FIELD AND EXPERIMENTAL STUDIES OF BOVINE PNEUMONIC PASTEURELLOSIS

by

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DECLARATION

I declare that the work presented in this thesis has been carried out by me. The serology was done in conjunction with Dr. E.M. Allan and Dr. N.J. Watt, Department of Veterinary Pathology and Mr. S. Edwards and Dr. P. Roeder, Central Veterinary Laboratory, Weybridge, the microbiology in conjunction with Dr. E.M. Allan and Dr. N.J. Watt, Department of Veterinary Pathology and the pathology in conjunction with Dr. E.M. Allan and Professor H.M. Pirie of the Department of Veterinary Pathology.

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(1) Allan, E.M., Selman, I.E., Wiseman, A., Pirie, H.M., Gibbs, H.A. and Watt, N.J. (1982). Acute fibrinous pneumonic and Pasteurella species. Proc. of XII World Congress on Diseases of Cattle, Amsterdam. 21-26.

(2) Allan, E.M., Gibbs, H.A., Wiseman, A. and Selman, I.E. (1983). Pasteurella haemolytica pneumonia in weaned housed single suckled calves. Vet. Rec. 112, 327.

(3) Allan, E.M., Gibbs, H.A., Wiseman, A. and Selman, I.E. (1984). The experimental production of bovine pneumonic pasteurellosis. 2. Pathological aspects in Bovine Respiratory Disease, a symposium. Ed. R.W. Loan, Texas A & M University Press, 500.

(4) Gibbs, H.A., Selman, I.E., Wiseman, A., Allan, E.M., Pirie, H.M. and Watt, N.J. (1982). Pasteurella species associated respiratory disease in immature cattle. Proc. XII World Congress on Diseases of Cattle, Amsterdam, 40-45.

(5) Gibbs, H.A., Allan, E.M., Wiseman, A. and Selman, I.E. (1983). Pneumonic pasteurellosis in housed weaned single suckled calves. Vet. Rec. 112, 87.

(6) Gibbs, H.A., Allan, E.M., Wiseman, A. and Selman, I.E. (1983). Experimental bovine pneumonic pasteurellosis. Vet. Rec. 113, 144.

(7) Gibbs, H.A., Allan, E.M., Wiseman, A. and Selman, I.E. (1984). The experimental production of bovine pneumonic pasteurellosis. 1. Clinical aspects. in Bovine Respiratory Disease, a symposium. Ed. R.W. Loan, Texas A & M University Press, 499.

(8) Gibbs, H.A., Allan, E.M., Wiseman, A. and Selman, I.E. (1984). Experimental production of bovine pneumonic pasteurellosis. Res. Vet. Sci. 37, 154-166.

SUMMARY

The condition known as shipping fever was a severe source of financial loss to the beef industry in North America, where it was regarded as being a disease in which stress or viral infection preceded a severe pneumonic pasteurellosis. In Britain, a similar disease, transit fever, was recorded but no extensive research had been conducted into the condition.

In these studies 29 incidents of acute respiratory disease, described as transit fever, were investigated in single-suckled calves, 24 of these were in recently housed single suckled calves and five in single suckled calves at foot with their dams. All the incidents occurred within 24 days of housing, irrespective of whether they were home-bred or purchased and all but one of the incidents occurred between October 1 and December 31. In 20 of the incidents in weaned calves the disease was confirmed on clinical, microbiological and pathological grounds as a pneumonic pasteurellosis. Pasteurella haemolytica A1 was recovered from slaughtered clinical cases of the disease in 18 of these incidents. The four other incidents which presented clinically as transit fever could not be confirmed as pneumonic pasteurellosis on either microbiological or pathological grounds. The five incidents in single-suckled calves at foot were all confirmed as pneumonic pasteurellosis, three associated with P.haemolytica A1 and two with P.haemolytica T10. Diagnosis of pneumonic pasteurellosis was based on the clinical findings of dullness, inappetence, pyrexia and pneumonia, usually with minimal coughing, isolation of Pasteurella spp. from a number of sites in the upper and lower respiratory tracts, and a distinctive pathology including consolidation, fibrinous pneumonia which could be diffuse or focal (nodules), fibrinous pleurisy and gross dilatation of the interlobular septa.

Examination of the affected cattle at post-mortem did not demonstrate the regular presence of viral or other microbiological agents at any stage of the disease process. The examination of nasopharyngeal swabs and paired serology from groups of cattle in-contact with the cases of confirmed pneumonic pasteurellosis indicated that although there was sometimes seroconversion to viruses known to cause respiratory disease (PI3 and RS viruses) this was not a consistent feature, and similar numbers of seroconversions were seen in monitor groups of similar calves in which no respiratory disease occurred. Similarly, the presence of P.haemolytica A1 in the nasopharynx and seroconversion to that organism within a group of suckled calves were at similar levels in groups of calves in which pneumonic pasteurellosis had been confirmed and those in which no respiratory disease had occurred.

The development of an experimental model was attempted using stationary phase cultures of an isolate of P.haemolytica A1, from an incident of confirmed bovine pneumonic pasteurellosis, together with P13 virus infection or hormonal and physical stress. Pneumonic pasteurellosis was not produced. However, the use of a log phase culture of P.haemolytica A1 in the absence of other infectious or stressor agents was successful. Calves were inoculated intranasally and intratracheally and the clinical signs seen were indistinguishable from those seen in field cases of confirmed pneumonic pasteurellosis. At post-mortem the infecting strain of P.haemolytica A1 was recovered in large numbers throughout the upper and lower respiratory tract and the pathology was indistinguishable from that seen in the field cases of confirmed pneumonic pasteurellosis.

As a result of these investigations it has been shown that transit fever as it occurs in Scotland is almost exclusively a primary pneumonic pasteurellosis.

Clinical signs

The clinical terms used are those described by Selman and Wiseman (181).

Abbreviations used in tables are: m = mucoid, mp = mucopurulent, D = died, K = killed, + = parameter present, ± parameter present but either mild in degree e.g. nasal discharge or occasional e.g. cough, - = parameter absent.

Microbiology

The names of the bacteria are those as used in Bergey's Manual of Determinative Bacteriology (37). Where the name of an organism occurs in the text for the first time it is written out in full, subsequent mentions are contracted to the initial letter of the genus with the species name in full.

Serology

Seroconversion was considered to have taken place when a four fold rise in titre had occurred. In the case of viruses an ELISA test was used and an increase of 0.25 (Farms 1-19 inclusive) or 0.20 (Farms 20-38 inclusive) was considered to indicate seroconversion. In the appendices 1 to 38 seroconversions are underlined. ND indicates that a particular assay has not been carried out.

Pathology

The term upper respiratory tract includes the nasal passages, nasopharynx and trachea with associated lymphoid tissue. The lower respiratory tract is considered to be the rest of the tract from the bifurcation of the trachea and includes the lower airways, lung lobes and associated lymphoid tissue. The following abbreviations are used:

NC = nasal conchae, Tr = trachea, RC = right cranial lung lobe, RM = right middle lung lobe, RD = right caudal lung lobe, BrLN = bronchial lymph node, RtLN = retropharyngeal lymph node, Ton = Tonsil.

Pharmaceutical preparations

Therapeutic agents are referred to by their generic name. Vaccines are referred to by their proprietary name.

References

In the reference section, the contractions for the various journals quoted are those given in Serial Sources for the Biosis Data Base published by the Biosciences Information Service, Philadelphia.

INTRODUCTION

The term "shipping fever" was first applied to the complex of diseases that occurred in army horses soon after they had been transported from their farms of origin to army barracks and was probably a streptococcal pneumonia complicating strangles (219). Later the term was used for a febrile pneumonia seen in cattle soon after arrival on feedlots. Shipping fever, a disease later to become known as transit fever, and subsequently defined as bovine pneumonic pasteurellosis, was first described in North America in the early part of this century. Similar diseases, including American Lung Disease (230) had been recorded earlier, and these may have been pneumonic pasteurellosis.

In North America shipping fever has been recognised as one of the greatest sources of loss to the beef feedlot industry; in 1972, "a light year for losses", the disease cost 76 million U.S. dollars due to the loss of 350,000 head of cattle (138). The economic impact of such losses to the American beef industry has prompted extensive research into the aetiology of the problem and the development of methods of prevention and/or control. Following the isolation of Pasteurella spp. from fatal cases of shipping fever in the early disease incidents (180), a variety of vaccines were produced. However, in several of the field trials of these early vaccines the mortality rate of cattle from shipping fever increased following vaccination, when compared with control (unvaccinated) animals.

Many attempts were made by the early workers on shipping fever to produce the disease in experimental cattle using cultures of Pasteurella spp. These efforts were generally unsuccessful, and the discovery of parainfluenza 3 virus in pneumonic feedlot cattle in 1959 (179) prompted theories that this virus might be incriminated in the pathogenesis of shipping fever (105). Indeed, during the following 25 years much of the experimental work has focussed on postulated viral-bacterial interactions.

Several experimental models of shipping fever have been developed which use a virus (BHV-1 or P13) and Pasteurella spp., and in the successful models the final, and sometimes fatal, lesion is that of pneumonic pasteurellosis (202). Most field investigations over the same period in North America have been restricted to either nasal swabbing and serological sampling of groups of range calves and feedlot cattle. Many microorganisms were isolated from these groups of cattle and seroconversions to potential respiratory pathogens were often widespread, with the consequence that each of these agents was considered to have a role in the aetiology of shipping fever (90,100). An additional problem in the field investigations was that clinical details were rarely available so that a specific diagnosis could not be made in sampled groups of calves. However, pathological examination of fatal cases of shipping fever usually demonstrated that the final fatal lesion was pneumonic pasteurellosis, but failed to demonstrate whether prior viral pneumonia had been present. The demonstration of any correlation between the microbiological and pathological findings in fatal cases and the isolations and serology in in-contact cattle was not possible as these studies were rarely carried out on the same group of calves.

In Britain, transit fever was first described in 1925 (102) and several reports of the disease appeared in the literature until the early 1940s many of which were concerned with whether the disease was or was not the pulmonary form of haemorrhagic septicaemia rather than any useful contribution to the understanding of the disease. The pathology described (102,221) was that of pneumonic pasteurellosis, and in the British descriptions Pasteurella spp. were the only organisms isolated. No further work was done on the condition in Britain either in the field or the experimental disease; the North American information and theories regarding a combined viral and bacterial aetiology were accepted without question (13).

In 1977, a severe form of infectious bovine rhinotracheitis was seen in Scotland (232), from which a highly virulent strain of BHV-1 was isolated. In the course of a large number of field investigations, farmers who regularly purchased weaned single suckled calves commented that until the emergence of IBR as a significant clinical problem, the commonest disease causing economic loss had been transit fever.

The aim of the present study was to investigate transit fever, as it occurred in Scotland, with due regard to the problems encountered when similar investigations had been carried out in North America. Investigation of outbreaks of transit fever in groups of calves with the purchase of affected animals was undertaken in order to define the condition in clinical, microbiological and pathological terms, and to develop an experimental model for the disease based on these findings.

CHAPTER 1

THE FIELD DISEASE

SECTION I

A REVIEW OF THE LITERATURE

1. Bovine pneumonic pasteurellosis

Early field reports of the disease in cattle known as shipping or transit fever

Shipping fever in cattle was first described as "Stockyards Pneumonia" in the United States of America in 1917 (97) when it was observed that "steers developed fever and pneumonia following railroad transportation and contacts in various stockyards, and that exposed animals were capable of transmitting the disease to local unexposed and unmoved cattle". Earlier reports of what would appear to be the same disease date from 1891 in cattle shipped from Canada to France (158) , and 1915 in the U.S.A. where an infectious pneumonia was seen in young cattle that had passed through public stockyards (130). Many of these early descriptions appear under the general heading of Haemorrhagic Septicaemia, sometimes being designated "the pulmonary form" of the disease, and this confusion over nomenclature and the relationship, if any, between haemorrhagic septicaemia and shipping fever is widespread throughout both the North American (17) and British literature (165) until the late 1950s. At this time two authors, Bain and Hudson (19,111), proposed that the term haemorrhagic septicaemia be restricted to a distinct epizootic disease caused by Roberts type 1 or Carter type B strains of Pasteurella multocida and that the name 'Pasteurellosis' be reserved for infections by the whole group of Pasteurellae, which would include the pneumonia described in these cattle as pneumonic pasteurellosis.

In 1921 an outbreak of pneumonia was described in a closely observed herd of dairy cattle at the Rockefeller Institute for Medical Research in New Jersey (122). Cattle that had been purchased for the institute, then assembled and shipped from outwith the state, developed pneumonia five to 14 days after shipment; of the ten cows clinically

affected two died and two were slaughtered. The clinical signs were high temperature, rapid respiration, dyspnoea, cough, dullness on percussion, bronchial breathing and albuminuria, and these were identical to those seen in purchased and in-contact cattle from within the state which were subsequently affected. Bacillus bovisepticus (sic) was isolated in pure culture from the lungs, but not from the blood, of affected cattle. One of the authors classified strains of Bacillus bovisepticus from pneumonia cases in cows and calves and found three groups; Group 1 was haemolytic and did not produce indole, Groups 2 and 3 were non-haemolytic and produced indole (121).

The term "shipping fever" was first used to describe a group of epizootic infections of horses which usually occurred after shipment of horses from the western U.S.A. to the east, or after transfer of country horses to city stables (152) and was later found to involve three diseases; strangles, influenza and contagious pneumonia (153). The term "shipping pneumonia" was used synonymously with "stockyards pneumonia" to describe a fever and pneumonia in stockyards in the U.S.A. in 1918 (97). In 1932, detailed descriptions of incidents of "shipping fever" in cattle in the state of Kansas were published (68). These showed that the incidence of the disease was highest in October/November and March, especially during cold, wet weather; and that the length of the rail journey was probably correlated with the severity of the disease. The disease was less severe when cattle did not pass through stockyards but went straight from ranch to feeder, and the death rate in animals that had been vaccinated with bacterin, mixed vaccines or aggressin, was three times greater than that of non-vaccinates. Hagan (88) described a bacterin as a killed in-vitro culture and an aggressin as a sterilised exudate produced in response to in-vivo culture. Twenty-six animals from this study, which had died of shipping fever, were post mortemed and Pasteurella boviseptica was isolated from the respiratory tract (no sites stated) of 21 cases (81%) (68,180).

The "pulmonary form of haemorrhagic septicaemia" was described in the Niagara peninsula of Canada in 1940 (204) in feeder cattle which had been shipped from Western Canada. The symptoms were described as fever (104-107°F), difficult rapid respirations, lachrymation and cough with occasional diarrhoea. The author commented that diarrhoea was less common in animals with severe respiratory symptoms but the "intestinal form" was easier to treat with bacterin, antiserum and alkali than the pulmonary form. Twenty-six shipping fever cases that occurred in the Toronto area of Canada were examined and the results published in 1954 (41). Antemortem diagnosis was made on the basis of an acute pneumonia with a high temperature; pathologically all but one of the cases had an acute bronchopneumonia with the interlobular tissue separated by serofibrinous exudate and fibrinous exudate on the pleural surface. Following the isolation of Pasteurella spp. from 25 of the 26 animals involved Carter concluded that "the shipping fever seen in central Canada is a true Pasteurellosis". In earlier work in 1925 P.boviseptica was isolated from the nasal passages of 15% of normal cattle (124) but there was no comparable data available at the time for isolation frequencies of Pasteurella spp. from non-pneumonic lungs. Fifty years later it was shown that P.haemolytica and P.multocida could both be isolated from 10.3% of non-pneumonic calf lungs (6).

The first reference in the British literature to an infectious pneumonia, with fever, in recently transported cattle was in 1925 (102) when a general practitioner from Aberdeenshire described in great detail the clinical and pathological features of a disease he termed "transit fever". Some years later, in 1939, an almost identical description of the disease in Banffshire was written by a different author (12). The disease occurred almost exclusively in cattle which had been "transhipped" from one part of the country to another and was most common from October to February. Irish and Orkney cattle were commonly affected when moved to

Aberdeenshire, whereas, apparently, home-bred cattle could only be affected if they were exposed to the "contagion" whilst standing at cattle marts; young stock bred on the farm had developed the disease following contact with newly purchased affected animals. Newly arrived cattle were most likely to develop the disease between seven and 10 days after purchase. Bacteriological examination of lungs from several affected animals demonstrated the presence of Bacillus bovisepticus "almost in pure culture". The clinical features were those of depression, with the head held low, fever, 104-108.5°F, a mucopurulent ocular and nasal discharge, and an occasional cough although coughing was often totally absent. At post mortem examination the lungs showed areas of hepatisation (i.e. consolidation) and sometimes the pleura were covered with a sero-fibrinous exudate. Shortly after Hepburn's paper an infectious pneumonia affecting adult dairy cattle of the Shorthorn type in Yorkshire and occurring in late November and early December was described (176). The clinical signs were loss of appetite, tachypnoea, pyrexia (up to 107°F), and a dry painful cough which was a major difference between this and Hepburn's description of the disease. At post mortem examination the lungs were consolidated and large amounts of blood stained serous fluid exuded from the cut surface; Bacillus bovisepticus (sic) was isolated in pure culture. The authors commented that the appearance of the lungs was "extremely characteristic of the disease and might easily lead one to think of contagious pleuropneumonia", but their final diagnosis was "the pectoral form of haemorrhagic septicaemia" and was differentiated from contagious pleuropneumonia (CBPP) by the sudden onset, and the acute pulmonary symptoms exhibited as compared with the chronic nature of CBPP. At about the same time a clinical anecdote (200) described an infectious disease of cattle which occurred in late November and early December and comprised three types, general febrile, respiratory, and arthritic. The general febrile type was considered most common with

fever (104-107°F), bronchial catarrh and conjunctivitis; the respiratory type showed signs of lobar pneumonia and accounted for the two fatal cases encountered; and the arthritic type was the rarest with loss of appetite, fever, uneasiness, and later painful joints. All the farms had become affected within a week and the author commented that at the time the weather was changeable with some fog, but proffered no further history, post-mortem or other details.

In 1930, Tweed and Edington (221) described a series of pneumonic lungs met with in the course of meat inspection which differed markedly in appearance from anything seen previously and which they considered might be due to a specific organism. Clinical histories were obtained for as many of the slaughtered cattle as possible and a total of seven adult cows and two calves (aged 3-4 months) were examined. Two of the cows were from an outbreak of infectious pneumonia in a dairy herd in damp foggy weather in November, three cows had been sent for slaughter by cattle dealers having recently passed through markets, one heifer was from a neighbouring farm to that on which the outbreak of infectious pneumonia had occurred and the final animal was from another herd of 14 animals seven of which showed signs of pneumonia. The two calves were from a group of nine, four of which had died, and the remaining five were all pneumonic. In a discussion of the origin of infection the role of predisposing causes - journey by road or rail, period of the year, bedding on old musty hay (calves only), and the introduction of a carrier of infection into the herd - was considered. The conclusions drawn were that these factors, alone or severally, served to lower the resistance to infection, bring animals into closer contact possibly with an infected animal, and encouraged bad ventilation, overcrowding and poor sanitary conditions. The clinical signs in these cases were described as depression, failure to feed, pyrexia (105-108°F), tachypnoea, nasal discharge and coughing. The disease was considered by the authors to be of an acute

nature for three or four days after which recovery or death ensued. At post-mortem examination all the lungs were consolidated and the interlobular septa were thickened, due to the presence of coagulated exudate. Healthy lobules were to be seen between the consolidated ones, which were dark red and showed hepatisation, the pleura were thickened with a grey fibrinous deposit on the surface, and in more chronic cases grey circular areas could be seen amidst the solid tissue. Again the authors commented that the appearance of the lungs was very similar to that seen in contagious bovine pleuropneumonia. In all cases Pasteurella boviseptica was readily isolated from consolidated lung tissue and was found, following culture and agglutination tests, to belong to Jones' Group 1 (121). Following the death of a calf after experimental inoculation of a culture of P.boviseptica isolated from one of the cattle previously described the authors concluded that the cases of pneumonia they had examined were due to an infection caused by Pasteurella boviseptica (Jones Group 1).

Despite these excellent clinico-pathological accounts of transit fever (102) and pneumonia due to P.boviseptica (221), considerable debate took place over a period of eight years within the veterinary profession in Britain (mainly through the columns of the Veterinary Record) as to whether or not haemorrhagic septicaemia existed in the country (75,86,89,133,140,141). Two accounts (89,133) described a haemorrhagic syndrome in yearlings grazing rough hill pasture, sudden death was a feature in both incidents, however on the one occasion when a post-mortem was carried out (133) bracken (Pteridium aquilinium) was found in the rumen. Retrospectively, the presence of bracken in the grazing and the sudden disappearance of the syndrome when the cattle were removed from that grazing suggested that these cattle had acute bracken poisoning. Another report in 1923 (141) described deaths in cattle with access to bracken in the summer of 1915. Bipolar organisms were isolated from the heart blood and bracken fronds were

found in the rumen. and it was suggested that bracken damaged the alimentary mucous membrane and allowed invasion by B.bovisepticus, although the author of this paper (who did not believe that bracken poisoning existed) thought that the earlier reports (89,133) were suggesting that bracken was the aetiological agent in haemorrhagic septicaemia, when in fact they were describing acute bracken poisoning as a completely separate disease entity. However, in the same paper (141) young, housed calves were described as becoming ill (no other clinical data) and being destroyed in extremis; B.bovisepticus was isolated, which was fatal for rabbits, and a haemorrhagic syndrome was seen at post-mortem in the calves and the rabbits. The role of B.bovisepticus in the aetiology of haemorrhagic septicaemia was considered proven by one worker (46) who found the organism in cattle dying from a haemorrhagic syndrome in Britain and drew parallels with his experience of haemorrhagic septicaemia in South Africa, whilst another author (123) considered the organism to be one of putrefaction following death from other causes.

Another clinico-pathological account in 1930 described what was almost certainly bovine pneumonic pasteurellosis on the post-mortem findings of thickened interlobular septa and fibrinous pleurisy as haemorrhagic septicaemia with pleuro-pneumonic symptoms (86). Two dairy cows died after three and four days respectively of respiratory disease including pyrexia, coughing and dyspnoea, and the pathological findings were as described above. A significant clinical observation was that abnormal lung sounds were not heard on auscultation. Bacillus bovisepticus was isolated from the lungs at post-mortem but the organism was not detected in blood cultures from live animals in the early stages of the disease, which made the dogmatic diagnosis of haemorrhagic septicaemia rather unfounded. The common absence of the organism from the blood is highlighted by an eminent bacteriologist (75) in a comparison of true haemorrhagic septicaemia seen in Egypt, India and the Far East with the detailed descriptions

of bovine pneumonia described in the British and North American literature in the 1920s and early 1930s (122,221) In true haemorrhagic septicaemia, organisms were present in blood, intestinal involvement was greater than pulmonary and subcutaneous oedematous swellings were common. By contrast in the accounts of bovine pneumonia considered (122,221) septicaemia was not a feature, pulmonary signs predominated and subcutaneous swellings were not recorded. In conclusion the bacteriologist made the definitive statement that the use of the term haemorrhagic septicaemia for these outbreaks of pneumonia in cattle was confusing and inaccurate, and that such a specific term should be reserved for barbone which had not been shown to occur in Britain. He also stated that these strains of Pasteurella spp. causing respiratory disease were probably normal inhabitants of the respiratory tract which invaded lung tissue when host resistance was lowered as a result of transit or bad management. However the term haemorrhagic septicaemia continued to be used to describe a haemorrhagic syndrome in cattle in Britain (167) and the nomenclature debate continued (67,76) until a suggestion was made (220) that haemorrhagic septicaemia should be known more specifically as Pasteurella septicaemia, and the respiratory disease caused by Pasteurella spp. should be called Pasteurella pneumonia. The two forms of the condition as seen in Britain were described thus; the acute type, usually seen in calves, where the lesions were those of septicaemia with haemorrhages in various parts of the body and P.boviseptica could be recovered from the blood, and the more chronic form which was usually met with in older cattle where the lesion took the form of an acute pneumonia with consolidated areas interspersed with thickened septa. He considered outbreaks of the disease (form unfortunately unspecified) as being fairly common during the winter months, and that young cattle may become affected after introduction of a newly purchased animal into the herd although outbreaks in young cattle often also arose without any new animals being added to the herd.

The role of Pasteurella spp. as primary pathogens was first challenged in 1938 (16). It was generally accepted that the hyperacute and acute form of pasteurellosis seen in cattle and buffalo in India called true haemorrhagic septicaemia or barbone was a primary pasteurellosis (16), but the question was raised as to whether the more chronic pneumonic forms satisfied any arbitrary criteria for acceptance as a primary pasteurellosis. The suggestion was made that Pasteurella spp. may already be present in the respiratory tract as a sub-pathogen and required a virus as a primary agent before it could initiate disease. At this stage, it would appear that no-one had read the work of Jorgensen (124), where Pasteurella spp. were isolated from nasal swabs in 15% of normal cattle.

Further accounts of pneumonic pasteurellosis continued to appear in the British literature under a variety of titles. Epizootic bovine pasteurellosis was described as a haemorrhagic septicaemia in a dairy herd where pathological lesions were confined to the lungs (218). An acute pneumonic incident in young stock was described (187); at post mortem examination the lesions were acute pleuropneumonia with semi-coagulated fibrinous or gelatinous pleural exudate. The conclusion was that the disease as it occurred in Britain in both septicaemic and pneumonic forms should be termed bovine pasteurellosis. (187).

Fourteen years after the first description of transit fever in Britain (102) another clinicopathological account of transit fever was published (12) the details of which were almost identical to those of the 1925 account (102). Six to ten days after arrival in the North of Scotland cattle from Ireland and the Orkneys became anorexic, pyrexic, tachypnoeic, had an oculo-nasal discharge and coughed occasionally. At post-mortem there was lobar pneumonia, hepatisation and a serofibrinous pleurisy. Despite repeated attempts at classification over the previous decade within the same journal this report of what is bovine pneumonic pasteurellosis on

epidemiological, clinical and pathological considerations carries an editorial footnote in the Veterinary Record which states "this condition appears to be identical with that described by Shirlaw (187) as haemorrhagic septicaemia". The paper mentioned in the footnote described bovine pasteurellosis as being pneumonic or septicaemic in presentation, and another report at about the same time (165) tabulated the differences between transit fever and haemorrhagic septicaemia. However, there was also still confusion amongst field and laboratory workers (36,62,69) who continued to describe haemorrhagic septicaemia as a haemorrhagic syndrome either in calves or in hill cows grazing bracken pastures.

Aetiology

An acute disease in deer, wild boars and cattle was described as two forms, exanthematous and pectoral, in 1878 (31) and eight years later a bacterium, designated Bacillus bovisepticus, was isolated from sick cattle that were clinically similar to those described in 1878 (112). In 1891, the same bacterium was isolated from cattle that had been shipped from America to France (158) and several further isolations of B.bovisepticus or Pasteurella boviseptica were made from cattle that had died from shipping or transit fever over the next 50 years (102,122, 180,204,221) which resulted in the acceptance, until the late 1940s, of P.boviseptica as the sole aetiological agent.

The first suggestion that transit fever may not be a primary pasteurellosis but that Pasteurella spp. could be "subpathogens" of the respiratory tract requiring a primary depressant such as virus infection, cold or faulty food was made in 1938 (16). The basis for this suggestion was that in the original description (112) of the haemorrhagic septicaemia diseases in 1886, Hueppe included fowl cholera, rabbit septicaemia, swine plague and the disease described in deer, wild boars and cattle in 1878 by Bollinger; as all were apparently caused by bipolar staining, ovoid, gram negative bacilli and at post-mortem widespread haemorrhages were seen. Subsequently, in 1904, the "viral aetiology of swine plague was established" (63) and after attention was drawn to this in 1938 caution was advised regarding the isolation of Pasteurella spp. from post-mortem material, and the classification of the "pasteurelloses" came under scrutiny. The hyperacute haemorrhagic septicaemia, known as barbone, which affected cattle and buffalo in India remained an undisputed primary pasteurellosis, although the editor of the Veterinary Record in his 1938 discussion emphasised that it was difficult to transmit infection using natural routes (e.g. inhalation and ingestion). The

conclusion was drawn that the pneumonic form of the disease was a pasteurellosis, but that Pasteurella spp. may not be the primary or sole agent. The suggestion that a primary viral agent might be involved in transit fever was never followed up in Britain. In North America, however, where a similar dispute over the primary aetiological agent began in 1944 (99), P13 virus was discovered in 1958 (1) and in addition to seroconversion in experimentally infected calves (2), antibodies to the virus were found to be widespread amongst recently moved feeder cattle (104). Several other microbiological agents were postulated as aetiological agents (in combination with the Pasteurella spp.) over the next decades, for example, Chlamydia (161), Mycoplasma spp. (41,90), bovine herpes virus 1 (116), as well as other agents such as stress (105, 201,129). Support for these other agents as significant aetiological factors was perpetuated by concurrent experimental work in which disease could not be produced using Pasteurella spp. alone but only when combinations of agents were used (95,119).

