbreaks in cattle.

In the natural state there is no doubt that the lesions on the feet of an affected animal must be a severe handicap to its ability to forage and may necessitate it attempting to seek food at periods during the day as well as at the usual time of during the night. Those affected hedgehogs found alive at Boughton and Oxborough were all found during the day; they appeared dazed, disinclined to move and when approached did not roll up; it seemed, in fact, that they were found only because of their inability to follow their normal habits. As the disease is likely to be fatal its occurrence among hedgehogs may not be suspected even if a dead animal be found; the mouth and feet are sites frequently infested with fly larvae, the activities of which soon remove traces of lesions.

In addition to the overt disease there is the condition in which the virus can be isolated from the tissues of apparently normal hedgehogs in that no external vesicular lesions are visible. An example of this has already been mentioned and the same thing has been described experimentally by Edwards (1931), Andrews *et al.* (1937) and Hulse & Edwards

(1937). In these animals the focus of infection is often in the respiratory tract and again the disease is likely to be fatal. Hulse & Edwards have also shown that hedgehogs infected just before hibernation may harbour the virus in their bodies for some weeks and then develop clinical foot-and-mouth disease on awakening and be capable of spreading the infection to other hedgehogs.

EXPERIMENTAL TRANSMISSION OF FOOT-AND-MOUTH DISEASE FROM HEDGEHOGS TO CATTLE AND VICE VERSA

A limited number of transmission experiments have been conducted at Pirbright, the results of which show that it is possible, under experimental conditions at least, for infection to pass by contact from infected hedgehogs to cattle and from infected cattle to hedgehogs (Andrews *et al.* 1937).

DISCUSSION

The occurrence of foot-and-mouth disease in the hedgehog under natural conditions gives grounds for speculation as to the part the hedgehog may play in the epidemiology of the disease. There is no reason to dissociate the Norfolk series of outbreaks in cattle from the occurrence of the disease in hedgehogs and it now remains to consider the part played by the hedgehog.

Although we have record of a few facts these are insufficient to enable a definite conclusion to be drawn. It would no doubt be possible under certain circumstances for the disease to occur in the hedgehog population and for the hedgehog to act as a natural reservoir of infection especially since it has been shown to be capable of harbouring the virus during hibernation. It seems improbable that this has ever been of more than rare occurrence as we now record only the second instance of the isolation of virus from the hedgehog under natural conditions and only the first instance of the finding of clinically affected animals.

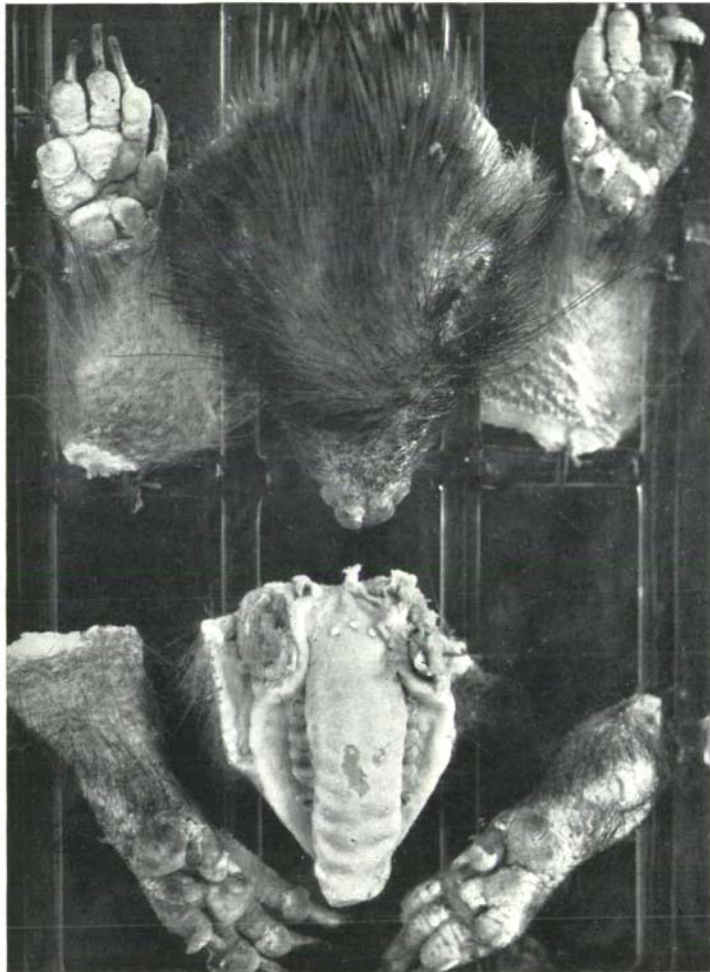
The chance of the disease spreading from infected farm stock to hedgehogs must depend principally on the relative numbers of each and on the length of time the disease goes unreported. The normal habitat of the hedgehog is rough ground, hedges, copses and woods, anywhere where there is a certain amount of cover, a type of country found in most parts of Britain excluding the higher ground. Hedgehogs are creatures of nocturnal habit and although only seen occasionally are relatively common as is evident when efforts are made to trap them. They are not infrequently found in and around farm buildings. Their activities cease during hibernation from

