

SOME EPIDEMIOLOGICAL OBSERVATIONS ON FOOT-
AND-MOUTH DISEASE, WITH SPECIAL REFERENCE
TO THE RECENT EXPERIENCE OF HOLLAND.

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(With a Map.)

IN his classical treatise on Contagions, Hieronymus Fracastorius of Verona has the following passage: "I recollect a singular contagion of the year 1514 which affected only oxen; it first showed itself in the district of Frioli, then gradually extended to northern Italy and thence reached our country. At first the ox went off its feed without any obvious cause, but if the herdsmen looked into the mouth a certain roughness and small pustules were noted on the palate and the whole oral cavity. It was necessary at once to isolate the infected beast from the rest of the herd, otherwise all became affected. Gradually the disease descended to the shoulders and thence to the feet, and almost all the beasts in which this happened recovered, but when it did not, they usually died" (Fracastorii, pp. 63-4). Probably, as in the parallel case of influenza, a careful search of earlier literature might show that foot-and-mouth disease had played its part before 1514. It is sufficient for my present purpose to establish that it has been recognised, very much in its actual clinical form for more than 400 years.

Its subsequent history, at least in broad outlines, could be written without much difficulty (for short summary see Gins and Krause, pp. 85 *et seq.*), but to the veterinarians of the mid-Victorian epoch, under the shadow of rinderpest, foot-and-mouth disease seemed a trivial matter, and quantitative details are scanty. There are cursory references to epidemics even in the eighteenth century and those of 1833 are mentioned in many textbooks but, as appears from the discussion at the first International Veterinary Congress (Gamgee, 505), the subject did not really attract much notice.

Since 1863, however, there has been a change in relative values so that there are copious materials for an account of foot-and-mouth disease in the last 40 or 50 years. For the purpose I have in view, such a general sketch would be of little value. I wish to present as clear a picture as I can paint of the fundamental epidemiological characters of foot-and-mouth disease and shall be less likely to fail if I describe carefully the facts relating to a few countries where very detailed information has been published. If such countries were environmentally and economically precisely similar, this would not suffice. But it happens that the two states which have published the most precise accounts of the facts observed within their territories, England and Wales and the Netherlands, are very differently circumstanced and an

account of foot-and-mouth disease based mainly on the records of these two countries will not be too one-sided. To these, then, I shall confine myself, only referring incidentally to other experience.

Before, however, entering upon this examination, a few generalities must be noted. The first is that in *all* countries, foot-and-mouth disease has displayed that irregularity of incidence which we see in its highest development in such an epidemic sickness as influenza. Thus in the German Empire, between 1886 and 1914, there was never a year in which *no* farms were infected with foot-and-mouth disease, but the variations from year to year have been enormous, from a minimum of 33 to a maximum of nearly a quarter of a million. For instance, in 1909 only 33 fresh infections were reported in the whole empire; in 1911 there were nearly a quarter of a million, in the former year the total number of farm animals involved was less than two thousand, in the latter more than $7\frac{1}{2}$ millions (Hoffman, p. 11). In Germany over this period there were six years, 1892, 1896, 1897, 1899 and 1911 when more than a million animals were involved, in 1892, 1899 and 1911, respectively 4 millions, 4 millions and $7\frac{1}{2}$ millions; the separate outbreaks were 105,929, 162,657, and 239,342. Between 1900 and 1910, foot-and-mouth disease, never absent indeed, was relatively unimportant.

In Holland (see Table I) there was little foot-and-mouth disease between 1880 and 1892; 1897 and 1911 were very bad years with respectively more than 40,000 and more than 70,000 affected farms and there were intervals of almost complete quiescence. In 1886-91 (inclusive) only four farms, two in 1886 and two in 1890 were infected and from 1902-6 (inclusive) there was another almost complete remission. Nocard writing in 1888 (quoted in the Report of the English Veterinary Department for 1889, p. 31) remarks that

Table I. *Outbreaks of foot-and-mouth disease since 1880.*

	Nether-lands	Great Britain		Nether-lands	Great Britain
1880	251	1461	1904	2	—
1881	675	4833	1905	—	—
1882	3	1970	1906	9	—
1883	634	18732	1907	17915	—
1884	32	949	1908	185	3
1885	97	30	1909	53	—
1886	2	1	1910	4	2
1887	—	—	1911	71325	19
1888	—	—	1912	305	83
1889	—	—	1913	54	2
1890	2	—	1914	208	27
1891	—	—	1915	1520	56
1892	1931	95	1916	124	1
1893	414	2	1917	15	—
1894	15489	3	1918	3537	3
1895	228	—	1919	31484	75
1896	1289	—	1920	53280	93
1897	42547	—	1921	684	44
1898	1350	—	1922	325	1140
1899	9780	—	1923	9200	1929
1900	4331	21	1924	88930	1440
1901	610	12	1925	30936	260
1902	35	1	1926	62656	204
1903	1	—			

“foot-and-mouth disease was exceptionally mild during 1887. We are in one of those intermittent periods observed in France and England, a period during which the disease without having completely disappeared, seems to have lost if not its virulence at least its power to spread, or to attack in a very short time a considerable number of subjects.” Indeed even in Germany between 1886 and 1890 foot-and-mouth disease was not very important; in Holland, as we have seen, it was not important at all, while as to England and Wales (which experienced a severe visitation in 1883), the writer of the Report of the Veterinary Department for 1890 (Appendix, p. 35), remarked, a little optimistically, that the disease had been “finally eradicated in 1885 under the severe restrictions enforced.” Those who delight in analogies may remark that the four or five years immediately prior to the winter of 1889 were singularly free from influenza.

The second general observation I have to make is that *every* official department whose reports I have examined is quite satisfied that the disease has been imported from the jurisdiction of some other government. It is not necessary to cite chapter and verse for this statement so far as our own country is concerned. In Holland, two successive commissions, the private commission of 1911 and the royal commission of 1919 satisfied themselves that if only diseased animals or carriers (animate or inanimate) could be stopped at the frontiers there would be an end of epidemic foot-and-mouth disease. While as to Germany, this summary of the report for 1907 (*Jahresbericht über die Verbreitung von Tiereseuchen*, 22nd year, 1907) is quite typical. A bad year, worst in Marienwerder—infection frequently introduced from Russia especially in Allenstein—outbreak in Neidenburg attributed to Russian-Polish potato diggers who the day after crossing the frontier passed the night in the first farm to be infected—outbreak near Dutch frontier attributed to smuggling of cattle—outbreak in Bavaria attributed to introduction of cattle from Switzerland. The cynical student of epidemiological literature will call to mind the similar official unanimity as to the foreign location of the *origin* of influenza.

*The recent history of foot-and-mouth disease in
England and Wales.*

Between 1877 and 1884, foot-and-mouth disease was prevalent in Great Britain. In no year did the number of outbreaks fall below 100 and in 1883 reached the large total of 18,732. In 1884 there were nearly 1000 but in 1885 only 30. In 1886 there was a single outbreak and then no more at all for five years. In 1892 the disease reappeared, in a year when, as we have seen, foot-and-mouth disease was widely prevalent in Germany (and also in France) although Denmark was almost free (88 outbreaks). Indeed, at the time when the first outbreak occurred in England, amongst some Danish oxen, there was no *known* disease in Denmark. It was noted, an observation which recurs over and over again in the reports of the ensuing quarter of a century, “that in all

the isolated outbreaks of 1885 as in those which have recently occurred the most careful inquiry failed to indicate the source of infection (A.R.V.D., 1892, p. 6). In the two following years there were only five outbreaks, but the remark is made (Report for 1894, p. 23) that the reappearance "at a time when the landing of foreign animals from countries in which foot-and-mouth disease existed had for a long time been prohibited, is evidence that something more than prohibition is necessary in order to obtain absolute security against the introduction of diseases which may be conveyed by mediate contagion."

It is implied, of course, that infection must somehow or other have been conveyed from beyond the seas and this axiom has been adopted by all scientific veterinarians since. Thus, in the report on the work of the Animals Division for 1902, a year in which only a single outbreak occurred, we read: "Searching investigations were instituted with a view to discover the origin of the outbreak, without eliciting any definite clue to the source of contagion. The fact that foot-and-mouth disease was at the time prevalent in Western Europe is, however, sufficient to account for its introduction into Great Britain, although the agency, whether of persons or things, by which it was actually conveyed remains unknown" (p. 19). From 1895 to 1900, no outbreaks occurred in this country, but in the report of 1899 attention is directed to the great prevalence of foot-and-mouth disease in France, Germany, and Holland (from which countries no live farm animals were imported into Great Britain).

