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## Foot-and-Mouth Disease\*

THE Foot-and-Mouth Disease Research Committee of the Ministry of Agriculture and Fisheries was first appointed in 1924, and although it has not succeeded in discovering any method of prevention, and the policy of slaughtering all infected and contact animals still continues, it has found out a good deal about the virus and its reaction with the body. The present, fifth, progress report covers the work done in the last five years, mainly at the experimental station at Pirbright and also at the Lister Institute, and the National Institute of Medical Research at Hampstead.

The size of the virus has been more accurately determined by means of Elford's graded filter membranes. It is held up by all membranes with an average pore diameter of 25  $m\mu$  or less, whence the diameter of the virus particles is about 8-12  $m\mu$ , compared with a molecule of oxyhæmoglobin with a diameter of about 4  $m\mu$ . It is indeed about the smallest pathogenic virus known, and is actually smaller than some protein molecules such as hæmocyanin or those recently described by Stanley as causing tumours. Size measurements have also been useful in distinguishing the virus from the much larger agent which causes vesicular stomatitis in horses and cattle, a disease which has similar clinical symptoms. Attempts to cultivate the virus *in vitro* in the presence of guinea pig or calf tissue have been only very moderately successful, and, unlike many viruses, it will not grow at all in the developing egg of the fowl or duck.

One of the most obvious objects which the Committee must have had in view from the beginning is some sort of protective inoculation such as has been used so successfully for cattle

plague. An attack of the disease confers an extremely solid resistance on a cow; but, as has been known for some time, there are several strains or sub-species of virus, and the recovered animal, unfortunately, is resistant only to that strain which caused its illness; it has, for example, been shown that an animal may be given three successive attacks by using three different strains, and it also follows that a cow which has survived a natural attack is by no means secure against picking up the disease again from another strain of virus. These embarrassing features are now known to be worse than was supposed, and recent work has shown a greater multiplicity of identifiable strains as well as the existence of a number which have uncertain characters; types hitherto unknown have appeared in Great Britain. Particularly inconvenient is the variation of infectivity for guinea pigs, since these are the standard animals used in testing for the presence of virus. Indeed, the prospect of finding an effective and practical method of immunization does not seem at all good.

A very interesting section of the report deals with the influence of diet on susceptibility, and it may surprise some of those who attribute so many ills to undernutrition to learn that well-fed, rapidly growing rats could be infected with a much smaller dose and took the disease much more severely than those which were fed on a meagre (but far from a starvation) diet. The animals which showed no symptoms after inoculation were in some instances found to be immune on subsequent testing after feeding up, showing that they had really been infected without any obvious illness; others, however, were susceptible, and in them presumably no infection at all had occurred.

\* Ministry of Agriculture and Fisheries. Fifth Progress Report of the Foot-and-Mouth Disease Research Committee. Pp. 386+26 plates. (London: H.M. Stationery Office, 1937.) (7s. net.)



Good feeding, especially with such eclectic foods as liver and carrot, produces a high degree of susceptibility in a few days, and it takes a long time for the effect to wear off after the animals return to a more ordinary diet. Similar results were obtained with guinea pigs and hedgehogs, and they are no doubt analogous to the old observation of Arkwright that the inflammatory reactions following certain irritating stimuli are much diminished in underfed animals. It may well be that foot-and-mouth disease was little obvious and did little harm among the scrawny cattle of past times in England, and it is just possible that some sort of vaccination with live virus might be a practical procedure if it was combined with deliberate underfeeding.

The major unsolved problem of the disease is, however, where the infection comes from and how it is spread. In the great majority of outbreaks, no perceptible source of infection can be identified, though for some time past they have been thoroughly examined by people fully alert to the various possibilities. With rare exceptions, each outbreak seems to be a thing of itself, and they are scattered about England in an apparently haphazard manner. Movements of cattle are, of course, continuously going on, and it has been suggested that some of them may be carriers of the virus without showing any signs of illness; the inquiries of the Committee do not, however, lend any support to this idea; nor do they favour the speculation that infection is brought from the Continent by birds, which are beyond the control of the most rigorous Ministry. With the dimming of what used to be the sharp boundary between live and dead, it is theoretically possible that the virus is frequently arising *de novo*, generated in cattle or pigs by some unknown influence. The great and apparently increasing variability of the virus is compatible with this idea, though it would be more orthodox to regard it merely as evidence that all the English outbreaks cannot have a common origin, or that the different sub-species of virus are not very permanent.

Spontaneous generation must, however, be the last resort of baffled epidemiologists, and the facts more reasonably suggest that infection is present in some common wild animal, very likely in a form which does not often cause any conspicuous mortality, as is often the case where an uncontrolled infection and its host come into some sort of permanent balance out of which, for reasons unknown, epidemics may arise. Of this line of

thought the Committee has made a reconnaissance, partly by laboratory experiments, partly by trapping animals around the Pirbright Station, and partly by surveys of infected localities by Elton and his colleagues from Oxford. But it has all been on such a slight scale that it can scarcely be called an exploration, and much more work needs doing in the field, where it is none too easy under the conditions of isolation and disinfection which are imposed on infected farms.

Several animals and some birds are capable of being slightly infected by artificial inoculation, but the results are irregular and seem to be of no particular importance. The short-tailed field-vole (at any rate the northern form) is freely susceptible and the infection can be carried on in the laboratory from one animal to another by inoculation; it will not, however, spread from an infected to a healthy animal by contact any more than it will in guinea pigs, which implies that voles cannot be important in Nature from the point of view of infection.

The greatest suspicion attaches to the hedgehog, which by tradition is in the habit of sucking cows' teats and drinking the milk. This may or may not be true—the direct evidence for it is thin—and it may well mean nothing more than that it had been observed that close association between hedgehogs and cows was apt to result in a smaller yield of milk—an obvious symptom of foot-and-mouth disease. Whether they were confusing fact with interpretation or not, our ancestors certainly had such a dislike of the hedgehog as a harmful animal that, as Charles Oldham has shown, churchwardens in the eighteenth century would pay as much (fourpence) for an urchin as for a polecat. These bits of history make a rational tale if we suppose, with G. C. Damant, that the hedgehog is the natural reservoir of the disease. The Committee has shown that it is indeed very susceptible, and takes the disease severely: it is also the only wild animal known in which infection spreads from diseased to healthy animals by contact, and the virus has been demonstrated in the expired air. Moreover, in the small surveys which have been made, a single live hedgehog caught in the neighbourhood of an outbreak near Bristol was found to be infected, although it had no naked-eye signs of disease. At Pirbright a cow was infected by stall contact with a diseased hedgehog, and a hedgehog was infected by contact with a diseased cow. The case against the hedgehog seems strong enough to justify much more extensive and intensive field work.