THE BEARING OF OUTBREAKS OF FOOD POISONING UPON THE ETIOLOGY OF EPIDEMIC DIARRHOEA.

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Introduction.

It is almost impossible to avoid some confusion when one has to deal with diseases which it is difficult to define clearly either by means of *symptoms* and *lesions*, or by means of some *causal agent* capable of demonstration in the majority of cases.

Diarrhoea is a symptom produced by a number of causes, and each one of these causes according to its *intensity* of action, or to the *state of the patient* may produce several types of diarrhoea.

Moreover, there is evidence to show that the agent which initiates an attack of diarrhoea may in the course of the illness caused by its action be superseded by other agents (*e.g.* certain bacteria generally present in the intestine), by which the course of the disease may be so completely altered as to make it difficult to recognise the relations between cause and effect.

In bringing forward certain facts which in my opinion establish clearly certain relations between food poisoning and epidemic diarrhoea, I must labour under a double difficulty, for neither food poisoning nor epidemic diarrhoea is a well-defined pathological entity.

Definition of Epidemic Diarrhoea.

By epidemic diarrhoea is generally meant *an infectious disease affecting a number of persons at the same time, more specially during the hot seasons,* and *the most constant symptom of which is diarrhoea.* One of its special features is its tendency to occur in certain poor populous districts, where it causes great mortality among children.

From descriptions I have been able to find in standard books of reference it appears to me that such terms as *English cholera, Cholera nostras, Cholera infantum, Choleraic or Choleriform diarrhoea, Septic diarrhoea, Summer diarrhoea, Infantile diarrhoea,* etc. must, generally speaking, be taken as synonyms of epidemic diarrhoea. To the morbid anatomist epidemic diarrhoea is an acute *gastro-enteritis.*

Chief Symptoms.

Epidemic diarrhoea is characterised by a certain number of symptoms, which have been summed up by Dr Ballard as follows:

The leading phenomena of the disease are diarrhoea, vomiting, convulsive phenomena; a bodily temperature at certain periods above, at other periods below, what is normal; reduction in quantity, or actual suppression of urine, embarrassed breathing, indications of pulmonary hyperaemia or inflammation, pallor of surface of the body, loss of bulk and flesh, and exhaustion with its well-known clinical features. Occasionally there is jaundice; now and then a fugitive rash has been observed on the body.

These symptoms agree with those given by various clinical authorities as characteristic of English cholera and infantile diarrhoea, but clinicians include intense thirst, pain and griping, cramps, bilious vomiting and diarrhoea among the important symptoms. Suppression of urine, convulsions and cramps are not among the characteristic features of the ordinary milder attacks of the disease.

Severe cases of the same disease may present features almost identical with those of Asiatic cholera, poisoning by certain organic and inorganic poisons, or even perforation of the stomach or bowel.

The difficulty of diagnosis of isolated cases is very considerable, and the nature of the disease is generally indicated by its epidemic and seasonal characters more than by any semeiotic feature.

Morbid Anatomy.

In fatal cases the lesions observed are not sufficiently characteristic to remove all doubts. Among post-mortem changes I may mention, absence of food in the stomach and small intestine, hyperaemic, swollen, sometimes ulcerated mucous membrane of the same parts. Accumulation of mucus, frequently bile stained, upon these mucous membranes. Degenerative changes in the liver and kidney. Hyperaemia of the

lungs, sometimes pneumonia. The spleen is variable in size and frequently small. There is nothing pathognomonic in any of these lesions.

Bacteriology of Epidemic Diarrhoea.

Exact notions regarding the bacteriology of forms of enteritis other than those connected with cholera, typhoid fever and anthrax, were very few before the year 1885, when the classical researches of Escherich upon the *Bacillus coli communis* became known. The researches of that observer showed that although the *Bacillus coli communis* is a constant inhabitant of the intestine, it is capable under certain circumstances of acquiring pathogenic properties. Hueppe in 1887 stated that it was capable of producing cholera nostras, a view which has also been supported at a later date by Gilbert and Girode and others. Lesage, Macé and Simon, Cumston, etc. have found the *Bacillus coli communis* in a large proportion of the cases of infantile diarrhoea which they have investigated, and believe that organism to be the cause or the most important cause of summer diarrhoea in children.

Other observers however have attributed to other organisms an important share in the production of epidemic diarrhoea.

As far back as 1884, Finckler and Prior found in cases of cholera nostras the *Spirillum* which has received their names.

Baginski, in Germany, Booker, in America, found in the stools and organs of children affected with infantile diarrhoea a number of micro-organisms, among which may be mentioned the *Bacillus lactis aerogenes*, the *Bacillus coli communis*, the *Proteus vulgaris*, *Staphylococci*, *Streptococci*, etc.

Booker does not believe that the summer diarrhoea of infants is due to any single organism, but nevertheless he regards with suspicion the *Proteus vulgaris*, and the *Streptococcus enteritidis*. Holst evidently attaches importance to the streptococci, for he has recorded in connection with several epidemics of summer diarrhoea, the presence of the *Streptococcus longus* in cows' milk which had been used by the patients. A streptococcus has also been found in connection with gastro-enteritis in adults.

Damaschino, Clado and Lesage have described a bacillus producing a green pigment, as the cause of a green diarrhoea of infants.

Klein attributes to the *Bacillus enteritidis sporogenes* which he has found in the intestines of children suffering from diarrhoea, an important share in the production of the disease.

This short and incomplete review is sufficient to show that the etiology of epidemic diarrhoea is as yet by no means clear.

It will be noticed, however, that the bacteria which have been suspected on good grounds of being the cause of outbreaks of summer diarrhoea belong chiefly to types of bacteria which are inhabitants of the alimentary canal. The virulence of several of these microbes has been shown to be capable of considerable variation.

The bacilli of the colon group appear to be most intimately connected with the epidemic diarrhoea both of adults and of children.

These bacilli resemble each other so closely in some respects that one is tempted to regard them as varieties of the same stock. Yet if one submits colon bacilli obtained from the intestinal contents of a number of cases of diarrhoea to the series of tests which are usually employed for diagnostic purposes, it is found that one or more of the reactions which are associated with the *Bacillus coli communis* of Escherich are frequently absent. The acidity which is generally produced very early in various media may be permanent, or replaced more or less rapidly by an alkaline reaction; milk is sometimes coagulated rapidly, sometimes very slowly or not at all, similar variations are observed with regard to the indol reaction, the fermentation of various sugars, the appearances of the growth on potato, and even the serum reaction. The serum reaction presents with regard to each of the many races of the *Bacillus coli* such a degree of specificity that it is deprived of much of its practical value for the purpose of a clinical diagnosis. In the investigation of limited outbreaks due to a definite source of infection this reaction may, however, be very useful for the purpose of determining whether a bacillus isolated from the implicated material or from some of the cases is the actual cause of the outbreak. It must however be remembered that the blood of patients suffering from this kind of infection gives a definite reaction only for a very limited period of time, and in very severe cases the serum reaction is generally very indistinct or absent.