In the early descriptions of the disease Bacillus bovisepticus (or Pasteurella boviseptica) was widely accepted as the sole aetiological agent (102,122,180,204, 221). The two most detailed accounts (102,122) described identical clinical signs of dullness, inappetence, fever, increased respiratory rate and depth, nasal discharge and occasional coughing in young cattle and dairy cows shipped from Ireland and Orkney to Aberdeenshire (102) and in dairy cattle rail-freighted from Pennsylvania and Michigan to New York (122). Lobar pneumonia with hepatisation and serofibrinous pleurisy was described, and B.bovisepticus was isolated from affected lungs in pure culture, in both accounts.

At about the same time in 1925 a study of the bacterial flora of the nasal passages of clinically normal cattle was made (124). A total of 250 cattle were sampled and 37 (15%) were positive for Pasteurella boviseptica. A detailed bacteriological report on cattle that had died

from shipping fever (180) seven years later reported P.boviseptica in 21 of 26 sets (81%) of lungs examined post-mortem, often in pure culture. Other bacteria found were Escherichia coli and Alcaligenes bronchiseptica. In the same report 83 sets of lungs from normal cattle were obtained from a packing station and P.boviseptica was not isolated, but E.coli and A.bronchiseptica were each present in 10% of lungs, together with Staphylococci and Streptococci, present in 43% and 39% of lungs respectively. Pasteurella boviseptica was also isolated from incidents of pneumonia in dairy cattle and calves in the North Midlands region of England and considered to be the causal organism (221). At this time the organism which had previously been referred to as Bacillus bovisepticus (Jones' group 1) or Pasteurella boviseptica and had been isolated from cases of pneumonia in cattle was renamed Pasteurella haemolytica (156) in recognition of its ability to produce haemolysis on blood agar and also to differentiate it from Pasteurella multocida which is non-haemolytic and which had also been referred to as Pasteurella boviseptica by earlier workers.

During the 1950s Pasteurella spp. were the micro-organisms most commonly isolated from field cases of shipping fever (41,42,45,128,160,162). Twenty-six cases of shipping fever diagnosed on the basis of an acute pneumonia and high fever in beef-type cattle that had been shipped from Alberta and Saskatchewan to Ontario were subjected to pathological and bacteriological examinations. Pasteurella haemolytica was isolated from 15 cases and Pasteurella multocida was recovered from 10 (41). Corynebacterium pyogenes and Mycoplasma spp. were isolated from two and four animals respectively. It was concluded that shipping fever as it appeared in central Canada was a true pasteurellosis because of the consistent recovery of either P.haemolytica or P.multocida (often in pure culture) from field cases, and the rapid response to treatment with antibacterial agents. The association between shipping fever and the stress caused by transport and mixing calves

was also highlighted and the observation was made that a haemorrhagic syndrome, which was classed as a systemic pasteurellosis, was the result of infection with P.multocida. In a further investigation (45) nasal swabs were taken from 33 beef cattle that were pyrexic and pneumonic on arrival at the Toronto stockyards from Western Canada and from 14 normal beef cattle that had not been shipped. Pasteurella haemolytica was recovered from 27 of the recently shipped cattle and Mycoplasma spp. from 16 animals. Isolation rates were higher in the clinical stages of the disease (80-100% for P.haemolytica, 50-66% for Mycoplasma spp.) but it was not stated if or how animals were treated. Blood cultures from seven febrile cases were negative for both organisms and P.multocida was not recovered from any animal. No samples were taken from clinically normal in-contact cattle that had been shipped with the clinical cases which would have been more meaningful in terms of comparing the distribution of P.haemolytica in clinically normal (but shipped) cattle and clinical cases of shipping fever. Three further accounts (128,160,162) described the isolation of Pasteurella spp. from 40% of sick animals using nasal swabs (160); P.multocida from the lungs of eight out of a total of nine cattle that had died from shipping fever (128); and P.haemolytica from the lungs of 56 newly weaned calves that had died from an acute fibrinous pneumonia with pleurisy in a population of 1000 calves, 442 of which were clinically affected (162).

In 1962, results were published of microbiological investigations into 13 epizootics of Shipping Fever (diagnosed on the basis of fever, dyspnoea and fibrinous pneumonia) over a three year period (49). Blood, nasal exudates and lung tissue were collected from Hereford cattle on farms throughout Colorado State. Weaned calves were most commonly affected (11 incidents) but in only one incident had the calves been transported; two incidents were seen in unweaned calves running with their dams. The total number of calves in the survey was 4667, individual ranch numbers varying between 227 and 704. Pasteurella

haemolytica was isolated in pure culture from the pneumonic lung tissue and pleuritic exudates from each of the calves that were post-mortemed in 12 of the 13 epizootics. In the thirteenth incident Pasteurella multocida (Carter group C) was the organism isolated in pure culture from pneumonic lung tissue and the same serologic type of P.multocida was isolated from nasal exudates of sick penmates. Pasteurella haemolytica was the only Pasteurella spp. isolated from nasal exudates of in-contact animals in nine of the 12 incidents where P.haemolytica was isolated in pure culture from the lungs of dead calves. In the remaining three epizootics both P.haemolytica and P.multocida were identified in nasal exudates.

In a more recent survey of shipping fever pneumonia in yearling feedlot cattle (116) microbiological isolations were carried out on 354 pairs of lungs from animals which had died from the disease. Pasteurella spp. were present in 221 lungs (62%) either alone or in combination with Mycoplasma spp. and/or BHV-1. However, no differentiation was made between P.haemolytica and P.multocida in this paper and therefore no conclusions as to the relative frequency of the two organisms in cases of shipping fever in Colorado can be made.

Two combined microbiological and pathological studies in Canada (172,179) compared isolations of Pasteurella spp. with the lesions seen at post-mortem. In the first study (179) 55 cases classified on initial examination by the pathologists as fibrinous pneumonia, fibrinous bronchopneumonia, pasteurellosis or shipping fever were retrospectively reviewed and reclassified as either fibrinous pleuropneumonia or fibrinous bronchopneumonia. The pathological re-classification was then correlated with the bacteriological isolations made from the pneumonic lung tissue at post-mortem. Thirty nine of the total 55 cases were classified as fibrinous pleuropneumonia and of these 29 (74%) were associated with P.haemolytica and 2 (5%) with P.multocida, four cases had other bacteria (precise details not given but included

Staphylococcus aureus, E.coli, C.pyogenes, Bacillus spp., Pseudomonas aeruginosa and Enterobacter spp.), and no growth was obtained from the remaining four cases. Sixteen cases of fibrinous bronchopneumonia were recognised, one (6%) was associated with P.haemolytica and 9 (56%) with P.multocida, one was associated with other bacteria (as above) and five yielded no growth. In eight of the 55 cases Mycoplasma agalactiae var bovis and/or Haemophilus somnus was isolated but they were always present in combination with either P.haemolytica or P.multocida. The second study is less detailed, P.haemolytica was isolated at necropsy from 83% of lungs with fibrinous pneumonia (172).

In all the reports on isolation of Pasteurella spp. from the nasal passages of live cattle with clinical signs of shipping fever (fever, hyperpnoea, tachypnoea) or from the lungs of cattle that have died from the disease no reference was made as to the treatment status of affected cattle. Treatment was only mentioned as one possible reason for the failure to isolate any bacteria from the lungs at necropsy (179).

Several studies have been carried out to assess the relative incidence of the various serotypes of P.haemolytica in incidents of bovine respiratory disease in general, and shipping fever in particular (26,44). Biberstein et al (26) examined 98 strains of P.haemolytica and, using an indirect haemagglutination test identified 11 different types, of the nine strains which came from cases of bovine pneumonia seven were type 1, and two were type 2. Carter (44) compared the typing of Biberstein et al (26) with an earlier division of P.haemolytica into two types (A and T) based on their ability to ferment arabinose or trehalose (192,194) and concluded that the type 1 strains, which included the 51 strains he had isolated from cases of shipping fever, fell into the type A classification. Further serological examination of A and T strains by Carter (44) with reference to the 11 previously described serotypes (26) showed the following distribution: Type A; serotypes 1,2,5,6,7,8,9 and 11; Type T; serotypes

3,4 and 10. The adoption of this standard system of nomenclature for P.haemolytica meant that the majority of early isolations from cattle with shipping fever as described by Carter (41) were of Pasteurella haemolytica biotype A serotype 1 (P.haemolytica A1).

Two papers were published in the British literature in the early 1970s which examined the serotypes of P.haemolytica isolated from pneumonic lungs and nasal swabs of normal calves (238) and subsequently monitored the prevalence of the different serotypes in the nasopharynges of calves on farms over a two year period (239). In the serotyping study (238) 59% of the isolates of P.haemolytica from 39 sets of pneumonic lungs were A1 and 20% were A2. In the field study (239), isolates of P.haemolytica were obtained either from nasal swabs from clinically normal or pneumonic calves or at post-mortem from the lungs of pneumonic calves, the calves were predominantly dairy or dairy-cross calves either home-bred or bought in at about two weeks of age; only one single suckled herd (pedigree Aberdeen Angus) was included. In the six pneumonic incidents investigated 15-80% of calves sampled (n = 10 to 40) were found to be carrying P.haemolytica in their nasal passages, and in four of these incidents P.haemolytica A2 was the predominant serotype isolated, being present in 12.5% to 50% of the calves sampled. Only six calves were examined post-mortem; all from pneumonic incidents in dairy and dairy-cross calves. Four of the calves post-mortemed were from an incident where 12.5% of 40 calves were P.haemolytica A2 carriers and 2.5% were P.haemolytica A1 carriers; post-mortem isolations were P.haemolytica A1 from the lungs of two calves and P.haemolytica A2 and P.haemolytica A7 from one calf each. The two calves post-mortemed from a pneumonic incident where 20% of 10 calves were P.haemolytica A1 nasal carriers both yielded P.haemolytica A1 from the lungs but as no details were given of clinical or pathological findings it is impossible to know whether the calves had pneumonic pasteurellosis or were pneumonic for other reasons.

In another American study (227) 43 strains of P.haemolytica isolated from the respiratory tract of cattle, 37 of which were deemed to have come from cases of shipping fever (diagnostic criteria not stated), were serotyped. Of the shipping fever isolates 34 were P.haemolytica A1 and three were P.haemolytica A2.

The isolation rate of Pasteurella spp. from the upper and lower respiratory tracts of apparently normal (i.e. non-pneumonic) cattle has been described by several workers. The earliest survey of normal cattle was in 1925 (124) when nasal swabs were taken from 250 cattle, 37 (15%) of which were found to be positive for P.boviseptica. Pasteurella haemolytica was not found in the nasal passages of 14 normal unshipped beef cattle that had nasal swabs taken for comparison of isolation rates with clinically affected shipped cattle (45). Nasal swabs were taken from healthy beef calves post-shipment to compare isolation rates of Pasteurella spp. with calves in the same groups that developed fever or other unspecified signs of shipping fever (178). A total of 152 normal animals were sampled, 30 (19.7%) of which were Pasteurella spp. positive, of these 19 carried P.multocida and eight carried P.haemolytica. In contrast 29 (47.5%) of 61 cases of shipping fever were positive on nasal swabbing for Pasteurella spp.. In the same study 19 (18.1%) of 105 lungs from clinically normal veal calves examined at an abattoir were Pasteurella spp. positive; 17 P.multocida and two P.haemolytica. These calves were clinically normal but histopathological examination often demonstrated an interstitial pneumonia without exudation; in the calves from which Pasteurella spp. were isolated the lesions were considered by the authors to be more extensive with acute peribronchiolar inflammation and a bronchiolar exudate.

Another description of the microflora of apparently healthy lung tissue of cattle (51) was prompted by the same authors having previously described a series of epizootics of shipping fever and the subsequent isolation of P.haemolytica and P.multocida in large numbers from the

pneumonic lungs of fatal cases (49). Their examination of tracheal mucosa, lung homogenates and bronchial lymph nodes from 88 healthy cattle at slaughter did not reveal the presence of Pasteurella spp., although it is worth noting that the lung homogenate examined was from the diaphragmatic lobe and a portion of apical or cardiac lobe may have been more appropriate. This finding was considered to be sufficient evidence to prove that Pasteurella spp. were not normal inhabitants of the lower respiratory tract of cattle, but their presence in the upper respiratory tract of normal cattle is discussed in a later paper by the same senior author (48). Several unsupported statements are made; that P.haemolytica and P.multocida can be isolated from the palatine tonsils of healthy cattle (but less frequently than C.pyogenes), and that Pasteurella spp. can be isolated from the nasal mucus of healthy cattle, this was considered to be an indication that they were colonising the upper respiratory tract and represented sub-clinical infection.

A detailed study of the nasal bacterial flora in healthy and pneumonia-prone herds was described in Canada in 1969 (142). Unfortunately, although the bacteria highlighted by the study were P.haemolytica and P.multocida, most of the calves sampled were less than nine months of age and the problem in the pneumonia-prone herds was "enzootic pneumonia". The only cattle that were directly relevant to shipping fever were a group of 43 young bulls transported to a testing station. From the results of this study the nasal bacterial flora of calves was classified into three components; basal, supplementary and transient. Pasteurella multocida and P.haemolytica were considered part of the basal flora and were judged to be widely distributed in the cattle population. Long term studies of P.haemolytica in the nasal passages suggested periods of active colonisation when isolations were frequent, followed by several weeks when twice daily swabbing failed to reveal the presence of the organism followed by a further period when isolations were frequent. It

was suggested that this rhythmic fluctuation reflects colonisation by the organism eliciting a host response that protects in nature. No such pattern was found with P.multocida. There was no consistent association between large numbers of a particular microorganism in the nasal passages and the presence of pneumonia in the animals, both young calves in the survey herds and the bulls at the testing station.

In the same survey the overall isolation rate from clinically normal animals in both the normal and pneumonia prone herds was 23% for P.haemolytica and 61.3% for P.multocida. A detailed breakdown of these figures on an age and herd basis gave the following information; in normal herds calves aged less than three months had percentage frequency of isolation figures of 13-89% (mean 59.4%) for P.multocida and 0-75% (mean 27.4%) for P.haemolytica, for calves aged three to nine months the equivalent figures were 33-90% (mean 59.6%) for P.multocida and 0-42% (mean 23%) for P.haemolytica. In the pneumonia-prone herds calves less than three months had percentage frequency of isolation of P.multocida ranging from 37-79% (mean 60%) and for P.haemolytica 0-36% (mean 17%), for the calves over three months the equivalent figures were P.multocida 47-72% (mean 60.4%) and P.haemolytica 0-13% (mean 7%). Thus there was no difference in isolation rates of P.multocida between pneumonia-prone and normal herds, but a lower isolation rate of P.haemolytica was found in the pneumonia-prone herds. Calves of equivalent age and type that became pneumonic from these herds had isolation rates of 47% for P.multocida and 27% for P.haemolytica. At the bull testing station the bulls were sampled on arrival and twice throughout the five month test period, isolation rates were 56% for P.multocida and 33% for P.haemolytica on arrival, and 49% for both species on routine testing. The isolation rates from pneumonic bulls were 50% for P.multocida and 79% for P.haemolytica.

Further work on the distribution of P.haemolytica over the nasal mucosa of cattle (164) showed that failure to isolate the organism did not mean that it was not present in the nasal passages but rather that it was only present in small numbers or that it was present in large numbers in a part of the nasal cavity not sampled by the nasal swab. In the same study the isolation patterns of P.haemolytica were studied using 15 selected anatomical areas in the nasal cavity of calves that had been shipped over long distances and were known to be carrying high numbers of P.haemolytica. The position of P.haemolytica on the mucosa was demonstrated, using a direct fluorescent antibody technique, to be at the surface of the epithelial cells and was not seen in or between cells. In heavily infected calves isolations were made from the majority of sites, in calves carrying a medium infection (based on total numbers of bacteria isolated) the organism was most frequently isolated from the dorsal or ventral meatuses, ventral turbinates or nasal septum, and in the calves with fewer numbers of the organism isolations were most often made from the ventral meatus or ventral turbinates. In cases where antemortem cultures were negative P.haemolytica was isolated from dorsal and ventral meatuses, and turbinates post-mortem.

In a study where the tracheal microflora was studied, by the culture of swabs of tracheal fluids obtained per os primarily for information about H.somnus (57), Pasteurella spp. (P.haemolytica and P.multocida) were found in all classes of feedlot cattle, both healthy and clinically ill. The Pasteurella spp. became more prevalent in clinically ill animals irrespective of whether the illness involved the respiratory tract or not, and there was only a very slight reduction in numbers of Pasteurella spp. isolated following treatment with antibacterials.

The first suggestion that viruses may be involved in the pathogenesis of pneumonic pasteurellosis was first made in Britain in 1938 (16). This followed the work of Shope (188) who had demonstrated in swine influenza that although inoculation of either the swine influenza virus or Haemophilus influenzae suis alone produced either a mild transient illness or no disease at all, simultaneous inoculation of both agents produced a clinical disease which was indistinguishable from swine influenza in the field.

In North America the failure to consistently reproduce shipping fever resulted in 1944 in the search for an agent which might possibly be associated with Pasteurella spp. (99). Pneumonic lung tissue was taken from fatal cases of shipping fever, Pasteurella spp. were cultured from the lung and a bacteria-free filtrate was also prepared. Guinea pigs were inoculated with both culture and filtrate and although Pasteurella spp. were isolated from the animals that received the filtrate and salmonellosis was also present, it was concluded that the presence of fluid from lung tissue enhanced the virulence of Pasteurella spp..

In 1957, nasal washings and pleural fluid were recovered from a group of steers which demonstrated fever and pneumonia in life and fibrinous pneumonia with pleurisy at post-mortem (174). These exudates were treated with penicillin and streptomycin, to kill the P.multocida that had been isolated, and inoculated into embryonated eggs. The allantoic fluids from these eggs after 48 hours incubation agglutinated sheep and chicken erythrocytes which suggested the presence of a viral agent. In 1959, the isolation of a myxovirus from the nasal mucus of feeder (store) calves showing clinical signs of shipping fever (tachypnoea, cough, pyrexic, nasal discharge, inappetence) was described (169). This virus, initially called SF4, was subsequently shown to be serologically

identical to PI3 virus (1) and was considered, at the time, to be the viral agent necessary to enhance the pathogenicity of Pasteurella spp. under experimental conditions. Serological studies on three calves showed increases in reciprocal titres over a 15 day sampling period; initial titres were 32, 64 and 256 all the calves having second titres of 512. Pasteurella multocida was present in the nasal mucus of five of the 11 calves sampled, and the authors of the paper remark that the aetiological role of the Pasteurella spp. should not be overlooked. The difficulties encountered in isolating the virus from previous shipping fever incidents were thought to be related to the comparatively short time that the virus was present in the upper respiratory tract, as although the virus was isolated up to four days after purchase, it could not be demonstrated in samples taken 16 days after purchase.

A contemporary serological survey for evidence of infection by parainfluenza 3 (SF4) virus (104) was conducted by sampling calves early in the feeding period and again three to seven weeks later. Of 191 calves studied, 131 (68.6%) had a significant increase in titre and similar changes were found in all the groups sampled. The authors concluded that infection with PI3 virus was widespread but a definite cause and effect relationship between this virus and shipping fever could not be established due to inherent difficulties in the clinical evaluation of mild and subclinical cases of shipping fever. They also noted that although the data did not preclude the possibility that PI3 virus was the primary infectious agent responsible for the majority of the cases of shipping fever observed, the results in three of a total of seven feedlots studied suggested that another infectious agent may have been the predominant primary cause of the illness observed as there were no significant increases in PI3 virus titres. In a later study on PI3 virus infections of cattle (2), 15 isolations of the virus were made in a two year period from the nasal secretions and lung tissue

of calves and older cattle on seven farms and one sales yard during the course of respiratory disease outbreaks. The virus was also isolated from nasal secretions of three apparently healthy veal calves at two abattoirs. Seroconversion to the virus was recorded in nine of 19 animals from which paired sera were taken. More serological and isolation studies followed these early reports (77,104, 131,139,206,236) and all reached similar conclusions, although with varying degrees of conviction. The conclusions were that the virus and serum antibody titres were widespread within the general cattle population and also present in cases of shipping fever in feeder cattle suggesting that the virus was an active and significant pathogen in the disease outbreaks studied. However, the results did not preclude the possibility that other agents may be involved.

Other viruses have been isolated from clinical cases of shipping fever including BHV-1 (38,116), bovine enterovirus and sporadic bovine encephalomyelitis virus (both originally classed as Chlamydia spp.) (161), and bovine virus diarrhoea virus (171).

Bovine herpes virus 1 was isolated from 65 (18%) of 354 pneumonic (shipping fever) lungs in Colorado (116) although in general it has been recognised that infectious bovine rhinotracheitis and shipping fever are two readily differentiated respiratory diseases (3). However, when IBR cases become pneumonic, the secondary lung infection is often associated with the isolation of Pasteurella spp. and lesions of fibrinous pneumonia and pleurisy (8,145).

The postulation of a possible aetiological role for BHV-1 in shipping fever has resulted from the development of a successful experimental model for bovine pneumonic pasteurellosis by infecting weaned calves with aerosols of BHV-1 followed four days later by P.haemolytica A1 (119). No evidence has been produced from the field that BHV-1 plays a significant role in the aetiology of shipping fever although vaccination against BHV-1 has been described as reducing the incidence of fibrinous pneumonia in the field

or protecting against experimental pneumonic pasteurellosis in the laboratory (202). In spite of the experimental work no field evidence has been produced to verify that the successful combination of agents used experimentally in any way reflects the aetiology and pathogenesis of shipping fever or bovine pneumonic pasteurellosis under field conditions.

Mycoplasma spp. (41,42,90) and chlamydia (161) have been isolated from clinical and fatal cases of shipping fever but experimental reinoculation of these agents into calves produced no clinical disease (80,161).

Geographical distribution

The distribution of bovine pneumonic pasteurellosis, often called shipping fever, appears, on the basis of published observations, to be restricted to the northern hemisphere. Bovine pneumonic pasteurellosis has never been recorded in the large beef-producing areas of the southern hemisphere e.g. South America and Australia. The only record of pasteurellosis in South America is of haemorrhagic septicaemia in Argentina in 1939 (15). This observation prompted a comparison of the beef cattle industry in North America (Texas) and Australia (Queensland) (113) which concluded that although management practices and environment were considered to be similar, the potential virus pathogens were present, and infection was widespread (from the evidence of serological studies) the absence of a sufficiently pathogenic strain of P.haemolytica probably prevented development of the disease. Only one published record of isolation of P.haemolytica from Australian cattle appeared in the literature (120).

The early reports from Europe and North America can be difficult to evaluate in terms of whether the disease described is bovine pneumonic pasteurellosis because of the confusion over the use of the term "haemorrhagic septicaemia"

as described earlier. The "exanthematous and pectoral forms of haemorrhagic septicaemia" were described in Germany in 1878 (31) and Bacillus bovisepticus (sic) was isolated from cattle arriving in France after shipment from North America in 1891 (158).

Pneumonic pasteurellosis was described in Scotland (12,102) and England (62,176) in adults, yearling and store cattle. In contrast reports from mainland Europe described the disease in Norway (159) and Belgium (225) as occurring in calves of less than three months of age. The disease has also been described in feeder (store) calves in Yugoslavia (32).

In North America the disease has been widely reported from both the United States (90,105,116,130,180) and Canada (41,147,204,211).

Seasonal incidence

A survey of illness and death in a population of 407,000 feedlot cattle (116) in Colorado reported that, although shipping fever pneumonia developed and was seen at post-mortem throughout the year, the incidence was much higher during fall and winter than during spring and summer. This seasonal incidence of disease is related to the economics of the beef cattle industry which dictate that large numbers of cattle are moved long distances at a time of year when the climate is changeable and often severe (135). These findings confirmed the observations of earlier U.S. workers who described the disease in both the fall and spring seasons (68,130) with the highest losses occurring in October and November, the disease being exacerbated by wet changeable weather. In Canada the disease was described in autumn and early winter (41,204) as that was when cattle were moved from the Western to the Eastern States. However, despite the descriptions of the disease in both autumn and spring, subsequent reports on the disease in North America have concentrated on the disease in autumn/early winter.

The reports of the disease from Britain confirm this seasonal incidence with outbreaks being described as occurring throughout the year but most commonly from October to February probably due to the prolonged cold and wet weather (102). These observations are repeated verbatim in a subsequent clinical survey of the disease (12) and in an account of Pasteurella spp. pneumonia in dairy cattle (221) the incident took place in November. A more recent respiratory disease incident in weaned suckled calves transported from all parts of Great Britain to a breed evaluation centre (14) occurred in late October and early November although the disease was never confirmed either microbiologically or pathologically as being similar to shipping fever.

Climatic factors

In the earliest descriptions of the disease the reason for the highest incidence of the disease during the autumn and winter months was presumed to be the changeable weather which predisposed to the disease (130). In his account of the disease in Scotland Hepburn (102) considered the disease to be commonest from October to February but attributed cases seen outwith this period over the previous two years to be the result of prolonged cold and wet weather. Later workers (42) considered that the weather was probably not such an important factor but that the seasonal increase in cases was related to the large numbers of cattle being shipped long distances at that time. In an extensive survey of shipping fever pneumonia in yearling feedlot cattle in Colorado (116) the authors concluded that chilling of the mucous membranes of the upper respiratory tract together with infection by viruses probably initiated the first steps in the pathogenesis of shipping fever by causing tissue changes that predisposed the nasopharynx to colonisation by Pasteurella spp. and the development of rhinitis. Several descriptions of the field disease make reference to the weather being mild with no unusual climatic conditions during transport of the calves to the

feedlot (105) or that calves were weaned when the weather was favourable (162). In both these accounts animals subsequently developed severe clinical signs of fever and pneumonia that were confirmed pathologically as shipping fever (fibrinous pneumonia with pleurisy). More recent experimental work using an experimental infection of BHV-1 and P.haemolytica A1 in a climatic chamber concluded that climate had no effect on the development and severity of the disease (201).

Age susceptibility

Most of the incidents in the literature refer to weaned single suckled (range) or store (feeder) calves aged from six to nine months (41,102,116,130). Many of the earlier descriptions include incidents which also affected adult cattle, mainly cows,(102,122) and young calves (159, 221).

Sex incidence

There is no published work on whether there is any difference between the sexes in the field incidence of the disease.

Type of cattle affected

Although there are references in the literature, especially amongst the early descriptions of the disease, to incidents that occurred in dairy cattle (102,122,221) the vast majority of descriptions have referred to the disease in beef cattle (41,90,116,191). The classical descriptions of the disease were in recently weaned calves which having been range-reared were then transported long distances with other calves, often from different ranches, to a feedlot where they developed the disease (135). Incidents of disease have been recorded in calves that have been weaned but remained on the same ranch (162), and in calves aged about six months but still running with, and being suckled by, their dams (233). Pneumonic pasteurellosis has also been

recorded in baby calves (under three weeks) of the dairy breeds and their crosses following transfer from the herd of origin to a rearing unit (159,225).

Breed susceptibility

Few field reports make reference to the breed of animals affected. In the earlier reports of what may now be considered atypical incidents, the affected dairy cattle were of the Holstein breed (122), and in the earliest report from Britain, the affected cattle were described as Orkney cattle (102) and it is not clear whether they were the Orkney breed as described by Youatt (243), "good milkers, good feeders, their heads are low, their backs high, their buttocks thin, their bones prominent, their horns short and bending towards the forehead", or whether they were some other breed and the description Orkney cattle referred to their geographical origins. Although the breed was not referred to in a description of the disease in newly weaned calves on a ranch in Montana (162) the photographs accompanying the paper were of Hereford (or Hereford X) cows and their white-faced calves.

Individual susceptibility

Individual susceptibility, other than that which is the direct result of fitting within the general limits of type of cattle affected, is rarely discussed in the literature. Carter (42) suggested as a direct result of his observations that the cattle most severely affected were those with pre-existing chronic pneumonia which he considered to be the result of low-grade virus infection.

Morbidity rate

The earliest reports of the disease (102,130) made no attempt to quantify the size of the problem other than to make statements such as "the percentage of cases in home bred cattle is not nearly so high" (compared with bought in cattle that had been transported).