In 1900, foot-and-mouth disease reappeared and was overt for three years, the numbers of confirmed outbreaks being 21, 12, 1.

The origin of these epidemics was not discovered. They led the Chief Veterinary Officer to remark that "the recent outbreak of foot-and-mouth may be said to be more than usually interesting from its extremely erratic character and its slow progress. It commenced in January 1900, and continued until the 12th of April, 1901, and during that period 33 outbreaks were discovered. Of these 21 were detected during the year 1900, but there were 12 in the first four months of 1901. The fact that a disease of so pronounced a character can linger for so protracted a period with long intervals of apparent freedom between the supposed termination of the old and the commencement of the new centres, accentuates the importance to be attached not only to early diagnosis but also to the rapid application of restrictions on movements in wide districts" (Report of C.V.O. 1901, p. 13). There followed another free period of 5 years; indeed, since there were but three outbreaks in 1908 and two in 1910, it would be fair to say that in the 9 years 1902–10 inclusive, foot-and-mouth disease was not a sensible cause of injury to British farmers.

This epoch came to an end in 1911, since when—excepting 1913, 1916, 1917, and 1918—there have never been less than 20 confirmed outbreaks while in 1922–4 there were 1140, 1929 and 1440.

From 1911 onwards, it will be convenient to follow the course of events in more detail and the experience of 1912—which had the largest number of

outbreaks between 1900 and 1920—is especially instructive because the number is large, but not so large as to preclude detailed examination in the published official reports, which was difficult when the outbreaks numbered hundreds or thousands.

In 1912 the number of confirmed outbreaks was 83 and they fell into three classes. The first included those directly traceable to animals landed from the s.s. *Slieve Bloom* on June 23rd, 1912. The links connecting at least 40 of the outbreaks with the cargo of the ship are well forged. It was proved that some of the animals on the *Slieve Bloom* had been in contact with foot-and-mouth disease on an Irish farm; at least 40 of the outbreaks were directly associated either with the beasts shipped, with lairs occupied by them or with persons having had contact with them; in some other outbreaks connection if not proved was possible. But among the 83 outbreaks were 26 which could in no plausible way be brought into association with the *Slieve Bloom* or her freight.

For instance, foot-and-mouth disease broke out upon a farm at Penrith the very day the *Slieve Bloom* berthed, and it broke out later in Sussex, Hampshire and Kent far beyond her possible sphere of influence. These 26 outbreaks were not all independent; they will be found to reduce themselves to 11 distinct foci. If then we make the somewhat generous supposition that all the other outbreaks should be debited to the *Slieve Bloom*, it appears that of 12 foci, 11 could not be traced to any agency without Great Britain. Amongst the endogenous foci—so far as appears—one deserves special notice. It was an outbreak affecting three farms in contact, direct or mediate, with 14 yearlings, three of whom showed healed lesions of foot-and-mouth disease. The history of these animals was carefully traced and of their numerous contacts two only, apart from the subjects of the outbreaks in question, become infected. Sir Stewart Stockman thought the incident illustrated further “the advantage of stamping out measures, which should aim at leaving no recovered animals alive, with the risk of their becoming prolonged, though intermittent, disseminators of infection” (Report for 1912, p. 28). This, however, seems to involve the hypothesis that an animal cannot pass through an attack of the disease in a clinically unrecognisable, or difficultly recognisable, form without being associated with animals suffering to an extent capable of detection. The history of the Hurst Green cases amongst the yearlings hardly bears that out.

Another interpretation of the events, although assuredly not proven, is at least equally plausible. We might suppose that the infectivity of the home-bred organisms when passed through home-bred animals, as in the Sussex series, is extremely low, but that a newly introduced strain, such as that brought from the Irish cattle of the *Slieve Bloom* was highly infective. This might explain why the spread of infection in the latter case was so extensive. A secondary inference would of course be that slaughter was an excellent policy in the one series and less excellent in the other.

In 1913 there were only two outbreaks of foot-and-mouth disease. In 1914, although the number of outbreaks was not large, they were widely disseminated.

A group was connected with the landing place at Birkenhead and formed the subject of a special inquiry (cd. 7326 of 1914), where experts differed as to the implication of certain imported Irish cattle.

Apart from this, outbreaks, including a series of 11 in Lincolnshire, occurred the origin of which could not be ascertained. The more numerous outbreaks of 1915 were also of unexplained origin, but these were in a period when detailed epidemiological field studies were impossible. In the three following years, foot-and-mouth disease was unimportant, but in 1919 with the largest number of outbreaks since 1912, no further discoveries were made. The report on this year of the Chief Veterinary Officer included a most interesting discussion of the subject.

Sir Stewart Stockman remarked that "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" (Report for 1919, p. 13). He noted further that the importation of hay and straw had been prohibited as long ago as 1908 and pointed out that the modal time of emergence of epidemics did not correspond with the usual dates of migration of birds from the countries where foot-and-mouth disease is endemic. He suggested (the statistical evidence is not perhaps very convincing) that of the 63 initial foci of the last 20 years the distribution in space was not random and thought that the "evidence, such as it is, is most in favour of particles of virus being carried by the air." He was, in fact, reluctant to abandon the axiom that foot-and-mouth disease in England was *always* an imported disease. Of the 95 outbreaks in 1920 in no case could the primary cause be detected. In 1921 one or two outbreaks were thought to be traceable to three Irish stripper cows landed in March, but a large majority of outbreaks went unaccounted for. In 1922, the worst year since 1884, it was not possible to discover the primary sources of infection.

"The most serious feature of the outbreaks in 1923-4 was the multiplication of apparently widely separated centres of infection between which no connection (with a few exceptions) has been traceable. There were no fewer than 91 of these separate centres over the whole period from August 1923 to May 1924 (inclusive), and for 5 months of this period continuously as many as 21 of these were active centres of infection" (Report of C.V.O. 1923, p. 4).

In the report on 1924 we read that "in a number of instances it is recorded that the origin of new centres was obscure. In spite of close inquiry, it was not possible to establish any connexion between the first outbreak in the initial centres and pre-existing outbreaks in this country, either by movements of animals or of persons or by removal of materials (feeding stuffs, etc.). The exclusion of traceable local or British sources of infection, however, does not necessarily involve the acceptance of a foreign origin in all these outbreaks since so much infection had recently existed in this country; it leaves the question of origin open" (Report of C.V.O. 1924, p. 4). In 1925 a Depart-

mental Committee reported (cmd. 2350 of 1925) but the report is of administrative rather than epidemiological interest.

Table I *supra* includes a summary of the annual recorded outbreaks since 1880. It has some value as an indication of the trend but not very much value. Not only is there the difficulty that cattle, sheep and pigs are all liable to suffer from the disease and the local distribution of animals at risk is not available, but we can obviously provide no statistics in the least comparable with either morbidity or mortality rates for human aggregates. It is usual to make a census of herds at intervals, but these are instantaneous pictures and cannot be supplemented, as can a census of men, by periodic registers of births, deaths and migrations. If it were possible to compile much more detailed vital statistics, not for the whole country but, say, for one or two of the counties falling within the groups of frequently and rarely infected (primary infections) areas to which Stockman referred in the report on 1919, the result might be repaying. I mean by detailed statistics, an exact register of births, deaths and migrations of all stock (at least of cattle, sheep, pigs and goats) over one or two years. At present when the probability of a local outbreak in most parts of the country is reasonably large it would be a more rewarding labour than normally. The object would of course be to ascertain whether the vital statistical histories of farms upon which outbreaks occurred were, in any possibly material respect, different from those of farms not attacked. In particular whether there be any correlation between frequency or extent of immigration of clean stock from parts of the country, or from the dominions, where foot-and-mouth disease is rare. This, however, is a question for the future. The immediate point is that, in the nature of things, our epidemiological description must be without quantitative precision and that a direct *arithmetical* comparison of English and Continental experience is impossible. With this caveat and having completed my sketch of the English epidemiological history I turn to that of Holland, material for which if not, from some points of view, quite so complete—it could hardly be so, having regard to the extent of the epidemics—is excellent and ample.

Foot-and-mouth disease in the Netherlands.

The history of foot-and-mouth disease in the Netherlands is of special value for three reasons: (1) The *extent* of the epidemics, which in some years have involved more than half the total number of farmers in the worse-stricken provinces. (2) The difference between the facilities for importation of the disease in different parts of the country, some provinces being almost surrounded by foreign territory, others almost surrounded by water. (3) The completeness of the official reports, which are much more enlightening than the reports of any other foreign country which I have so far examined.