I cannot in the time at my disposal discuss this aspect of the question at greater length[1].

[1] A recent paper by Dr M. H. Gordon gives a fairly complete account of our present knowledge of the Bacteriology of Epidemic Diarrhoea. *Practitioner*, August, 1902.

Epidemiological features of Epidemic Diarrhoea.

The epidemiological features of summer diarrhoea so well brought out by Ballard's investigation would therefore appear for the present to constitute the most satisfactory proofs of the specific character of summer diarrhoea. I will refer to them at a later stage.

Food Poisoning.

The resemblance between many outbreaks of food poisoning and epidemic diarrhoea is very great; this resemblance would be even clearer if certain special forms of food infections such as botulism were entirely separated from the general mass of cases.

Van Ermengem describes under the name of *botulism* a state brought about by the ingestion of various articles of food such as ham, tinned or preserved foods, oysters, mussels, etc., which is characterised by comparatively slow onset (12 to 24 hours after infection), secretory troubles, paralysis of certain muscles, dysphagia, constipation, retention of urine, absence of fever, etc. Van Ermengem has found that these symptoms were produced by a bacillus to which he has given the name of *Bacillus botulinus.*

Botulism differs considerably from the more *common form of food poisoning* with which we are specially acquainted in this country.

This last form of food poisoning is however very imperfectly understood, as may be seen by consulting our chief books of reference. Observers are generally of the opinion that in the large majority of cases food poisoning results from the ingestion of the flesh of animals suffering from certain forms of septicaemia, enteritis, or pneumo-enteritis, whose flesh owes its noxious properties to various bacilli resembling more or less closely the *Bacillus enteritidis* of Gaertner. There is good evidence to show that this kind of infection occurs at times, but I will show that the mode of infection is usually different, and the result of a more general kind of contamination.

Works on Hygiene and Public Health attribute the outbreaks of diarrhoea which usually attract attention, mostly in connection with hospitals and other public institutions, to the consumption of *water* containing an excess of mineral waters, or contaminated with sewage; to *milk* which has been exposed to effluvia in ill-ventilated places, or which has undergone fermentation; to *tinned meats, pork-pies, ham, game, fish, cheese.* In the latter cases the symptoms are usually

supposed to be the results of the action of some chemical poison (Ptomaines, Tyrotoxicon, etc.) produced during putrefaction, so that the disease is generally described under the name of *ptomaine poisoning*, a name which I consider to be misleading in the great majority of cases.

Outbreaks of diarrhoea due to the consumption of food are not clinically distinguishable as a group from summer diarrhoea or cholera nostras. Thus Taylor tells us that *acute gastro-enteritis* (*English cholera*), which occurs occasionally during the summer months, is set up by unsuitable ingesta such as sausages, meat, pies, shell-fish, or food in a state of decomposition. He also says that there is reason to believe that some of these cases are due to *ptomaine poisoning*. The similarity of the causes of food poisoning and summer diarrhoea is clearly indicated by a great number of clinicians.

Thus although we have grown accustomed to designate by different names certain types of diarrhoeal diseases, it is obvious that these various names do not indicate a reasonable belief in the existence of so many diseases, but relate rather to the *mode of occurrence of a single disease, or of a small group of closely allied diseases.* General evidence seems to show that the most common forms of food poisoning give rise to symptoms resembling closely those of epidemic diarrhoea. Outbreaks of food poisoning may occur at all times of the year, but they are generally most frequent at the time when epidemic diarrhoea is most prevalent. That they affect adults as well as infants appears to be due chiefly to the kinds of food which produce them, but certain foods, such as milk, which are partaken of both by infants and adults, give rise in both to attacks of diarrhoea similar to typical attacks of epidemic diarrhoea of unknown origin.

Now I consider that the chief difficulty which workers have experienced in searching for the actual cause of epidemic diarrhoea, is due to the fact that they have looked for it in the alvine discharges, or in the organs of patients who have died from the disease.

If, as is reasonable to believe, the bacteria causing epidemic diarrhoea are intestinal bacteria, it is obvious that a great difficulty must be experienced in determining which of these bacteria is responsible for the disease. Many of these bacteria are virulent when introduced into the tissues, many of them increase in virulence in the course of an attack of diarrhoea, and several of them have a tendency to escape from the intestine and penetrate into the various tissues of the body immediately after death or even during the last hours of life at the end of an exhausting illness.

On the supposition that epidemic diarrhoea is generally the result of a more *widely disseminated, and less massive form of bacterial infection of food* than is the case with regard to the more definite outbreaks of food poisoning, we should be able to utilise the occurrence of certain outbreaks of food poisoning for the purpose of turning the difficulties which we have generally to contend with in the investigation of epidemic diarrhoea.

It is with that object that I have for the past eight years investigated the action of bacteria which had given rise to outbreaks of food poisoning, and have also studied certain pathogenic properties of the cows' milk which is supplied to our towns, and which is responsible for much of the infantile mortality due to epidemic diarrhoea. During these eight years I have had opportunities to study several outbreaks of infection due to milk, cheese, pork-pies, tinned salmon and other foods. I have also been able to study the pathogenic action of over 2000 samples of milk upon guinea-pigs. By comparing the properties of bacilli obtained from noxious articles of food, and of those obtained from animals which had suffered from the effects of inoculation with various samples of milk, I have been able to satisfy myself that these bacilli, with few exceptions, belonged to the colon group of bacilli.

To show the nature of the evidence obtained I will now give a short account of three of these investigations. A more complete analysis of the statistical data I have accumulated cannot yet be attempted.

Manchester Outbreak of Diarrhoea due to the Consumption of Milk, November 1894.

In the early part of the month of November 1894 there occurred in Manchester an extensive outbreak of diarrhoea attributable to the consumption of milk. This outbreak was investigated by Dr Niven, from whose report I take the following particulars. (Report on the Health of Greater Manchester, 1894, pp. 102 *et seq.*)

On Nov. 7 Dr H. Ashby sent a note to Dr Niven in reference to a number of cases of illness which had occurred in Victoria Park, Manchester. The symptoms were those usually associated with English cholera. Those attacked were all supplied by one milk dealer, and Dr Ashby was of opinion that circumstances pointed to milk being the cause of the outbreak. Dr Niven ascertained that the attacks in the great majority of instances had occurred on the night of November 5, and in the early part of November 6. As a rule the persons attacked

had partaken of unboiled milk. One lady however was of opinion that all the milk brought into her house had been boiled. About 8 or 9 hours elapsed between the taking of the incriminated milk and the occurrence of symptoms of illness.

