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**FOOT-AND-MOUTH DISEASE: THE QUESTION
OF INVASION.**

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THE way by which foot-and-mouth disease is brought into Great Britain and similarly situated countries from time to time, notwithstanding the fact that into the former in particular the importation of susceptible live stock is prohibited, is as mysterious as it is interesting. The subject has given rise to spasmodic discussions, but the possibilities do not seem to have been methodically debated in relation to the actual facts, so far as they are known. The happenings from the beginning of 1919 have provided more material than in former years for a closer analysis of the subject. The results do not bring finality to a question which for years has baffled the best scientists in Europe, but it may be that by elimination they indicate the direction to be followed in future inquiry.

It may be accepted as established that Great Britain, freed from the disease in enzootic form, is only invaded when the disease is prevalent on the Continent, particularly when it prevails in the north of France, Belgium, and Holland. In the light of recent experience, it would also appear that the greater the prevalence the more frequent are the invasions.

Live stock being excluded, it is not unnatural that general suspicion should have fallen upon human beings from the Continent where the disease is raging, and on imported feeding stuffs and litter. It may be mentioned, however, to save further discussion, that the importation of hay and straw, save for exceptional purposes, has been prohibited since 1908, and that the position as

regards foot-and-mouth disease has not apparently been modified in consequence.

For purposes of analysis and discussion outbreaks of foot-and-mouth disease fall into two classes: initial outbreaks of invasion, and secondary outbreaks which are local ramifications from the initially established centre. As regards the latter, investigation by the Ministry has seldom failed to establish satisfactorily the way by which disease has spread. Much useful information on this subject is available. It has been dealt with in former reports. It is with initial outbreaks of invasion, however, that this article is mainly concerned, and there have been sixty-three in the last twenty years. The term is applied by the writer to those outbreaks which arise after the country has been free from the disease for more or less long periods, which are far in excess of what we have reason to believe represents the viability of the virus inside or outside the bodies of animals—months or years—and to outbreaks occurring almost simultaneously in parts of the country very remote from each other—Surrey and Northumberland, for example—which have no possible connection with each other, except, perhaps, through the still mysterious agency whereby the virus travels long distances and in certain directions, this being apparently the same problem as that of invasion from without the country.

The above classifications of outbreaks may at first sight appear somewhat artificial. It will be apparent that it is not so, however, if due consideration be given to the following facts:—

(a) That there is often an excessively long interval of time between outbreaks—months and even years.

(b) That simultaneous but widely separated outbreaks may occur without any possible ordinary connection (feeding stuffs, men, etc.), between them.

(c) That for the last twenty years the policy of immediately slaughtering all affected animals and actual contacts before virus can be freely manufactured and disseminated by them has been almost exclusively followed, together with complete disinfection of infected premises both by chemical agents and prolonged isolation.

(d) That recurrences after re-stocking formerly infected premises with susceptible animals are practically unknown.

(e) That the same premises are almost never hit twice, as it were, by invasions after more or less long intervals.

In every outbreak it is customary for the Ministry's inspectors to collect the fullest information possible regarding articles brought on to the place and their origin. Similarly, the recent movements of animals and human beings connected in any way with the premises are inquired into and recorded. Obviously, however, it is only information of this kind in connection with initial outbreaks which might throw light on the manner of invasion, and it is such information which has been utilised for the purposes of this article.

Feeding Stuffs, Packing Materials, and Human Beings.—These represent the communications between animals of the farm and the outside world, and it is not unnatural that they should have been the objects of sustained suspicion. The object of the inquiries, which have been made over a period of years, was to find whether

any credible factor repeated itself in a number of outbreaks, or whether any lines of evidence from a series of initial outbreaks would converge on one point, for example, on a cargo or consignment of feeding stuffs, etc. It may be said at once that it has not been possible to establish anything of the kind. It is true that grave suspicion has sometimes rested on a certain article, mainly on account of its advent synchronising with the appearance of disease on the premises, but in almost every case further inquiry has shown that the same consignment has been distributed to many other premises, where no disease has occurred. It is also a fact that occasional outbreaks have arisen near camps in which soldiers from the Continent have been concentrated. On the other hand, in such cases no actual communication was established between the soldiers and the premises which became infected. Moreover, initial outbreaks have been known to occur in the past in the same locality when there were no soldiers or other persons to suspect, and in the vast majority of cases no outbreaks arose near camps of the kind.

The most that can be said of the above evidence is that it is not in favour of the view that infection is generally brought to this country by men and such articles as have been mentioned. But, in addition, there is the fact that in many initial outbreaks the premises have been far removed from others, the animals had received only food stuffs grown on the place, and the attendants had not been off the place for weeks before the disease appeared. The weightiest evidence, however, against men, food stuffs, etc., being responsible for the importation of initial infection has arisen in the last year or so, during which the invasions have been exceptionally frequent. It will be shown later that invasions have repeated themselves during the last twenty years in more or less defined areas of the country though not on the same premises, and that large parts of England and Wales and the whole of Scotland and Ireland have escaped entirely or almost so—there has been one initial outbreak in Scotland (at Edinburgh) in the last twenty years. These immune areas receive the same class of food stuffs, etc., and are visited by the same class of human beings, and it is almost inconceivable that over a period of twenty years certain areas could receive all the infected persons and things which came into the country and others escape entirely, if persons and food stuffs were generally responsible for the importation of infection. This is all the more remarkable when it is remembered that in over 80 per cent. of the outbreaks of anthrax infection is conclusively shown to arise from imported feeding stuffs and manures, and that the outbreaks follow the lines of distribution, sparing no part of the country in which they are used, Scotland, for example, being as heavily hit in proportion as England.