One of the earliest reports of an epizootiological study (68) records three neighbours purchasing 80 cattle each, in good weather, from the Wichita stockyards which were then shipped to their final destination together. The morbidity, as determined by animals considered to be sick, in the three groups was as follows; group one 12.5%, group two 25%, group three 50%. A later study of two groups of calves in each of two years following shipment from western ranches to feedlots (105) determined morbidity as the number of calves in each group with a rectal temperature of 104°F or greater. Temperatures were taken daily for 10 days after arrival and the morbidity rates for each group were 70.8, 80.7, 24.1, and 58.0%. Clinical cases developed in a number of the calves subsequently but no comment is made as to what percentage of pyrexic calves became clinically ill (i.e. pneumonic).

In an outbreak of the disease in newly weaned calves that had not been transported the morbidity rate in the first 1000 calves weaned was 44.2% (162).

In 1958 an estimated 10% of the 750,000 to 800,000 beef cattle fed in Illinois developed shipping fever (129). Figures were also given for the number of cases reported by some veterinarians for other states (Kansas, 4343 cases reported by 20% of the practising veterinarians; Ohio, over 12,000 cases reported by less than 50% of the veterinarians; Minnesota, 2765 herds affected reported by 16% of the veterinarians). A survey of illness and death in yearling feedlot cattle in Colorado (115) gave an overall morbidity rate (from all causes) in a population of 407,000 cattle of 5.1%; in 75% of these the clinical diagnoses were respiratory tract disease. At post-mortem examination 75% of the fatal cases of respiratory tract disease were attributed to shipping fever, so it would be reasonable to assume that the morbidity rate due to shipping fever was in the region of 2.9%.

Mortality rate

Many of the early reports are of individuals or small groups of cattle that had died and in which a fibrinous pneumonia was found at post-mortem examination (102,122,221). In the epizootiological study in Kansas in the late 1920s (68) vaccinated and unvaccinated cattle are compared; and in the light of their results and observations by later workers (147) i.e. that vaccination with Pasteurella bacterins would appear to increase the mortality rate the results for unvaccinated cattle only will be discussed. The Kansas study gave a mortality rate of 1.02% of 4119 head of cattle and in the three groups of 80 each purchased and transported from Wichita by neighbouring farmers the mortality rates were 6.25, 2.5 and 0.0%. The mortality rate in the outbreak of Pasteurella pneumonia in newly weaned calves that had not been moved (162) was 5.6% for the first 1000 calves weaned.

In the Colorado feedlot study (115) the overall mortality rate in a population of 407,000 animals was 0.96%, 75% of these deaths were attributed to shipping fever pneumonia giving a mortality rate of 0.72% for shipping fever.

Economic impact

The majority of authors agree that in general terms respiratory disease in cattle is one of the greatest sources of loss to the cattle industry, in both the dairy and beef sectors. The first estimate of the economic impact of shipping fever on the beef industry in the United States was given by the U.S. Department of Agriculture (191) who estimated that the disease cost the beef industry in the order of 25 million dollars per year in the mid 1950s. Losses from shipping fever in the United States in 1972, described as a light year for losses (138), when over 350,000 cattle died from the disease cost the industry 76 million dollars and total costs including treatment, decreased performance etc., were estimated at 300 million

dollars for that year. Other estimates of the cost included U.S. figures for 1973 (30) of the disease losses being equivalent to several dollars per head marketed from feedlots, this estimate did not include treatment and production losses. In an Alberta feedlot survey (47) the losses resulting from bovine respiratory disease (including infectious bovine rhinotracheitis and shipping fever) were calculated as 9.6 million dollars annually. The economic losses from shipping fever were not due solely to deaths but the sick animals which recover. These were expensive in terms of treatment (drugs and veterinary fees), weight loss, poor feed conversion (in both the acute and convalescent periods), the extra labour requirement in identifying, treating and subsequent supervision in the recovery period, condemnation at slaughter either in the acute phase or because of adhesions etc. following the chronic and recovery phases, and ultimately because of the huge scale of the problem a smaller supply of beef (30,114,138). Kennedy (127) suggested that these so-called "pulmonary cripples" may represent a greater source of financial loss than the acutely ill cases.

Other predisposing factors

In the Kansas study (68) it was shown that the mortality rate in cattle vaccinated with either bacterin or aggressin was higher, 3.58% of 5661 vaccinates, than in the non-vaccinates, 1.02% of 4119 animals. When animals were vaccinated at the stockyards and again at the farm the scale of the losses increased to 11.2% in a group of 381 animals whose treatment on the farm was with bacterin, and to 10% in a group of 90 vaccinated at the yard and given aggressin on the farm.

Clinical signs

Ever since the first descriptions of shipping or transit fever appeared in the literature the disease has tended to be defined on a clinical, and to some extent an epidemiological, basis. The reason for this is that in spite of the disease being first recorded over a century ago (158), and the intense observation, research effort and discussion that has been in progress since the early 1950s (41,78,90,116,240) there is still no general consensus of opinion as to the aetiology (240).

In the original description of the disease as it occurred in Scotland (102), the clinical signs were described thus; "In the initial stages the affected animal stands with a stiff, cramped sort of posture of the limbs, the head carried low and extended forwards, the ears drooping backwards; sometimes grinding of the teeth, occasional fits of rigors, and fever, the temperature being anything from 104° to 108.5°F; pulse much accelerated; the respirations may, or may not, however, depart materially from the normal, and at this stage there is usually constipation. Very frequently there is a muco-purulent discharge from the eyes and nostrils, and there may be an occasional emission of a short suppressed sort of cough, but often no cough exists. The initial symptoms are, however, of a most insidious and deceptive character, so much so that owners are entirely misled and see little or nothing amiss with the animals until about the seventh or tenth day after the date of purchase, when one or more of the new arrivals present serious symptoms, and are obviously very ill. An examination of the affected animal at this stage, shows high fever, pulse much accelerated, the respirations quickened and of laboured and painful character, the animal moaning, and salivating at the mouth. Less acutely affected cases show pyrexia, the temperature being 104° to 106°F, the pulse accelerated and if the lungs are implicated, auscultation may reveal the usual pneumonic sounds. Sometimes, however, one finds great difficulty in making out any hepatised portion of the lung, the pneumonia

being most insidious and difficult to detect. This feature is not difficult to explain, when one has made an examination of a number of lungs after death, in which case one invariably finds but a small portion of the lung substance involved in the diseased process".

In the most recent (1979) edition of the standard text on disease of feedlot cattle (114) the clinical signs of shipping fever are described; "following an incubation period of two to five days the body temperature rises to 40° to 42°C. In the early stages of the disease the general attitudes are depicted at the time of morning feeding when affected animals remain recumbent or stand isolated with their heads downward. Hair coats are rough, muzzles dry, and appetites diminished. In more advanced stages, animals are profoundly depressed, weak, fatigued, and gaunt. Live weights are reduced. Mucopurulent discharges extend from the nostrils, and the muzzles are encrusted with dehydrated exudate; forcible removal of the crust leaves a denuded haemorrhaging surface. Profuse lacrimation and purulent conjunctivitis are seen in the eyes. Respirations are rapid and accompanied by coughing and sometimes oral breathing. Auscultations reveal fibrinous pleuritis and pneumonia in the ventral parts of the lungs. Some animals have mucoid diarrhoea, some purulent otitis, and a few tonic clonic convulsions. Other signs, such as edema from right heart failure may subsequently develop as complications".

Fifty four years separate the descriptions but the clinical signs were similar. The earlier description by Hepburn (102) is probably more accurate as a description of bovine pneumonic pasteurellosis than the later one by Jensen (114) where the disease would appear to be complicated perhaps by infectious bovine rhinotracheitis (profuse lacrimation, encrustation of the muzzle with dehydrated exudate following a mucopurulent nasal discharge) or even bovine virus diarrhoea (forcible removal of the crusts from the muzzle leaves a denuded haemorrhaging surface,

some animals have a mucoid diarrhoea). Hepburn was more realistic in his claims as to the limits of auscultation which "reveals the usual pneumonic sounds" as compared with Jensen who interpreted the auscultatory findings as "reveals fibrinous pleuritis".

In an account where the main clinical features were described as part of a differential diagnosis exercise (3) the clinical signs of shipping fever were given as; "a rectal temperature of 104° to 108°F, variable diarrhoea, rapid respiration with abdominal breathing and a painful cough, the animal standing with head lowered and elbows abducted, a rhinitis is present with nasal discharge, there is tracheitis and on auscultation there are decreased vesicular sounds anteroventrally, increased bronchial sounds and a pleuritic friction sound".

Many of the clinical accounts gave incubation periods for the disease, where the term "incubation period" was not being used in an accurate way. It would seem impossible to define the interval between an animal becoming infected with a potential pathogen and then being clinically affected by that same pathogen when the majority of workers cannot agree on the particular pathogen(s) responsible, and most of the agents implicated in the field disease are present in the normal bovine respiratory tract (6,124). In fact, what was frequently referred to in the instances where "incubation period" was quoted was the time interval between the animals arriving at the feedlot and their developing clinical signs of shipping fever. In the earliest British clinical account (102) cattle did not develop clinical signs until seven to ten days after purchase, and the earliest Canadian account (204) stated that cases were first seen three to four days after arrival. Sinha and Abinanti (191) gave two to 14 days as the time after arrival of the cattle at their destination when clinical signs were first seen, and added that in mild cases the only evidence of infection was loss of weight and condition which occurred within two weeks following shipment. Other authors have quoted figures of seven to ten days

after arrival or ten to 14 days after stress (30). In a well documented account of the disease in recently weaned calves that remained on the same ranch (162) the calves were weaned and confined in a pen for four to five days and then turned out into a meadow. The first animals were seen to be ill on the day they were turned out and the following day nine animals were found dead and fibrinous pneumonia was confirmed at post-mortem. The course of the disease was usually quite short in individual animals, some died within 24 hours of first being seen to be ill or recovered within several days to a week (105) and the disease lasted about two to three weeks within the herd (30,114). Two studies have been made as to the timing of death from respiratory disease after arrival at the feedlot (116,172) in the Colorado study 72% of the deaths from respiratory disease were within the first 45 days of the fattening period, and in the other study (172) all the deaths resulting from respiratory disease occurred within 25 days of arrival at the feedlot.

An attempt was made (by non clinicians) to quantify the clinical signs in cattle with pneumonic pasteurellosis (212,213); animals were designated "sick" or "well" on the basis of rectal temperature and plasma fibrinogen levels and these parameters were correlated with pneumonic lesions at slaughter. The conclusions reached by these authors were that some of the parameters measured related to the degree of pneumonia present in the lungs and, in general, the animals which developed pneumonia were probably more susceptible to the effects of P.haemolytica than those which did not develop pneumonia.

Immune events

The field investigations of the immune events that accompany shipping fever have been restricted to studies of antibodies to the various postulated aetiological agents in serum and nasal secretions. Other evidence such as animals that recovered from the initial acute episode of the disease did not suffer from the acute syndrome again, although they

may go on to develop chronic respiratory conditions such as bronchiectasis or chronic pneumonia (105,115,127) was purely inference from what has been written as no-one has ever specifically described it.

The first extensive serological study of shipping fever in Canadian cattle was carried out in 1954 (170) and involved the sampling of 1665 of 9410 cattle before shipment from Alberta and Saskatchewan, and repeat sampling from 1479 cattle on arrival at the owners' premises in Ontario and Quebec. The animals sampled represented 12.7, 13.5, and 25.4% respectively of three groups of cattle, one injected with Pasteurella bacterin, one injected with Pasteurella antiserum and a control group that had received no treatment. The serum antibody levels were measured by complement fixation tests with suspensions of P.multocida (types A,B and C) and P.haemolytica (biotype and serotype not specified) as antigens. As the source of the P.haemolytica cultures used in antigen production was G.R. Carter, who in a subsequent publication described all his "shipping fever" strains as being P.haemolytica biotype A serotype 1 (44) it may be reasonable to assume that the sera were examined for activity against P.haemolytica A1.

The majority of sera collected in Western Canada before shipment and before any treatment was instituted, were negative to all the Pasteurella antigens used. A small number of samples fixed complement (titres of 40 to 80) to one or more of the antigens (P.multocida A (A) 0.95% of samples, B (B) 0.27% and C (C) 1.91%; P.haemolytica (H) 0.54%); and a larger number of samples had titres of between two and 20 (A 11.31%, B 3.75%, C 14.2%, H 8.7%) and the authors concluded that these "serologically reactive" animals might serve as a focus of infection during transit. One hundred and forty eight animals in the serum treated group were bled between six and eight hours after treatment with the antiserum, and of these cattle about 25% showed activity with the A and C antigens, 15% with the B antigen and the rest were negative.

When these cattle arrived at their destinations in Ontario and Quebec all the groups showed increased percentages of sera reacting with all four antigens and especially with P.multocida type C and P.haemolytica. The respective percentages of samples with titres greater than 40 (maximum 640) to the antigens A, B, C and H were as follows; bacterin group 17.0, 6.3, 12.7, 2.5; serum group 2.7, 2.1, 9.9, and 18.0; control group 6.2, 7.5, 19.5 and 22.1.

The lungs of cattle in the survey that died of shipping fever yielded P.multocida type C and P.haemolytica at post mortem examination and it may be reasonable to assume that the corresponding increase in titre to these two organisms in the serum treated and control groups was the result of infection during transit from West to East Canada. In the bacterin treated group the presence of titres to the three types of P.multocida in the second sample was attributed to be at least partly due to the injection of the bacterin itself, and the titres to P.haemolytica to be the result of contact infection.

Shortly after this extensive serological survey was reported, the discovery of parainfluenza 3 virus in calves suffering from shipping fever (169) led to a number of investigations of the disease where serum haemagglutinating antibody to PI3 was measured sequentially in calves in field outbreaks of shipping fever. In the initial report (169), three sets of paired sera were examined from the same group of calves from which the virus had been isolated, but not from the virus positive calves. These sera had initial reciprocal titres of 32, 64, and 256 all of which had increased to 512 15 days later.

Haemagglutination-inhibition titres to PI3 virus in three groups of bought-in feeder calves, all of which developed respiratory disease within one week of arrival, were measured (178). In the first group of 61 calves sampled on arrival 57 had reciprocal titres of 20 or less and four of 40 or greater, 27 calves were sampled at the

end of their first week in the feedlot when 16 had titres of 20 or less and 11 of 40 or greater. Convalescent sera (taken at least three weeks after arrival) from seven calves within the same group which had shown clinical signs of shipping fever all had titres of 40 or greater (2x40, 3x80, 2x160) and similar trends were seen in the other groups for which detailed figures were presented.

Data for three groups of calves are given in a description of a shipping fever epizootic of mixed viral aetiology (171), in one of the groups of 18 sample calves the PI3 titres remain level or fall in 16 of the calves and there is only a modest rise in the other two from 40 to 80. Parainfluenza 3 virus was never identified in this group although there are several isolations of an unidentified virus. In the other two groups seroconversion occurred in one of two calves in one group and two of five calves in the other.

In the Canadian study which sought to quantify the clinical findings in pneumonic pasteurellosis (213) an attempt was made to work out a method to predict the clinical outcome of the disease. Serum antibody-titres to P.haemolytica A1 were measured in four groups of calves over the four week period immediately following their arrival in eastern Canada from the west. No precise titres were given, but the mean titres increased over the four week period in all groups and in animals that had been designated both "sick" and "well" on the basis of increased rectal temperature and plasma fibrinogen. The most marked changes occurred between days one and seven. The unspecified number of animals having serum antibody to P.haemolytica A1 was considered to be very high compared with the few nasal washings that contained measurable but low and inconsistent levels of HAI antibody to P.haemolytica, which was in marked contrast to that found in experimental cattle (65). In the same study the levels of serum antibody to PI3 virus increased over the four week period, the most marked change occurring between days 14 and 21.

In a study of P.haemolytica in calves in Britain (239) incidents of pneumonia were investigated and calves at risk monitored on seven farms, only one of which concerned beef (pedigree Aberdeen Angus) calves which were young (only age quoted is one week) and running with their dams. The serological results were only discussed in general terms and only low titres (less than 20) to P.haemolytica were found. The only reference to the beef calves was that serological evidence of PI3 and reovirus was found in both sick and healthy animals.

Pathology

The disease has always been recognised as a distinct entity by its pathology as well as the clinical and epidemiological findings. However a modern review of the lesions of shipping fever (168) declared that there were few detailed descriptions of the pathology in the literature, and none of potentially non-fatal cases that had been electively killed in the early stages of the disease.

Distribution of the lesions has often been omitted from descriptions of the macroscopic lesions (168) and this is especially true of the more recent descriptions of the disease, although very few of these referred to naturally occurring cases. Early reports described the lesions occurring in the anterior lobes (98), confined to the apical lobes although sometimes affecting the cardiac lobes (102), affecting the lower borders of the lungs and often the whole of the apical lobe (162), affecting one-third of the lung or more without reference to actual distribution (87), or the lower two-thirds of the lungs which were enlarged, firm, heavy and of flesh-like consistency (179).

The descriptions also referred to consolidation with thickening of the interlobular septa (221), congestion, haemorrhage and outpouring of fibrinous exudate into the lungs, with atelectasis and emphysema in the portions of the lungs adjacent to the pneumonic areas, bronchitis,

bronchiolitis with intraluminal haemorrhage and thrombosis of the lymph vessels and vascular system (87).

In the early reports of the pathology of the disease in Canada (41) 26 cases were examined pathologically as well as bacteriologically. The amount of lung tissue involved varied from cases in which only the anterior and cardiac lobes were severely affected to those in which all lobes were involved. The distribution was patchy and the inflammatory process was sublobular, lobular or lobar. Lobules were congested, oedematous, sometimes consolidated and red to grey in colour. The interlobular septa were dilated by serofibrinous exudate and there was fibrinous pleurisy.

In his differential diagnosis approach Adams (3) listed the pathological findings of rhinitis, sinusitis, variable laryngitis, fibrinous pleuritis and fibrinous pneumonia. A concise description of the lesions was given as acute fibrinous pneumonia usually with pleural involvement in a paper on field cases of bovine respiratory disease (127). Catarrhal inflammation throughout the upper respiratory tract, swollen haemorrhagic bronchial mucous membranes with intraluminal fibrin, mucus and blood was also described (114). This description which detailed the lung pathology as a fibrinous pneumonia with pleurisy, was probably a pneumonic pasteurellosis but the upper respiratory tract pathology suggests that it was secondary to BHV-1 infection and not true shipping fever.

The scarcity of macroscopic descriptions in the literature was matched by a similar lack of microscopic detail, and much of the detail available was considered to cast doubt on the authenticity of the lesion as being pneumonic pasteurellosis in a review article (168). A fibrinous pleuritis was described in an early account (221) together with thickening of the interlobular septa where coagulated material had blocked septal lymphatics and blood vessels. The presence of fibrin in the interstitial tissue of the septa, and fibrinous plugs in the septal

lymphatics were described by other authors (41). In a microscopical study of the lungs from 48 animals the interlobular lesions were described as fibrinous in 47 animals, emphysematous in 27, oedematous in 38, and fibrosed in five cases (87). Thrombosis of the septal lymphatics was seen in 39 of these cattle.

The presence of fibrin was considered central to the pathological diagnosis of shipping fever (168) and fibrinous pneumonia was further subdivided into fibrinous pleuropneumonia and fibrinous bronchopneumonia by other workers (179) who considered that P.haemolytica was the pathogen thought most likely to cause the former and P.multocida the latter. Other lesions, apart from the fibrinous pleurisy and pneumonia, were not consistently described in the various accounts of the histopathology of the disease (168). Several authors described bronchiolitis (41,87,221); sometimes the lumina were filled with pus cells and their disintegrated products (221) or with degenerating mononuclear cells (41). Few, if any, inflammatory changes in the mucosa of bronchi or bronchioles were described in one account (179) even where the lobules were surrounded by thrombosed lymphatics in the interstitial tissue, however, the lumina of these airways often contained neutrophils, cellular debris and fibrin. The alveolar lesions have been described as serous exudation with desquamation of the lining alveolar epithelial cells (221), or fibrinous exudate containing neutrophils within the alveoli, areas of emphysema, some normal alveoli and occasional intra-alveolar haemorrhage (41). "Dark cells" were described, packed into the alveolar spaces and ducts (179); these dark cells were of two types, large round macrophages with pale eosinophilic cytoplasm, or fusiform cells, and were present in the alveolar areas, along thrombosed lymph vessels, and at the edge of necrotic areas when coagulation necrosis was present on a lobular scale.

Some of the descriptions of the pathological lesions of field cases of shipping fever were confused by

the use and subsequent misuse and misinterpretation of terms such as; red hepatisation, grey hepatisation, atelectasis, emphysema, gangrene and abscesses (87). Whereas others described in their typical case of shipping fever a polymorphonuclear exudate into bronchi and alveoli, an absence of fibrin, the presence of peribronchiolar cuffing with inflammatory cells and foci of suppuration within the parenchyma (78,132), none of which are described in the classical descriptions of the pathology (168,179).

2. Other forms of pasteurellosis in cattle

Conditions due to infection with *Pasteurella haemolytica*

Pasteurella haemolytica has been described as the causal organism in a single case of bovine mastitis (143). The cow was housed with homebred calves and bought-in feeder cattle both of which groups had shown clinical signs of shipping fever. *Pasteurella haemolytica* had been isolated from nasal swabs taken from both groups of calves. Subsequently one cow developed shipping fever and one cow had clinical signs of mastitis without pneumonia. The cow was pyrexic, depressed, and had a very swollen quarter which produced a serous secretion. *Pasteurella haemolytica*, which was considered to be identical to that isolated from the calves on the basis of serological testing, was isolated from the milk. The homebred calf sucking the mastitic cow was never pneumonic although many other calves in the group developed clinical pneumonia.

In New Zealand a progressive oedema, beginning in the submandibular region and extending down the throat to the brisket, down the front legs and along the belly, has been described in dairy cows (39). The lymph nodes of the head were also involved. The oedema fluid was initially clear or slightly haemorrhagic but later became grey-brown and foetid. All the cases described were pyrexic (104°F) in the early stages with reduced milk yield. Death was usually the result of airway obstruction by the oedema. Treatment with oxytetracycline appeared to be

successful. The causative organism was described as a Pasteurella sp. which was haemolytic, and thus probably P.haemolytica.

Conditions due to infection with Pasteurella multocida

Haemorrhagic septicaemia, a disease caused by P.multocida capsular types B and E, has been described in cattle and buffaloes in tropical Asia and Africa (20). The acute clinical disease was characterised by fever, salivation and dullness in the early stages, followed by recumbency and respiratory distress and death within 24 hours of the onset of clinical signs, as a result of endotoxin shock. In the "throat" form of the disease oedema spread from the ventral neck to the brisket and occasionally into the forelimbs.

Mastitis caused by P.multocida in cattle has been described twice in the literature, (23,216). Both of these accounts were published in the early 1950s in North America. The mastitis was locally severe but no systemic reaction was present in 14 cows which were affected in one herd (23). No cases of shipping fever were recorded in the herd in the year prior to the mastitis outbreak, but an isolate of P.multocida, indistinguishable from the organism subsequently cultured from the mastitis cases, had been recovered from a cow which was pneumonic and died six months prior to the outbreak of mastitis.

3. Pneumonic pasteurellosis in other species

Sheep

An acute, febrile and apparently contagious pneumonia of adult sheep was reported in Iceland in 1931 (66). The problem occurred on several adjacent farms, and a mortality rate of about 20% was recorded. Pathological examination of the fatal cases revealed consolidation of the anterior lung lobes, pleurisy, pleural and septal thickening and focal lesions with central dark red zones surrounded by grey tissue. In the majority of fatal cases

only 30% of the lung tissue was affected, and so it was suggested (66) that the death was unlikely to be due solely to the impairment of pulmonary function. Isolations of bipolar-staining Gram-negative bacteria that were neither indole-producers nor haemolytic were made from affected lungs. Despite the apparent lack of haemolysis, these organisms were most likely to have been P.haemolytica since some workers (26) have emphasised that under certain circumstances haemolysis may not be detected unless colonies are removed from the agar surface. Other workers have reported the isolation of non-haemolytic strains of P.haemolytica from sheep (134). In the Iceland outbreak, nasal swabs were taken from shepherds, dogs, diseased and apparently healthy sheep in an attempt to trace the source of the infection. Pasteurella haemolytica was not isolated from the dogs or the men but was widespread in apparently healthy, diseased (i.e. pneumonic) and recovered sheep flocks. The subsequent use of a phenol-killed vaccine in this outbreak appeared to reduce the mortality rate.

A similar acute, apparently contagious pneumonia was described in England (134), Wales (154), Scotland (199), Norway (237), North America (156), and New Zealand (175). The affected animals were usually adult and the onset of disease was often related to lambing, dipping or driving. In the Welsh description (154) it was suggested that the crowding of sheep together during these procedures was more important than the procedure itself in the subsequent development of the disease. This theory was supported by the description of two groups of sheep which were purchased at the same market and driven the same distance (several miles) to their destination. One group completed the drive in one day and remained healthy; the other group were driven part of the way, housed overnight, completed the drive next day and subsequently developed pneumonic pasteurellosis.

Pasteurella haemolytica was isolated from all these latter incidents, and only one non-haemolytic strain was described (134); however, there was a wide variation in the numbers of organisms isolated from the lungs of fatal cases despite the consistency of the lesions present (154).

Later bacteriological work on isolates of P.haemolytica from fatal cases of pneumonic pasteurellosis in sheep (192) involved 86 cases from 60 disease outbreaks. These were mainly mature animals but included a few two month old lambs. In 75 cases where the lesion was restricted to pneumonic pasteurellosis only biotype A organisms were recovered. Two seven month old lambs with biotype A pneumonia also had a bacteraemia, and in nine six month old lambs biotype T organisms were also isolated. However this latter group of lambs came from three farms, two of which were known to be having concurrent problems with biotype T septicaemia (198). In all these lambs clearly demarcated areas of apical pneumonia were present in contrast to the more widespread consolidation of the anterior lung lobes described in pneumonic pasteurellosis (192).

In two later surveys of the incidence of the various serotypes of P.haemolytica in fatal cases of pneumonic pasteurellosis (72,209) the A biotypes were isolated from pneumonic lesions in all ages of sheep. Of the 11 biotype A serotypes, five (1,2,6,7 and 9) were responsible for 90% of outbreaks of pneumonic pasteurellosis; of these A1 (10%), A2 (64%) and A6 (9%) predominated. Biotype T organisms have rarely been isolated from pneumonic lung tissue (81) and lesions were usually associated with a concurrent septicaemia.

The isolation of P.haemolytica from normal sheep, both live and dead, has been described (10,26,29,85,189, 190). In a slaughterhouse survey of 100 heads from clinically healthy sheep P.haemolytica was recovered from the tonsils of 95% of the heads examined (85). Sixty five per cent of these tonsil isolates were biotype T.

Pasteurella haemolytica was isolated from nasopharyngeal swabs of 64% of the heads, but only 6% of these isolates were biotype T. Ninety-nine of the 100 heads were found to have P.haemolytica at either or both of the sites sampled, but no isolations of P.multocida were made. In another study (10), the isolation of P.haemolytica from the nasal cavity, trachea and lung tissue was compared in apparently healthy and pneumonic sheep. The nasal cavity in 73% of normal sheep yielded isolates of P.haemolytica whereas in the same sheep the organism was only recovered from 5% and 6% of tracheal swabs and lung samples respectively. In pneumonic sheep the comparable isolation rates were 78% nasal cavity, 54% trachea and 54% lung, which underlined the lack of correlation between nasopharyngeal and tracheal lower respiratory tract isolations. However, no indication was given in this work as to the serotypes involved.

Studies on the carrier state of sheep in flocks with a history of pneumonic pasteurellosis demonstrated that when outbreaks of disease occurred there was often a narrowing of the spectrum of serotypes of P.haemolytica recovered and/or one serotype would predominate (29). The spread of P.haemolytica within a flock was shown to be most rapid between the lambs, and a newly-introduced serotype could spread to all the lambs in a flock within a period of about 12 days (190). However if a new serotype was introduced via a ewe, there could be a lag period of several weeks before the serotype appeared in the lambs at foot; subsequent spread was rapid although there appeared to be a variation between serotypes. The spread of the organism between ewes was very slow and persistence was poor, so it was suggested that this was probably because the adult sheep already had a well established respiratory flora.