In the last 35 years, Holland has experienced 8 epidemics on the grand scale, in 1894, 1897, 1911, 1919, 1920, 1924, 1925 and 1926. In no year since 1892 has she been entirely free of the disease except 1905, but in 1893, 1895, 1902–6,

1908–10, 1912–14 and 1916–17, it was not a serious cause of loss. The epidemic of 1911 was an extremely serious one, more than 70,000 herds were infected; a report published in 1912 by the Director-General of the Department of Agriculture affords a very complete view of events. In order to understand



the story it is essential to have a correct notion of the geographical lay-out in Holland (see Map). Of the eleven provinces into which the country is divided, four of the western provinces, North Holland, South Holland, Friesland and Utrecht, have no frontiers upon a foreign state. Friesland is indeed a peninsula,

bounded on the south-west by the Zuider Zee, on the north-west and north, by the North Sea. Landwards to the east she is bounded by Groningen and Drenthe. Leeuwarden, the only city, has less than 46,000 inhabitants. Zeeland, the most southerly of the western provinces has a land frontier with Belgium. Proceeding eastwards, Limburg and North Brabant march with both Germany and Belgium, while the remaining four eastern provinces, Groningen, Drenthe, Overijssel and Gelderland, have extensive frontiers on Germany.

According to the census of 1921, the three provinces containing the largest population of cattle are Friesland, Gelderland and South Holland, with respectively 331,089; 301,094 and 296,918. North Brabant and Overijssel have each rather more than 200,000 and each of the other provinces, except Groningen with 98,621, between 100,000 and 200,000. The numbers of individual stock holders are not in the same order, Gelderland and North Brabant having much the largest numbers, and Friesland, both in 1910 and 1919, had not many more than half the number in Gelderland. Between 1910 and 1919 there seems to have been a decided decrease in the number of separate stock holders, amounting to more than 17 per cent. for the nine provinces Friesland, Gelderland, North Brabant, North Holland, South Holland, Utrecht, Zeeland, Drenthe and Limburg. (This is based on a comparison of the figures contained in the Report of the Agricultural Department on the epidemic of foot-and-mouth disease in 1911, p. 53, and the data of the Royal Commission on the epidemic of 1918-19.) The density of cattle population in 1921 was greatest in Utrecht, 143 per 100 hectares and more than 100 per 100 hectare in South Holland, Friesland and Overijssel. The least thickly populated provinces are Groningen (49) and Zeeland (47). It also appears that the age constitution of the herds is quite different in different provinces. In the appendices to the Report of the Royal Commission (*Bijlagen behoorende bij het Verslag der Staatscommissie in zake Mond- en Klauwzeer*) will be found elaborate statistics of the animals composing infected herds. They are classified as bulls, milch cows, dry-cattle and heifers (*Droogvee en Pinken*) and calves. Taking the number of milch cows as 100 in each case and taking North Brabant, Gelderland, Friesland, Utrecht, and Limburg as examples, the proportion of dry-cattle varies from 97·8 in Gelderland to 35·7 in Friesland, that of calves from 51·3 per cent. in Gelderland to 29·7 in Utrecht.

The classification given in the Year Book (*Jaarcijfers voor Nederland*, 1925/6, pp. 200-1) differs from that of the Commission and relates to the Census of 1921, but illustrates the same diversity. The cattle population is classified as (1) bulls, (2) milch cows and pregnant cows, (3) beasts for fattening, (4) young beasts. The ratio of (2) to (4) is very variable. Thus in Friesland it is as 18 to 14, but in Zeeland as 2 to 4.

If, as I have no doubt is the case, the age and sex constitution of a population is an important aetiological element in its epidemiological history, these differences are of importance. But without local and technical knowledge—not to speak of more detailed statistics—which I do not possess I can do no more than point out the heterogeneity.

In 1910 only four outbreaks of foot-and-mouth disease are known to have occurred in all Holland. The *first* cases of the epidemic of 1911 all occurred in provinces with frontiers on Germany, the very first, on February 1st, 1911 (nine months after the last recorded case in Holland), in Limburg. The stock owner here was said to have had contact with miners from infected areas in Germany, but it is noted that, at this time, no cases were known to have occurred in any of the German parishes actually on the frontier. Three more provinces with German frontiers were infected within a fortnight, Drenthe on February 11th, Groningen on February 16th, Gelderland on February 17th.

Table II. *Holland. Attack rate per 1000 stock holders during foot-and-mouth epidemic of 1911.*

1911	Zeeland	Friesland	North Holland	South Holland	Utrecht	Limburg and Brabant	Gelderland Overijssel Groningen Drenthe
February	0	—	0.05	—	—	0.29	0.12
March	0.10	0.03	3.15	—	0.62	0.38	0.27
April	0	0.37	6.86	0.62	3.08	0.61	0.54
May	0	—	143.48	33.39	65.53	1.85	0.71
June	1.35	1.40	417.36	288.96	183.18	18.22	5.16
July	8.56	71.76	114.61	150.68	71.17	36.99	12.40
August	44.44	244.19	42.65	40.27	27.80	33.65	23.57
September	35.99	137.82	12.56	13.26	18.84	19.14	53.78
October	17.67	22.18	4.98	3.52	3.89	4.21	23.86
November	4.69	2.58	1.32	1.89	0.34	0.97	6.44
December	2.38	1.00	1.06	0.88	0.46	0.21	1.54

But Overijssel did not have cases until April 12th. Apart from the supposed contact with miners, the introduction of infected foodstuffs is alleged specifically with respect to Limburg but the evidence given amounts to no more than reasoning by exclusion, for emphasis is put upon the fact that the earliest cases occurred in isolated farms without mediate contact with persons or animals from Germany. The Drenthe outbreak is rather vaguely attributed also to importation of fodder, but no origin could be assigned to the Groningen cases. For Gelderland, smuggling of German cattle is assigned while for North Brabant, which was first infected on February 18th, fodder of German origin is again assigned.

These origins are conjectural, but there is at least no doubt that the first recorded cases were in provinces marching with Germany and that, with the exception of the populous province of North Holland, which first reported cases on February 22nd (origin unknown), the central and western provinces were not seriously implicated for several weeks. It might perhaps have been expected that the epidemic would more or less rapidly extend from east to west. In fact it followed precisely the reverse order; the western provinces were first heavily attacked and the disease extended to the east. From the very full statistics published I have been able to study the process of spreading. Of course the best plan is to examine monthly maps (which are given in the Dutch Report) but expense of reproduction renders this impossible. As an admittedly inferior substitute I take the ratio per mille in each month of

infections in that month to the number of stock holders previously unaffected. Thus if the estimated total number of stock holders in a province were 100,000 and in February 500 infections were declared and in March 1000, we should put the attack rate for February as $500/100,000$ and for March $1000/99,500$, etc. This is not an accurate method. In the first place the census of stock holders was made in 1910 and I have used the figure for total stock holders, not the smaller figure for farmers having horned cattle (the latter is too small since in one province it would make the percentage attacked more than 100, and foot-and-mouth disease frequently attacks swine, less often sheep), and in the second place it neglects re-infections. So treated the data yield the following results. (I have grouped Groningen, Drenthe, Overijssel and Gelderland together, as the German Provinces, and North Brabant and Limburg together as the Mixed Provinces.) In February 1911, only the German and Mixed Provinces had attack rates of more than 0.1 per mille. In March the rate in North Holland rose to 3.15 per mille, the German and Mixed Provinces being still below 1 per mille. The rate rapidly increased in North Holland to 143 per mille in May, 417 in June and then as rapidly declined, 115 in July, 43 in August, 13 in September, 5 in October, 1 in November and 1 in December. South Holland followed a parallel course but had a lower maximum 289. Friesland had her maximum in August (244) two months later, Zeeland a much lower maximum (45) also in August. These are the western provinces. Utrecht's maximum (183) was in the same month as North Holland's. The two mixed provinces had their much lower maximum (37) a month later than North Holland, while the four German Provinces did not reach their maximum (54) until September, a month after Friesland and three months after North and South Holland, and exhibit a much more slowly rising and long continued curve. In October, when the North Holland rate had fallen to 5 per mille, the rate in the German provinces was 24. In other words the epidemic was more severe and began sooner in the provinces least exposed to direct contamination. The particular history of the Friesland outbreak is remarkable. I have already alluded to the *relative* isolation of this province. The first case was reported on March 29th, and 12 more occurred in April; in every instance the policy of slaughter was adopted. No plausible origin of this first outbreak was assigned. The authors of the official account seem to attach importance to the fact that the owner of the first infected animals was in the habit of visiting a marsh land extensively fouled by the excrement of wild geese, but no evidence is afforded entitling us to find these birds guilty of smuggling in infection. By April 15th, the local epidemic seemed to be extinct, an apparent triumph of the policy of slaughter which had been adopted. On June 24th another case occurred in Friesland and by June 30th 35 herds in 20 parishes, quite unconnected one with another, were infected. This time the winds of heaven instead of the geese were implicated. It is pointed out that by June North Holland was widely infected, and that between June 15th and 30th the winds were *almost continuously west, south-west and south-south-west, so that*