If, then, the usual communications between the animals of the farm and the outer world do not account for the conveyance of something—virus of foot-and-mouth disease in this case—which arrives on the farm with a certain degree of frequency, other possible methods of communication must be considered, even if they appear at first sight fanciful.

It has been previously stated in this article that certain parts of the country were hit, as it were, initially with much greater fre-

quency than others, and that some have escaped altogether. The outbreaks have been examined over a period of twenty years, and a list of the initial ones, together with the exact dates and localities, has been compiled.

The counties in which two or more initial outbreaks have arisen in that period are as follows: Bedford, three; Devon, two; Dorset, two; Durham, three; Essex, three; Hants, two; Kent, eight; Lancaster, two; Lincoln, two; Northumberland, two; Somerset, five; Suffolk, two; Surrey, three; Sussex, five; Warwick, two; Wilts, three; Yorks (West Riding only), four; and Denbigh, two.

In the following counties initial outbreaks arose once in the same period: Cambridge, Chester, Cumberland, Gloucester, Hants (Isle of Wight), Hereford, Leicester, Norfolk, Oxford, Stafford, Carmarthen, and Midlothian.

No initial outbreaks have arisen in Berkshire, Buckinghamshire, Cornwall, Derby, Herefordshire, Hunts, London, Middlesex, Monmouth, Northampton, Nottingham, Rutland, Salop, Westmorland, Worcester, Ridings of Yorks (except the West), Isles of Scilly. None have arisen in Welsh counties except Denbigh and Carnarvon, or in Scottish counties except Midlothian.

From the above it will be seen that about one-fifth of the counties of Great Britain were hit twice or oftener, the highest records being for Kent and the neighbouring county of Sussex, Somerset, and the West Riding of Yorkshire; that in about one-eighth of the counties only one outbreak arose; and that in about one-third there were no initial outbreaks. If, however, the counties be grouped according to locality, taking, for example, the area represented on the east and south by Sussex, Surrey, Herts, Bedford, Cambridge, Norfolk, Essex, and Kent, it will be seen that twenty-seven (about 43 per cent.) of the sixty-three initial outbreaks in the last twenty years have appeared in this area. Taking the southern section of the country represented by Hants, Dorset, Wilts, Somerset, and Devon, fifteen (24 per cent.) have arisen there. In both groups there are areas, such as Cornwall and Middlesex, in which no such outbreaks have occurred. There are also small areas, for example a strip along the north coast of Wales in Carnarvon, Denbigh, and Flint, where they have arisen at least often enough to be remarkable.

It does not seem likely from what has been said that the incidence of invasion in these areas can depend entirely on fortuitous circumstances, and it is possible that if the explanation of this incidence were forthcoming it would also explain the method of invasion.

No support having been found for the ordinary methods of conveyance of virus, it seems justifiable to explore the possibility of the virus being air-borne for long distances, either by air currents or birds. As regards air currents, when affected cattle are allowed to remain alive on open pastures or at work, as is customary on the Continent, it is no uncommon thing to see strings of viscous slobber from the mouth whirled up into the air and dispersed into minute parts which disappear from sight. This material is known to be infective in infinitesimal doses, and it can therefore stand a high dilution. What becomes of it after it gets into the air is obviously a question which cannot be answered definitely. It is a fact, however, that even in this country, where the official method

of handling diseased animals—housing and almost immediate slaughter—gives few opportunities for virus to spread, dispersion in the direction of a strong prevailing wind has been occasionally observed to a distance of a few miles, although no ordinary communication could be traced by the minutest inquiry.

Having regard to the distance which volcanic dust can be borne in the air, it seems reasonable to believe that very small particles of infected mucus could be carried long distances by air currents, even in clouds, and be washed down in rain. Accepting this as possible, the next question which arises is, whether there exists more frequently anything in the form of air pockets of negative pressure in the areas mostly invaded which could account for the suspended virus descending to earth or water. These are problems which obviously should be discussed with those who are now exploring the air.

As regards birds, it immediately suggests itself that if birds in general are responsible there should be definite periods of invasion, given prevalence of disease in other countries, which synchronise with those of the migration of birds inwards. There are two migratory seasons, during both of which birds arrive in or leave this country. In the autumn certain birds leave to winter elsewhere. These can be disregarded as importers. Others arrive to winter in this country. These can probably be disregarded, as most of them come from the north, where the disease seldom prevails. In the spring months birds come in mainly from the south for breeding purposes, whilst others depart for the north.

In going back over the outbreaks in the period of twenty years, however, it appears that the lowest records of invasion are March (four), April (one), and May (none). July, in which there is no migration, shows eight. September, October, and November, when birds may be expected from the north and north-east, which are not the lands of prevalence as regards foot-and-mouth disease, show respectively seven, seven, and four, while December, during which there is practically no migration inwards, shows nine.

These data are against the suggestion that there is any general relation between the migration of birds and invasion by foot-and-mouth disease. They do not, however, exclude the agency of those birds, such as ducks, geese, and gulls, which may, outside the migratory seasons, travel long distances for food. For purposes of closer investigation it might be assumed: (*a*) That such birds might in their travels frequent contaminated pastures or drinking places and afterwards deposit virus in this country from their feet or plumage; (*b*) that they might swallow infected material, such as water and food contaminated by slobber and pieces of membrane from the mouths of cattle, and afterwards excrete the virus in a still active state. It is hoped that experiments which are to be conducted on the viability of the virus may determine the possibilities as regards (*a*), and that as regards (*b*) feeding experiments with the virus, using birds, may show at least whether the virus can pass through their intestines unchanged and render their excretions infective for lengthy periods.