Pigs

The species-specific effects of the cytotoxin produced by P.haemolytica on neutrophils and alveolar macrophages would appear to be restricted to ruminants (125). One description of fibrinous pneumonia in pigs attributed to P.haemolytica has been recorded (25). However, subsequent study of the organism by other workers (157) considered it to be a slightly atypical member of Haemophilus sp.

4. An appraisal of the literature relating to the field disease

In the early literature the term haemorrhagic septicaemia was used to describe a pneumonia of recently assembled suckled calves, subsequently the same disease was described as shipping or transit fever. However, the disease was never defined in epidemiological, clinical, microbiological and pathological terms by the same group of workers. Many of the investigations revolved around incomplete investigations where often a final pathological diagnosis was not made. In addition to these single discipline studies of clinical signs, pathology or microbiology many other studies failed to define the type and age of calf studied and the conditions of management under which it was kept. The role of viruses in the pathogenesis of the disease was widely assumed because viruses had been isolated from calves with the disease and also because experimental workers had failed to reproduce the disease using Pasteurella spp. alone. As a result there appeared to be a reluctance to attribute the role of a primary pathogen to Pasteurella spp. although there was widespread agreement that the final, fatal lesion was that of pneumonic pasteurellosis.

SECTION II

MATERIALS AND METHODS

Initial contact with farmers

A number of practising veterinary surgeons known to have clients who purchased weaned suckled calves (Figs.1,2) in the autumn, either to fatten or sell as big stores next spring (Fig.3) were contacted. Several requests were made including access to the farms of interest, the opportunity to purchase untreated early cases of 'transit fever', and the possibility of sampling calves on arrival at the farm and several weeks later.

Following the approach to the veterinary surgeons a number of suitable farms where calves could be examined and sampled were suggested. Initial visits were made in late summer to inform the farmer of the object of our field research, to discuss the number of calves purchased, housing and handling facilities and also to assess, on the basis of this first meeting the likely level of co-operation and enthusiasm of the farmer (or farm manager) and his staff.

Some farms were rejected for sampling of calves because the handling facilities were poor or non-existent. Recently weaned single suckled calves are often wild and afraid, so handling had to be as free from stress as possible, especially in view of the role that stress was thought to play in the aetiology of the disease.

On these farms with poor handling facilities visits were still made to record details of calves purchased, sick calves etc. and sick animals were purchased.

Collection of epidemiological information

All the co-operating farmers were visited or telephoned on a weekly or fortnightly basis from late September until mid January. The following information was requested; date and number of calves purchased,

Fig. 1. Single suckled calves at foot with their dams

Fig. 2. Recently-weaned single suckled calves in market.

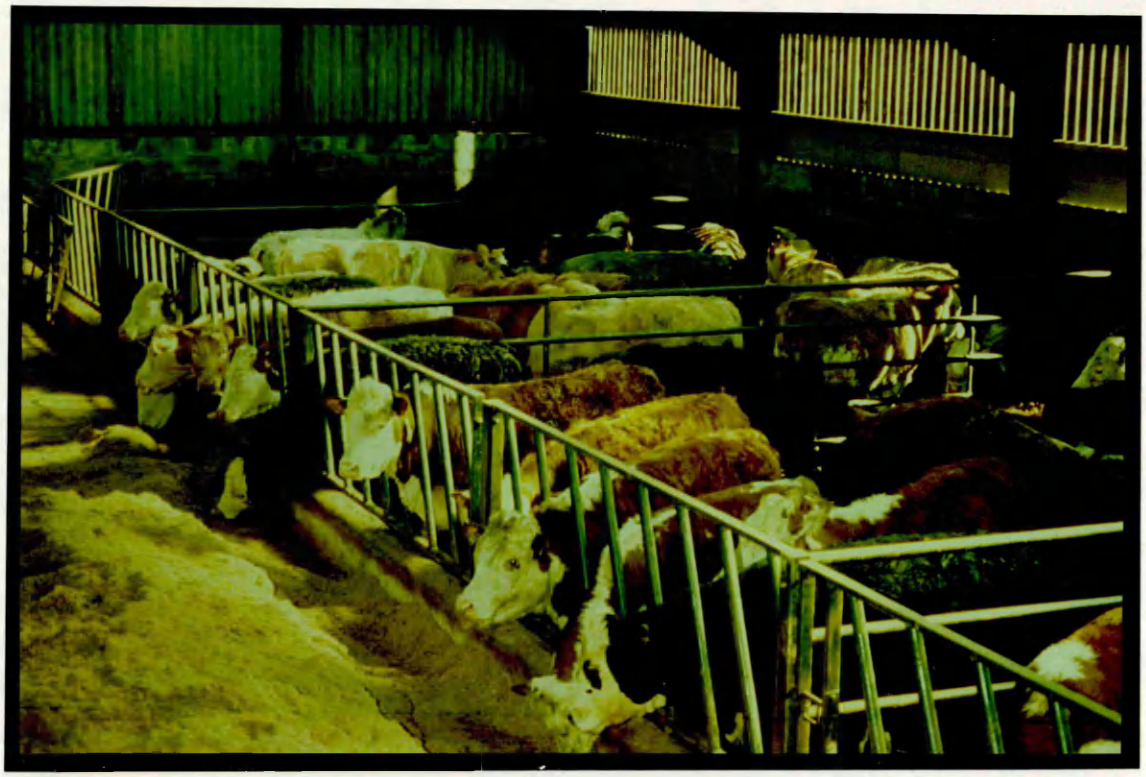

Fig. 3. Older weaned suckled calves in a fattening unit.

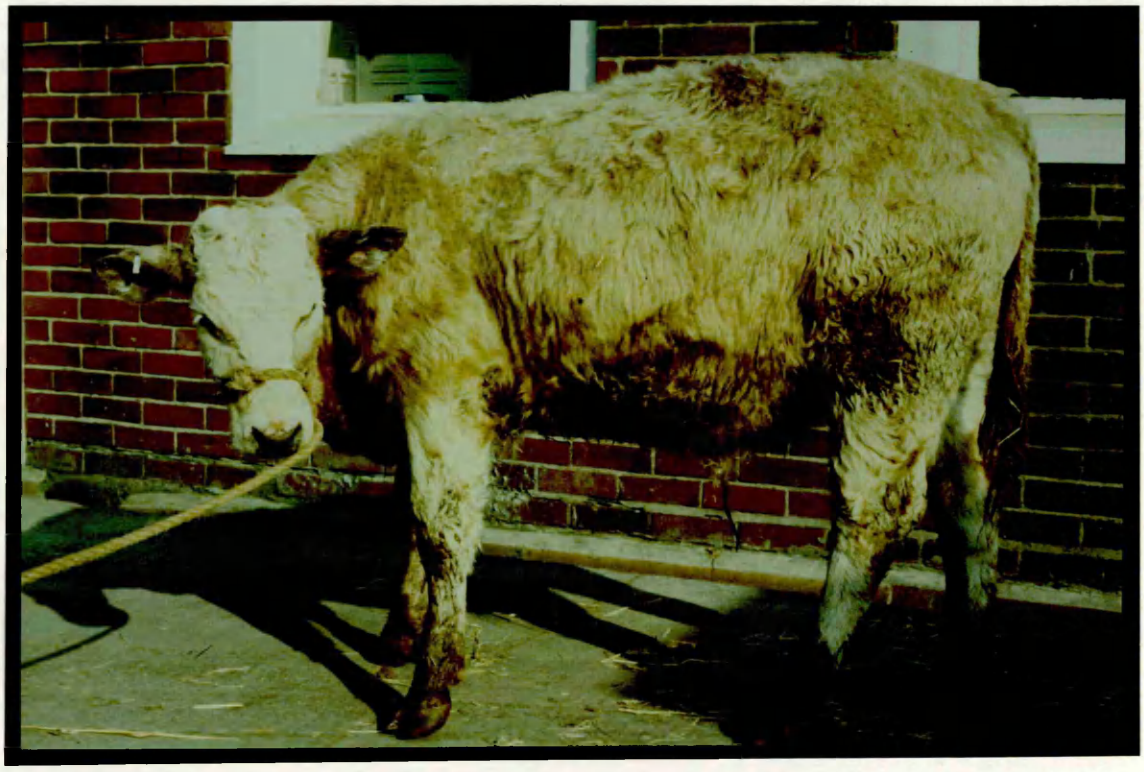

Fig. 4. A "dull" case of pneumonic pasteurellosis.

source, type of calf (whether weaned for some time or recently weaned), date of arrival at farm, and any procedures e.g. anthelminthic dosing, vaccination, implantation etc. carried out on arrival. Subsequent details requested were, the number and source of calves that had died, the number treated for 'transit fever' including treatment (drug and duration), response to treatment and subsequent clinical course.

Sampling of groups of calves

On co-operating farms with good handling facilities selected groups of calves were blood sampled for serological studies and nasopharyngeal swabs (human laryngeal swabs, Exogen Ltd., Clydebank, Glasgow) were taken for the isolation of viruses, mycoplasmas and bacteria. The calves were sampled as soon after arrival on the farm as practicable and the same calves were sampled again three to four weeks later, individual identification being recorded at each sampling. Both affected and non-affected (monitor) groups of calves were examined in this way. On farms 1 and 2 which were investigated as part of a pilot study, repeat nasopharyngeal swabbing was not carried out, however, convalescent blood samples were taken.

Examination of individual calves

Individual calves were examined on the farm when group sampling or routine visits were carried out. Some calves from farms that were not visited or calves that became ill between visits were purchased and examined on arrival at Glasgow University Veterinary School. Clinical examination included the following observations, demeanour, rectal temperature, respiratory rate and character, presence or absence and type of cough, nasal discharge and ocular discharge, together with any other significant clinical findings. Healthy weaned single suckled calves are difficult to catch, usually unapproachable and very alert. The description of demeanour in the calves with

bovine pneumonic pasteurellosis was as follows; alert/ bright/wild indicated that the calf was behaving as would be expected in a healthy animal, quiet indicated that a calf could be approached, caught and tied up for examination with relative ease, and dullness was when clinical examination could be carried out without the need for any restraint (Fig. 4).

The extent of the clinical examination varied with the circumstances under which it was carried out on the farm and where possible cattle were examined again at the Veterinary School, immediately prior to slaughter. Clinical terms used are as defined by Selman and Wiseman (181).

Serological examination of blood samples

Clotted blood samples were taken using 7ml plain vacutainer tubes (Becton-Dickinson) and transported back to the Veterinary School. They were centrifuged at 1300g for 30 minutes and the clot removed. The serum was pipetted into plastic bijoux bottles and stored at -20°C.

The sera were examined for the presence of antibodies to; Pasteurella haemolytica A1, P.haemolytica A2, P.multocida, Mycoplasma bovis, parainfluenza-3 virus, respiratory syncitial virus, bovine herpes virus-1, and bovine virus diarrhoea-mucosal disease virus.

An indirect haemagglutination test was used to measure serum antibodies to P.haemolytica A1, P.haemolytica A2 and P.multocida Type A (189). Mycoplasma bovis antibodies were measured by an indirect immunofluorescent test (5).

Viral serology was carried out by the Central Veterinary Laboratory, Weybridge using an ELISA test for the measurement of antibodies to PI3 virus, RSV and BHV-1 and using a microtitre serum neutralisation test for the measurement of antibodies to BVD-MD virus.

Identified paired sera were examined on the same occasion from each group of calves.

Microbiological examination

Nasopharyngeal swabs from live calves and tissues taken from affected cattle at post-mortem examination were examined for the presence of viruses, mycoplasmas and bacteria. Examination for the presence of viruses was carried out as described by Bryson (35) and for mycoplasmas and bacteria by the methods described by Pirie and Allan (166) and Allan (5). When laboratory time permitted full bacteriological and mycoplasmal identification was carried out, at other times examination was only carried out for viruses and Pasteurella spp.

Pathological examination

Selected cattle were promptly transported to the Glasgow Veterinary School, where they were housed in isolation, examined clinically and then slaughtered.

All systems were examined at post-mortem and samples of tissue were taken for microbiological and histopathological studies from standard sites in the respiratory tract and adjacent structures (5); nasal conchae (NC), trachea (Tr), right cranial lung lobe (RC), right middle lung lobe (RM), right caudal lung lobe (RD), tonsil (Ton), and bronchial lymph node (BrLN). On some occasions, if the presenting pathology suggested lesions elsewhere in the respiratory tract, samples of tissue were taken from the retropharyngeal lymph node (RtLN) or left lung lobes. Tissues were collected in 10 per cent formol saline and processed by standard methods for histopathological examination. Samples of tissues were taken from adjacent sites for microbiological examination as previously described.

Immunofluorescent examination of tissues

Samples of tissues from the respiratory tract were examined by a standard immunofluorescence technique on trypsinised paraffin-embedded sections for the presence of PI3 virus antigen, RSV antigen and P.haemolytica A1 (208).

SECTION III

RESULTS

A total of 31 incidents of acute respiratory disease were investigated, all of which were referred by practising veterinary surgeons as incidents of transit fever. On visiting two of the farms it was obvious from the clinical presentation that the disease problem was not transit fever, and four other acute respiratory disease incidents subsequently failed to satisfy a diagnosis of bovine pneumonic pasteurellosis, either on bacteriological or pathological grounds.

A total of 20 incidents of confirmed bovine pneumonic pasteurellosis were seen in housed weaned single suckled calves, and a further five incidents in single suckled calves at foot.

In addition six groups of apparently healthy housed weaned single suckled calves and three groups of apparently healthy single suckled calves at foot with their dams were sampled at housing and all but two of the weaned groups of calves were sampled again three to four weeks later.

1. A study of 20 incidents of confirmed bovine pneumonic pasteurellosis in housed weaned single-suckled calves

Epidemiology

The seasonal distribution of the incidents is shown in Fig. 5 . The date on which the first calf was noticed to be ill was taken as the date on which the respiratory disease outbreak started and on the basis of this data, 19 of the incidents occurred between October 1 and November 30. The other incident occurred in March and was the only springtime incident investigated. The majority of these incidents were studied in 1982 and 1983; the autumn of 1982 was wet and most weaned single suckled calves were housed immediately after purchase or movement from the farm of origin. However, the autumn of 1983 was dry and many

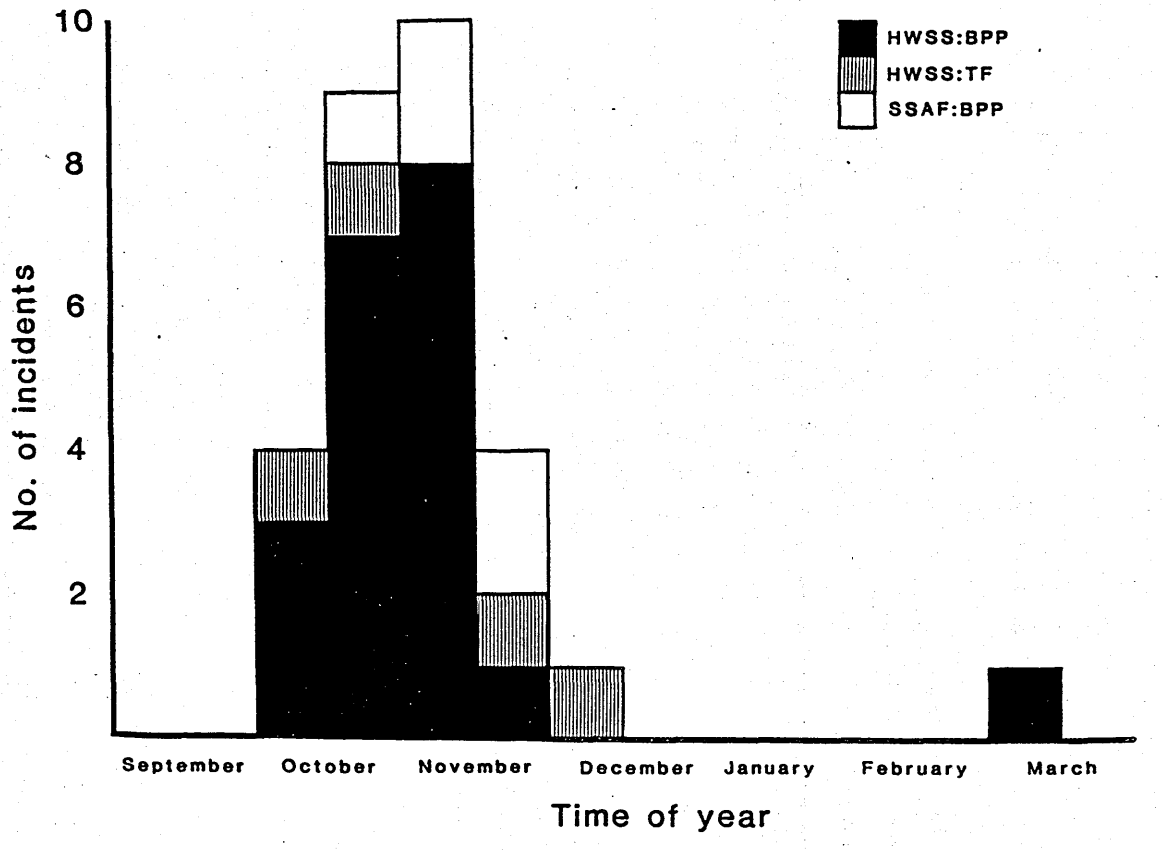

Figure 5. The seasonal distribution of 29 incidents of acute respiratory disease in suckled calves.

(HWSS housed weaned single suckled, SSAF single suckled at foot, BPP bovine pneumonic pasteurellosis, TF transit fever like).

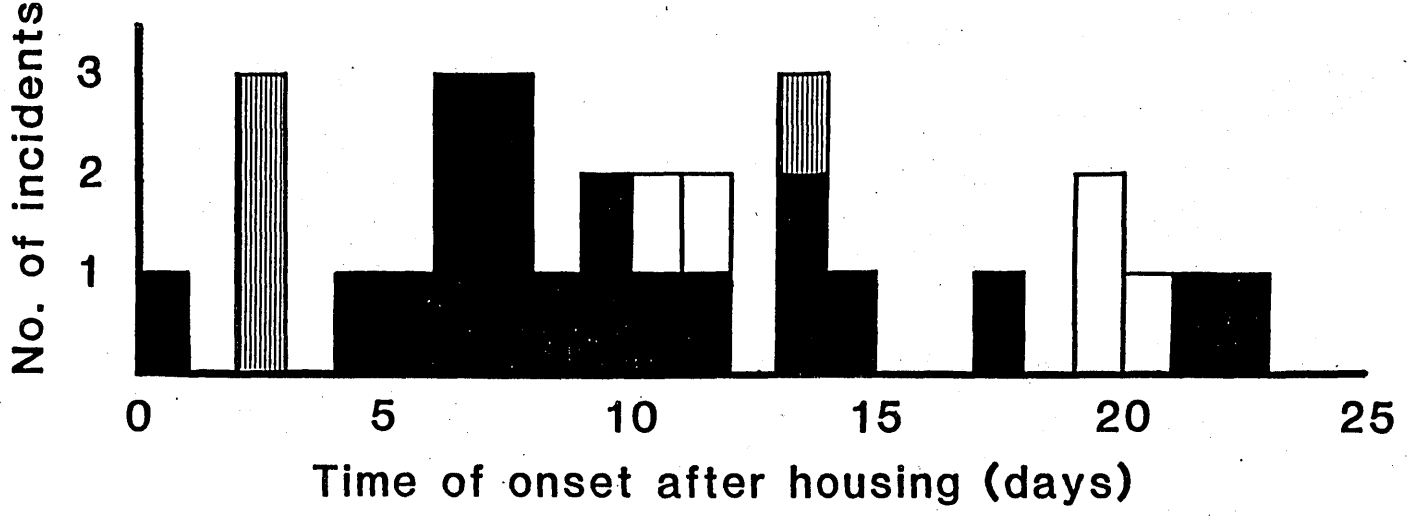

Figure 6. The time of disease onset after housing in 29 incidents of acute respiratory disease in suckled calves.
(■ housed weaned single suckled calves, pneumonic pasteurellosis; ▥ housed weaned single suckled calves, transit-fever like; □ single suckled calves at foot, pneumonic pasteurellosis).

TABLE 1. Morbidity, mortality and case fatality rates in 20 incidents of confirmed bovine pneumonic pasteurellosis in weaned single suckled calves.

FARM REFERENCE	NUMBER OF CALVES			MORBIDITY RATE(%)	MORTALITY RATE(%)	CASE FATALITY RATE(%)
	AT RISK	ILL	DEAD			
1	28	8	0	28.6	0	0
2	25	6	1	24.0	4.0	16.7
4	39	6	0	15.4	0	0
5	210	27	0	12.9	0	0
7	107	5	0	4.7	0	0
8	520	41	0	7.9	0	0
9	20	6	0	30.0	0	0
10	184	12	1	6.5	0.5	8.3
11	60	16	1	26.7	1.7	6.3
12	90	12	1	13.3	1.1	8.3
13	20	2	0	10.0	0	0
14	223	22	0	9.9	0	0
20	123	13	0	10.6	0	0
21	220	3	0	1.3	0	0
22	480	73	4	15.2	0.8	5.5
23	98	3	0	3.1	0	0
26	80	10	0	12.5	0	0
27	21	13	0	6.2	0	0
30a	640	85	0	13.3	0	0
30b	68	4	0	5.9	0	0

farmers bought calves and turned them out until the weather became wet, when they were housed. This difference in management was reflected in the date of onset of incidents of bovine pneumonic pasteurellosis; in 1982, the wet year, the disease was seen in the first half of October; whereas in 1983, the dry year, incidents were not encountered until the second half of October. The latest autumn incidents in both years were seen in late November, because all the calves which came from the later sales were housed immediately.

No incidents of bovine pneumonic pasteurellosis were seen in weaned single suckled calves until they were housed, irrespective of the interval between arrival on the farm and housing. The onset of disease after housing is shown in Fig. 6. In 16 (80%) of the incidents clinical signs were seen within 14 days of housing, with a peak in incidence at about a week, but occasionally the disease was not seen until three weeks after the calves were housed. In one incident the disease was seen within one day of the calves being housed; on this farm purchased weaned suckled calves had been mixed with home-bred calves in a small paddock prior to housing. There was no difference in the pattern of onset of disease after autumn housing between 1982 and 1983. The single springtime incident occurred seven days after housing.

The morbidity, mortality and case fatality rates are shown in Table 1. There was a wide variation in the calf numbers between the farms on which bovine pneumonic pasteurellosis was diagnosed, and in the relative importance that rearing weaned suckled calves played in the overall farm economy. The overall morbidity rate for an at risk population of 3446 housed weaned single suckled calves on 19 farms was 10.7%. However this figure was calculated on the basis of the number of calves ill as reflected in the number of calves treated. Although bovine pneumonic pasteurellosis was confirmed at post-mortem in at least one calf from each disease incident it can only be

presumed that the disease seen in other calves on the same farm was the same. The morbidity rate varied from 1.3% to 30.0%, with some of the highest morbidity rates (24% or above) in at risk populations of 60 calves or less, however there was no definite correlation between numbers at-risk and morbidity rate. The majority of housed weaned single suckled calves travel through markets but incidents five and 27 occurred when calves were weaned and transported from hill land to the rearing units under the same ownership. Nevertheless, the morbidity rates of these two incidents are similar to those in purchased calves.

The overall mortality rate was 0.2% with a case fatality rate of 2.2%. This was based on calves that died naturally either on the farm or at Glasgow University Veterinary School. Calves that were electively slaughtered as part of the investigation were not included in the deaths from disease with the exception of one calf that was slaughtered in extremis. The mortality rate varied from zero to 4% and the case fatality rates between zero and 16.7%; no difference was seen between the 1982 and 1983 seasons.

Clinical signs

The first signs of illness detected on the farm were often dependent on the standard of stockmanship. On some farms the first indication of disease would be an animal found dead, whereas on other units sick animals were recognised in the early stages of the disease because they were standing alone, appeared unusually quiet or failed to come up to the trough or feeding passage to feed (Fig. 7). Inappetence could be difficult to assess in recently weaned calves as a reluctance to feed can often be considered normal because of the sudden and dramatic change in diet.

A total of 30 animals from 19 incidents of confirmed bovine pneumonic pasteurellosis were examined (Table 2). One or two calves were examined from most incidents, but on farm nine a group of six calves were

Fig. 7. An early case of bovine pneumonic pasteurellosis.

TABLE 2. Clinical findings in 30 housed weaned single suckled calves from 19 incidents of confirmed bovine pneumonic pasteurellosis.

Farm	Case No.	Day of illness	Demeanour	Rectal Temperature (°F)	Respiratory rate per min.	Cough	Nasal discharge	Auscultation (Adventitious sounds)	Antibacterial therapy
1	82392	4	Dull	106.0	84	±	m	-	-
1	82412	4	Dull	104.0	66	+	-	-	-
4	89612	1	Dull	104.5	72	-	m	-	-
5	89839	10	Alert	106.1	60	-	m	-	+
7	89328	1	Quiet	103.0	70	±	mp	Soft crackles	-
8	89490	21	Quiet	102.4	60	±	mp	-	+
8	89599	7	Dull	103.0	66	±	m	-	+
9	89573	5	Quiet	102.4	72	-	-	-	+
9	89574	5	Quiet	103.1	45	-	m	-	+
9	89575	5	Bright	101.8	50	±	m	-	+
9	89576	5	Quiet	103.1	50	±	m	-	+
9	89577	5	Dull	102.6	75	±	m	-	+
9	89578	5	Bright	102.2	40	±	m	-	+
10	89906	1	Dull	107.6	60	-	m	Solid	-
10	89938	7	Dull	106.0	66	-	-	-	+
11	89884	2	Quiet	105.1	40	±	mp	Squeaks, crackles	-
12	89329	1	Quiet	104.4	50	±	mp	-	-
12	89776	1	Alert	106.0	90	-	m	Solid, whistles	-
13	89717	12	Dull	105.6	80	-	-	Solid	+
14	89600	2	Quiet	103.0	90	-	m	Crackles, squeaks	-
20	93094	1	Dull	106.5	72	-	-	-	-
21	93267	2	Dull	104.5	40	+	mp	-	+
21	93268	2	Dull	108.0	30	-	mp	Crackles	-
22	93379	2	Wild	103.5	70	-	m	Squeaks, crackles	-
22	93380	2	Dull	103.0	50	±	mp	-	-
23	93350	6	Dull	103.6	70	-	-	Squeaks	+
26	93116	8	Dull	102.2	30	-	-	Squeaks	+
27	93240	1	Alert	104.0	75	-	m	-	-
30a	93151	1	Dull	105.2	72	-	-	-	-
30b	94545	4	Dull	100.8	65	-	-	Solid, squeaks	+

m - mucoid; mp - mucopurulent; ± - occasional cough.

obtained after the disease had been diagnosed in a calf that was found dead and the rest of the group were seen to be ill. No animals were examined live from Farm two.

Of the 30 animals examined, 15 were untreated and 15 had received antibacterial therapy. All 15 of the untreated cases had been ill for less than four days, eight having been ill for one day and five for two days. The treated cases had been ill for between two and 12 days except for one calf that had been ill for 21 days.

Twenty-four (80%) of the calves examined were considered to be quiet or dull (Fig. 4); of these 11 had received antibacterial therapy and 13 were untreated. Of the 13 untreated calves examined in the first two days of the disease three were described as wild, bright or alert, four as quiet and six as dull. Previous treatment or duration of illness did not appear to have any effect on the demeanour of the calf.

A wide range of rectal temperatures were recorded but in untreated calves the temperature was never below 103.0°F and in three cases values of 106.5°F, 107.6°F and 108.0°F were found. Ten of the 15 treated calves had rectal temperatures of 103.1°F or less; the temperatures of the other five calves were 103.6°F, 104.5°F, 105.6°F, 106.0°F and 106.1°F after illness lasting six, two, 12, seven and ten days respectively.

Respiratory rates ranged from 30 per minute to 90 per minute with wide variation in both treated and untreated calves irrespective of the duration of illness. Two untreated calves had respiratory rates of 30 and 40 per minute respectively after being ill for two days, and in both these calves respiration appeared painful and crackles could be heard on auscultation. The respiratory rates of the remainder of the early untreated cases were 50 per minute or above with eight calves having respiratory rates of 70 per minute or above. The maximum respiratory rate in two untreated cases after one and two days of

illness was 90 per minute; the maximum recorded in a treated calf was 80 per minute after 12 days of illness.

Coughing was not a feature of the clinical cases of bovine pneumonic pasteurellosis examined. Seventeen (56.7%) of the 30 cases examined were never heard to cough, and 11 (36.7%) only coughed occasionally, usually when being handled. Two calves (6.7%) were heard to cough on several occasions. There was no difference in the amount of coughing between treated and untreated calves, nor was the presence or absence of coughing related to the duration of illness.