Altogether 160 cases were reported, occurring in 47 families; none of these proved fatal, but in several instances the symptoms were severe.

I need not enter here into a consideration of the steps taken by Dr Niven to establish the relationship between the outbreak and the milk supplied from one farm. The evidence so collected established clearly the relation.

On visiting the farm, Dr Niven ascertained that close to the farm-house there was a tip of *midden-privy refuse*, which was estimated to contain 40,000 tons of material of that kind. The farm was bordered by two streams which met below. The one coming from the tip was very foul, the other comparatively clear, but also contaminated with sewage and with matter from a *tripe-boiling place*. The water used to wash the pails was tepid; its temperature taken by Dr Martin on one occasion was 92° F. The water used in cleansing the milk-pails was kept in a foul cistern. The cows drank from a pool in the yard which received drainage from the cowshed midden. The storage of milk over-night was such as to expose it to warmth and contamination from the cowsheds.

Whilst this investigation was proceeding I was making a bacteriological examination of the only sample of suspected milk which could be obtained on the 8th of November. I will refer again to this, but it is convenient to state here that without any knowledge of what Dr Niven was finding, I reported to him that the *Bacillus coli communis* which was abundant in the milk, indicated sewage or faecal pollution, and that it was probable that some contaminated water had found its way into some of the vessels used for collecting or distributing the milk.

Meanwhile Dr Niven on continuing his investigation discovered a fact which had originally been concealed from him, viz., that on Nov. 8 a cow affected with inflamed udder (garget) had been removed from the farm and slaughtered on Nov. 10.

Several cases of bacterial infection due to the consumption of milk had been recorded in Germany, and in those cases the infection of the milk had been attributed to some disease of the cow.

On this basis Dr Niven concluded that the outbreak in Manchester was probably due to the disease of the cow which had been removed

from the farm. It is probable that the farmer on hearing complaints from his customers on the 6th and 7th of November got alarmed, and knowing that one of his cows was affected with garget, disposed of it at once to remove evidence of culpable neglect on his part.

Thus it came to pass that the Victoria Park outbreak was attributed to some affection of the udder of one cow, a conclusion which had the support of opinions expressed with regard to some previous outbreaks of the same kind.

Results of the Bacteriological Examination of the Milk.

The examination of milk led me however to a different conclusion.

The only sample of the milk which had produced illness was 3 days old when it reached me, it was firmly clotted, strongly acid, and had an unpleasant, sour smell. Six adults or adolescents and an infant who had partaken of this milk had been taken ill (with violent diarrhoea, sickness and pain) after a period of incubation lasting about 12 hours.

I gave large doses of this milk to two guinea-pigs and two young rats without producing any distinct illness in those animals.

On microscopical examination *very few cells* were found, *no pus*, the fat globules were partly confluent. A very large number of bacteria were found, the most abundant being short, very motile bacilli resembling the *Bacillus coli*, large discrete *Cocci*, and a *Streptococcus* with large segments[1]. Anaerobic and aerobic cultures in milk and bouillon yielded a very abundant growth of several organisms. I was specially struck with the abundance of bacilli which belonged to the *Bacillus coli* group. Of these there were 3 varieties, one (A) having all the cultural characters of the typical *Bacillus coli communis*; another (B) which gave all the usual chemical cultural reactions of the *Bacillus coli communis*, but which produced on gelatine, thick colonies with rough mammillated surface; a third one (C) had most of the characters of the *Bacillus enteritidis* of Gaertner.

On testing the virulence of these organisms by intraperitoneal, and subcutaneous inoculation, I found that a single loopful of pure culture on agar of the bacillus C produced the death of guinea-pigs within 24 to 30 hours. The only lesions found after death being a slight amount of peritonitis, intense hyperaemia of the small intestine, congestion of the lungs: there was no enlargement of the spleen.

[1] The streptococcus was not virulent. Streptococci are very frequently present in cows' milk having absolutely no noxious properties.

Pure cultures of the bacillus were recovered from the blood of the heart.

A similar result was obtained by injecting 2 c.c. of a pure bouillon culture of the same bacillus under the skin of another guinea-pig.

Bacillus A proved much less virulent; an abscess formed at the seat of inoculation from which pure cultures of the *Bacillus coli* were obtained.

Bacillus B did not appear to be virulent.

In the light of the feeding experiments these results at first surprised me, but taking into consideration the state of the milk when it reached the laboratory, it seemed to me quite possible that the virulence of the milk had diminished as a result of the acid fermentation which had taken place during the 3 days it had been kept. That the milk had been virulent was sufficiently proved by the effects which it had produced in 7 human beings.

Further investigation has shown me that the most noxious among the samples of milk which I have studied had either an alkaline or an amphoteric reaction.

Faecal pollution the probable source of the 1894 *Victoria Park epidemic.*

The milk which had caused the Victoria Park outbreak contained therefore among other organisms a large number of bacilli indicating faecal pollution rather than an infectious disease of the cow's udder.

If the udder had been diseased it is difficult to understand why the outbreak occurred suddenly, and was caused by one or two milk deliveries alone.

In addition to this the cow which was suspected of having caused the outbreak was suffering from obvious mastitis, a lesion which as far as we know is not produced by the *Bacillus enteritidis*.

Non-tuberculous mastitis occurs frequently in milch cows, and I shall be able to show that there is no evidence that the milk of cows affected with such lesions is specially noxious.

It seemed to me easier to believe that milk-cans or other vessels had been infected on a certain occasion owing to the use of water heavily polluted with excreta of *a specially virulent kind*, and that the virulent bacteria so introduced had multiplied rapidly in the milk. There was also a distinct possibility of infection through dust, but this seemed to me less probable, considering the fact that the milk must have been exposed to very massive pollution. The state of things observed by

Dr Niven on the occasion of his visits to the farm, when they became known to me, confirmed me in my belief in the extraneous origin of the infection, a belief which I communicated to Dr Niven at the time.

Faecal pollution of milk a reasonable explanation of many cases of epidemic diarrhoea.

If in this case faecal pollution of the milk had produced an outbreak of disease indistinguishable from epidemic diarrhoea except by its time of occurrence and limited extent, it was reasonable to consider the possibility of a more intimate connection than had been generally admitted between epidemic diarrhoea and faecal contamination of milk.

Such contamination does frequently occur, as can easily be ascertained by inspection of badly-kept dairy farms, and by the microscopical and bacteriological examination of milk. It is even difficult to conceive how slight faecal pollution of cows' milk can entirely be prevented under any circumstance. Under ordinary conditions this contamination is apparently without serious effects, but when some animals in a herd are affected with intestinal inflammation, virulent bacilli must frequently escape from their bowel and infect more or less directly a portion of the milk, when that fluid is not collected under conditions of strict cleanliness. In summer these bacteria find in milk a suitable medium for rapid growth and multiplication, so that milk originally wholesome may thus be rapidly rendered noxious. On this supposition cows' milk would become most infectious at the time when epidemic diarrhoea is most prevalent, and would affect most severely infants of the age at which cows' milk becomes their chief food, *i.e.* at the time of weaning, which is the age at which mortality from infantile diarrhoea is greatest.