infection might have been blown into Friesland from North Holland. However this may be, Friesland suffered an epidemic of the first order of severity. The province contained 32,180 stock holders, of whom 18,635 owned horned cattle. In all 13,249 stock holders were infected. In order of severity, the most severely damaged provinces in 1911 were North Holland, South Holland, Friesland and Utrecht. No subsequent epidemic is reported in precisely the same form. There is a special, and detailed, official account of the course of the disease between 1912 and 1916 and the report of a Royal Commission on the epidemic of 1918–19 (containing, as mentioned above, very full statistics of losses in herds). The annual reports of the veterinary division provide statistics of the monthly records of outbreaks in each province and verbal appreciations of the local epidemiological features. These descriptions, however, cannot be completely correlated with the provincial statistics for they are given not under provinces but under veterinary inspectorial areas of which there are 13, located as follows: Groningen (Groningen), Leeuwarden (Friesland), Zwolle (Overijssel), Arnhem (Gelderland), Utrecht (Utrecht) Amsterdam, Alkmaar (North Holland), Rotterdam, Leiden (South Holland), Middelburg (Zeeland), 's Hertogenbosch (North Brabant), Venlo, Maastricht (Limburg).

The actual data are shown in Table III. How imperfect they are from the statistical point of view, even taking them at their face value, is obvious. The unit is a herd in which a case of disease has been reported and there is no distinction between an outbreak affecting a herd of hundreds of cattle and a case in a villager's pig. A human parallel would be if we counted in, say, a water-borne epidemic of typhoid, 100 cases in a large institution, and one case each in six households as seven outbreaks and also reckoned 20 isolated cases scattered through the land as another 20 outbreaks.

This would be unsatisfactory statistical material under any circumstances, even if the data were accurate, and they are not accurate. A convincing proof that the data are not accurate is to be found in the Report on the Agricultural Department for 1919 (*Verlag van de Bevindingen en Handelingen van het Veeartsenijkundig Staatstoezicht in het jaar 1919*, pp. 149–50); it is contained in the report on the veterinary district of 's Hertogenbosch. It appears that during the 1918–19 epidemic 2297 cases in 128 parishes were officially reported and these, and similar statistics, form our arithmetical basis. Now in the second half of 1919 a sub-commission of the Royal Commission on foot-and-mouth disease undertook an investigation of the total financial losses due to foot-and-mouth disease, and they did not confine their attentions to the farmers who had notified the occurrence of foot-and-mouth disease in their animals. The result was that the number of stock holders who had suffered losses (all given in detail) from foot-and-mouth disease exceeded the number who had notified the existence of the disease by approximately *one thousand* and it also appeared that everyone of the 139 parishes of the district had had cases of foot-and-mouth disease. The reporter remarks, with a touch of cynical humour, that even the 2297 reported cases probably exceeded the number

Table III.

1911	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Noordbrabant	-	1	4	14	32	578	1937	2002	1192	251	49	14	6,074
Gelderland	-	1	24	66	103	741	1637	2179	2909	844	100	30	8,634
Zuidholland	-	-	-	18	962	8045	2983	677	214	56	30	14	12,999
Noordholland	-	1	58	126	2619	8525	1044	344	97	38	10	8	10,870
Zeeland	-	-	2	-	-	26	165	849	657	311	81	41	2,132
Utrecht	-	-	8	40	848	2215	703	255	168	34	3	4	4,278
Friesland	-	-	1	12	-	45	2305	7281	3106	431	49	19	13,249
Overijssel	-	-	-	1	1	18	137	992	2554	698	157	33	4,591
Groningen	-	13	12	3	-	-	16	90	1153	793	209	37	2,326
Drenthe	-	4	4	9	-	2	28	153	989	858	375	100	2,522
Limburg	-	24	29	39	129	1007	1222	766	329	77	26	2	3,650
Totals	-	44	142	328	4694	19,202	12,177	15,588	13,368	4391	1089	302	71,325
1912													
Noordbrabant	5	17	4	1	-	2	-	1	1	-	-	-	31
Gelderland	8	23	11	8	-	5	1	1	-	-	2	-	59
Zuidholland	8	5	13	12	6	-	-	-	-	-	3	2	49
Noordholland	7	5	7	-	2	-	-	-	-	-	-	-	21
Zeeland	9	10	2	1	-	-	-	-	-	-	-	-	22
Utrecht	3	3	-	-	1	-	-	-	-	-	-	-	7
Friesland	6	2	5	3	2	-	-	-	-	-	-	2	20
Overijssel	6	4	-	-	1	2	1	-	-	-	-	-	14
Groningen	11	11	7	5	4	2	-	-	-	-	-	2	42
Drenthe	9	2	13	1	-	-	-	1	-	-	-	-	26
Limburg	3	8	-	-	2	1	-	-	-	-	-	-	14
Totals	75	90	62	31	18	12	2	3	1	-	5	6	305
1913													
Noordbrabant	-	2	-	-	-	-	-	-	-	-	1	-	3
Gelderland	2	2	4	2	1	-	-	-	-	-	-	-	11
Zuidholland	8	6	2	3	-	1	-	-	-	-	-	-	20
Noordholland	1	1	1	-	-	-	-	-	-	-	-	-	3
Zeeland	-	1	-	-	-	-	-	-	-	-	-	-	1
Utrecht	1	-	1	-	-	-	-	-	-	-	-	-	2
Friesland	-	1	1	-	-	-	-	-	-	1	-	-	3
Overijssel	-	-	1	1	-	-	-	-	-	-	-	-	2
Groningen	2	-	-	-	-	-	-	-	-	-	-	-	2
Drenthe	1	-	1	-	2	-	-	-	-	-	-	-	4
Limburg	1	-	-	-	-	-	-	-	1	-	1	-	3
Totals	16	13	11	6	3	1	-	-	1	1	2	-	54
1914													
Noordbrabant	-	1	-	-	-	-	-	-	-	-	2	32	35
Gelderland	-	-	-	-	-	-	-	-	-	2	42	42	86
Zuidholland	1	1	-	-	-	-	-	-	-	-	1	6	9
Noordholland	-	1	1	1	-	-	-	-	-	-	-	1	4
Zeeland	-	1	-	-	-	-	-	-	-	-	-	1	2
Utrecht	-	-	1	-	-	-	-	-	-	-	-	-	1
Friesland	-	1	-	-	-	-	-	-	-	1	1	3	6
Overijssel	-	-	-	-	-	-	-	-	-	-	4	7	11
Groningen	-	-	-	-	-	-	-	-	-	-	-	-	-
Drenthe	-	-	-	-	-	-	-	-	-	-	-	-	-
Limburg	-	-	-	-	-	-	-	-	-	2	13	39	54
Totals	1	5	2	1	-	-	-	-	-	5	63	131	208
1915													
Noordbrabant	50	21	21	9	26	2	-	1	-	9	6	30	175
Gelderland	17	13	2	8	-	-	3	1	3	9	7	15	78
Zuidholland	4	29	9	26	46	75	80	9	6	11	21	16	332
Noordholland	-	2	-	7	9	-	-	-	-	-	8	5	31
Zeeland	3	1	1	9	5	-	5	32	8	12	4	5	85
Utrecht	-	3	-	-	7	4	1	-	-	8	13	8	44
Friesland	2	-	-	1	-	-	-	-	-	3	24	6	36
Overijssel	11	3	1	-	-	2	2	-	-	62	51	8	140
Groningen	-	-	-	-	1	-	-	1	-	4	19	8	33
Drenthe	1	-	-	-	-	-	1	-	-	2	3	3	10
Limburg	22	16	12	5	29	103	37	24	71	117	77	43	556
Totals	110	88	46	65	123	186	129	68	88	237	233	147	1520

Table III—contd.