No nasal discharge was present in 11 (36.7%) calves; 12 (40%) calves had a mucoid discharge and seven (23.3%) a mucopurulent discharge. There was no difference in presence and nature or absence of a nasal discharge between treated and untreated calves, and no correlation with the duration of illness. Two of the calves which had a mucopurulent nasal discharge were found to be carrying BHV-1 and clinical infectious bovine rhinotracheitis was later diagnosed in a different group of cattle on that farm.

Auscultation of the affected calves usually revealed harsh respiration which could be attributed in part to the tachypnoea. Squeaks were heard in six calves and were usually most audible anteroventrally. Crackles were recorded in five cases, all of which were untreated, and two of these cases were mentioned previously as they had low respiratory rates, thoracic pain and pleurisy. Other features noted on auscultation were that there was a lack of "normal" respiratory sounds over some areas of the lung fields in four animals, and the lungs sounded solid; whistling sounds were recorded also in one of these cases.

Microbiology of calves at post-mortem

The complete respiratory tract was examined for the presence of bacteria, mycoplasmas and viruses in 32 of the 33 housed weaned single suckled calves from 20 incidents of confirmed bovine pneumonic pasteurellosis. In one case (89545 from Farm 9) a portion of lung only was submitted by the practising veterinary surgeon.

The distribution of recognised respiratory pathogens from all 33 cases is shown in Table 3.

Pasteurella spp. (P.haemolytica A1, A2 and P.multocida) were isolated from the respiratory tract of 29 calves. Potential respiratory pathogens were not isolated from one calf (82412) and Pasteurella spp. were not isolated from a further three calves (93267, 93379 and 93380). Only one of these four calves had received antibacterial therapy.

Pasteurella haemolytica A1 was the most commonly isolated organism being isolated from 25 calves; in 22 cases from both the upper and lower respiratory tracts and from the upper or lower respiratory tract in two and one cases respectively. In 23 calves P.haemolytica A1 was the only Pasteurella spp. to be isolated, in the other two calves it was present in combination with P.multocida. In one of these combined isolations P.haemolytica A1 appeared to be dominant being present in both the upper and lower respiratory tract with P.multocida being confined to the upper respiratory tract, whereas in the other animal P.multocida appeared to dominate with the distribution of recovery of the organisms being reversed. Pasteurella haemolytica A1 was the sole potential respiratory pathogen isolated from 18 of the calves.

Pasteurella haemolytica A2 was isolated from one case where it was the only potentially pathogenic organism detected.

TABLE 3. Isolation of recognised respiratory pathogens at post-mortem from 33 housed weaned single suckled calves from 20 incidents of confirmed bovine pneumonic pasteurellosis.

Farm	Case No.	Pasteurella haemolytica		Pasteurella multocida	Haemophilus sp.	Mycoplasma		PI3 virus	BHV-1
		A1	A2			M.bovis	M.dispar		
1	82392	-	UL	-	-	-	-	-	-
1	82412	-	-	-	-	-	-	-	-
2	82541	UL	-	-	-	L	-	UL	-
4	89612	UL	-	-	-	-	-	-	-
5	89389	UL	-	-	-	-	-	-	-
7	89328	UL	-	-	-	-	-	-	-
8	89490	UL	-	U	-	-	-	-	-
8	89599	UL	-	-	-	-	L	-	-
9	89545	-	-	L	-	-	-	-	-
9	89573	UL	-	-	-	-	-	-	-
9	89574	U	-	UL	-	L	-	-	-
9	89575	-	-	U	-	-	-	-	-
9	89576	UL	-	-	-	-	L	-	-
9	89577	UL	-	-	-	-	-	-	-
9	89578	UL	-	-	-	-	-	-	-
10	89906	UL	-	-	-	-	-	-	-
10	89938	UL	-	-	-	-	-	-	-
11	89884	UL	-	-	-	UL	-	-	-
12	89329	UL	-	-	-	-	-	-	-
12	89776	UL	-	-	-	-	-	-	-
13	89717	UL	-	-	-	-	-	-	-
14	89600	-	-	UL	-	-	-	-	-
20	93094	UL	-	-	-	-	-	-	-
21	93267	-	-	-	L	-	-	-	U
21	93268	UL	-	-	-	-	-	-	U
22	93379	-	-	-	-	L	-	-	-
22	93380	-	-	-	-	UL	-	-	-
22	93378	L	-	-	-	-	-	-	-
23	93350	UL	-	-	-	-	-	-	-
26	93116	UL	-	-	-	-	-	-	-
27	93240	UL	-	-	-	-	-	-	-
30a	93151	U	-	-	-	-	-	-	-
30b	94545	UL	-	-	-	-	-	-	-

PI3 virus Parainfluenza-3 virus
BHV-1 Bovine herpes virus 1
U Upper respiratory tract
L Lower respiratory tract

Pasteurella multocida was isolated from five of the 33 cases examined. In two cases it was present in combination with P.haemolytica A1 as previously described, and in three cases it was the only potential respiratory pathogen isolated being present in one calf throughout the respiratory tract and in either the upper or lower respiratory tract in the other two calves.

Mycoplasma spp. were isolated from seven calves; in two calves, both from the same farm, Mycoplasma bovis was the only potential pathogen isolated. It was also found in combination with P.haemolytica A1 in two cases, and with P.haemolytica A1 and P.multocida in one calf. Mycoplasma bovis was always present in the lower respiratory tract in all five animals, and was also present in the upper respiratory tract in two calves. Mycoplasma dispar was isolated from the lower respiratory tract of two calves, both of which had P.haemolytica A1 in both upper and lower airways.

Viruses were only isolated from two disease incidents. Parainfluenza 3 virus was recovered from the upper and lower respiratory tract of the dead calf from Farm two in combination with P.haemolytica A1 and M.bovis. Bovine herpesvirus 1 was isolated from the upper respiratory tract of both calves from Farm 21, once in combination with Haemophilus sp. and once with P.haemolytica A1.

A total of 27 other micro-organisms were isolated at post-mortem from the respiratory tracts of the 33 calves. Mycoplasma bovirhinis was the most commonly isolated organism (25 calves), with Micrococcus sp. (8 calves), Streptococcus bovis (7 calves), Acinetobacter anitratus, Bacillus coagulans, Acholeplasma laidlawii, and Proteus sp. (all 6 calves) being the next most commonly isolated species. All these organisms were present throughout the respiratory tract, although not always in each calf, with the exception of Proteus sp. which together with Escherichia coli (4 calves) were only found in the

upper respiratory tract, presumably as the result of contamination. Twelve other micro-organisms were isolated from single calves.

The number of other species of microorganisms present in any individual calf varied between zero and seven. Single calves had zero and seven other organisms, seven calves carried one organism, four calves two organisms, eight calves three organisms and six calves had four and five other organisms.

One hundred isolations were made in total, 47 from the upper respiratory tract alone, 27 from upper and lower respiratory tracts and 26 from the lower respiratory tract in individual calves.

Microbiology and serology of in-contact groups of calves

Twelve of the 20 farms from which cases of bovine pneumonic pasteurellosis were examined clinically and at post-mortem were visited and the in-contact group of cattle were sampled microbiologically and serologically. On seven farms nasopharyngeal swabs were taken on only one occasion early in the disease. On a further five farms nasopharyngeal swabs were taken early in the disease and again three to four weeks later, and a total of seven farms were sampled twice for paired serology. Some farms were only sampled on one occasion because despite an earlier critical assessment of the standard of handling facilities and on-farm co-operation, sampling was difficult for one or both of these reasons. The exception to this was farm nine where all the calves were killed after the initial sampling.

The isolation of recognised respiratory pathogens from these groups of cattle is shown in Table 4.

The first sampling was carried out as soon as practicable after the disease was diagnosed by the practitioner usually within 24 hours of notification by telephone.

TABLE 4. Number of isolations of recognised respiratory pathogens from nasopharyngeal swabs taken from in-contact housed weaned single suckled calves in confirmed incidents of bovine pneumonic pasteurellosis.

Farm reference	4		5		10		26		27		1	2	9	12	21	22	23
Time of sampling	1	2	1	2	1	2	1	2	1	2	1	1	1	1	1	1	1
No. of calves sampled	11	10	22	22	21	21	12	12	40	39	7	9	6	16	42	13	26
Pasteurella haemolytica A1	4	1	1	-	5	3	-	2	4	4	-	4	2	-	12	1	11
Pasteurella haemolytica A2	-	-	-	-	1	3	-	-	-	-	-	-	-	-	1	-	-
Pasteurella haemolytica A6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pasteurella haemolytica UT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Pasteurella multocida	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Mycoplasma bovis	-	9	-	5	6	-	-	-	-	-	1	2	-	1	-	-	-
Mycoplasma dispar	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Bovine Herpesvirus - 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parainfluenza - 3 virus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Respiratory syncitial virus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Nine of the 12 groups of in-contact cattle sampled in the initial stages of the disease were found to have P.haemolytica A1 in the nasopharynx, and the percentage of calves from which the organism was isolated ranged from 7.7% (Farm 22) to 28.6% (Farm 21).

Clinical cases from eight of these nine farms were found to have P.haemolytica A1 in the lower respiratory tract at post-mortem examination. The other P.haemolytica A1 positive group of cattle were on Farm nine where P.multocida had been isolated from a piece of lung as the whole respiratory tract was not available. However, P.haemolytica A1 was isolated from the upper and lower respiratory tracts of four and the upper respiratory tract of one calf when the group of six sampled calves were slaughtered an hour after sampling. Pasteurella multocida was not isolated from the nasopharynx of any calf. On Farm one, four of nine calves sampled had P.haemolytica A1 in the nasopharynx, but no isolations of P.haemolytica A2 were made. This was the complete converse of the post-mortem isolations, where P.haemolytica A2 was present throughout the respiratory tract and P.haemolytica A1 was not isolated.

Pasteurella haemolytica A2 was isolated from two groups of cattle, both of which were also positive for P.haemolytica A1, but the two serotypes were never present together in any one calf. One farm produced a single isolate of an untypeable P.haemolytica; P.haemolytica A1 was also isolated from this group but from different calves.

Only five groups of calves were resampled three to four weeks later. Pasteurella haemolytica A1 was found to be present in four groups of cattle, in one of which (Farm 26) no isolations of P.haemolytica A1 had been made at the first sampling. No isolations of P.haemolytica A1 were made from one group of cattle that had previously been positive (Farm 5). In the groups of cattle that were positive on both occasions, only one calf (Farm 4) was found to have P.haemolytica A1 twice.

Pasteurella haemolytica A2 was isolated from the same group of calves that had been positive at the first sampling, and the calf positive on the first occasion remained so.

Pasteurella multocida was only isolated on one occasion at the second sampling on Farm five.

Mycoplasma bovis was isolated from four groups of calves at the first sampling, with isolation rates of between 6.3% (Farm 12) and 28.6% (Farm 10); and from two different groups of calves at the second sampling with isolation rates of 22.7% (Farm 5) and 90% (Farm 4). A single isolation of M.dispar was made at the first sampling on Farm 12.

Parainfluenza 3 virus was isolated from one in-contact calf on Farm two at the first sampling. No other viruses were isolated.

A total of 20 other species of microorganisms were isolated, and there was little difference in the variety and number of isolations made at either the first or second sampling. The commonest species isolated were M.bovirhinis, A.laidlawii, Micrococcus spp., Bacillus spp., Acinetobacter spp., Corynebacterium spp., and A.lignieresii.

Paired serology was carried out on seven of the 20 incidents of confirmed bovine pneumonic pasteurellosis in housed weaned single suckled calves. The number of calves seroconverting to each of the potential respiratory pathogens is shown in Table 5. Antibodies to P.multocida were not measured in all groups because of laboratory problems with the test, and the BVD-MD serology is not complete because of staffing problems at the Central Veterinary Laboratory, Weybridge.

On farms one and two no seroconversions to P.haemolytica A1 or A2 were demonstrated, but initial titres to P.haemolytica A1 in all calves on both farms were high, and with the exception of one calf on each farm,

TABLE 5. Number of seroconversions to recognised respiratory pathogens in in-contact housed weaned single suckled calves from incidents of confirmed bovine pneumonic pasteurellosis.

Farm reference:	1	2	4	5	10	26	27
No.of calves sampled:	5	9	10	44	19	12	39
Pasteurella haemolytica A1	0	0	6	13	7	2	28
Pasteurella haemolytica A2	0	0	0	18	8	3	18
Pasteurella multocida	ND	0	ND	ND	ND	ND	ND
Mycoplasma bovis	1	0	0	10	3	2	4
Bovine herpesvirus 1	0	0	1	0	0	0	0
Parainfluenza 3 virus	3	8	4	4	8	0	32
Respiratory syncitial virus	0	1	1	3	1	0	34
Bovine virus diarrhoea virus	1	0	ND	ND	ND	ND	ND

ND not done

initial titres to P.haemolytica A2 were also high. On the other five farms seroconversion to P.haemolytica A1 was demonstrated in 16.7% to 70% of the calves sampled.

On farm four all the calves from which P.haemolytica A1 was isolated and from which paired serology was obtained seroconverted to the organism. Only one isolation of P.haemolytica A1 was made at the first sampling on Farm five, this calf did not seroconvert (initial titre 8), however the only calf from which P.haemolytica A1 was isolated at the second swabbing had seroconverted by that time.

All five calves from which P.haemolytica A1 was isolated (2 at initial sampling, 3 at second sampling) on Farm ten seroconverted. On Farm 26, P.haemolytica A1 was isolated from two calves at the second sampling, by which time both had seroconverted. On Farm 27, a total of eight calves were positive for P.haemolytica A1, four at each sampling; of these paired serology was available for seven (the other ran away). Four seroconverted, two had high initial titres (64) and the other calf did not seroconvert (initial titre 8).

Of the seven farms on which paired serology was available, seroconversion to P.haemolytica A2 was seen in four of the groups of calves, with 25 to 40% of the calves seroconverting. On farm ten, P.haemolytica A2 was isolated from nasopharyngeal swabs from the same calf at both samplings, this calf also seroconverted to the organism.

Seroconversions to M.bovis were recorded on five of the seven farms, involving from 10.2% to 22.7% of the calves sampled.

Seroconversion to BHV-1 was recorded in only one calf on Farm four, where clinical IBR had never been seen and vaccination was not carried out. Seroconversions to P13 virus were recorded in six of the seven groups sampled. The percentage of calves which seroconverted

within the groups varied from 9.1% to 82.1%. Seroconversions to RS virus were seen in five groups of calves, usually single calves, except on Farm 27 where 87.2% of the calves seroconverted, the same farm which had the highest seroconversion rate to Pl3 virus. One seroconversion to BVD-MD virus was recorded.

Pathology

A total of 33 housed weaned single suckled calves from 20 incidents were examined at post-mortem, and 29 of these were admitted live to Glasgow University Veterinary School and electively slaughtered within 24 hours of admission, following clinical examination. Two calves had died, one on the farm (82541) and one whilst awaiting slaughter (89938), and a further two died on the farm and the whole respiratory tract (93378) or a lung lobe (89545) was obtained. The details are shown in Table 6.

Fibrinous pneumonia was present in 24 of the lungs examined either at a gross or histopathological level. In at least one animal from every incident fibrinous pneumonia was detectable grossly because of the presence of dilated interlobular septa (Figs.8 and 9) and microscopically there was a fibrinous reaction within the lung tissue (Fig.10). Fibrinous pleurisy was present in only nine cases (Fig.8).

Pasteurella nodules (Figs.11 and 12) were seen in eight calves and in many of these cases the fibrinous pneumonia was not extensive or severe. Often only small focal lesions were present within areas of normal lung tissue.

Other pathological features such as bronchiolitis and cuffing pneumonia were seen but were not a consistent finding.

Pasteurella haemolytica Al could be demonstrated in the affected tissues by immunofluorescence (Fig.13), and in the localised lesions it was present within the nodules but not in the surrounding, apparently normal, lung tissue.

TABLE 6. Pathological findings in 33 housed, weaned single-suckled calves from 20 incidents of confirmed bovine pneumonic pasteurellosis.

Farm	Case No.	Days ill to P.M.	Died or killed	Fibrinous pneumonia	Nodules	Pleurisy	Antibacterial treatment	Pasteurella sp. isolated
1	82392	4	K	+	+	-	-	A2
1	82412	4	K	-	-	-	-	-
2	82541	2	D	+	-	-	+	A1
4	89612	1	K	+	-	+	-	A1
5	89389	10	K	+	+	-	+	A1
7	89328	1	K	+	+	-	-	A1
8	89490	21	K	+	+	+	+	A1 + M
8	89599	7	K	+	+	-	+	A1
9	89545	1	D	+	-	+	+	M
9	89573	5	K	-	-	-	+	A1
9	89574	5	K	-	-	-	+	M + A1
9	89575	5	K	-	-	+	+	M
9	89576	5	K	+	+	+	+	A1
9	89577	5	K	-	-	-	+	A1
9	89578	5	K	-	-	-	+	A1
10	89906	1	K	+	-	-	-	A1
10	89938	7	D	+	-	-	+	A1
11	89884	2	K	+	-	+	-	A1
12	89329	1	K	+	-	-	-	A1
12	89776	1	K	+	-	-	-	A1
13	89717	12	K	+	+	-	+	A1
14	89600	2	K	+	-	-	-	M
20	93094	1	K	+	-	-	-	A1
21	93267	2	K	-	-	-	+	-
21	93268	2	K	+	-	+	-	A1
22	93379	2	K	+	-	-	-	-
22	93380	2	K	+	-	-	-	-
22	93378	1	D	+	-	-	+	A1
23	93350	6	K	+	-	-	+	A1
26	93116	8	K	+	-	+	+	A1
27	93240	1	K	-	-	-	-	A1
30a	93151	1	K	-	-	-	-	A1
30b	94545	4	K	+	+	+	+	A1

A1 Pasteurella haemolytica A1
A2 Pasteurella haemolytica A2
M Pasteurella multocida

K killed
D died

P.M. Post mortem

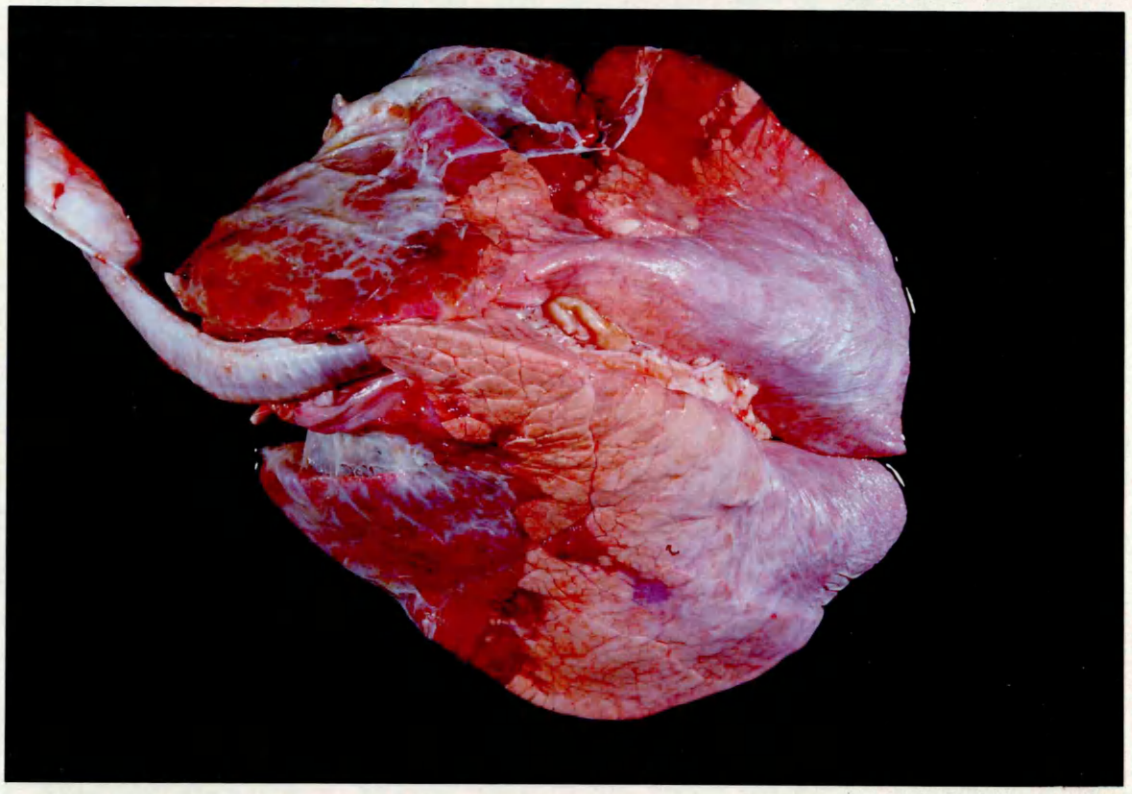

Fig. 8. Lungs from confirmed case of bovine pneumonic pasteurellosis showing consolidation, dilated interlobular septa and pleurisy.

Fig. 9. Transverse section of lung showing marked dilatation of interlobular septa and thickened pleura.

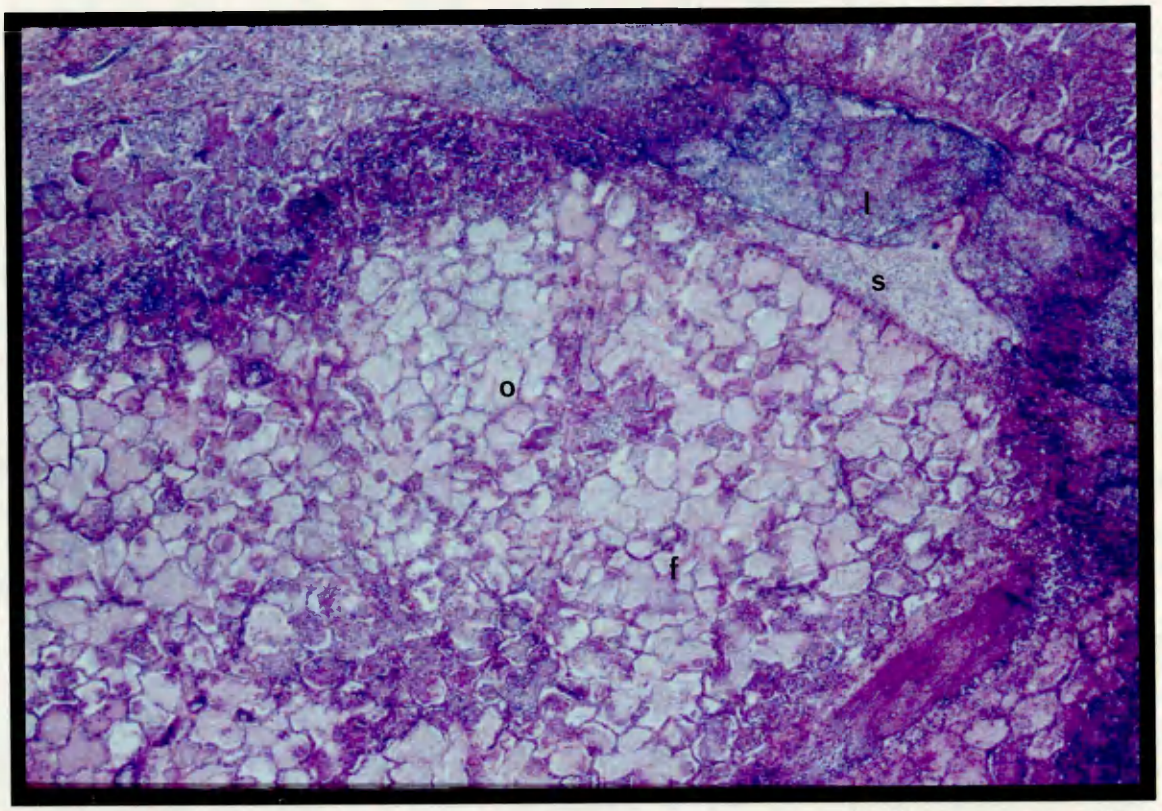

Fig. 10. Flooding of the alveoli with oedema[o] and fibrin[f] in early pneumonic pasteurellosis. The adjacent interlobular septum[s] is dilated and fibrin can be seen in the lymphatics[l].
(Haematoxylin and eosin x 40)

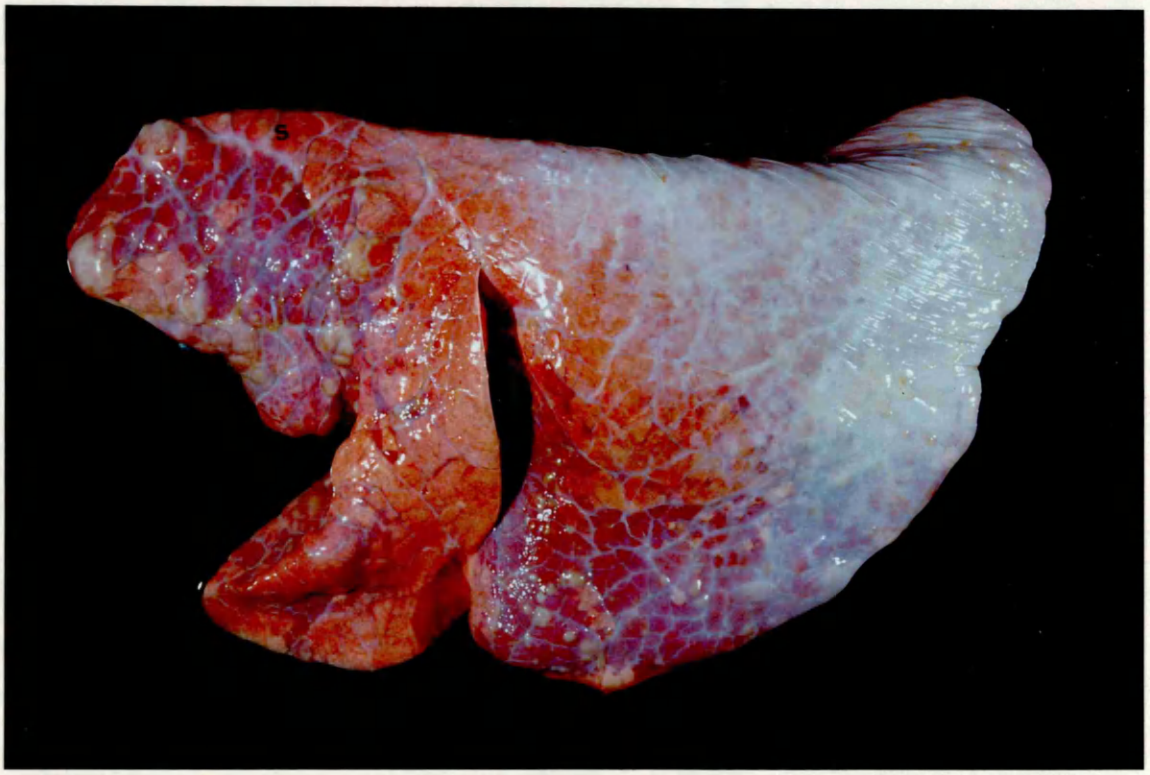

Fig. 11. Lungs from confirmed case of pneumonic pasteurellosis showing multiple Pasteurella nodules.