Working upon that hypothesis I began an investigation which I have carried on for the last 7 years, taking advantage of the large number of samples of milk which were sent to me for the detection of tubercle bacilli.

These samples were representative of the milk supplied to the inhabitants of large towns. Some were collected at railway stations on their arrival from the country, others were collected at the farms and represented the mixed milk of a small number of cows; finally many samples were collected from single cows, which, with few exceptions, had disease of the udder. In the latter case the milk was always collected in sterilized bottles by a veterinary surgeon, who was directed to take every precaution to prevent contamination of the milk by dirt

of any kind. By means of these samples I thought that it would be possible to recognise whether bacilli similar to those which had produced the Victoria Park outbreak were frequently present in the milk supplied to the public. The lesions produced in guinea-pigs inoculated with it would, I thought, allow me to detect their presence. It would also be easy to recognise the influence of disease of the udder, and of the keeping of milk in warm and cold weather for various lengths of time.

Examination of cows' milk (as supplied to towns) for the detection of bacteria capable of producing infection of a septic character.

Putting aside a number of preliminary examinations which had to be made for the purpose of determining the course to be followed in the investigation, nearly 2500 samples of milk have been examined in my laboratory since 1896.

During the years 1896 and 1897 I received many samples from a distance, mostly from Liverpool, these were sent in sterilized bottles, no precaution being taken to keep the temperature of the milk down. Specimens collected in Manchester under my direction were usually brought to the laboratory by hand, immediately after collection, either at the railway station or at the farm. As I have already explained, milk from diseased cows was collected by a veterinary surgeon, the cow being milked direct into sterilized bottles which I supplied. Having satisfied myself that milk coming from a distance, without precaution being taken to keep it cool, was infectious in a large proportion of cases, I refused at the beginning of 1898 to examine any more specimens unless they were collected in sterilized bottles, and packed in refrigerating boxes which I provided for the purpose. Since that time I have noticed a considerable improvement, and although many of the samples have been sent to me from distant places, including a town over 190 miles distant from Manchester, I have had much fewer cases of infection than used to be the case when unrefrigerated milk was forwarded from towns in the neighbourhood of Manchester.

This is shown by the following figures:

TABLE I. (See Diagram I, p. 92.)

Mortality from all causes occurring in guinea-pigs inoculated with cows' milk from 1896 *to* 1901 *inclusive.*

A. *Unrefrigerated mixed or unmixed milk examined during the years* 1896 *and* 1897.

Year	No. of samples	No. of samples causing the death of 2 animals inoculated in less than 10 days		No. of samples causing the death of 1 of the inoculated animals in less than 3 days		Total
1896–97	148	5	3·3 %	11	7·4 %	10·7 %

B. *Refrigerated mixed or unmixed milk examined from* 1898 *to* 1901.

1898	111	0	0 %	3	2·7 %	2·7 %
1899	175	1	0·57 %	1	0·57 %	1·14 %
1900	802	4	0·50 %	25	3·1 %	3·60 %
1901	694	1	0·14 %	8	1·1 %	1·24 %

N.B. The number of samples of milk coming from a great distance has gradually increased from 1896 to 1901.

The inference to be drawn from these gross results is clear: a certain proportion of the samples of milk contained bacteria which under favourable circumstances gave to the milk noxious properties. The development of these noxious properties could be checked in a large proportion of cases by preventing the growth of these bacteria. The difference between refrigerated and non-refrigerated milk would have been very much greater *if the milk had invariably been cooled at the farm immediately after the milking of the cows.* The mortality would have been diminished still further in the last three years if the veterinary surgeons collecting milk at farms at a distance from Manchester had been able to carry refrigerators with them; owing however to the number of specimens they had to collect in a single round they found it inconvenient to carry a refrigerator about with them, and all that could be done was to bring the samples as rapidly as possible to the laboratory where they were dealt with without further delay. The rise of mortality which occurred in 1900 was in great part due to the veterinary inspector getting in the habit of keeping a certain number of samples overnight before delivering them to the laboratory; an accident which I did not discover at once.

To find out whether the infectious bacteria present in the milk were chiefly derived from diseased udders or from extraneous contaminations, it is necessary to compare the effects produced by mixed

milk generally collected at railway stations, with those produced by the milk obtained from single cows affected with disease of the udder.

The following tables explain themselves.

TABLE II.

148 *samples of milk examined before* 1898. *Generally kept for more than 24 hours. No precaution being taken to keep the temperature of the milk low by artificial means.*

	Mixed milk collected at railway stations or town dairies	Milk collected direct from the udder of diseased cows. The milk being collected in sterilized vessels
	Per cent.	Per cent.
Milk producing no marked noxious effect	37·74	45·76
Milk producing chronic infection (non-tuberculous) not fatal	37·74	29·12
Milk producing acute infection rapidly fatal	17·76	0
Milk producing tuberculosis	6·66	24·96
Totals	99·90	99·84

TABLE II *a*. (See Diagram II, p. 92.)

By the exclusion of tuberculous milk the following percentages are obtained.

	Mixed milk	Unmixed milk
	Per cent.	Per cent.
Milk producing no marked noxious effect	40·38	60·5
Milk producing chronic infection not fatal	40·38	38·5
Milk producing acute infection rapidly fatal	19	—
	99·76	99·0

From these results it is obvious that the fatal infection produced in as many as 19·2 % of the animals inoculated with non-tuberculous mixed milk could be attributed to disease of the cow's udder *in a very few if any of the cases.* In fact in this first set of observations there was not a single case of general rapidly fatal infection produced by milk obtained from diseased udders.

Table III.

500 *samples of milk examined during the year* 1900 *for the Manchester Corporation. All these samples were collected in bottles sterilized in the laboratory, and were generally examined in less than* 10 *hours after the time of collection or refrigerated when kept longer. The mixed milk coming from country farms was not refrigerated during the transit by train between the farm and town, and the unmixed milk collected by the veterinary inspector was also not refrigerated during the transit from the farm to the laboratory. The samples of mixed and unmixed milk were generally obtained from the same farms at short intervals.*

	Mixed milk collected at railway stations or dairy farms 357 samples	Unmixed milk of diseased cows with diseased udder 143 samples
	Per cent.	Per cent.
Milk producing no marked noxious effect	67·2	62·2
Milk producing chronic infection not fatal	18·7	13·9
Milk producing acute infection rapidly fatal	1·68	1·39
Milk producing tuberculosis	12·3	22·3
	99·88	99·89

Table III *a*. (See Diagram III, p. 93.)