1916	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Noordbrabant	26	7	1	-	-	-	-	-	-	-	-	-	34
Gelderland	1	1	-	-	-	-	-	-	-	-	-	-	2
Zuidholland	10	27	8	1	-	-	-	-	-	-	-	-	46
Noordholland	1	2	-	-	-	-	-	-	-	-	-	-	3
Zeeland	2	5	-	-	-	-	-	-	-	-	-	-	7
Utrecht	1	-	-	-	-	-	-	-	-	-	-	-	1
Friesland	-	1	-	-	-	-	-	-	-	-	-	-	1
Overyssel	1	-	-	-	-	-	-	-	-	-	-	-	1
Groningen	1	-	-	-	-	-	-	-	-	-	-	-	1
Drenthe	-	-	-	-	-	-	-	-	-	-	-	-	1
Limburg	12	3	12	1	-	-	-	-	-	-	-	-	28
Totals	55	46	21	2	-	-	-	-	-	-	-	-	124
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1917													
Noordbrabant	-	-	1	8	1	1	-	-	-	-	-	-	11
Gelderland	-	-	-	-	-	-	-	-	-	-	-	-	-
Zuidholland	-	-	1	-	-	-	-	-	-	-	-	-	1
Noordholland	-	-	-	-	-	-	-	-	-	-	-	-	-
Zeeland	-	-	-	-	-	-	-	-	-	-	-	-	-
Utrecht	1	-	-	-	-	-	-	-	-	-	-	-	-
Friesland	-	-	-	1	-	-	-	-	-	-	-	-	1
Overyssel	-	-	-	-	-	-	-	-	-	-	-	-	-
Groningen	-	-	-	-	-	-	-	-	-	-	-	-	-
Drenthe	-	-	-	-	-	-	-	-	-	-	-	-	-
Limburg	-	-	1	-	-	-	-	-	-	-	-	-	2
Totals	1	-	3	9	1	1	-	-	-	-	-	-	15
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1918													
Noordbrabant	-	-	1	-	-	-	-	-	-	18	92	235	346
Gelderland	-	-	-	-	-	-	-	9	12	6	36	179	242
Zuidholland	-	-	-	-	-	-	5	-	2	10	535	1251	1803
Noordholland	-	-	-	-	-	-	-	-	-	3	54	190	247
Zeeland	-	-	-	-	-	-	-	-	-	3	19	46	68
Utrecht	-	-	-	-	-	-	-	-	91	130	225	303	749
Friesland	-	-	-	-	-	-	-	-	-	-	-	3	3
Overyssel	-	-	-	-	-	-	-	-	1	7	-	2	10
Groningen	-	-	-	-	-	-	-	-	-	-	-	-	-
Drenthe	-	-	-	-	-	-	-	-	-	-	-	-	-
Limburg	-	-	-	-	-	-	3	-	-	8	8	50	69
Totals	-	-	1	-	-	-	8	9	106	185	969	2259	3537
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1919													
Noordbrabant	108	138	168	75	123	514	574	520	840	515	46	77	3698
Gelderland	83	113	102	32	201	123	488	839	1274	327	34	38	3654
Zuidholland	478	432	123	253	1382	1662	437	84	57	25	19	41	4993
Noordholland	211	240	196	170	900	1029	357	115	41	15	4	10	3288
Zeeland	29	40	28	16	25	132	151	161	352	185	47	25	1191
Utrecht	98	45	38	35	-	-	-	-	-	-	-	-	216
Friesland	-	7	4	3	567	2228	2020	1039	710	238	37	17	6870
Overyssel	12	132	86	58	167	426	328	380	364	201	21	26	2201
Groningen	-	-	1	7	42	195	289	312	402	201	146	62	1657
Drenthe	2	64	27	2	55	100	162	319	606	307	86	28	1758
Limburg	59	27	12	11	34	107	470	267	354	475	111	31	1958
Totals	1080	1238	785	662	3496	6516	5276	4036	5000	2489	551	355	31,484
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1920													
Noordbrabant	50	139	556	713	1176	1399	2160	1116	627	203	119	171	8429
Gelderland	10	51	188	356	1115	1502	2662	2654	667	163	85	62	9515
Zuidholland	65	595	1173	1333	1333	367	79	104	58	45	77	46	5275
Noordholland	8	138	502	837	1542	497	226	108	63	33	65	23	4042
Zeeland	24	17	33	87	130	281	729	729	357	99	51	33	2570
Utrecht	-	-	166	314	543	230	101	35	75	13	8	6	1491
Friesland	17	10	172	898	3122	2082	765	150	133	69	31	46	7495
Overyssel	10	25	218	222	803	605	587	492	308	150	112	52	3584
Groningen	11	6	62	281	692	692	315	167	95	78	72	63	2534
Drenthe	16	3	97	365	785	699	584	407	257	112	50	34	3409
Limburg	27	79	204	271	490	807	1644	448	414	131	281	140	4936
Totals	238	1063	3371	5677	11,731	9161	9852	6410	3054	1096	951	676	53,280

Table III—*contd.*

1921	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Noordbrabant	49	11	7	5	4	2	1	—	—	—	2	1	82
Gelderland	34	18	12	10	11	1	2	4	2	—	1	2	97
Zuidholland	25	17	14	30	5	2	9	13	—	1	—	1	117
Noordholland	17	9	7	8	3	—	2	—	—	1	1	2	50
Zeeland	9	10	2	8	3	2	—	—	—	6	6	3	49
Utrecht	4	3	3	—	2	—	—	—	—	—	—	1	13
Friesland	17	21	9	6	4	—	1	5	5	1	—	—	69
Overijssel	13	7	7	3	2	2	—	4	1	2	1	1	43
Groningen	29	13	3	2	5	—	3	—	3	1	1	1	61
Drenthe	10	3	10	3	—	1	—	3	1	—	—	—	32
Limburg	40	14	11	3	1	—	—	—	—	—	1	2	71
Totals	247	126	85	78	40	10	18	29	12	12	13	14	684
1922													
Noordbrabant	2	—	1	—	—	1	—	—	—	1	17	6	28
Gelderland	2	4	2	1	1	—	—	—	1	—	6	1	18
Zuidholland	1	4	1	1	—	—	—	—	—	24	95	28	154
Noordholland	2	—	3	—	—	—	—	—	—	—	10	3	18
Zeeland	2	—	1	1	—	—	—	—	—	2	21	2	29
Utrecht	—	—	—	—	—	—	—	—	—	1	6	—	7
Friesland	—	1	—	1	2	—	—	—	—	2	14	3	23
Overijssel	1	—	1	—	—	—	—	—	—	—	2	2	6
Groningen	—	—	1	—	2	4	—	—	—	4	5	—	16
Drenthe	—	—	—	—	—	—	—	1	—	2	—	—	3
Limburg	2	—	—	3	—	—	—	—	—	1	11	6	23
Totals	12	9	10	7	5	5	—	1	1	37	187	51	325
1923													
Noordbrabant	—	—	—	1	—	4	5	8	18	39	23	12	110
Gelderland	3	2	2	2	—	2	8	14	6	71	57	14	181
Zuidholland	11	13	5	11	96	190	384	917	1537	971	296	126	4557
Noordholland	3	1	—	5	4	7	3	53	354	807	565	274	2076
Zeeland	—	2	1	—	—	3	2	1	9	47	15	9	89
Utrecht	—	1	—	8	24	15	32	131	567	642	243	66	1729
Friesland	2	2	1	1	2	—	—	6	6	30	63	11	124
Overijssel	—	—	—	—	—	—	—	—	6	11	21	16	54
Groningen	—	1	—	—	—	—	—	—	—	4	1	—	6
Drenthe	—	—	—	—	—	—	—	—	—	6	6	3	15
Limburg	5	—	1	9	20	30	42	46	52	30	8	16	259
Totals	24	22	10	37	146	251	476	1176	2555	2658	1298	547	9200
1924													
Noordbrabant	24	69	376	593	935	1089	2619	2130	632	366	204	289	9,326
Gelderland	11	69	236	325	816	1647	3104	4137	1689	854	201	249	13,338
Zuidholland	61	72	1201	2131	2666	1839	963	386	142	70	31	37	9,599
Noordholland	59	28	125	618	2425	3354	1021	263	120	88	76	19	8,196
Zeeland	4	14	94	121	198	382	639	621	262	97	47	68	2,547
Utrecht	23	14	99	398	964	1668	997	318	31	15	7	6	4,540
Friesland	6	26	72	244	515	2738	7602	4092	579	86	33	55	16,048
Overijssel	5	22	112	174	316	823	1962	2943	1309	517	102	65	8,350
Groningen	4	2	22	62	226	743	1533	1431	684	295	113	66	5,181
Drenthe	3	16	17	40	223	455	1378	2817	1722	639	117	51	7,478
Limburg	11	37	43	40	135	176	763	1554	587	393	293	295	4,327
Totals	211	369	2397	4746	9419	14,914	22,581	20,692	7757	3420	1224	1200	88,930

which would have been reported had not the idea got wind (in spite of all contradictions) that the government intended to compensate farmers for their losses. In the face of this evidence—and much other evidence which could be quoted—it would be foolish to place any confidence in the accuracy of the data. At the same time it would be foolish to regard the data as quite worthless. Suspicion of whatever is the Dutch equivalent of red tape, general obstinacy

and inertia may be supposed to be pretty evenly distributed through the agricultural areas of Holland so that, *when an epidemic is under way*, we may reasonably suppose that the incidence is understated to about the same extent all through the country. But we must be cautious at two points. (1) In an inter-epidemic period we must be quite sceptical as to a clean bill of health. (2) In dealing with an area under restriction on movement or with adjoining districts, when there is a strong motive to conceal cases, we may be absolutely confident that motive is not resisted.