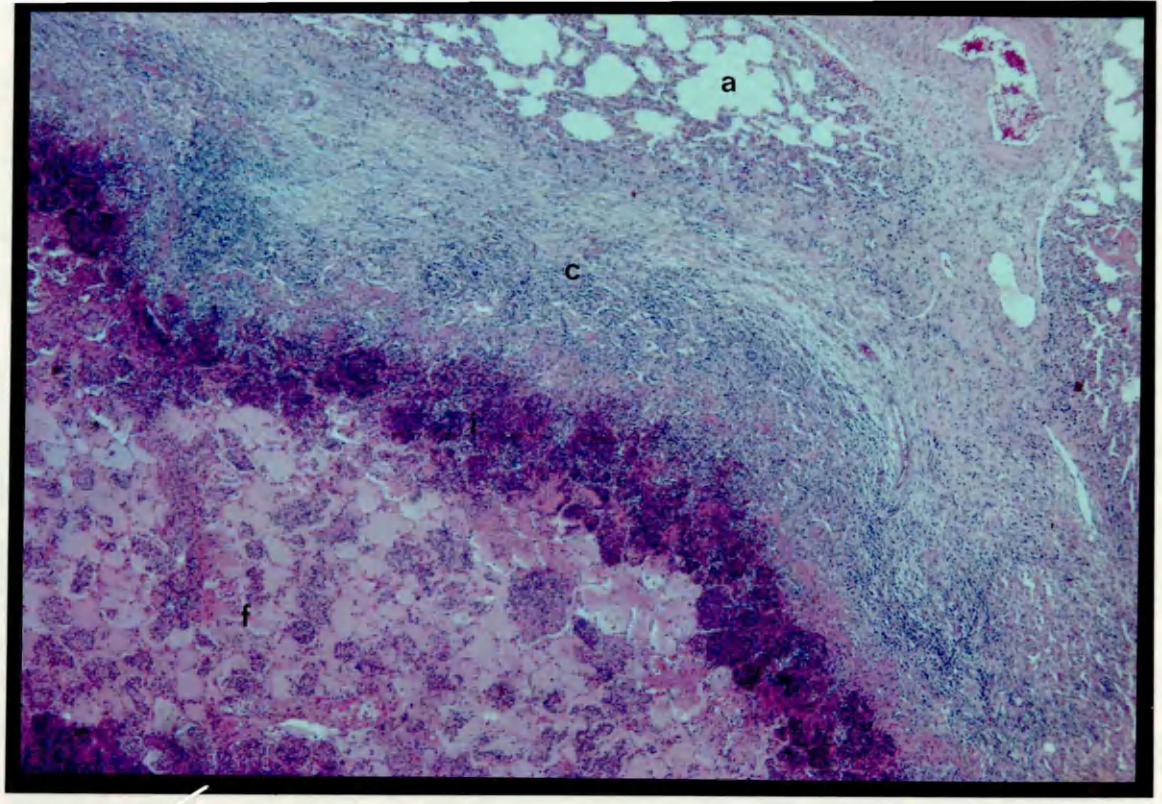

Fig. 12. Section through a Pasteurella nodule showing focus of fibrinous pneumonia[f] with surrounding cellular infiltration[i] and fibrous capsule[c]. Adjacent alveoli[a] appear normal. (Haematoxylin and eosin x 40)

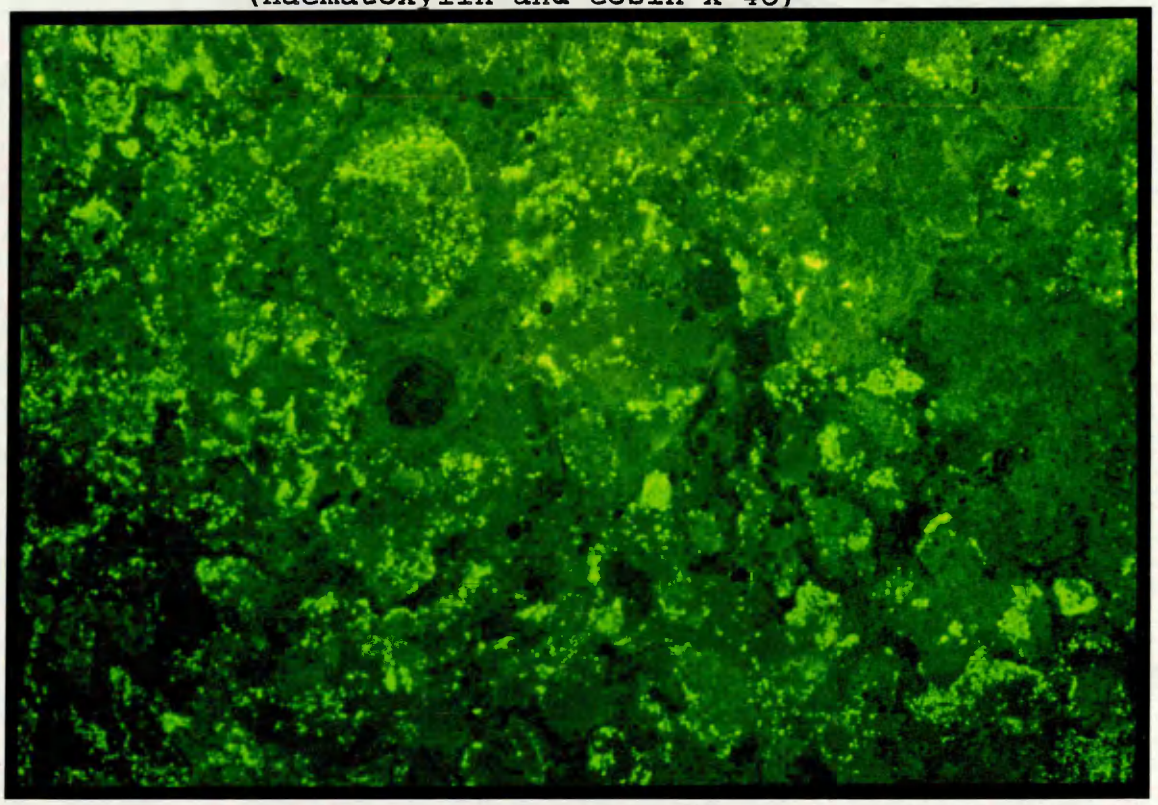

Fig. 13. Pasteurella haemolytica A1 demonstrated by immunofluorescence in section of lung from confirmed case of pneumonic pasteurellosis. (x 40)

Sections from all calves slaughtered were examined by immunofluorescence for the presence of Pl3 virus, RS virus and BVD-MD virus. Only one calf (82541) shown to be positive for PI3 virus and this was confirmed by isolation of the virus from the tissues. No other calf showed positive immunofluorescence for any other viral antigens.

Routine disease control procedures (on-farm)

A variety of vaccines, anthelminthics, prophylactic antibiotics and growth promoting agents were administered to calves on the farms under study.

Anthelminthic dosing was the procedure most commonly carried out on weaned single-suckled calves at housing. Benzimidazoles were used on eight farms (nos, 2,4,5,8,12,22,26,27 (7,14,20,30a,30b) ivermectin on five and a levamisole/oxyclozanide combination on three farms (10, 13, 21).

Six farms administered a temperature sensitive mutant of bovine herpes virus-1 when the calves were housed. (8,11,20,22,30a,30b). Five farms injected calves with a long acting penicillin formulation, (5,8,23,30a,30b), and on one farm calves were implanted with oestradiol 17β. (7).

Often a combination of procedures was carried out; on three units vaccination, anthelminthic dosing and prophylactic antibiotics were administered. Five farms dosed with anthelminthic in combination, either with BHV-1 vaccination (2 farms), prophylactic antibiotics (2 farms) or oestradiol implantation (1 farm).

Three farms carried out no procedures on calves when they arrived at the farm. (1,9,23).

Treatment of clinical cases

Fifteen of the 30 calves examined clinically and 18 of the 33 calves examined post-mortem had received antibacterial therapy (Table 6). All three treated cases that

died had received oxytetracycline. Of the 15 treated live cases, six had received oxytetracycline either alone (3 calves), or in combination with potentiated sulphonamides (2 calves each), or neomycin (1 calf). Six calves had received neomycin, as either the only drug (5 calves) or with oxytetracycline (1 calf). Four calves had been treated with potentiated sulphonamides either alone (1 calf) or in combination with oxytetracycline (2 calves) or penicillin (1 calf). Two calves received penicillin, either alone or with potentiated sulphonamides, and one calf received amoxycillin.

Farm follow-up visits

On all the farms where follow-up visits were made, the calves recovered rapidly following antibacterial therapy. This was usually oxytetracycline and was used on a group basis if farmers encountered an escalation in the number of sick animals over the first few days of an outbreak. Treatment with oxytetracycline at a dose rate of 10 mg/kg (by the intramuscular route) was recommended, for a minimum of three days.

2. A study of six incidents of acute respiratory disease (transit fever), not confirmed as bovine pneumonic pasteurellosis, in housed weaned single suckled calves

Six of the 31 incidents referred by general practitioners as transit fever outbreaks were not confirmed as bovine pneumonic pasteurellosis either on clinical, microbiological or pathological criteria. Clinical examination, by the author, of the cattle on two of these farms ruled out the possible diagnosis of bovine pneumonic pasteurellosis. On one farm (Farm 16) bought-in weaned suckled calves had been mixed with home bred dairy calves, the calves were dull but not pyrexic, tachypnoeic (80 per min), hyperpnoeic and had a frequent cough. Microbiological, serological and pathological examination confirmed a diagnosis of cuffing pneumonia due to infection with M.bovis.

In the second outbreak (Farm 17) 36 calves had arrived from various markets in Northern Ireland after travelling for up to three days by sea and road. Three days after arrival some calves were noticed to be dull, inappetent and coughing. Transit fever was diagnosed by the practising veterinary surgeon. When examined by the author five hours later, 24 of the 36 calves in the group were affected, they were pyrexic (105°F), hyperpnoeic, tachypnoeic and there was widespread, frequent coughing. All the affected calves had a profuse mucoid nasal discharge, mucopurulent in a few cases, and some calves had plaques in the nares. Only an occasional calf had conjunctivitis or ocular discharge, and pneumonia was not present. A diagnosis of infectious bovine rhinotracheitis was made on clinical grounds and BHV-1 was subsequently isolated from four of ten nasal swabs taken at this time.

The remaining four incidents of acute respiratory disease, presented on clinical and epidemiological grounds as transit fever, although they could not subsequently be classified as bovine pneumonic pasteurellosis for reasons of pathology and/or microbiology.

TABLE 7. Morbidity, mortality and case fatality rates in four incidents of acute respiratory disease (transit fever) in housed weaned single suckled calves that were not confirmed as bovine pneumonic pasteurellosis.

FARM REFERENCE	NUMBER OF CALVES			MORBIDITY RATE (%)	MORTALITY RATE (%)	CASE FATALITY RATE (%)
	AT RISK	ILL	DEAD			
3	200	13	0	6.5	0	0
6	120	22	1	18.3	0.8	4.5
25	45	3	0	6.7	0	0
29	280	14	1	5.0	0.4	7.1

Epidemiology

The seasonal incidence and time of onset after housing of the four incidents that presented as transit fever are shown in Figures 5 and 6 respectively. The only difference between these and the incidents of confirmed bovine pneumonic pasteurellosis in housed weaned single suckled calves is the clustering of three of the incidents three days after housing. The seasonality of the incidents was early and late October, late November and early December.

The morbidity, mortality and case fatality rates are shown in Table 7; the average figures for the four incidents are 8.1%, 0.3% and 3.8% respectively.

Clinical signs

Only three calves were examined clinically (Table 8), one from each of three incidents. The calf from the fourth incident was found dead and had not been seen to be ill.

Two calves, which had been sick for three and 13 days respectively, were dull on admission and the third calf, sick for one day, was alert. None of the calves were pyrexic, and none were heard to cough but all had a mucoid or mucopurulent nasal discharge. Only one calf (89421) was tachypnoeic after being ill for 13 days, this calf had been seen on the farm a week prior to slaughter when it was dull, pyrexic and pneumonic. The temperature had returned to normal after repeated antibacterial therapy, but the calf remained inappetent, hyperpnoeic and tachypnoeic. One calf, ill for three days, was dyspnoeic and had a marked expiratory grunt. This calf was considered to be *in extremis* when examined, and would probably have died.

TABLE 8. Clinical findings in three housed weaned single suckled calves which presented as acute respiratory disease (transit fever) but could not be classified as bovine pneumonic pasteurellosis.

Farm	Case No.	Day of illness	Demeanour	Rectal Temperature (°F)	Respiratory Rate (per min.)	Cough	Nasal Discharge	Auscultation	Antibacterial therapy
3	89421	13	Dull	103.0	60	-	mp	-	+
6	89481	3	Dull	102.0	24	-	mp	grunt	-
25	93114	1	Alert	102.0	40	-	m	-	-

mp = mucopurulent m = mucoid

TABLE 9. Post-mortem microbiological and pathological findings in four calves from incidents of acute respiratory disease (transit fever), that were not confirmed as bovine pneumonic pasteurellosis.

Farm	3	6	25	29
Case number	89421	89481	93114	93593
Duration of illness (days)	13	3	1	0
Died or Killed	K	K	K	D
Antibacterial treatment	+	+	-	-
Pasteurella haemolytica A1	UL	UL	-	ND
Pathology				
Fibrinous pneumonia	-	-	-	+
Nodules	-	-	-	-
Pleurisy	-	-	-	-
Proliferative bronchiolitis/ alveolitis	+	+	+	-
Arteritis and bronchiolar reaction	+	-	-	-
Septicaemia	-	-	-	+

D = died
K = killed
U = upper respiratory tract
L = lower respiratory tract
ND = not done

TABLE 10. Microbiological and serological findings in in-contact housed weaned single suckled calves from three incidents of acute respiratory disease (transit fever) not confirmed as bovine pneumonic pasteurellosis.

Farm reference:	3		25		29	
Time of sampling:	1	2	1	2	1	2
No.of calves sampled:	14	16	18	18	10	10
Isolations: (NP swabs)						
Pasteurella haemolytica A1	1	-	1	-	4	-
Pasteurella haemolytica A2	-	-	1	-	-	-
Pasteurella multocida	-	1	-	-	-	-
Mycoplasma bovis	-	2	-	-	-	-
Mycoplasma dispar	1	-	-	-	-	-
Seroconversions:						
Pasteurella haemolytica A1		3		3		1
Pasteurella haemolytica A2		3		6		-
Pasteurella multocida		ND		ND		ND
Mycoplasma bovis		2		1		-
Bovine herpesvirus 1		-		1		-
Parainfluenza 3 virus		1		9		3
Respiratory syncitial virus		9		-		3
Bovine virus diarrhoea virus		ND		ND		ND

NP = nasopharyngeal
ND = not done

Microbiology of calves at post-mortem

The only potential respiratory pathogen isolated at post-mortem was Pasteurella haemolytica A1, which was present in both the upper and lower respiratory tracts of two of the three calves examined (Table 9). Calf 93593 was found dead and was unsuitable for microbiological examination when it arrived at G.U.V.H.

Microbiology and serology of in-contact groups of calves

Groups of in-contact cattle were sampled on three of the four farms (Table 10). Single isolations of P.haemolytica A1 were made on Farms three and 25 at the first sampling and four isolations were made from the 10 calves sampled on Farm 29. No isolations of P.haemolytica A1 were made from any calves at the second sampling. Single isolations of P.haemolytica A2 and M.dispar were made from the first sampling on Farms 25 and three respectively. Pasteurella multocida and M.bovis were isolated from one and two calves respectively on the first sampling on Farm three. Viruses were not isolated from any of the calves sampled.

Seroconversions were recorded on all three farms to P.haemolytica A1 in from 10% to 18.8% of the calves sampled. However on Farm 3 the highest reciprocal serum titre at the second sampling was eight, whereas on the other farms values of greater than 128 were found. Seroconversions to P.haemolytica A2 were seen on two farms (3 and 25) involving 18.8% and 33.3% of the calves sampled.

Seroconversions to M.bovis were recorded on two farms involving one and two calves respectively.

One seroconversion to BHV-1 was recorded on Farm 25 in the absence of vaccination or disease.

Seroconversions to P13 virus were recorded on all three farms, with from 7.1% to 50% of calves affected.

Seroconversions to RS virus were seen on two farms affecting 30% and 64.3% of calves.

Pathology

One calf (93593) had fibrinous pneumonia which was accompanied by evidence of septicaemic spread with colonisation of blood vessels in the liver and lymph nodes. Proliferative alveolitis and/or proliferative bronchiolitis was seen in two calves as the sole lesion, and the fourth calf had only mild pulmonary lesions of arteritis and a bronchiolar reaction (Table 9).

Routine disease control procedures (on-farm)

Farm three and Farm 29 represent different incidents (1982, 1983) at the same unit where calves received a benzimidazole anthelminthic at housing. On Farm six a temperature sensitive mutant of BHV-1 was administered and on Farm 25 calves received ivermectin and zeranol.

Treatment of clinical cases

Two of the four calves examined had received antibacterial therapy prior to admission. Calf 89481 (Farm 6) had been treated with penicillin, streptomycin and betamethasone and subsequently with oxytetracycline and chloramphenicol. Calf 89421 (Farm 3) had been treated with potentiated sulphonamides followed by oxytetracycline. Both calves had failed to respond to treatment.

Farm follow-up visits

The total number of cases treated on each unit is shown in Table 7. On all units the farmer's veterinary surgeon treated subsequent cases for transit fever i.e. with a broad-spectrum antibacterial, and all responded to treatment.

3. A study of five incidents of bovine pneumonic pasteurellosis in single suckled calves at foot

Epidemiology

Five incidents of confirmed bovine pneumonic pasteurellosis were seen in single suckled calves, still running with their dams, which had recently been housed. All the incidents took place in late October and November (Fig. 5) and were seen at intervals of between 11 and 21 days after housing. One incident (Farm 19) occurred in a pedigree Charolais herd, the other incidents were in commercial beef suckler herds.

The morbidity, mortality and case fatality details are shown in Table 11. The overall morbidity rate was 26.7%, mortality rate 3.7%, and the case fatality rate 13.8%.

Clinical signs

A total of eight single suckled calves from four of the incidents were examined clinically, and all but one of these calves had already received antibacterial therapy. The clinical details are detailed in Table 12. Most of the calves were dull, and those cases which had been ill for two weeks or more had the appearance of respiratory cripples; thin, dejected, empty, hyperpnoeic and tachypnoeic, with occasional or frequent coughing.

One calf (89902) from Farm 18 had a normal temperature and respiratory rate and was alert, but on auscultation the lungs 'sounded solid' and squeaks were heard especially anteroventrally. Crackles and squeaks were also heard in the respiratory cripples.

The two sickest calves were from Farm 28 where one calf had been found dead and several other calves were ill. These were dull, pyrexic and tachypnoeic and one had an occasional cough and a nasal discharge. The more pyrexic of the two calves had been treated with

TABLE 11. Morbidity, mortality and case fatality rates in five incidents of confirmed bovine pneumonic pasteurellosis in single suckled calves at foot.

FARM REFERENCE	NUMBER OF CALVES			MORBIDITY RATE (%)	MORTALITY RATE (%)	CASE FATALITY RATE (%)
	AT RISK	ILL	DEAD			
15	59	22	1	37.3	1.7	4.5
18	209	48	4	23.1	1.9	8.3
19	45	18	8	40.0	17.8	44.4
24	140	37	4	26.4	2.9	10.8
28	34	5	1	14.7	2.9	20.0

TABLE 12. Clinical findings in eight single suckled calves at foot from four incidents of confirmed bovine pneumonic pasteurellosis.

Farm	Case No.	Day of illness	Demeanour	Rectal Temperature (°F)	Respiratory Rate (per min.)	Cough	Nasal Discharge	Auscultation (adventitious sounds)	Antibacterial therapy
15	89861	4	Quiet	102.6	50	-	-	-	+
18	89902	4	Alert	101.8	30	-	m	solid squeaks	+
18	90122	29	Dull	102.8	90	±	-	crackles	+
19	89491	28	Dull	103.8	66	+	-	squeaks	+
19	89492	28	Dull	102.8	60	+	-	squeaks	+
19	89638	14	Dull	103.2	60	±	-	-	+
28	93524	1	Dull	104.8	60	-	-	-	+
28	93527	1	Dull	103.4	60	±	m	-	-

m = mucoid ± = occasional cough

TABLE 13. Isolation of recognised respiratory pathogens from 16 single suckled calves at foot from five incidents of confirmed bovine pneumonic pasteurellosis.

Farm	Case number	Pasteurella haemolytica A1	Pasteurella haemolytica T10	Pasteurella multocida	Haemophilus somnus	Haemophilus sp.	Mycoplasma bovis
15	89807	-	-	-	-	-	-
15	89861	UL	-	-	-	-	-
18	89902	-	-	-	-	-	L
18	90122	U	-	-	-	U	UL
18	90172	-	-	-	-	-	UL
19	89491	-	-	-	-	-	-
19	89492	-	-	-	-	-	UL
19	89638	UL	-	-	-	-	L
19	89988	-	-	-	UL	-	L
24	93509	-	-	-	-	-	-
24	93510	-	-	L	-	-	-
24	93679	-	L	-	-	-	-
24	93680	-	L	-	-	-	-
28	93524	U	UL	-	-	-	-
28	93527	-	L	-	-	-	-
28	93523	-	-	-	-	-	-

U = upper respiratory tract L = lower respiratory tract

oxytetracycline and betamethasone. Tachypnoea was a consistent feature except in calf 89902 mentioned earlier, although few calves were pyrexic. However, the majority had already received antibacterial therapy, often on several occasions. Nasal discharge was not a feature, with only a slight mucoid discharge being present in two cases.

Microbiology of calves at post-mortem

Sixteen calves were examined microbiologically at post-mortem from the five farms (Table 13). Eight calves were killed after clinical examination at G.U.V.H. and eight calves had died on the farm of origin. Ten of the calves examined had received antibacterial treatment.

Pasteurella haemolytica was isolated from at least one calf from every incident, although on two farms this was only from either the Upper (Farm 18) or the lower (Farm 24) respiratory tract. Pasteurella haemolytica A1 was isolated from calves from farms 15, 18, 19 and 28, and was only present in the upper airways in 2 incidents (18 and 28), either alone (18) or with P.haemolytica T10 (28). On farm 18 P.haemolytica A1 was the only Pasteurella sp. isolated. Pasteurella haemolytica T10 was isolated from the lower respiratory tract of two calves from farm 24 and from lower respiratory tract of two calves from farm 28 (one of these calves also had P.haemolytica A1 and T10 in its upper airways). Pasteurella multocida was isolated from the lower respiratory tract of one calf from farm 24.

Haemophilus somnus was isolated from the upper and lower respiratory tracts of a calf found dead on Farm 19 and Haemophilus sp. from the upper airways of a calf from Farm 15.

Mycoplasma bovis was widespread throughout the respiratory tracts of calves from farms 18 and 19.

Viruses were not isolated from any of the calves examined.

Microbiology and serology of in-contact groups of calves

Three of the five farms were sampled on two occasions and on one farm only the initial sampling was carried out. Pasteurella haemolytica A1 was isolated from 77.8% of calves on Farm 19 and 10% of calves on Farm 28 at the initial sampling; however at the second sampling only one isolation was made , this from a previously negative calf on Farm 28. Pasteurella haemolytica A2 was isolated from one calf on Farm 28 at the second sampling. Pasteurella haemolytica T10 was never isolated from nasopharyngeal swabs.

Mycoplasma bovis was isolated from 33.3% of calves on Farm 19 at the first sampling and 44.4% of calves at the second sampling, at which time it was also demonstrated in 70% of the calves on Farm 15, from which no isolations had been made at the initial sampling.

Despite the absence of isolations of P.haemolytica from the calves on Farm 15, four seroconverted to P.haemolytica A1 and two to P.haemolytica A2. Two calves on Farm 19 seroconverted to P.haemolytica A1, one of which was positive on nasopharyngeal swabbing at the first sampling, when the other calf had yielded an untypable Pasteurella sp. Nine calves on farm 28 seroconverted to A1, including the calves positive for the organism on first and second samplings. Only two calves, on Farm 15, seroconverted to P.haemolytica A2. Other seroconversions in single calves also occurred to M.bovis (Farm 19) where the organism persisted in the nasopharynx, and to PI3 virus (Farm 15).

Details of the isolations and serology are shown in Table 14.

Single seroconversions to M.bovis and PI3 virus were seen on one and two farms respectively. No

TABLE 14. Microbiological and serological findings in in-contact single suckled calves at foot from four incidents of confirmed bovine pneumonic pasteurellosis.

Farm reference:	15	15	19	19	24	28	28
Time of sampling:	1	2	1	2	1	1	2
No.of calves sampled:	10	10	9	9	15	10	10
Isolations (NP swabs)							
Pasteurella haemolytica A1	-	-	7	-	-	1	1
Pasteurella haemolytica A2	-	-	-	-	-	-	1
Pasteurella multocida	1	-	-	-	-	-	-
Pasteurella sp.	-	-	1	-	-	-	-
Mycoplasma bovis	-	7	3	4	ND	-	-
Serology							
Pasteurella haemolytica A1		4		2			9
Pasteurella haemolytica A2		2		-			-
Pasteurella multocida		ND		ND			ND
Mycoplasma bovis		-		1			-
Bovine herpesvirus 1		-		-			-
Parainfluenza 3 virus		1		-			1
Respiratory syncitial virus		-		-			2
Bovine virus diarrhoea virus		ND		ND			ND

NP = nasopharyngeal
ND = not done

seroconversions were seen to BHV-1. Two seroconversions were seen to RS virus, both on farm 28.

Pathology

Of the 16 calves examined pathologically, 11 had evidence of fibrinous pneumonia (Table 15). Nodules were seen in five cases and two calves from Farm 15 had pleurisy. Both lesions were present in calves irrespective of whether or not they had received antibacterial treatment, although neither lesion was seen in calves that had been sick for more than 19 days. The calf that had been ill for 19 days presented as being unable to stand, so the pneumonia may have been of shorter duration, but precise details of clinical history were unobtainable. Fibrinous pneumonia was seen in at least one calf from every disease incident and in the presence of P.haemolytica A1, P.haemolytica T10, or both.

Routine disease control procedures (on farm)

Calves on Farm 15 were dosed with benzimidazole and vaccinated with temperature sensitive mutants of BHV-1 and PI3 virus at housing. Ivermectin was given to calves when housed on Farms 18 and 28. No routine treatments were administered on Farms 19 and 24.

Treatment of clinical cases

Ten of the 16 cases examined had received antibacterial treatment. On Farm 15 the calves were treated with tylosin and potentiated sulphonamides. Oxytetracycline, chloramphenicol and the potentiated sulphonamides were used on Farm 19; chloramphenicol and the potentiated sulphonamides on Farm 18, chloramphenicol on Farm 24, and oxytetracycline on Farm 28.

Additional therapy included betamethasone (Farms 15 and 28) and dexamethasone and tripelennamine on Farm 24.

All the longstanding cases had been treated on more than one occasion, usually with more than one antibacterial.

TABLE 15. Pathological findings in 16 single suckled calves at foot from five incidents of confirmed bovine pneumonic pasteurellosis.

Farm	Case No.	Days ill to P.M.	Died or killed	Fibrinous pneumonia	Nodules	Pleurisy	Antibacterial treatment	Pasteurella sp. isolated
15	89807	1	D	+	-	+	+	-
15	89861	4	K	+	-	+	+	A1
18	89902	4	K	+	+	-	+	-
18	90122	29	K	-	-	-	+	-
18	90172	1	D	+	-	-	-	-
19	89491	28	K	-	-	-	+	-
19	89492	28	K	-	-	-	+	-
19	89638	14	K	+	+	-	+	A1
19	89988	1	D	-	-	-	-	-
24	93509	19	D	+	-	-	+	-
24	93510	13	D	+	-	-	+	M
24	93679	1	D	+	-	-	-	T10
24	93680	1	D	-	-	-	-	T10
28	93524	1	K	+	+	-	+	T10 + A1
28	93527	1	K	+	+	-	-	T10
28	93523	1	D	+	+	-	-	-

A1 = P.haemolytica A1
T10 = P.haemolytica T10
M = P.multocida

Farm follow-up visits

On all the affected farms there were several longstanding cases that had been treated on several occasions but had failed to improve clinically, these respiratory cripples were all eventually culled. Prompt treatment of subsequent cases with antibacterial drugs, usually oxytetracycline, and without the use of corticosteroids produced an immediate improvement.

On one farm (19), that had had a severe problem with respiratory disease for several years before bovine pneumonic pasteurellosis was diagnosed, a sheep pasteurellosis vaccine (Ovipast, Hoechst UK Limited) was used in subsequent batches of calves. The incidence of respiratory disease was dramatically reduced (see Farm 38) of monitor calves) and no cases of bovine pneumonic pasteurellosis were seen. However, improvements in management and therapy of sick calves were also introduced at the same time.

4. Microbiological and serological monitor studies on 11 groups of recently housed single-suckled calves (8 weaned and 3 at foot)

Monitoring studies on single suckled calves were carried out on eight farms, four with housed weaned single suckled calves and four with housed single suckled calves at foot. Of the weaned calves, two groups were recently purchased, one was a mixture of purchased and home-bred, and the fourth was home-bred. Of these eight units, five (2 weaned, 3 at foot) were confirmed incidents of bovine pneumonic pasteurellosis the previous year.

Paired samples were obtained from seven of the eight farms, but on one farm, two groups of cattle were sampled at housing only because of handling problems.

During the monitoring period, from October to December, respiratory disease was encountered on four of the Units.

Farm 31 purchased a total of 600 weaned single suckled calves of which nine were treated for pneumonia. This treatment figure was a gross underestimate of the total cattle affected; on visits to the unit many more calves were obviously dull, tachypnoeic and hyperpnoeic than had been noticed and treated by the stockmen.