By the exclusion of tuberculous milk there remain 424 *samples of non-tuberculous milk.*

	Mixed milk collected at railway stations or dairy farms 313 samples	Unmixed milk of diseased cows with diseased udder 111 samples
	Per cent.	Per cent.
Milk producing no marked noxious effect	76·6	80·1
Milk producing chronic infection not fatal	21·4	18·0
Milk producing acute infection rapidly fatal	1·9	1·8
	99·9	99·9

N.B. It is to be noticed that when conditions of keeping and temperature are equalised, mixed and unmixed milk have much the same properties.

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To find out the conditions which favoured the development of infectious properties I have prepared the following tables[1], which include only specimens which had been collected before special precautions were taken to prevent bacterial multiplication.

TABLE IV. (See Diagram IV, p. 93.)

1. *Mixed milk coming from a* DISTANCE OF OVER 40 MILES, *and generally kept for from* 24 TO 60 HOURS, *and even longer in a few cases. (Tuberculous samples excluded.)*

Mean temperature Fahr. in the shade (Manchester) during time the specimens were kept	Specimens producing no noxious effects	Noxious specimens	Totals	Percentage of good specimens
30° to 35°	7	5	12	58·0
35° to 40°	7	11	18	38·5
40° to 45°	2	3	5	40·0
45° to 50°	1	4	5	20·0
50° to 55°	—	—	—	—
55° to 60°	0	2	2	0·0
	17	25	42	39·0

TABLE V. (See Diagram V, p. 94.)

2. *Mixed milk coming from a short* DISTANCE (GENERALLY UNDER 20 MILES), *most of them kept for* LESS THAN 10 HOURS *(with the exception of* 5 *out of the* 7 *bad specimens, and* 4 *out of the* 22 *good specimens which had been kept somewhat longer. Tuberculous samples excluded).*

Mean temperature Fahr. in the shade (Manchester) during time the specimens were kept	Specimens producing no noxious effects	Noxious specimens	Totals	Percentage of good specimens
50° to 55°	1	0	1	100·0
55° to 60°	8	1	9	88·8
60° to 65°	11	4	15	73·2
65° to 70°	—	—	—	—
70° to 75°	2	2	4	50·0
	22	7	29	75·68

[1] For details see an article which I published in 1897, "The examination of cow's milk for the detection of pathogenic properties," *Journal of Comparative Pathology and Therapeutics*, 1897.

TABLE VI. (See Diagram VI, p. 94.)

3. UNMIXED MILKS *kept for various lengths of time, but* COLLECTED FROM THE UDDER *in sterilized vessels.* (*Tuberculous samples excluded.*)

Mean temperature Fahr. in the shade (Manchester) during time the specimens were kept	Specimens producing no noxious effects	Noxious specimens	Totals	Percentage of good specimens
35° to 40°	6	0	6	100·0
40° to 45°	3	2	5	60·0
45° to 50°	5	2	7	71·5
50° to 55°	—	—	—	—
55° to 60°	—	—	—	—
60° to 65°	0	3	3	0·0
	14	7	21	67·2

The influence of time is well shown by the number of specimens remaining good even at a high temperature when the milk had been kept only half-a-day.

On the other hand, the influence of temperature is still more evident, for in every category the number of good specimens is almost inversely proportional to the height of the temperature. Still it is important to keep the two factors of time and temperature in mind. *What is produced in a few hours in summer may occur also in winter when the milk has been kept a long time.*

When the clear relation existing between time of keeping plus temperature and the noxious properties of a certain number of samples of milk, is contrasted with the ambiguous results obtained when an attempt is made to connect these noxious properties with disease of the udder (tuberculosis being excluded), it is difficult not to feel convinced that infection of the milk outside the udder, and the conditions under which milk is kept, are the most important factors causing it to acquire infective properties.

I have found a close resemblance between the lesions produced in guinea-pigs by the inoculation of milk which had given rise to limited outbreaks of summer diarrhoea, and that produced in the same kind of animals by the injection of many samples of mixed milks obtained on the market. In both cases I have very frequently isolated from the blood or local lesions of acutely infected guinea-pigs bacilli belonging to the colon bacillus group. These bacilli were often the only organisms found, especially when the animals were killed before the termination of their illness. In about 90 % of the cases of fatal septicaemia due to

milk inoculations of guinea-pigs I have been able to isolate from the blood bacilli resembling closely, or identical with, those obtained twice from milk causing intense diarrhoea in children and adults. They have a similar resemblance to bacilli which I have isolated from the organs of patients suffering from cholera nostras of doubtful origin, and from the organs of several patients suffering clearly from food poisoning; I have also found the same kind of bacilli in cheese which had given rise to severe attacks of food poisoning. These microbes retain their virulent properties even after being cultivated for several generations outside the body. They multiply with extraordinary rapidity at Summer temperature. They resemble the *Bacillus coli communis* or the bacilli of the colon group in their pathogenic action, their mode of growth on gelatine, agar, potato, milk, lactose agar, glucose gelatine, and in their size, shape, and motility, allowance being made for the variability of the bacilli of this group.

I have not found any reason to alter these views which I published almost in the same terms in 1897. Since I first expressed, in 1894, my belief in the connection between the infections of food by colon bacilli and Summer diarrhoea, Dr Klein's work on the *Bacillus enteritidis sporogenes* has appeared. *Klein's bacillus, which has no relation to the colon group,* would apparently have to milk the same relation as the bacilli of the colon group, being introduced into that fluid through faecal pollution. All I have said in favour of the view that bacilli of the colon group are essential factors in the production of Summer diarrhoea might be said of the *Bacillus enteritidis sporogenes.* The chief difficulty which I find in accepting Dr Klein's theory is, that out of the large number of samples of milk I have examined by inoculation, I have not found more than two samples per 1000 producing lesions which could be attributed to the *Bacillus enteritidis sporogenes,* whilst during the same time I have found that from 100 to 200 or more per 1000 samples according to the season or length of keeping, were capable of causing infection attributable to a bacillus of the colon group. Streptococci did not seem to be responsible for a greater proportion of cases than the *Bacillus enteritidis sporogenes*[1].

[1] It is somewhat difficult to estimate the share taken by staphylococci and streptococci in the production of lesions following milk inoculations, they are found frequently enough in animals dying more than 10 days after inoculation, and they may in such cases be associated or not with bacilli of the colon group, but they are not usually found in animals dying from acute septicaemia. It is probable that in many instances their presence is due to secondary infection.

Comparison of Epidemiological Data and of Bacteriological Data resulting from the examination of Cows' Milk.

A consideration of the facts brought to light by the valuable contributions of Dr Ogle, Dr Ballard, Dr Newsholme and others, impresses me with the belief that temperature is on the whole the most important of the factors determining the rate of mortality from epidemic diarrhoea.