Let us now scrutinise the figures and see what we can learn. There are four periods of great epidemic prevalence, viz. 1911, 1918–19, 1920, 1924–6. In 1915 and 1923 the prevalence was too great to be qualified as merely sporadic. In 1912, 1913, 1914 (until the month of November which may be linked to the 1915 experience) 1916, 1917, the first 8 months of 1918, 1921 and 1922 foot-and-mouth disease was merely sporadic. But in no single year was the country free from cases. The longest period of practical freedom is from June 1913 to October 1914, in that period 14 cases were reported, 3 each in North and South Holland, 2 each in North Brabant, Friesland, and Limburg, 1 each in Zeeland and Utrecht. This period was ended not by a great epidemic but by the moderate prevalence beginning in November 1914 and ending in March 1916. Having regard to the fact that this was in the war period, our distrust of the precision of the data must be redoubled, but it is impossible to believe that over this period the disease was really on anything like the scale of 1911 or 1918–19. The next phase begins in the late summer of 1918 (believers in epidemic constitutions will not fail to note that there is a coincidence in time with the pandemic of influenza) and there is an epidemic which is practically a continuous phenomenon running to May 1921. The first maximum is in December 1918, the next in June 1919, the third in May 1920. The first phase is the mildest, the third by far the most severe. From May 1921 to May 1923 there is an intermission, then a short epidemic period with a maximum in October, followed by the greatest epidemic yet recorded, having a maximum in July 1924.

A study of the excellent spot maps contained in the Department of Agriculture's Report (*Verslag over het Mond- en Klauwzeer in 1912–1916*) shows that in October 1914 only a single outbreak of foot-and-mouth disease occurred in Holland (in Friesland) except in the provinces with a German frontier, and there were only five outbreaks in all. At this time foot-and-mouth disease was present in seven of the German frontier districts and seriously epidemic a little to the east. The subsequent development in time and place is quite consistent with an outspread from Germany. In December only 10 of the outbreaks (out of 131) were in provinces without a foreign frontier. The subsequent development remained consistent with this hypothesis and South Holland alone, apart from the border provinces, suffered severely, contributing 332 to the total of 1520 outbreaks in 1915. The largest contributors in South Holland were Hof van Delft with 32 and Stompwijk with 40 outbreaks. By March 1916 the outbreak was practically at an end. "On the 6th of April 1916 the last case was

confirmed at Hof van Delft and with this the epidemic of foot-and-mouth disease which began on October 11th, 1914, came to an end." There were indeed no more save a few sporadic cases until the latter months of 1918. Throughout the period from the dying out of the 1911 epidemic to that of the 1918-19 outbreak the policy of isolation and slaughter was regularly carried out.

The epidemic of 1918-19 began (statistically speaking) in Gelderland in August. Before this month 9 outbreaks only had been recorded since June 1917, 1 in March 1918 in North Brabant, 5 in South Holland in July and 3 in Limburg also in July. In August there were 9 outbreaks in Gelderland and outbreaks continued in that province so that with the exception of October 1918 when only 6 were recorded, there were not again less than 10 until June 1921; there was a first low maximum of 179 in December 1918, a second maximum of 1274 in September 1919 and a third and largest of 2662 in July 1920. South Holland developed an epidemic almost synchronously and much more intensely, a first maximum of 1251 in December 1918, a second of 1662 in June 1919, a third of 1333 in April 1920. Utrecht started with a bound, 91 cases in September 1918 after 30 months of freedom, but the first maximum of 303 in December 1918 was followed by a decline and there was no epidemic in 1919. The third phase began in March 1920 and reached a maximum of 543 in May. North Holland had no 1918 maximum but one in June 1919 and a second in May 1920.

In Table IV are shown the dates of emergence, the dates of maxima and the measures of the maxima expressed as percentages of total incidence. As before, the provinces of North and South Holland, Friesland and Utrecht

Table IV. *Holland. Dates of maxima during outbreaks in 1918-20 and measures of maxima expressed as percentages of total incidence.*

	First maximum			Second maximum			Third maximum			Total outbreaks 1918-20
	Date	No.	% of total	Date	No.	% of total	Date	No.	% of total	
Noordbrabant	Dec. 1918	235	1.9	Sept. 1919	840	6.7	July 1920	2160	17.3	12,473
Gelderland	Dec. 1918	179	1.3	Sept. 1919	1274	9.5	July 1920	2662	19.8	13,411
South Holland	Dec. 1918	1251	10.4	June 1919	1662	13.8	Apr. 1920	1333	11.0	12,071
North Holland	Dec. 1918	190	2.5	June 1919	1029	13.6	May 1920	1542	20.4	7,577
Zeeland	Dec. 1918	46	1.2	Sept. 1919	352	9.2	July 1920	729	19.0	3,829
Utrecht	Dec. 1918	303	12.3	Jan. 1919	98	4.0	May 1920	543	22.1	2,456
Friesland	—	—	—	June 1919	2228	15.5	May 1920	3122	21.7	14,368
Overijssel	—	—	—	June 1919	426	7.4	May 1920	803	13.9	5,795
Groningen	—	—	—	Sept. 1919	402	9.6	May 1920	692	16.5	4,191
Drenthe	—	—	—	Sept. 1919	606	11.7	May 1920	785	15.2	5,167
Limburg	Dec. 1918	50	0.72	Oct. 1919	475	6.8	July 1920	1644	23.6	6,963

suffered most. Passing to the epidemiological reports, the clinical type in 1918 is described as mild everywhere. In the Arnhem district the origin was traced to calves purchased in Utrecht market. In Leiden the disease is described as very infectious but of low virulence. Attention is directed to the existence of foot-and-mouth disease in Belgium (then occupied by the Germans) and the fact that information was given too late for any effective action by the Dutch

authorities. The opinion is expressed that withdrawal of the policy of slaughter (in October 1918) amounted to abandoning any hope of stopping the epidemic.

The descriptions of 1919 concur in reporting a change of type. Thus Leeuwarden reports that in the pasture season the type changed from mild to extremely severe, especially in the month of July when 215 full grown cattle died. The Leiden inspector notes that heifers escaped most lightly and that pigs and sheep were not much affected. Venlo mentions that districts next to heavily infected areas sometimes escaped altogether or with a few scattered cases. The general tone of the reports is rather pessimistic and the point is made that individual animals and whole herds were often attacked twice or even three times. In 1920 Groningen reports heavy mortality of young calves and of pigs and the cattle after recovery were often infertile and afflicted with respiratory trouble (*dampigheid*).

Leeuwarden complains of heavy mortality, complete failure of immunisation through previous natural attack, serious after effects in recovered animals—respiratory trouble, infertility, mastitis, abortion. Zwolle also reports the frequent attacks of animals which had been attacked before, Arnhem makes a similar comment. Utrecht stresses the heavy mortality of young animals and after effects on adults. Alkmaar notes that 1566 stock holders who were affected in 1919 were again affected. Amsterdam speaks of the malignancy of the disease, Leiden complains of recurrences and of heavy losses of sheep-farmers at lambing season. Middelburg, 's Hertogenbosch, Venlo and Maastricht all mention the short duration of immunity.

In summary, it appears that the first phase of the 1918–20 epidemic was mild, the second and third severe. It also appears that the second phase was characterised by a high frequency of second attacks.

The reports of 1921 all concur in speaking of the type as mild and mainly affecting young animals.

The last seven months of 1921 and the first nine of 1922 were periods of quiescence. But in November 1922 all provinces except Drenthe were again returning cases. In 1922–3 South and North Holland and Utrecht were the storm centres. South Holland produced, in the last three months of 1922, 147 of the total 325 outbreaks of the whole year. In 1923 these two provinces and Utrecht were responsible for 90·9 per cent. of the whole number of outbreaks. North Holland's maximum of 807 was in October, South Holland's maximum, 1537 was in September and Utrecht had a maximum of 642 in October. Every province except Groningen was reporting outbreaks in December 1923. The type of disease was generally mild although Amsterdam reported some variations of type.