Farm 32 had a mixed population of 73 purchased and 58 home-bred weaned suckled calves. Seven purchased and 11 home-bred calves were treated for pneumonia within one month of being housed.

Farms 36 and 38 treated 13 of 120 and four of 47 single suckled calves at foot respectively.

Pasteurella haemolytica A1 was isolated from five of the six groups of weaned calves at housing from between eight and 70% of the animals in these groups (Table 16). There was no obvious link between isolation rates of P.haemolytica A1 and whether the calves were purchased or home-bred. Isolation rates were 10%, 19% and 70% in

TABLE 16. Microbiological and serological findings in 11 groups of monitor calves.

Farm reference:	32		33		34		35		36		37		38		31	31	16		17	
Time of sampling:	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	1	1	2	1	2
No.of calves sampled:	21	20	21	20	10	10	10	10	30	28	11	11	7	7	13	25	8	8	10	10
Isolations (NP swabs)																				
Pasteurella haemolytica A1	1	5	4	-	7	2	1	1	-	1	-	-	-	1	-	2	-	-	2	-
Pasteurella haemolytica A2	-	-	-	-	3	2	2	-	2	-	-	-	1	1	-	2	-	-	-	-
Pasteurella haemolytica A6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Pasteurella multocida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Bovine herpesvirus 1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	4	-
Seroconversions																				
Pasteurella haemolytica A1		15		2		7		2		22		3		1				-		1
Pasteurella haemolytica A2		4		6		6		4		14		1		1				1		7
Pasteurella multocida		ND		ND		ND		ND		ND		ND		ND				ND		ND
Mycoplasma bovis		-		-		-		1		-		1		1				4		2
Bovine herpesvirus 1		1		-		-		-		-		3		-				-		-
Parainfluenza 3 virus		8		11		7		9		16		3		-				3		7
Respiratory syncitial virus		6		1		6		8		17		1		-				2		2
Bovine virus diarrhoea virus		ND		ND		ND		ND		ND		ND		ND				ND		ND.

Farms 16,17 acute respiratory disease incidents (16, M.bovis; 17, IBR)
Farms 31-35 housed weaned single suckled calves
Farms 36-38 single suckled calves at foot

NP = nasopharyngeal
ND = not done

groups that remained healthy and 0%, 4.8% and 8% in groups that subsequently developed respiratory disease.

Pasteurella haemolytica A1 was not isolated from any single suckled calves at foot immediately after housing.

One month after housing the isolation rates had remained constant or fallen in all the healthy groups of weaned calves (10%, 0% and 20% respectively). In the one group of calves that were sampled at this time following an outbreak of respiratory disease (Farm 32), the isolation rate increased from 4.8% to 23.8%. Two isolations of P.haemolytica A1 were made from single suckled calves at foot after one month of housing, one in each of the two groups affected with respiratory disease.

Isolations of P.haemolytica A2 were made from five groups of calves (3 weaned, 2 at foot) at housing and from two groups of calves (1 weaned, 1 at foot) a month later. Isolations were made on both occasions from both healthy and sick calves with isolation rates between 8% (Farm 31) and 30% (Farm 34).

Single isolations of P.haemolytica A6 (Farm 31) and BHV-1 (Farm 35) were also made immediately after housing.

Seroconversions to P.haemolytica A1 were seen in all groups of calves irrespective of type or disease status. Seventy-five per cent of the group of weaned calves that developed respiratory disease seroconverted; however, seroconversion rates in groups of healthy weaned calves were 9.5%, 20% and 70%. In the groups of calves at foot 14.3% and 46.7% of calves in groups that had respiratory disease seroconverted compared with 9.1% of calves in a healthy group

Seroconversions to P.haemolytica A2 were also widespread; 20% of diseased weaned calves, 28.6%, 40% and 60% of healthy weaned calves. In the groups of calves at

foot 14.3% and 46.7% of diseased groups, and 9.1% of healthy groups seroconverted.

Single seroconversions to M.bovis were seen in three groups of monitor calves.

Seroconversions to BHV-1 were seen on two farms affecting 5% and 27.3% of calves.

Seroconversions to PI3 virus were seen on six farms, involving from 27.3% to 90% of calves.

Seroconversions to RS virus were seen on the same six farms where seroconversion to PI3 virus had been recorded, involving from 5% to 80% of the calves.

Two further groups of housed, weaned single-suckled calves, from which paired samples were available can be included in this section. These two incidents did not present clinically as transit fever, and were subsequently shown to be Mycoplasma bovis infection (Farm 16) and IBR (Farm 17).

No potential respiratory pathogens were isolated at either sampling from the calves on Farm 16. Pasteurella haemolytica A1 and BHV-1 were isolated from 20% and 40% of the calves on Farm 17 at housing, but were not re-isolated. Pasteurella multocida was isolated from 30% of the calves one month later.

One calf (Farm 17) seroconverted to P.haemolytica A1, whereas 12.5% and 70% of calves on Farms 16 and 17 respectively seroconverted to P.haemolytica A2. Seroconversions to M.bovis (50%, 20%), PI3 virus (37.5%, 70%) and RS virus (25%, 20%) were seen on Farms 16 and 17 respectively. No seroconversions to BHV-1 were detected.

SECTION IV

DISCUSSION

Detailed investigations of 29 incidents of transit fever resulted in 25 being classified as bovine pneumonic pasteurellosis. Twenty of these occurred in recently weaned and housed single suckled calves and five in single suckled calves, recently housed but still running with their dams. These findings were in keeping with those in North America where, despite suggestions that other agents may be involved in the aetiology of shipping fever (105) it has been accepted that Pasteurella species are responsible for the fibrinous pneumonia and the fatal outcome of the disease (211). In the other four incidents, which presented clinically and epidemiologically as transit fever, the single animals examined post-mortem either did not have lesions of fibrinous pneumonia (three incidents) or had lesions of fibrinous pneumonia and septicaemia (one incident).

In the confirmed incidents of bovine pneumonic pasteurellosis where more than one calf was available for pathological and microbiological examination, fibrinous pneumonia and pleurisy, Pasteurella nodules and the isolation of P.haemolytica were not always consistent findings in all the calves. Thus, it is possible that in the four transit-fever like incidents, not confirmed as pneumonic pasteurellosis, the single calf available for post-mortem study was not representative of the affected group. It was perhaps significant that in each of these latter incidents the farmer had himself selected the animal for further study.

All but one of the incidents of pneumonic pasteurellosis occurred between October and December, and the development of the disease in housed, weaned single suckled calves appeared to be related to the housing of the cattle together in a confined space, rather than to travelling and/or marketing. The evidence for this was

that in the dry autumn of 1983 many of the purchased calves were turned out to grass for several weeks before being housed; no incidents of pneumonic pasteurellosis were seen when the calves were outside and the subsequent development of the disease once the calves came indoors was similar to that seen in previous years when calves were housed immediately after purchase. The importance of housing, rather than driving or marketing, in the development of pneumonic pasteurellosis in sheep has also been suggested by Montgomerie (154). A relationship between the development of pneumonic pasteurellosis and housing was also demonstrated in the single suckled calves at foot, in the absence of travelling, mixing with "foreign" cattle, or other stresses such as weaning. Similarly, incidents of bovine pneumonic pasteurellosis were seen in the absence of mixing or marketing in calves that had been reared as single suckled calves in the highlands, weaned and moved to rearing farms elsewhere and in calves weaned and moved indoors on the same farm.

In contrast to the housed weaned single suckled calves where the majority of incidents seen within 10 days of housing, all the outbreaks of pneumonic pasteurellosis in single-suckled calves at foot occurred from 10 to 22 days after the calves were housed. The reasons for this difference in disease onset were not clear-cut but it may be that in these self-contained herds the strain of P.haemolytica is enzootic and a higher infective dose is necessary to overcome group immunity, or just that farmers housing home-bred single suckled calves are less aware of the potential disease risk and thus less vigilant than their counterparts who buy in single suckled calves. Other possible reasons are the stress of housing with the establishment of a dominance hierarchy in cows and calves and the presentation of creep feed to the calves. Martin and others in Ontario (147,149) studied factors affecting mortality in over 38,000 feedlot cattle during a two-year period and demonstrated an apparent relationship between the feeding of cornsilage or cornbased rations and an increase in the mortality rate.

Comparison of the Scottish situation with that in North America where feedlot cattle are often not housed but kept in uncovered pens would suggest that it is keeping the calves in close confinement rather than housing per se that is the precipitating factor in the development of bovine pneumonic pasteurellosis. Work on respiratory disease in humans has shown that the development of clinical infection is controlled by the number of individuals in a group irrespective of the floor area or volume of air available per individual (33). This would appear to be true for calves also as incidents of bovine pneumonic pasteurellosis have been seen in groups of cattle in well ventilated spacious buildings as well as in poor, crowded housing conditions.

The morbidity, mortality and case fatality rates for pneumonic pasteurellosis in housed, weaned single suckled calves were 10.7%, 0.2% and 2.2% respectively. The comparable figures for shipping fever in North America are; in yearling cattle three to four per cent morbidity and 20% case fatality, and in weaned calves 25% morbidity and 20% case fatality (114). There was considerable variation between units, which may have reflected the level of stockmanship, as the morbidity rate was based on the number of calves treated; thus the over-cautious stockman often produced a higher morbidity and lower mortality rate. On the other hand, on some farms stockmanship was relatively poor with many obviously pneumonic cattle being left untreated, or treated some time after clinical signs had developed. The size of the enterprise did not seem to have any effect on morbidity or mortality rate.

In single suckled calves at foot, morbidity, fatality and case fatality rates were generally higher than in the weaned calves (26.7%, 3.7% and 13.8% respectively). This feature was also noted and commented on by Palotay and others who investigated an outbreak of pneumonic pasteurellosis in range calves (162) and these figures are comparable with those given by Jensen for calves (114). This may be due to lack of vigilance on the

part of the farmer or farmworker as mentioned above or because, as a result of the relative homogeneity of the population especially in respect of previous exposure to Pasteurella species and subsequent immune response, once infection becomes established all calves are equally susceptible. All the incidents of pneumonic pasteurellosis in calves at foot were seen in calves over three months of age. This may be because of the relative imbalance which develops between the immune status of the dam and the calf once maternal immunity has waned. The single suckled calf at foot will have antibodies to Pasteurella spp. obtained via the colostrum, but because these herds are often calved and kept outdoors there will be insufficient stimulation of endogenous immunity by Pasteurella spp. throughout the summer grazing period, whereas the cows are more likely to have Pasteurella spp. within the respiratory tract and thus maintain adequate antibody levels. Subsequently, at housing, the calves are enclosed with the cows and if pneumonic pasteurellosis develops the calves are all equally susceptible as they have not received sufficient immune stimulation on previous occasions to mount a rapid anamnestic response, so widespread severe disease develops quickly. In contrast a group of purchased, weaned single suckled calves from different sources may be heterogeneous with regard to previous exposure to P.haemolytica and will respond to active infection with a potentially pathogenic strain accordingly, as the clinical response to infection has been shown to be related to initial low serum titres to P.haemolytica on arrival at feedlots (54,212).

In this field study the purchase of cattle with bovine pneumonic pasteurellosis which had not received any antibacterial therapy was central to the clinico-pathological investigation of the disease. Previous pathological descriptions have been made from fatal cases (116,210) although Thomson while suggesting in 1974 (210) that it would be useful to look at non-fatal cases, nevertheless did not include the criteria that they should

be untreated. The untreated cases examined in this study had been ill for periods of up to five days. The lesions in the early cases consisted predominantly of fibrinous pneumonia, with or without pleurisy, with a few nodules present from day one onwards. Such nodules have previously been considered to be a later stage development (73) although evidence is presented in Chapter II that they have been seen in experimental animals slaughtered three days after initial infection with P.haemolytica A1. The presence of nodules in cases that had been ill for only one day may indicate either that they had been ill for longer but not noticed or that a partial immune response had been mounted rapidly by the calf following field infection.

The presence of fibrinous pneumonia, pleurisy and nodules either singly or in combination was associated, in the vast majority of cases, with the isolation of P.haemolytica from the upper and lower respiratory tract. Pasteurella haemolytica A1 was the most commonly isolated pathogen; it was usually isolated alone, but in two cases it was associated with P.multocida, once as the predominant pathogen and once apparently as a subsidiary pathogen in terms of positive sites and numbers of isolations. Pasteurella haemolytica A1 is now recognised in North America as the Pasteurella spp. commonly associated with shipping fever (211), where previously P.multocida was thought to be the more important species (155).

Two incidents of pneumonic pasteurellosis were associated with the isolation of P.haemolytica T10 from the respiratory tract. Since these incidents were in single suckled calves at foot and in both cases the farms had sheep flocks in addition to the suckler herds the P.haemolytica T10 may have been transmitted to the calves from the sheep where it is recognised as a cause of septicaemia (26). However, the method of spread, if any, is obscure; on one farm the suckler cows and calves shared accommodation (at different times) with lambing ewes, but on the other farm Scottish Blackface sheep were kept under traditional (extensive) conditions and there was little,

if any, direct close contact between sheep and cattle. Nevertheless, on this second farm pneumonic pasteurellosis had been confirmed in ewes at the same time as the problem was present in the calves, although the serotype of P.haemolytica involved was not determined.

Pasteurella haemolytica A2 was isolated from one case of pneumonic pasteurellosis. Although this calf had Pasteurella nodules in the lungs, the significance of P.haemolytica A2 is doubtful as there was a suspicion that this group of calves had had respiratory disease immediately prior to being sold to the farm on which the pneumonic pasteurellosis incident occurred.

The significance of viruses in the aetiology of shipping fever has been emphasised by many workers in North America (240) but in this field study, although there was evidence of viral activity in several outbreaks of the disease, there was no clinical, pathological or microbiological evidence to suggest that viruses were involved as primary pathogens in the pathogenesis of pneumonic pasteurellosis. Bovine pneumonic pasteurellosis was seen in herds which routinely vaccinated against infectious bovine rhinotracheitis using intranasal administration of a temperature sensitive mutant of BHV-1. This is in direct contradiction of the extrapolation made by Jericho and co-workers of experimental work (117) where they considered that prior exposure to BHV-1, irrespective of whether it was natural infection or intranasal vaccine, prevented the development of pneumonic pasteurellosis. However in their experimental model BHV-1 infection was necessary prior to inoculation with P.haemolytica A1 in the induction of pneumonic pasteurellosis, and the BHV-1 vaccine prevented the development of IBR and consequently the production of pneumonic pasteurellosis.

Parainfluenza type 3 virus was present in one group of weaned single suckled calves in which pneumonic pasteurellosis was diagnosed. It was isolated from one live calf in the group and demonstrated by isolation and immunofluorescence in the lung tissue of a calf that had

died. Eight of the nine calves in this group seroconverted to the virus and it was considered that in this group alone PI3 virus may have had a role in the development of the resultant respiratory disease. However subsequent experimental data (Chapter 2, Experiment 6) clearly confirmed that the strain of P.haemolytica A1 isolated from this incident was capable per se of producing pneumonic pasteurellosis, a primary bacterial pneumonia.

Parainfluenza type 3 virus was not isolated from nasopharyngeal swabs or respiratory tract tissues nor was it demonstrated by immunofluorescence in material from any of the other outbreaks of pneumonic pasteurellosis and transit fever like incidents in housed weaned single suckled calves or single suckled calves at foot. On the other hand, seroconversions to PI3 virus were widespread throughout both diseased and healthy groups of cattle investigated. In the housed weaned single suckled calves with pneumonic pasteurellosis seroconversions occurred in 86% of groups sampled involving from nine to 82% of the calves; equivalent figures for the transit fever like incidents were 100% (7-50%), for the single suckled calves at foot with pneumonic pasteurellosis 66% (10%), for weaned monitor calves 100% (40-90%) and for sucking monitor calves 66% (27-57%).

Many of the incidents of bovine pneumonic pasteurellosis were investigated early in the development of the disease, a situation which should have maximised the chances of virus recovery and/or the demonstration of viral antigen by immunofluorescence in lung tissue (35). The demonstration of PI3 virus in only one incident, despite the widespread incidence of seroconversions, suggests that infection with PI3 virus while common, clearly does not seem to have an important role to play in the pathogenesis of bovine pneumonic pasteurellosis in weaned single suckled calves in Scotland. This is in contrast to the viral role accepted for many years in North America although much of the early evidence did not indicate much clinical disease despite widespread seroconversion (104). This hypothesis

has been perpetuated by experimental findings such as the ability to reduce clearance times of P.haemolytica A1 (137) and also the use of PI3 virus in the production of bovine pneumonic pasteurellosis using the Jericho model (117). However, other Canadian work has attributed less significance to the role of PI3 virus in the pathogenesis of bovine pneumonic pasteurellosis (235).

Respiratory syncitial virus was never isolated from any of the calves either at post-mortem, or from nasopharyngeal swabs from any groups of affected or non-affected calves. However, this virus is very labile and the difficulties encountered in attempting to isolate the virus are well documented (224). Respiratory syncitial virus can be demonstrated by immunofluorescence in lung tissue at post-mortem and all these examinations were negative. Seroconversion to the virus was seen in affected groups of weaned single suckled calves and affected groups of single suckled calves at foot. However the seroconversion often occurred in occasional individual calves. Only one group showed seroconversion in more than ten per cent of sampled calves. To date, this virus has never been suggested as one of the so-called predisposing factors in cattle but it has been used in association with P.haemolytica in the production of experimental pneumonic pasteurellosis in sheep (4,215).

Bovine virus diarrhoea - mucosal disease virus was not isolated or demonstrated in lung tissue by immunofluorescence at any time during these investigations although not all the serological results are available. From the results that are to hand there is no evidence of widespread, consistent seroconversion to this virus and it is unlikely that it plays any part in the development of pneumonic pasteurellosis.

Mycoplasma bovis was isolated from 22% of the calves at post-mortem and from six groups of in-contact weaned single suckled calves and two groups of single suckled calves at foot. Seroconversion to this organism was also seen

in ten to 23% of calves from 60% of these incidents of pneumonic pasteurellosis. The role, if any, of M.bovis in the pathogenesis of, or susceptibility of calves to pneumonic pasteurellosis is difficult to evaluate. There is little doubt that it is a respiratory pathogen capable of producing respiratory disease in its own right (7), but equally it is widespread in distribution in both dairy and beef calves in Britain from evidence of isolation at post-mortem, nasopharyngeal swabs and serology(unpublished observations). However, isolation and seroconversion often appear independently and often in the absence of clinical disease. It is interesting to note that one of the incidents referred as transit fever, but which on clinical examination by the author was disregarded as such because of the clinical picture of normal temperatures and widespread coughing, was shown later on microbiological, serological and pathological grounds to be the result of M.bovis infection. A synergism between M.bovis and P.haemolytica has been postulated on the basis of experimental work on two gnotobiotic calves given P.haemolytica (culture of mixed serotypes) and M.bovis which showed a more severe clinical and pathological reaction than individual gnotobiotic calves given either agent alone (110). However, such limited studies on gnotobiotic calves cannot be considered to reflect the field situation. The possible role of M.bovis is further questioned in investigations of the effect of various microorganisms and chemicals on the clearance time of P.haemolytica A1 from calf lungs where it was demonstrated that prior administration of M.bovis had no effect on clearance time (80,136).

There was no obvious demonstrable difference in isolation rates of Pasteurella spp. from nasopharyngeal swabs taken from affected and unaffected groups of cattle. On several farms the species or serotype of Pasteurella sp. isolated from nasopharyngeal swabs was not that isolated from the lungs of calves with lesions of bovine pneumonic pasteurellosis at post-mortem, and judged on the basis of

numbers isolated and positive immunofluorescence to be the causal organism. Similarly seroconversion rates in affected and non-affected groups were comparable, both for Pasteurella spp. and the various respiratory viruses.

The lack of correlation between isolation of P.haemolytica, serum antibody response and disease has been described by a number of authors (52,241), although other authors (45,71,106) have noted low isolation rates of P.haemolytica from healthy unstressed calves and high isolation rates from calves with respiratory disease. Cattle which died from pneumonic pasteurellosis in Ontario had lower levels of antibody and cytotoxin neutralising activity to P.haemolytica than cattle dying from other causes (184). In this study none of the fatal cases were examined serologically. In the non-fatal cases that were slaughtered the reciprocal serum titres were very variable, from 2 to greater than 128.

In summary this field study of transit fever in beef calves in Scotland demonstrated that the disease is usually a pneumonic pasteurellosis. The onset of disease, usually between October and December, was related to the housing of the cattle and occurred within a month of that event. The clinical findings were dullness, inappetence, pyrexia and pneumonia, usually with minimal coughing. At post mortem examination Pasteurella spp. were isolated from the upper and lower respiratory tracts. The pathology was distinctive with consolidation, fibrinous pneumonia, which could be diffuse or focal (nodules), fibrinous pleurisy and gross dilatation of the interlobular septa. In housed weaned single suckled calves 18 of the 20 incidents investigated could be attributed to P.haemolytica A1, whereas in the five incidents in single suckled calves at foot three were due to P.haemolytica A1 and two were due to P.haemolytica T10. Evidence of viral activity was widespread within newly assembled groups of both affected and apparently healthy calves, and this evidence together with the lack of demonstration of viral involvement in the cattle examined pathologically was taken to support the view that viruses are not important in the pathogenesis of pneumonic pasteurellosis.

CHAPTER 2

THE EXPERIMENTAL DISEASE

SECTION I

A REVIEW OF THE LITERATURE

1. Bovine pneumonic pasteurellosis

The literature concerning the experimental production of bovine pneumonic pasteurellosis is very extensive and often confusing. It is often unclear, especially in the earlier accounts as to whether the authors were trying to characterise the causal organism or reproduce the disease, and in later accounts a wide variety of organisms were often inoculated in poorly controlled experiments where greater emphasis appears to have been placed on the theory of multiple aetiology rather than in assessing the effect of the individual agents.

Early attempts to reproduce the disease

Most early reports were made in the 1920s and 1930s (Table 17) and discussed the possible relationship between pneumonic pasteurellosis and haemorrhagic septicaemia (64,69,140); many of the experimental systems employed succeeded in producing haemorrhagic septicaemia-like lesions in cattle (101,180) and rabbits (60,140,221). The inocula used were also very variable: in some the bacterium was characterised before inoculation either as *Bacillus bovisepticus* (122) or *Pasteurella boviseptica* (180,221) whereas in other experiments it was merely described as a bipolar organism (140) or *Pasteurella* spp. (101) and in the latter case where the organism was an indole-producer it was probably *Pasteurella multocida*. Other experiments involved the inoculation of saline emulsions of either lymph node (64) or cerebral hemisphere (69) from cattle with a haemorrhagic syndrome into rabbits or guinea pigs. In all but three (99,122,221) of these early experiments the experimental animals, rabbits, guinea pigs or cattle, died within four days after inoculation and at post-mortem examination all the rabbits

YEAR	AUTHOR(S)	INOCULUM & SOURCE	SPECIES, DOSE & ROUTE	CLINICAL SIGNS	PATHOLOGY	ORGANISMS RECOVERED	COMMENTS
1921	Jones & Little	Bacillus bovisepticus Pleural fluid from cow with pneumonic pasteurellosis	2 calves (1) 2.5cc pleural fluid subcutaneously (2) 10cc 24 hour culture of B.bovisepticus intratracheally	Nil	ND	ND	
1923	Maguire	Bipolar organisms Heart blood 2 year old heifer	Rabbits "Minute quantities of inoculations"	Death	Haemorrhagic septicaemia	Bipolar organism	
1930	Tweed & Edington	Pasteurella boviseptica bovine pneumonic lung	Rabbits: (1) Intraperitoneal (2) Subcutaneous (3) Intravenous	(1)&(2) no disease (3) death Death 36 hrs.	Septicaemia. Subcutaneous haemorrhages	ND	Jones Group 1 strains - Indole negative so probably P.haemolytica
1932	Scott & Farley	Pasteurella boviseptica Post mortem isolation from field cases of Shipping Fever	7 calves intravenous and subcutaneous	Pyrexia, stiffness, inappetence and death	Haemorrhagic syndrome	P.boviseptica	
1936	Hellesnes	Pasteurella spp. Field case of pectoral form of haemorrhagic septicaemia (HS)	2 cows (1) intratracheally (2) subcutaneously	Death 4 days p.i.	(1) Pectoral form of HS (2) Septicaemia	ND	
1939	Downham & Yarrow	Saline emulsions of lymph node Cattle with haemorrhagic syndrome	Rabbits Guinea pigs Subcutaneous and intraperitoneal	Death within 36 hrs.	Haemorrhagic septicaemia	Pasteurella spp.	
1939	Foggie & Lamont	Saline emulsion of cerebral hemisphere Calf dying from haemorrhagic syndrome	Rabbit	Death		Pasteurella septicaemia-haemorrhagica	Pasteurella spp. identified by medical bacteriologist who thought P.boviseptica implied species specificity
1944	Heath & Byrne	Pasteurella boviseptica Post mortem material from dead field cases of "Shipping Fever"	Mice - intranasal Guinea pigs - subcutaneous intranasal intraperitoneal 5 Yearling cattle - intratracheal	NIL Death intraperitoneal Transient pyrexia	NIL ND ND	NIL ND P.boviseptica	Very small doses i.e. 0.1 cc. culture given

Table 17. Early attempts to reproduce the disease.

and guinea pigs and most of the calves had lesions of haemorrhagic septicaemia. In one cow, inoculated intratracheally with Pasteurella spp. died four days after inoculation from "the pectoral form of haemorrhagic septicaemia" (101), the organism was probably P.multocida as a second cow inoculated subcutaneously died of classical haemorrhagic septicaemia. In the other experimental inoculations no clinical signs, other than a transient pyrexia were described.

In only four of these early experiments did the organisms used come from cases of bovine pneumonic pasteurellosis or shipping fever (122,180,221). All the other inocula were preparations of organisms obtained from cattle suffering from a haemorrhagic syndrome (64,69,101, 140). In the 1940s an attempt was made to demonstrate the presence of hypothetical agent which was thought to be part of a postulated multiple aetiology for shipping fever; yearling cattle were inoculated intratracheally either with a culture of P.boviseptica or a filtrate of a culture of lungs recovered from fatal cases of shipping fever (99). The inoculations were made using a nebuliser which only delivered a total dose of 0.1 ml of culture to each calf, and although one death occurred in these cattle following infection it was in a calf which received a supposedly bacteria-free filtrate, but P.boviseptica was recovered in pure culture from the lungs at necropsy.

Experimental models which involved mixing field cases of shipping fever with susceptible calves

There are two descriptions (Table 18) of the attempted production of shipping fever in susceptible experimental calves by mixing them with bought-in feeder calves that had developed the clinical disease, both from the same group of research workers (100,222). The experimental design was similar in both instances; groups of Aberdeen-Angus calves (6-8 months) were purchased and subsequently developed clinical signs of shipping fever

YEAR	AUTHOR(S)	DONOR CATTLE			MICRO-ORGANISM RECOVERED FROM DONOR CATTLE	EXPERIMENTAL CATTLE			MIXED (DAYS)	CLINICAL RESPONSE		SERO-LOGICAL RESPONSE		PATHOLOGY G.		PATHOLOGY M.		MICRO-ORGANISMS RECOVERED EXPTL.	COMMENTS
		AGE	TYPE	NO.		AGE	TYPE	NO.		DON.	EXP.	DON.	EXP.	DON.	EXP.	DON.	EXP.		
1962	Heddleston et al	6-8mths	A.Angus	40	PI_3 P.multocida P.haemolytica	3-6mths	Hol. X Fr.	6	15 days after arrival of AA cattle	+	+	+PI_3	+PI_3	+	+	ND	+	PI_3 P.haemolytica P.multocida	
1962	Vardaman et al	7-8mths	A.Angus	27	PI_3 P.multocida P.haemolytica	7-8mths	Hol. X Fr.	5	4 days after arrival	+	+	ND	+PI_3	ND	+	ND	ND	PI_3 P.haemolytica P.multocida	

Table 18. Experimental models which involved mixing field cases of shipping fever with susceptible calves.

(pyrexia, tachypnoea, purulent nasal discharge and coughing), at which point they were mixed with groups of Holstein-Friesian cross calves. Differences between these two experiments were in the age of the dairy-cross calves used, three to six months (100) or seven to eight months (222) and the interval between arrival of the beef calves and the development of shipping fever, four days (222) or 15 days (100), when the dairy-cross calves were introduced. Following mixing, both groups of dairy-cross calves became ill and the disease was similar to that seen in the beef calves, but in the experiment where mixing of the older dairy-cross calves occurred four days after arrival of the beef calves the disease in both types of calf was considered to be relatively mild (222).