November to February or March, but during the rest of the year there is certainly opportunity for an infective agent to pass from farm stock to hedgehogs and vice versa.

In connexion with the Norfolk series of outbreaks in cattle the following possibilities exist: a few hedgehogs may have become infected directly or indirectly from the cattle but were not responsible for any further spread; this probably occurred on D.F. 7906 at Oxborough where three affected hedgehogs were found some 10 days after the disease had been confirmed and the cattle slaughtered and buried, the cattle having only been at this place for 2 days before slaughter. On the other hand, a few hedgehogs may have become infected from cattle and these individuals were responsible for further spread of the disease to cattle; this seems reasonable in the case of the last two outbreaks at Boughton. It would provide a possible explanation for the outbreaks at D.F. 7904 and D.F. 7905 which, it will be remembered, occurred after an unexpectedly long interval. It might be argued that the fact that in both cases only two or three of the herd were found to be affected at the time of confirmation and slaughter was not inconsistent with what one would expect if an infected hedgehog had introduced the disease. On the other hand, once the disease exists in an area, subsequent outbreaks are usually detected at an early stage so that the chance of spread in the herd before slaughter is diminished. There is also the possibility that the disease may have started in hedgehogs by contact with infective kitchen waste and that they subsequently transmitted the disease to the cattle on D.F. 7901, thus providing an origin for the primary outbreak, a suggestion that can neither be confirmed nor refuted.

Lastly, there is the question of whether the disease spread among the hedgehog population. The small number of apparently normal animals that could be tested from the same district showed no evidence of previous experience of the virus so the only information we have of the existence of the disease in the hedgehogs is the finding of nine affected animals out of a total of fifty-six over a period of 11 weeks. We have already stated that the time factor is such that direct or indirect infection from the diseased farm stock could account for the infection of those hedgehogs found with lesions. The relation between the time of finding the affected hedgehogs, the estimated age of their lesions, the incubation period of the disease in hedgehogs and the time when affected cattle were present or when infected premises had not been disinfected makes this possible.

When we consider where the affected hedgehogs were found, however, it is not so easy to draw the same conclusion. Hedgehog A was found at a point 350, 600 and 400 yards respectively from the nearest piece of ground covered by the affected cattle on



The feet and head of hedgehog G showing ruptured and unruptured vesicular lesions of foot-and-mouth disease on the pads of the feet, the tongue and the snout.

D.F. 7901, 7902 and 7904 and Hedgehog F was found three-quarters of a mile from infected premises. If it was neither likely nor possible for these animals to have travelled these distances from the known sources of infection then we are led to assume that they became infected as a result of spread of the disease presumably among the hedgehog population. We have no definite information about the normal range of movement of the hedgehog such as that provided by Elton (1937) for the vole by systematic trapping and marking. One is tempted to suggest that three-quarters of a mile would seem to be indicative of a definite migration but it is known that some small mammals sometimes migrate when they are ill. In view of the crippling nature of the feet lesions in foot-and-mouth disease, however, it seems unlikely that any long distance could be covered after their development. Whether there was any spread of the disease among the hedgehogs must remain an open question, but we cannot ignore the possibility that hedgehog F was one of a population of which we did not catch the intermediate diseased individuals connecting it with the infected premises.

It can be stated, however, that in certain circumstances the disease in cattle may be transmitted to hedgehogs which, whether they spread the infection to other hedgehogs or not, must exist as a menace to the health of the remaining susceptible stock in the neighbourhood.

SUMMARY

1. The occurrence under natural conditions of foot-and-mouth disease in the hedgehog, *Erinaceus europaeus*, is reported in connexion with outbreaks of the disease among farm stock in Norfolk during the summer of 1946.
2. Foot-and-mouth disease may be fatal in the hedgehog which decreases the chance of finding affected animals and of revealing the existence of the disease.
3. In this series of outbreaks it seemed probable that affected hedgehogs were responsible in some instances for spreading the disease to cattle and the possible role of the hedgehog in the epidemiology of the disease is discussed.

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