At the beginning of 1924 all provinces were returning cases but only North and South Holland more than 30. Statistically this is the worst year yet recorded and at the end of it three provinces were still returning over 200 cases. South Holland had a maximum in May, North Holland and Utrecht in June, Friesland, Groningen, Zeeland and North Brabant in July, Gelderland,

Overijssel, Drenthe and Limburg in August. In December the incidence was again increasing in North Brabant, Gelderland, Friesland and Zeeland. The districts reports are to the following effect.

Table V. *Holland. Dates of maxima during outbreaks of 1923-4 and measures of maxima expressed as percentage of total incidence.*

	First maximum			Second maximum			Total outbreaks 1923-1924
	Date	No.	% of total	Date	No.	% of total	
Noordbrabant	Oct. 1923	39	0.41	July 1924	2619	27.8	9,436
Gelderland	Oct. 1923	71	0.53	Aug. 1924	4137	30.6	13,519
South Holland	Sept. 1923	1537	10.9	May 1924	2666	18.8	14,156
North Holland	Oct. 1923	807	7.9	June 1924	3354	32.6	10,272
Zeeland	Oct. 1923	47	1.8	July 1924	639	24.2	2,636
Utrecht	Oct. 1923	642	10.2	June 1924	1668	26.6	6,269
Friesland	Nov. 1923	63	0.4	July 1924	7602	47.0	16,172
Overijssel	Nov. 1923	21	0.3	Aug. 1924	2943	35.0	8,404
Groningen	—	—	—	July 1924	1533	29.6	5,187
Drenthe	—	—	—	Aug. 1924	2817	37.6	7,493
Limburg	Sept. 1923	52	1.1	Aug. 1924	1554	33.9	4,586

Groningen reports numerous after effects. Leeuwarden describes the conditions as unfavourable, the primary sores observed less frequently in the mouth and more often on the udders. Zwolle finds the type mild and deaths mostly of young animals but mastitis after recovery was very troublesome. Arnhem and Utrecht also report to this effect. Leiden and Rotterdam, Middelburg and 's Hertogenbosch report the type mild but very infectious. Maastricht emphasises the infectiousness with low virulence.

I have not seen any detailed official reports of later date so my account of the Dutch experience ends with the records of 1924¹. Since 1918, when the policy of slaughter was abandoned, there has been a succession of epidemics; the epidemiological tendency has been towards mildness, so far as mere fatality is concerned, since the second phase of the 1918-19 epidemic, but the infectivity of the 1923-4 outbreak has been the highest yet recorded while the frequency of second or even third attacks has been a matter of general comment.

I hope that the above summary of the Dutch experience may be of use to other epidemiologists who will not be interested in the remainder of the paper, although lack of knowledge of agricultural conditions and imperfect knowledge of the Dutch language have no doubt caused me to omit facts which a more instructed student would find significant.

I now pass to a commentary upon the events described.

Some deductions.

The events just described have been closely studied in the country where they occurred and in 1919, as mentioned above, a Royal Commission was appointed which reported in 1921. The Commissioners were chiefly concerned

¹ In 1925, according to the official Year Book, there were 30,936 outbreaks, 11,582 of these in Friesland 6181 in North Holland, 4890 in South Holland. The only provinces with less than 1000 outbreaks were Zeeland (279) and Limburg (150). In 1926 there were 62,656 outbreaks.

with practical issues which do not directly concern me. A majority were of opinion that the policy of slaughtering-out was right. They gave considerable weight to the favourable experience of England and Wales and they published a chart showing the monthly incidence of outbreaks in Holland from 1892 to 1920 (inclusive) distinguishing the periods when slaughtering-out was enforced. "This chart," they remarked, "clearly shows that the policy of slaughtering has repeatedly rooted out the disease" (p. 83). A member of the Commission (Heer Wesbonk) dissented from this conclusion. It appears from the chart that slaughtering was first resorted to in August 1894 at nearly the height of the epidemic. In 1892 there had been a minor epidemic (about 500 outbreaks in the month of maximum) which came to an end without slaughter. In 1893 there were a good many cases in January and February but the disease dwindled away (without slaughter) during the year. In 1895 slaughtering was not adopted but the prevalence was low. Slaughtering was carried out from December 1895 to December 1896, but in the later months of 1896 the disease was showing a rising incidence and a large epidemic developed in 1897 (slaughter was apparently discontinued at the end of 1896). There is no further indication in the chart of slaughtering until May 1907. Between 1897 and 1907 there were two small epidemics in 1898-9 and 1900, sporadic prevalence in 1901-3 and complete intermission from June 1904 to November 1906. Slaughter was maintained only for a month in 1907; during 1907 an epidemic of the same magnitude as that of 1894 developed. Slaughter was resumed in August 1908 and continued until the epidemic of 1911. It was not adopted again until March 1913 (during 1912 foot-and-mouth disease was sporadic). Thereafter it continued to be the regular practice until October 1918 (*vide supra*). It will be noticed that from the beginning of 1913 to the end of 1918 there was no severe epidemic of foot-and-mouth disease (with respect to 1915, see above) and throughout this period slaughter was the rule. But there was an equally long or longer period of substantial freedom, viz. from the beginning of 1901 to the middle of 1907 in a period when slaughtering-out was not the practice. As a statistical epidemiologist I am led by a study of this chart to agree with Heer Wesbonk's dissentient note. *The chart* affords no evidence that the policy of slaughtering had the least effect, good or bad, upon the epidemiological history of foot-and-mouth disease in the Netherlands.

The Commission discussed other factors and a very interesting chapter of the report drafted by Prof. J. Poels should be noticed. Although by injection of infective matter it is possible to produce in animals who have passed through a natural attack, elevation of temperature and other indications of blood infection, it is very difficult to produce in this way the clinical disease, if the animals experimented upon had recently sustained a natural attack. The simplest explanation would be that natural attack sets up (1) a local tissue immunity which persists for some time, (2) a general humoral immunity which is more transitory. "The possibility cannot be excluded that the infectious matter from a carrier which has been passed through one or more susceptible

cattle is again in a condition to cause the disease in animals which have already passed through it and acquired some measure of immunity. It is conceivable that this may explain the recrudescence of foot-and-mouth disease, without importation of infective matter from elsewhere, under circumstances which produce on the uninstructed the impression of a spontaneous origin" (pp. 28-9).

The history of foot-and-mouth disease in Holland since 1921 supports this interpretation. Thus the frequent comment in 1924 (see p. 483, *supra*) that the primary lesions were less frequently observed in the mouth than upon the udders accords with (1), while the short intervals between and the extreme infectiousness of the recent outbreaks accord with (2). Of course this is not the only possible explanation of the facts, the question of successive infections with viruses of different immunological types cannot be neglected. Magnusson and Hermansson recently reported from Sweden, where foot-and-mouth disease has been mildly epidemic for some time, the following striking observation. They had under observation a herd in which foot-and-mouth disease broke out twice, at an interval of 12 weeks. When the second outbreak occurred the authors had in their possession living virus derived from the first outbreak and they obtained virus from the second outbreak. These experiments were made. A cow, a sucking pig and a hog were inoculated with Virus 2 and all suffered from typical attacks. They recovered and 17 days later received Virus 1; all fell ill again and were worse than before. Two calves inoculated with Virus 2 and typically affected showed, a week later, no immunity against a passaged virus of the Swedish 1925 epidemic. Among 32 cows, 1 calf and a pig who received Virus 1 and 1-2 months later Virus 1 again, there were no second attacks. Of 5 cows, 2 calves and a pig which, from 14 days to 2 months before, had passed through an experimental attack due to Virus 2, all but 1 cow proved sensitive to Virus 1. Twenty-four guinea-pigs inoculated with Virus 1 were, with one exception, refractory (1-3 months later) to a second dose, while 20 guinea-pigs receiving Virus 2 were, with two exceptions, sensitive (1-3 months later) to Virus 1. This experiment is hard to explain on any other hypothesis than that of a difference of immunological type. Such differences in immunological type would not, however, account for a different distribution of the local lesions in successive epidemics, noted above, unless we make the assumption, for which there seem to be no valid grounds, that the several viruses differ not only in their antigenic properties, but also in their tissue affinities. How far the other important suggestion, viz. the effect of passage through non-immunes, is valid, cannot be decided on the evidence at my disposal. What one really wants to know is whether in those herds in which, what Prof. Topley and I call the rate of circulation of non-immunes is high, the interval between successive outbreaks is shorter than where the circulation rate is low. Topley and I have shown that in such an infection as *Mouse-pasteurellosis*, the epidemicity of the disease is greatly influenced by the rate of addition of non-immunes. If a herd be protected from contact with non-immunes (*e.g.* as in our experiments by destroying or removing new-born

animals and making no additions to the original stock) an epidemic disease tends to die out and may not recur. If additions of small numbers at long intervals are made the disease will usually recur, but at longer intervals and with less severity than when larger numbers of additions and at shorter intervals are made. We think we have made it probable that the *regular* addition of small numbers at short but constant intervals is more dangerous than the addition of large batches at long intervals. All these additions are of animals certainly neither suffering from nor—so far as a sedulous bacteriological examination will reveal the truth—carrying the disease. Now in the cattle population of such a country as Holland, at least since the end of 1918, foot-and-mouth disease may be said never to have completely died out while each year non-immunes are added by natural increase. But the rate of addition is not the same in different provinces for the age constitutions are different (*vide supra*). No doubt the ratio of breeding animals and calves to the total population of a herd is determined by the precise type of stock farming, but the details for individual herds are, naturally, not published. It would be extremely instructive to learn whether this great series of natural experiments confirms or refutes our results, which have been, *mutatis mutandis* confirmed by Dudley with respect to the succession of epidemics in boarding schools and institutions.