Dr Newsholme's able and exhaustive "Contribution to the Study of Epidemic Diarrhoea" (*Public Health*, x. p. 139, 1899—1900) leaves no doubt upon this subject. The influence of other conditions is fully discussed in Dr Newsholme's address, but although those conditions have undoubtedly to be considered, they are in my opinion of secondary importance with regard to their relation to case incidence.

Dr Newsholme concludes that the disease is due to a particulate poison which infects the air, and is swallowed, most commonly with food, especially milk. In this he agrees with Ballard, and with regard to milk he is also in agreement with the position I had previously taken.

In discussing the influence of milk, however, Dr Newsholme does not attach so much importance as I had done to infection at the cow-shed, either through dirty udders, dirty hands, or dirty vessels. He is of opinion that milk is probably generally infected during storage at home in places where it is exposed to pollution by infective dust.

My results do not exclude infection at the home of the consumer, or during transit from the farm, but they indicate that infection at the farm, or through vessels infected at the farm and used by the farmer for the storage and carriage of milk, must be of paramount importance. *None of the milk I have examined had been exposed to any influence attributable to a consumer's home.* It will be noticed that a large proportion of the samples of milk obtained from cans at railway stations or at the farms *is already infectious before it reaches the consumer*; also that the degree of noxiousness acquired through infection is proportional to the length of time the milk has been kept, and the temperature which it has been exposed to, before it reaches the consumer. It seems to me that the most dangerous form of infection which takes place at the consumer's home is that which results from the placing of fresh milk in vessels or feeding-bottles which have previously contained infected milk, and which have not been sufficiently cleansed or sterilized

afterwards. It is therefore obvious that long keeping and high temperature are the two important factors which determine whether a sample of infected milk will contain a sufficient quantity of bacteria or bacterial products to produce infection. The conditions necessary for this development of noxious properties are generally more easily attained during transit from the farm in hot railway vans, than after the milk has reached the home of the consumer. The same factors are of course at work at the last place, but usually the time is shorter and the temperature lower. Infection, long keeping, and high temperature are all compatible with many town cellars or pantries, but taking all the facts I have collected into consideration it appears to me that infection at the farm or through milk-cans or other vessels is by far the most important factor. According to this view the explanation of a large proportion of cases of infantile diarrhoea becomes an easy matter; infection through cows' milk explains readily the special incidence of the disease and the high mortality of infants between the 3rd and the 12th month. The difficulty of obtaining fresh milk in the centre of poor populous districts would also explain why so much of the milk consumed by poor children of large towns is infectious, for such milk has often to travel over considerable distances under very unfavourable conditions. The better classes are generally supplied with fresher milk than the poorer classes[1]. A rapidly multiplying bacillus when once introduced into a feeding-bottle which is not frequently sterilized will render the bottle itself a source of infection to all the milk subsequently placed in that bottle. Such an accident is more likely to occur in homes which are unclean, where the mother who works out of doors has to leave her last born to the care of a previously born child or of strangers.

The epidemic diarrhoea of adults is not so easily explained, because milk does not form such an important part of the regular food of the adult population, and also because the adult is much less liable to suffer from the consumption of contaminated food. It is however to be remembered that milk is not the only food which is exposed to faecal contamination, meat, fish, molluscs, vegetables, fruit, fresh or preserved, are all liable to pollution, specially when prepared for consumption in dirty premises.

The study of outbreaks like the one I have recently investigated in Derby has convinced me that specific faecal pollution, generally at the time of manufacture, of various prepared articles of food, is responsible for a large number of epidemics of food poisoning.

[1] Condensed milk *is not*, as is often supposed, *sterilized* in the process of manufacture; it often contains a large number of bacteria of various kinds and a variable amount of dirt.

Some remarks about the Derby outbreak of food poisoning.

The pork-pies which caused the Derby outbreak contained a large number of bacilli having characters closely allied to those of the *Bacillus enteritidis* of Gaertner, and of various bacilli which I had isolated from pathogenic milk during the last eight years. A careful examination of the pies led me to the conclusion that the meat of the pies had been infected by coming in contact with some infectious faecal matter. An inspection of the premises where the pies had been prepared convinced me that such an infection was not only possible but probable, and I was even able to indicate the part of the premises where the infection had occurred. My conclusions were entirely confirmed by subsequent enquiries conducted by Dr Howarth, who found that the meat which had been used in the preparation of the most noxious batch of pies had been exposed to special faecal pollution, owing to the cleaning of apparently diseased bowels in a room where the pie meat was left in uncovered vessels.

A specially interesting feature of the Derby outbreak is, that although a large number of persons (at least 130) fell ill in Derby, none died in that town during the epidemic (one fatal case occurred a considerable time afterwards from complications which were possibly, though not necessarily, the result of the infection).

Of the cases (about 90) occurring outside the borough, some at a considerable distance, at least four ended fatally. (I was able to prove the presence of the *Bacillus enteritidis Derbiensis*[1] in the organs of two of these fatal cases; I had not an opportunity to examine the organs of the others.)

Thus the pies had increased in virulence on being kept, just as milk does when it is sent from a distance to a town, and is not consumed soon after collection.

Is there a specific bacillus capable of causing Epidemic Diarrhoea?

I have previously stated that from the milk which caused the Victoria Park epidemic I isolated several bacilli belonging to the colon group, one of which was very virulent, causing rapid septicaemia when injected into the peritoneum, and somewhat less rapid septicaemia when injected under the skin of guinea-pigs. The chief lesions observed after

[1] Report on the Recent Outbreak of Food Poisoning in Derby. Derby (Richard Keene, Limited), 1902.

death were congestion of the small intestine, which contained only mucus, more or less bile stained, great congestion of the lungs; the spleen was small or slightly enlarged. From the blood of the heart and of all the organs the bacillus could easily be recovered. This bacillus had characters resembling closely those of *B. enteritidis* (Gaertner). The lesions observed in about 90 % of the guinea-pigs which succumbed rapidly to the inoculation of milk supplied to towns, were similar to the above, with the difference *in a few cases* that the spleen was enlarged, or that peritonitis was more marked. The bacillus isolated from the blood of these animals resembled more or less closely the bacilli obtained from the milk which had caused the Victoria Park epidemic. In four cases out of ten a pure culture of a bacillus resembling Gaertner's bacillus was obtained; in the other cases I found a mixture of bacilli belonging to the colon group, some approaching the type of Gaertner's bacillus, others resembling more the *Bacillus coli* (Escherich).

Animals fed on the pies which had caused the Derby epidemic presented after death lesions similar to those which I have described above (according to the duration of the experimental illness the spleen was either small or enlarged), and the bacillus isolated from their blood had characters allied to those of Gaertner's bacillus.

From the blood of two patients who had died from the consumption of the Derby pies the same bacillus as that obtained from the organs of guinea-pigs fed on the pies was isolated, but it was accompanied by bacilli identical with or resembling *Bacillus coli communis.*

All these facts put together, as well as many of those which have been previously recorded, indicate that the infectious properties which food acquires frequently in summer, and which give rise to the *ordinary or common type of epidemic diarrhoea* are generally due to bacilli belonging to the colon group of bacilli of which the *B. coli communis* (Escherich) and the *B. enteritidis* (Gaertner) are probably two extreme types. I have come also to the conclusion that the varieties of these bacilli which are the most important sources of infection are those which resemble the bacillus of Gaertner, and which therefore produce *no permanent acidity, coagulation, or distinct smell when grown in milk.* Very few of the infectious samples of milk which I have examined during the last five years had a distinct acid reaction, so that *absence of acidity and marked smell in milk is not, as generally believed, an index of safety.*

It is probable that the most dangerous kind of faecal infection is that produced by matter containing bacilli resembling the Gaertner's

bacillus. *Such an infection is probably connected with the existence of an infectious diarrhoeal disease liable to occur in the lower animals as well as in man.* I have not however been able to satisfy myself entirely regarding this point.

It is certain however that bacilli presenting the characters of the ordinary *B. coli communis* are seldom capable of producing such a rapid infection as that produced by the *B. enteritidis*, or by closely allied bacilli such as the *B. enteritidis Derbiensis*. I hope that an investigation which I am at present conducting with the cooperation of Dr A. Sellers will allow me to speak before long more definitely regarding the properties of this group of bacilli.

General Conclusions.

1. *Epidemic diarrhoea of the common type occurring in this country* is apparently in the great majority of instances the result of infection of food by bacilli belonging to the colon group of bacilli which are present at times in faecal matter.

2. It appears that this infection of food does not generally lead to serious consequences unless the infection is massive from the first, or the food is kept for a sufficient length of time and under conditions of temperature favouring the multiplication of these bacilli.

3. Milk which is the most common cause of epidemic diarrhoea in infants is frequently infected at the farm or (through vessels) in transit.

4. Other foods than milk are also liable to infection before they reach the consumer.

5. Of the bacilli of the colon group, which are capable of rendering the milk infectious, those which do not produce a large amount of acid, and do not coagulate milk are the most virulent, and are probably the essential cause of epidemic diarrhoea.

Preventive measures against Epidemic Diarrhoea.

The preventive measures which seem to me to be most clearly indicated by the above conclusions are the following.

1°. Measures securing *cleanness* of cows, dairy hands, cowsheds, milk vessels etc.[1] Similar measures are also needed with regard to persons or

[1] See in this connection a paper by W. H. Park (1901) "The great Contamination of the Milk of Cities. Can it be lessened by the action of Health Authorities?" *Journ. of Hygiene*, Vol. I. p. 391. *Ed.*

things coming in contact with any other article of food, manufactured or not.

This I think is generally admitted to be a most important element of good sanitation, but absolute cleanness is most difficult to obtain if not practically impossible. Infection must therefore occur now and again.

2°. To guard against the worst effects of accidental faecal infection the food should be *consumed fresh,* when possible.

3°. When the food cannot be consumed fresh it should be *refrigerated, i.e.* kept at a temperature below 4° C.

4°. Where the food cannot be eaten fresh or refrigerated whilst it is kept, it should be thoroughly *sterilized* by heat (*i.e.* by thorough cooking).

N.B. The above precautions refer only to epidemic diarrhoea; other forms of infection may be dealt with in other ways, thus the only safeguard against tuberculous milk is boiling or entire exclusion of tuberculous cattle from our herds.

It will be obvious to the reader that for much of the information I have collected for the purpose of interpreting my experimental work I am indebted to many friends and colleagues. Among these I wish to especially mention Dr James Niven to whom I offer here my best thanks.

DIAGRAM I. (See Table I.)

Effects of refrigeration on the lethal properties of milk. Percentage of samples examined which have proved fatal to 2 guinea-pigs in less than 10 days.

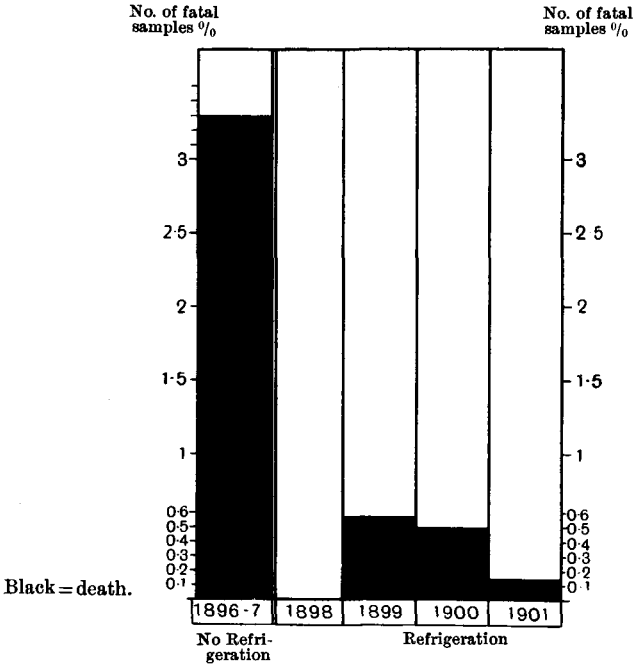
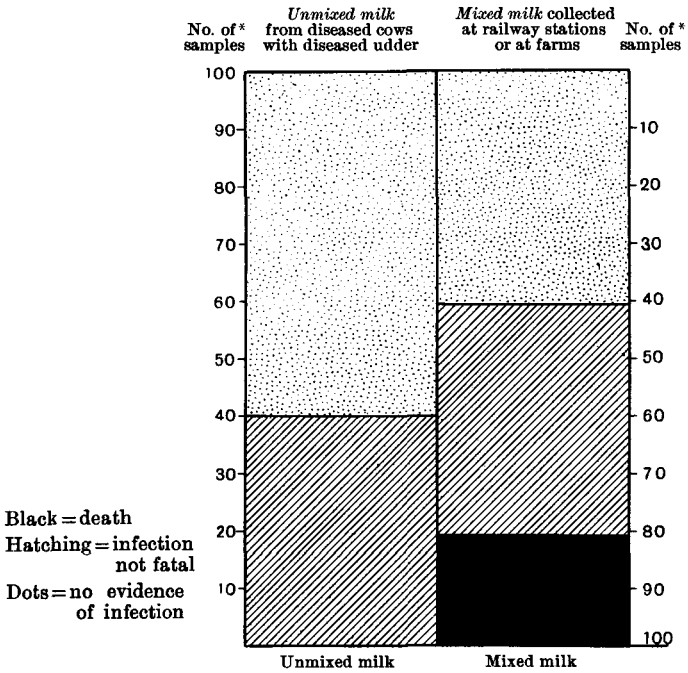


DIAGRAM II. (See Table II *a*.)