If we suppose for a moment that the hypothesis of Greenwood and Topley is really applicable to the epidemiological problem of foot-and-mouth disease, and we are justified in making that assumption *provisionally* because none of the facts revealed by the present study of Dutch experience are discordant with it, various conclusions follow.

In the first place, so far as Holland of the present day is concerned, slaughtering-out would not be a promising policy. The number of animals now alive which have passed through an attack of the disease and *may* be effective carriers must be so large that *effective* slaughtering-out would be economically ruinous and the mere slaughtering-out of the implicated and in-contact animals in new outbreaks would be futile. In the second place, *the supervision of the non-immunes* is a matter of extreme importance. To add to the herds of a district which has been regularly and severely ravaged by foot-and-mouth disease, cattle from areas (within or without the country) where the disease has been absent or little prevalent, is courting an outbreak in the accepting herds. Indeed the introduction of non-immunes is quite as dangerous as the introduction of sick or carrying animals. But this is only a fraction of the problem of regulation of importation of non-immunes. After all, most non-immunes enter *per vias naturales*. Assuming that the prevention of breeding from survivors of attack is economically impossible, the rigorous and early isolation of these and other new comers from other members of the herd might well be possible¹. Here a definite field experiment would be of much interest.

¹ It may perhaps be urged, in view of such work as that of Bedson, that active immunisation rather than *any* method of isolation will provide the practical solution.

To put the matter epigrammatically—and so of course not quite accurately—supervision of non-immunes rather than supervision of infected or recovered animals would be the guiding principle. In this way we should expect to see the epidemics diminish in magnitude and become spaced out. Ultimately we should suppose that the cattle population would reach the position enjoyed in 1902 or 1914, *i.e.* foot-and-mouth disease would not be a cause of serious economic loss but would still be present in the herds sporadically. Supposing that position to have been reached, would the application of the policy of slaughter *then* be appropriate? Having regard to the long land frontiers of Holland, I should say that it would not succeed because (as past experience seems to prove) it is impossible either to prevent the introduction of infective animals or to discover their location until after a delay which renders all hope of elimination impossible. When we are dealing with an isolated community in which the *materies morbi* of some infectious disease either has never existed or has died out (the latter condition is not equivalent to even a long interval of freedom from *clinical* cases) and the re-importation of infective material is difficult and, when it occurs, will be promptly brought to the notice of the authorities, ruthless destruction of diseased animals and in-contacts seems to me a logical proceeding. In Holland, so far as I can judge from the evidence open to me, these conditions are not fulfilled. It is doubtful whether the home population has during the last 15 years been free from even clinical cases over more than 12 months at a time, it is certain that infectious material can and does frequently pass the frontiers and it is probable that the co-operation between stock holders and government officials is inadequate.

How far the policy of slaughter is logically applicable to our own country is a different question.

I have set out above (pp. 467–471) the epidemiological history of foot-and-mouth disease here, so far as it is available to me. It is, I think, rather difficult to believe that the facts are adequately explained by any simple hypothesis of importation and, if the disease again becomes formidable, it would be interesting if some of the lines of inquiry suggested above were followed out. Much importance seems to me to attach to the tracing of the movements of cattle originating in districts (whether at home or in the dominions) absolutely or relatively free from foot-and-mouth disease. I think this analysis, great as are its shortcomings, proves how interesting an epidemiological field is presented by the facts of infectious disease among domestic animals. I have pointed out that the statistical information is, from several points of view, defective, and I suggest that an attempt might be made to collect more detailed information not for the whole population of a country—an evidently impossibly costly undertaking—but for special areas. I would also add that such investigations should be pursued—whether conducted by officials or by private investigators—on wholly academic lines. A perusal of many papers and reports on foot-and-mouth disease and other plagues of animals suggests that a considerable proportion are tendentious. The bias of the private investigator is

usually against the official policy of his country and, as an inevitable consequence, there is a tendency for official reports to stress the arguments in favour of whatever official practice has been customary. Of course one sees something of this in the literature of human epidemiology but I am sure it is accentuated in veterinary literature. Personally, I do not find any reason to criticise the actual policy of the authorities here or elsewhere, but I do find many quite important unsolved problems which are not beyond the reach of solution if all interested in the study of epidemiology pool their resources.

REFERENCES.

(Citation is confined to works from which data have been extracted or which are specifically mentioned in the text.)

OFFICIAL SOURCES.

(1) *England and Wales.*

For the earlier years up to 1893. The Appendices to the *Reports of the Veterinary Department of the Board of Agriculture.*

From 1894. The Annual Reports of *Proceedings under the Diseases of Animals Acts, etc.*, containing the Annual Reports of the Chief Veterinary Officer, and issued by the Board of Agriculture (now Ministry of Agriculture and Fisheries).

Also: *Report of the Departmental Committee appointed by the Minister of Agriculture and Fisheries to consider the Outbreak of Foot-and-Mouth Disease which occurred in 1923-4* (cmd. 2350 of 1925).

(2) *The Netherlands.*

(a) Annual Publications (all issued by the Department of Agriculture, Commerce and Trade).

Verslag aan de Koningin van de Bevindingen en Handelingen van het Veeartsenijkundig Staats-toezicht to 1920. [An annual publication corresponding closely to the English *Proceedings under the Diseases of Animals Acts* and from 1921 onwards *Verslag aan den Minister van Binnenlandsche zaken en Landbouw over de Werkzaamheden van den Veeartsenijkundig dienst en den Gezondheidstoestand van den Veestapel.*]

(b) Special publications.

Het Mond- en Klauwzeer in Nederland in 1911. (A special report issued by the Department of Agriculture in 1912, No. 1.)

Verslag over het Mond- en Klauwzeer in 1912-16. (A special report issued by the Department of Agriculture in 1916, No. 4.)

Verslag van de Staatscommissie in Zake Mond- en Klauwzeer. (Report of the Royal Commission appointed to consider the epidemic of 1918-19. The first volume contains the Report, the second volume statistics and reports of sub-commissions.)

(3) *Germany.*

Jahresbericht über die Verbreitung von Tierseuchen im Deutschen Reiche. Berlin.

UNOFFICIAL PUBLICATIONS.

BEDSON, S. P., MAITLAND, H. B., BURBURY, Y. M. (1927). Further observations on Foot-and-Mouth Disease. *J. Comp. Path. and Therapeutics*, **40**, 5-36.

DUDLEY, S. F. (1926). *The Spread of Droplet Infection in Semi-Isolated Communities.* (Medical Research Council, S.R.S. No. 111.)

FRACASTORI, H. (1893). *De Contagionibus.* (Meunier's edition.) Paris.

- GAMGEE, J. (1866). *The Cattle Plague*. London.
- GINS, H. A. and KRAUSE, C. (1924). *Ergebnisse d. Allgemein. Path. u. Path. Anat.* 20ter J. II Abt. II Teil, pp. 805–912.
- GREENWOOD, M. and TOPLEY, W. W. C. (1925). *J. Hygiene*, **24**, 45–110.
- HOFFMANN, L. (1921). *Die Bekämpfung und Ausrottung der Maul- und Klauenseuche*. Hannover (Schaper).
- MAGNUSSON, H. and HERMANSSON, K. A. (1926). *Acta Scan. Path. et Microbiol.* **3**, 736–48.
- NEVERMANN, L. (1915). *Arch. f. Wissen. u. Prakt. Tierheilk.* **41**, 177–210.
- TITZ, C. (1923). *Arch. a. d. Reichsgesundheitsamte*, **53**, 187.

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