Showing the proportion of noxious samples of milk per centum of samples tested by inoculation. (Tuberculous samples excluded.)



* The figures on the right side of the diagram give the percentage of good specimens, those on the left the percentage of bad specimens.

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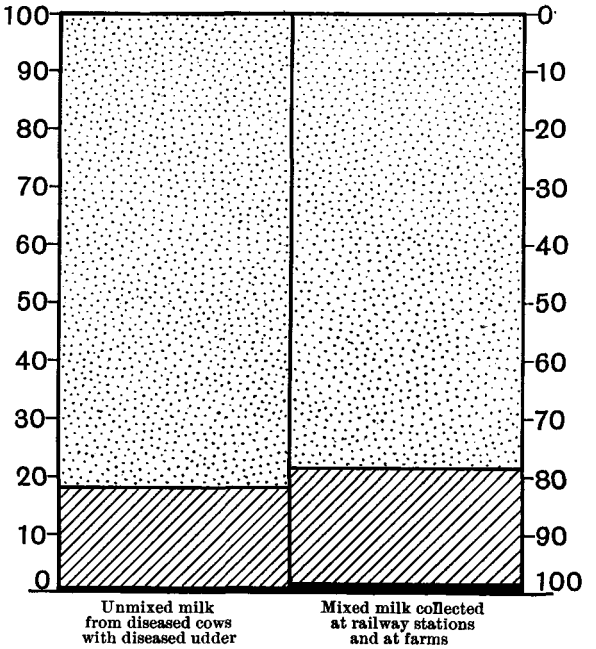
DIAGRAM III. (See Table III *a*.)

Showing the proportion of noxious samples of milk per centum of samples tested by inoculation during the year 1900.
500 *Manchester samples only, most samples examined in less than* 10 *hours after collection.*



Black = death. Hatching = infection not fatal. Dots = no infection.

DIAGRAM IV. (See Table IV.)

Effects of temperature *upon the noxious properties of milk sent to Manchester from a distance of* over 40 miles *and kept for* 24 to 60 hours. (*Tuberculous samples excluded.*)

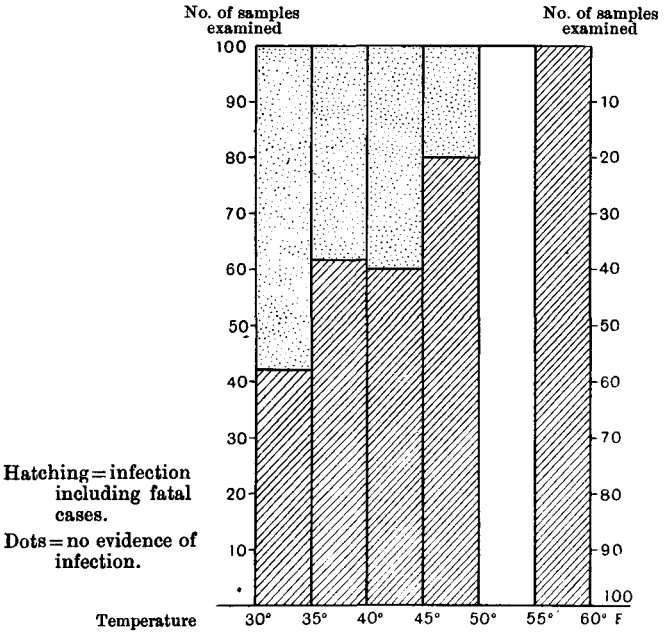


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DIAGRAM V. (See Table V.)

Effects of **temperature** *upon the noxious properties of milk sent to Manchester from a distance of* **less than 20 miles,** *and generally kept for* **less than 10 hours.** (*Tuberculous milk excluded.*)

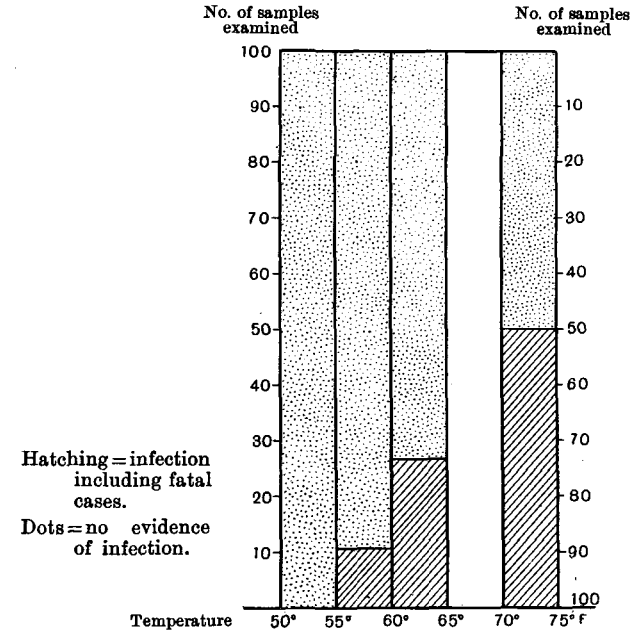
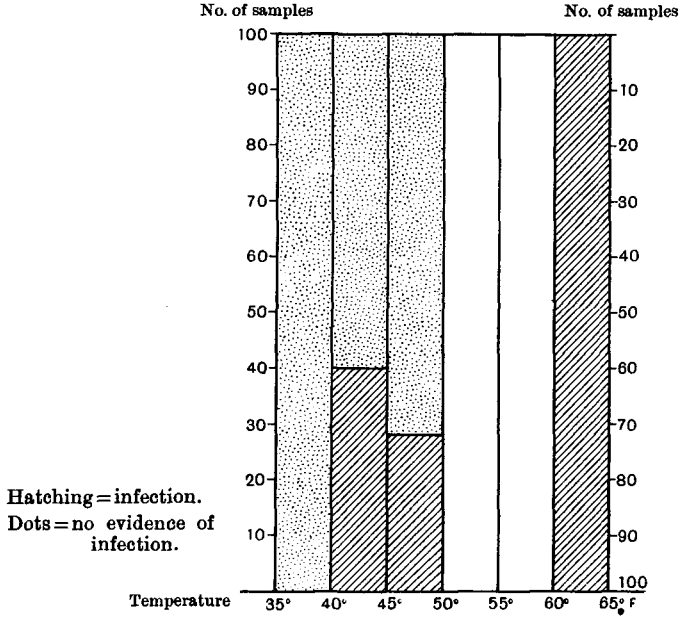


DIAGRAM VI. (See Table VI.)

Effects of **temperature** *upon samples of unmixed milk from* **diseased cows,** *collected in sterilized bottles and with care, but* **kept for various lengths of time.** (*Tuberculous milk excluded.*)



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