In both experiments P13 virus, P.multocida and P.haemolytica were isolated from nasal swabs taken from the beef calves when clinical disease was first seen, and these organisms were also isolated from the respiratory tracts of both groups of dairy-cross calves at necropsy. A serological response to P13 virus was demonstrated in both groups of dairy-cross calves and in the one group of beef calves in which titres were measured (100).

None of the beef calves in either experiment died or were killed and examined post-mortem, but a total of six dairy-cross calves were slaughtered and necropsied 10 to 20 days after mixing with the beef calves. Gross pathological findings were described as purulent lobular pneumonia in the most severely affected calves (100) and small areas of consolidation in the apical lung lobe in the group of calves which had transient pyrexia with coughing. Histopathology was detailed for the severely affected calves only and the predominant cell type was the polymorphonuclear leucocyte (100). Fibrinous pneumonia, widespread consolidation and pleurisy were not described in either experiment at gross or microscopical level.

The isolation of PI3 virus, P.multocida and P.haemolytica from the nasal passages of the 'donor' beef calves and from the lungs of the 'recipient' dairy cross calves demonstrated that these organisms can be transmitted under field conditions. Heddleston (100) attributes the more severe clinical signs in one experiment to infection with Pasteurella spp. per se since HAI titres to PI3 virus did not start to increase until 33 days after exposure, and seroconversion was not evident until day 48.

Experimental models which used nasal exudates, blood or pathological material from field cases of shipping fever

Not unexpectedly, variable results have been encountered following the inoculation of apparently healthy calves with nasal exudates and lung suspensions from live or dead field cases of shipping fever (77,105,161,177). In the earliest experiment carried out in 1957 (105) the blood and nasal exudates were not examined microbiologically before inoculation into dairy calves. No clinical response followed infection, and no other post-inoculation investigations were carried out. However inoculation of beef calves with a ten per cent suspension of lung from a fatal field case (161) produced clinical signs of pyrexia, pneumonia, respiratory distress, mucopurulent nasal discharge and coughing. Consolidation of the anteroventral areas of the lung was found at necropsy two weeks after inoculation. It is particularly unfortunate that the lung suspension that reproduced this reaction was not examined microbiologically before inoculation of the experimental animals, since, later, the same workers carried out a similar inoculation of two beef calves using a lung suspension that was known not to contain Pasteurella spp. and failed to reproduce clinical disease (161). (Table 19).

Other workers (77) inoculated calves intranasally, and intravenously with blood, nasal exudates, nasal washings and lung suspensions taken from acute field cases of shipping fever, the clinical

YEAR	AUTHOR(S)	EXUDATES/ETC.			EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGY		MICRO-ORGANISMS ISOLATED	COMMENTS
		SOURCE	MICRO-ORGANISMS ISOLATED	INOCULUM	AGE	TYPE	NO.			G.	M.		
1957	Hoerlein & Marsh	Feeder Calves 6m.o. Hereford X Acute phase of SF	ND	Blood & Nasal Exudates given i/v, s/c & i/n	3-4mths	Dairy	9	-	ND	ND	ND	ND	
1959	Palotay & Christensen	Fatal SF cases	ND	10% suspension of lung	150kg	Beef	2	+	ND	+	ND	ND	
		Fatal pneumonia cases	Free from Pasteurella spp.	10% suspension of lung	150kg	Beef	4	-	ND	ND	ND	ND	
1961	Gale, King & Sayer	Acute field cases of SF	Pasteurella spp.	Nasal washings i/n Defibrinated blood i/v	3-6mths	Dairy	2	+	ND	+	+	-	Necropsy performed 6-8 wks post-infection
			P.haemolytica	Blood i/v Nasal washings i/n	3-6mths	Dairy	5	+	ND	+	+	Mycoplasma P.haemolytica	Necropsy 3 wks post-infection
			P.multocida	Lung tissue Nasal washings	3-6mths	Dairy	2	-	ND	-	-		
			P.multocida + Mycoplasma	Nasal washings	3-6mths	Dairy	4	-	ND	-	-	P.multocida from s/c inoculation site	
			No organisms isolated	Blood Nasal washings Lung suspension	3-6mths	Dairy	1	+	ND	+	+	P.haemolytica P.multocida Mycoplasma	
			ND	Blood Nasal washings Lung suspension	3-6mths	Dairy	22	-	ND	-	-	ND	
1964	Saunders & Berman	Field cases of SF	-	Aerosol	6mths	Dairy	2	-	PI_3+	ND	ND		

Table 19. Experimental models which used nasal exudates, blood or pathological material from field cases of shipping fever.

diagnosis of which was based on depression, fever, anorexia, coughing, dyspnoea and nasal discharge. Examination of the inocula was performed in five of the six experiments and usually resulted in the isolation of Pasteurella spp. (P.haemolytica and P.multocida). On one occasion Mycoplasma spp. were isolated in combination with P.multocida and the inoculum from one field case did not yield any micro-organisms. A clinical response was seen in three of the five experiments and varied from fever, tachypnoea, coughing and mucopurulent nasal discharge to a transient pyrexia, and of the 36 calves inoculated 17 were transiently pyrexic but only seven developed respiratory signs.

Detailed assessment of the above work reveals that respiratory signs were seen in calves inoculated with exudates containing Pasteurella spp. alone or with exudates, the micro-organism content of which had not been determined. Clinical evidence of respiratory disease was not seen in calves given combinations of Pasteurella spp. and Mycoplasma spp. or given exudates from which no micro-organisms were isolated. In calves that developed respiratory signs, consolidation of the anteroventral areas of the lung was seen at necropsy with a purulent bronchiolitis and peribronchiolitis, and some cases had oedema of the interlobular septa with a mild cellular invasion. However some doubt must be expressed as to the significance of these lesions since frequently post-mortem examinations were not carried out until weeks or months after inoculation. Gale and others (77) concluded from these experiments that they had reproduced a mild form of shipping fever with less extensive pathology than that associated with the field disease, although the lesions were similar.

Exposure of two dairy calves to an aerosol of pooled nasal washings from four calves, two of which had clinical signs of shipping fever, produced only a transient pyrexia (177). It is of particular interest that although the inoculum was thought not to contain PI3 virus (on the

basis of cytopathic effect on bovine embryo kidney cell cultures) the calves seroconverted to that virus over the three-week period immediately post-inoculation.

Experimental models which used P.multocida alone

Pasteurella multocida was inoculated into dairy and dairy-cross calves by four different groups of research workers over a ten year period from 1954 to 1964 (41,78,103,197) (Table 20). The inocula, which included lung suspension (41), 18 to 24 hour broth culture plus liver suspension from infected experimental rabbits or mice (78), and a broth culture with a final egg passage to encourage encapsulation and enhance pathogenicity (103) were given by aerosol, intratracheal, intraperitoneal, intramuscular and subcutaneous routes. One group of workers (103) recovered P.multocida from a nasal swab and detected a serological response (as measured by the haemagglutination test) in one of three calves inoculated, in the absence of any clinical signs. No clinical signs were produced and no pathological observations were made in any of these experiments.

In 1978, a clinical response was claimed but no details other than pyrexia were given when beef calves were inoculated transthoracically into the caudal lung lobe with an 11 to 24 hour broth culture of P.multocida (56). Pasteurella multocida was recovered from the lungs at necropsy and lesions of fibrinous pneumonia and pleurisy were present. Since this group of calves also had an intercurrent BVD-MD virus infection (diagnosed on the basis of clinical signs of oral ulceration and diarrhoea and the presence of ulceration in the alimentary tract at necropsy) the pathogenic role attributed to P.multocida must be in doubt.

YEAR	AUTHOR(S)	ADMINISTRATION OF *Pasteurella multocida*			EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGY		MICRO-ORGANISMS RECOVERED	COMMENTS
		CULTURE	ROUTE	DOSE	AGE	TYPE	NO.			G.	M.		
1954	Carter	Lung suspension	Aerosol and i/t	20ml	1mth & 4mths	Dairy	2	-	ND	ND	ND	ND	
1958	Gale & Smith	18-24hr broth + infected rabbit or mouse liver	s/c) i/m) i/t) i/p)	2ml) 20ml) 1.5 x 10^{10}/ml	4-11wks	Dairy	7	-	ND	ND	ND	ND	Chemical stressing did not produce results either
1963	Hetrick *et al*	Broth culture + 1 egg passage	i/t	5ml diluted allantoic fluid	2-6mths	Hol.xFr.	7	-	+	ND	ND	*P.multocida*	Nasal swab isolation
1964	Sorensen *et al*	?	Aerosol	?	150kg	Holstein X	3	-	ND	ND	ND	ND	
1978	Corstvet *et al*	18-24hr broth	t/t into caudal lung lobe	10^{10}/calf	180kg	Beef	7	+	ND	+	ND	*P.multocida*	Intercurrent BVD infection

Table 20. Experimental models which used *P.multocida* alone.

Experimental models using P.haemolytica alone

The early research workers had variable success in the 1920s and 1930s in reproducing pasteurellosis in cattle, and this was attributed by some authors (99) to the failure to include in the inocula a hypothetical agent which was an essential component in the aetiology of shipping fever. However, in 1954, Carter (41) post-mortemed a number of cattle that had died as a result of shipping fever and isolated Pasteurella spp. from the lungs in large numbers and in pure culture. Field observations indicated that the disease responded rapidly to antibacterial therapy, and on these grounds Carter (41) concluded that shipping fever was probably a primary pasteurellosis, and carried out experimental inoculation of calves with P.haemolytica (Table 21). In the first series of experiments inoculation of four month old Jersey calves with blood or lung suspension from clinical cases of shipping fever by the intravenous, intratracheal and intranasal routes respectively failed to produce any signs of disease (41) (Table 21).

In a later series of experiments (43) six to 16 week old calves were inoculated by the intranasal and intratracheal routes with broth cultures of P.haemolytica isolated from clinical cases of shipping fever. Of these 19 calves inoculated with cultures made directly from nasal swabs or washings from clinical cases of shipping fever, eight showed clinical evidence of pneumonia the onset of which varied from two up to 20 days after inoculation. The pneumonic calves were all inoculated by the intranasal route alone, except for one group of four calves which were also given citrated blood from acute shipping fever cases by the intravenous route. Pulmonary consolidation was a consistent finding at necropsy and P.haemolytica was reisolated from lung tissue. The most severe clinical signs and pathology were seen in a group of four calves given a young (6 to 8 hour) culture of P.haemolytica. Unfortunately this group of calves, in addition to an acute pneumonia, also had lesions of

YEAR	AUTHOR(S)	ADMINISTRATION OF *Pasteurella haemolytica*			EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGICAL LESIONS		MICRO-ORGANISMS RECOVERED	COMMENTS
		CULTURE	ROUTE	DOSE	AGE	TYPE	NO.			G.	M.		
1954	Carter	1.Blood from clinical case of 'Shipping fever	i/v	20ml	4mths	Jersey	1	-	ND	ND	ND	ND	
		2.Suspension of lung from clinical case	i/t and i/n	20ml 10% suspension	4mths	Jersey	1	-	ND	ND	ND	ND	
1956	Carter	1.Broth culture	i/t and i/n	5ml 10ml	1½ to 3mths	Dairy bull calves, free from evidence of *P.haemolytica* infection by serology and no clinical pneumonia.	2	-	Precise details of serology are not given but an increase in titres over an undefined time interval is described with the maximum titre being 1/180 but no correlation between increasing titre and clinical or pathological findings.	-	-	-	Some success in reproducing clinical disease with intranasal inoculation of youhg cultures.
		2.Nasal washings from clinical case	i/n	20ml			1	-		-	-	+ *P.multocida*	
		3.Agar culture of *P.h.* from SF case	i/n	50ml in tryptose phosphate broth			2	-		-	-	+ *P.multocida*	
		4.*P.h.* recovered from sick calf in (3)	i/n and i/t	20ml broth 5ml broth			2	-		-	-	-	
		5.Primary culture from nasal swab of SF case	i/n	50ml			4	+		+	+	+	
		6.24hr.chick embryo	i/n	20ml			2	-		-	-	-	
		7.Morbid lung suspension from acute fatal case of SF	i/n				2	-		-	-	-	
		8.6-8hr broth culture + blood from acute cases	i/n (broth) i/v (blood)	20ml 30ml			4	+		+	+	+	
		9.Young broth culture	i/n	10ml			3	+		+	+	+	

YEAR	AUTHOR(S)	ADMINISTRATION OF *Pasteurella haemolytica*			EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGICAL LESIONS		MICRO-ORGANISMS RECOVERED	COMMENTS
		CULTURE	ROUTE	DOSE	AGE	TYPE	NO.			G.	M.		
1958	Gale & Smith	18hr broth	s/c i/m i/t	2ml 2ml 10ml	4-11mths	Healthy, dairy	2	-	ND	ND	ND	- (blood culture)	
1959	Palotay & Christensen	12hr broth	i/t	10ml	?	Beef	4	+	ND	ND	ND	ND	
1960	Collier	24hr broth	aerosol	.1ml		Hereford heifer	4	+	ND	ND	ND		

chronic pneumonia from which C.pyogenes was recovered. These, probably incidental pathological findings, led Carter to conclude that a pre-existing pneumonic lesion was necessary for the production of bovine pneumonic pasteurellosis, and he failed to appreciate that his success was probably the result of using a young culture of the organism isolated from a clinical case.

Pasteurella haemolytica was given alone to small numbers of calves as "single agent controls" in larger experiments designed to investigate the multiple aetiology theory (78,177). Two calves were inoculated with P.haemolytica by the subcutaneous, intramuscular and intratracheal routes (78) and one calf exposed to an aerosol (177); in both experiments an 18 hour broth culture was used, no clinical signs were seen and no pathological examinations were carried out.

However, in two groups of four beef calves, one group given ten ml of a 12 hour broth culture of P.haemolytica intratracheally (161) and the other group exposed to one ml of an aerosol of a 24 hour culture of P.haemolytica (50) a clinical response was recorded. Both groups of calves developed clinical signs considered by the researchers themselves to be typical of, if not so severe as, field cases of shipping fever. Fever, hyperpnoea, tachypnoea and occasional coughing were described but as no pathology was carried out it is impossible to be dogmatic that this was pneumonic pasteurellosis. In one of the experiments (50) the experimental cattle were stated to be free from infection with Pasteurella spp. on the basis of examination of nasal swabs and sera but there was no mention any post-inoculation bacteriological examination or serological testing. Similar clinical signs and a serological response were described in two four-month old colostrum-deprived calves inoculated intratracheally with 2×10^{10} P.haemolytica as an eight-hour broth culture (21). The calves attained a maximum reciprocal titre of 80 by seven days after

inoculation, the serum titres being measured by indirect haemagglutination and P.haemolytica was recovered from nasal mucus.

Following this series of experiments where P.haemolytica was given alone as a control in experimental regimes designed to investigate the importance of other microbiological agents in shipping fever, and as a result of its predicted secondary role no pathology was carried out, pathological examination of experimental cattle became a more regular occurrence.

Fibrinous pneumonia, fibrinous pleurisy and intra-alveolar haemorrhage were produced in one month old calves injected adjacent to the prescapular lymph node with a small volume of a concentrated suspension of P.haemolytica (48). In addition oedema at the injection site and swelling of the lymph node were also described but it was not stated as to whether these were clinical or pathological features.

A more conventional route of inoculation produced acute pneumonia with dyspnoea and pyrexia in 13 dairy-cross calves aged from two days to six weeks inoculated by the intranasal and intratracheal routes with an 18 to 24 hour broth culture of P.haemolytica (58). The necropsy findings in this series of experimental infections described three forms of pasteurellosis; a septicaemia seen as a peracute disease in younger calves, fibrinous pleuropneumonia and a purulent-necrotic pneumonia with abscess formation which occurred in subacute cases. Pasteurella haemolytica was recovered from the lungs at post-mortem, but no serological response was recorded using indirect haemagglutination.

Other authors have reproduced pneumonic pasteurellosis in order to study the pathology or immunology of the disease, rather than investigate the pathogenesis. In a series of such investigations four month old calves were sedated with xylazine and inoculated

with 25 ml of an 18 hour broth culture of P.haemolytica A1 by endotracheal or intrabronchial tube (74, 229). The clinical signs following inoculation were described (74) in general terms as pyrexia, hyperpnoea, tachypnoea, dullness and coughing without details of individual calves or time of onset. An inconsistent serological response was also noted. At necropsy lesions of fibrinous pneumonia with areas of coagulative necrosis and zones of coagulative necrosis surrounded by granulation tissue were described in calves killed three and seven days respectively after inoculation (73). Fusiform elongate, dark, basophilic macrophages and mononuclear cells were described as enclosing these necrotic areas and streaming out of the alveolar ducts. No attempts were made to re-isolate the infecting organism or to demonstrate its location within the pneumonic lesions.

In another series of experiments where P.haemolytica A1 and BHV-1 were used to reproduce bovine pneumonic pasteurellosis in order to investigate the effects of vaccination against BHV-1 on the experimental disease, four, four month old beef calves were each given an aerosol of an 18 hour broth culture of P.haemolytica, each calf receiving 10^6 bacteria, as a single pathogen control group (119). No clinical response to infection was detected and no pathological changes were seen at necropsy. In a subsequent experiment where the P.haemolytica A1 aerosol challenge was prepared from fresh rather than frozen broth culture the calves succumbed to pneumonic pasteurellosis (201). The dramatic response to infection with P.haemolytica A1 in the second experiment occurred despite vaccination against the BHV-1 component of the model, a procedure which had protected calves on previous occasions from the subsequent development of clinical and pathological signs of bovine pneumonic pasteurellosis.

Exposure to an aerosol of P.haemolytica, delivering a total calf dose of 10^9 organisms, was also used as a method of reproducing pneumonic pasteurellosis in order to

study the bovine pulmonary macrophage response to P.haemolytica (223). Eight calves were infected and became pyrexic (no other clinical details are recorded), and P.haemolytica was recovered from the lungs at necropsy but no pathology is described.

An unorthodox route of inoculation was used as the challenge method in a vaccination experiment where P.haemolytica A1 was given transthoracically into the caudal lung lobe (56). Eight 180 kg beef calves each received 10^{10} organisms in five ml of an 18 to 24 hour broth culture and were pyrexic following inoculation (no other clinical details were documented). At necropsy pneumonia, pleuritis and septicaemia were described and P.haemolytica A1 was recovered from lung tissue and demonstrated within the lung by immunofluorescent techniques. This experiment cannot be considered as infection with P.haemolytica A1 alone because clinical signs (diarrhoea) and pathological evidence of BVD-MD infection were described and serological studies indicated that the virus was active in all calves throughout the experimental period. The pathological findings attributed to P.haemolytica A1 were most severe in the calves that had severe BVD-MD lesions at necropsy which must cast doubts on the experiment as an uncomplicated P.haemolytica A1 vaccination and challenge experiment.

Experimental models which used mixed inocula of P.haemolytica and P.multocida

The use of mixed inocula of P.haemolytica and P.multocida was never fully justified by the research workers who used the bacteria in combination (78,96) except that they had both been isolated on previous occasions from field cases of shipping fever (Table 22).

Two such experiments are recorded, both as part of larger experiments, and the total number of calves inoculated was three (78,96). In the first of these experiments (78), a single dairy calf was inoculated with

YEAR	AUTHOR(S)	ADMINISTRATION OF *Pasteurella haemolytica* and *Pasteurella multocida*			EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGY		MICRO-ORGANISMS RECOVERED	COMMENTS
		CULTURE	ROUTE	DOSE	AGE	TYPE	NO.			G.	M.		
1958	Gale & Smith	18-24hr broth + lung suspension	s/c i/t	2ml 20ml 1.5×10^{10}/ml	4-11mths	Dairy	1	-	ND	ND	ND	ND	
1963	Hamdy *et al*	6-8hr broth	i/t i/n	2ml 3ml	3-4mths	Dairy	2	-	ND	-	ND	-	

Table 22. Experimental models which used mixed inocula of *P.haemolytica* and *P.multocida*.

an 18 to 24 hour broth culture and lung suspension by the subcutaneous and intratracheal routes, and in the second experiment (96) two dairy calves were inoculated with a six to eight hour broth culture by the intranasal and intratracheal routes. No clinical signs were seen in any of the calves and in the single experiment where necropsies were performed (96) no gross pathological lesions were seen.

Experimental models which used Pasteurella spp. and hormonal stress

The inability of the early research workers to consistently reproduce the clinical and pathological signs of shipping fever led other researchers to question the role of the Pasteurella spp. in the disease (78). In 1958, an attempt was made to determine whether Pasteurella spp. were merely secondary invaders, or were capable, under certain conditions of stress, of invading their host and becoming primary pathogens (78). Hormones, thought to act as stress factors, were administered to calves prior to inoculation with Pasteurella spp.. Cortisone acetate was given daily by intramuscular infection for three days, before inoculation of five calves with 18 to 24 hour broth cultures of Pasteurella spp., (Table 24) by the subcutaneous and intratracheal routes. Four calves were given P.multocida and one P.haemolytica. No clinical reaction was seen in any of the calves and no further investigations were carried out. Subsequently a single calf was treated with stilboestrol acetate prior to inoculation of P.multocida but, again, no clinical signs were seen.

The use of cortisone in two calves before intratracheal inoculation of a ten per cent suspension of lung tissue from a fatal case of shipping fever produced a transient pyrexia but no clinical signs of respiratory disease (161), and no clinical signs of disease were seen in two Holstein calves given an aerosol of P.multocida following a five day treatment with cortisone (177).

YEAR	AUTHOR(S)	ADMINISTRATION OF *Pasteurella* spp.			CHEMICAL STRESS	EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGY		MICRO-ORGANISMS RECOVERED	COMMENTS
		CULTURE	ROUTE	DOSE		AGE	TYPE	NO.			G.	M.		
1958	Gale & Smith	18-24hr broth (*P.multocida*)	s/c i/t	2ml)1.5x 20ml)10^{10}/ml	Cortisone acetate	4-11mths	Dairy	4	-	ND	ND	ND	ND	
		18-24hr broth (*P.multocida*)	s/c i/t	2ml)1.5x 20ml)10^{10}/ml	Stilboestrol	4-11mths	Dairy	1	-	ND	ND	ND	ND	
		18-24hr broth (*P.haemolytica*)	i/t	2ml 1.5x 10^{10}/ml	Cortisone acetate	4-11mths	Dairy	1	-	ND	ND	ND	ND	
1959	Palotay & Christensen	10% lung suspension from SF case (no Pasteurellae isolated)	i/t	10ml	Cortisone	150kg	Beef	2	+	ND	ND	ND	ND	Transient pyrexia
1964	Saunders & Berman	18hr agar culture *P.multocida*	Aerosol	2-4ml (10^9/ml)	Cortisone 50-75mg/day for 5 days pre-exposure	?	Holstein	2	-	-	-	-	-	

Table 23. Experimental models which used *Pasteurella* spp. and chemical (hormonal) stress.

Experimental models which used *Pasteurella* spp. and physical stress

The regular occurrence of shipping fever in cattle that had recently been transported into feedlots, often over vast distances, under extreme weather conditions and with little if any food or water available during that time, prompted several studies which incorporated a temperature stress into their attempts to experimentally reproduce shipping fever (Table 24). In the first experiment described in 1963 (96) two weaned dairy calves were exposed to an ambient temperature of 104°F for 30 minutes followed by 34°F for 30 minutes prior to being inoculated with a six to eight hour culture of *P.haemolytica* and *P.multocida*: a clinical response (tachypnoea, pyrexia and coughing) was noted in both calves, but at necropsy only one was found to have lesions, consisting of a few scattered foci of pneumonia throughout all the lung lobes. *Pasteurella multocida* was re-isolated from the lungs of both calves. In another study, (197), three calves were kept in a cold room at a temperature of between five degrees and 20°F for 72 hours after exposure to an aerosol of *P.multocida*. All three calves developed signs of pneumonia that the authors considered to be indistinguishable from those of shipping fever; at post-mortem examination five days after "exposure" one calf had consolidation of the cardiac lung lobe, interstitial oedema and fibrinous pleurisy and pericarditis. The other two calves were killed 25 days after exposure and each had well defined abscesses in the cranial and cardiac lung lobes. In addition all three calves were stated to have had clinical and pathological evidence of BVD-MD infection, although no descriptive details of the signs and lesions were given and virus isolation was not carried out. Throughout this report of a superficially successful model details were not given of clinical signs, timing of post-mortem examination in relation to stressing or inoculation, or post-mortem microbiology or histopathology which made a critical evaluation of the work impossible.

YEAR	AUTHOR(S)	ADMINISTRATION OF *Pasteurella* spp			PHYSICAL STRESS	EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGY		MICRO-ORGANISMS RECOVERED	COMMENTS
		Culture	Route	Dose		Age	Type	No.			G.	M.		
1963	Hamdy *et al.*	6-8 hr broth *P.haemolytica* & *P.multocida*	i/t & i/n	2ml i/t 3ml i/n	Temperature 104°F for 30 mins then 34°F for 30 mins	3½ mths	Dairy	2	+	ND	+	ND	*Pasteurella multocida*	
1964	Saunders & Berman	18 hr agar culture *P.multocida*	aerosol	2-4 ml (10^9/ml)	Trucking 6hrs pre-exposure (6-48 hrs in bad weather)	?	Dairy	2	-	ND	ND	ND	ND	Given BVD virus 48 hrs prior to trucking and inoculation Developed clinical BVD
1964	Sorensen *et al*	*P.multocida*	aerosol	?	Temperature (5-20°F for 72 hrs after exposure)	?	Dairy	3	+	ND	+	ND	ND	Concurrent natural BVD infection
1979	Breeze & Magonigle	*P.multocida* 5 hr. broth	Endo-tracheal tube	20ml broth	Hot and cold water hosing and intra-tracheal acetic acid pre-inoculation	7 wks	Holstein	14	+	ND	+	+	*P.multocida*	

Table 24. Experimental models which used *Pasteurella* spp. and physical stress.

At about the same time other workers, in an attempt to simulate natural physical stressors, subjected an unspecified number of experimental calves to between six and 48 hours "trucking" which ended six hours prior to aerosol infection with an 18 hour culture of P.multocida (191). No clinical signs of pneumonia were seen, although the calves developed clinical signs of BVD-MD having been given BVD-MD virus 48 hours prior to trucking as an added stressor. More recently in an experiment designed to evaluate a novel antibacterial formulation (34), 14 seven week old Holstein calves were hosed with hot and cold water alternately for several minutes on four occasions in the 30 hours prior to inoculation with 20 ml of a five-hour culture of P.multocida (origin not stated) by endotracheal tube. In addition these calves were given intratracheal acetic acid at 24 and six hours before inoculation to produce tracheal irritation. All calves became ill and recumbent within two hours of the inoculation of P.multocida and in the non-medicated group of four calves, two died 20 hours and 110 hours after inoculation.

Tachypnoea, coughing and dyspnoea were clinical features in all the calves in this group and at necropsy the first calf that died was found to have fibrinous pneumonia with interlobular oedema and fibrinous pleurisy; the second calf had areas of consolidation throughout the lungs with fibrinous pleurisy. Histologically the lesion was an early fibrinous pneumonia in both calves. Pasteurella multocida was recovered at necropsy from the lungs of both of the untreated control calves.

Experimental models which used Pasteurella spp. and Mycoplasma spp.

Two experimental models were described in the literature with Mycoplasma spp. being used as an agent in addition to Pasteurella spp. in attempts to determine their respective roles in shipping fever (41,96) and both were unsuccessful. The species of Mycoplasma spp. used to

YEAR	AUTHOR(S)	ADMINISTRATION OF *Pasteurella haemolytica*			ADMINISTRATION OF MYCOPLASMA	EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGY		MICRO-ORGANISMS RECOVERED	COMMENTS
		CULTURE	ROUTE	DOSE		AGE	TYPE	NO.			G.	M.		
1954	Carter	10% lung suspension	i/t	20ml	10ml broth i/v	2mths	Holstein	1	-	ND	ND	ND	ND	
1963	Hamdy *et al*	6-8hr broth *P.haemolytica* + *P.multocida*	i/t & i/n	2ml	i/t & i/n (2&3ml)	3½mths	Dairy	2	-	ND	-	ND	*Pasteurella* spp. *Mycoplasma*	Isolations from nasal swabs in life only not at p.m.

Table 25. Experimental models which used *Pasteurella* spp. and *Mycoplasma* spp.

infect the calves was not described in either experiment except to state that it had been isolated from field cases of shipping fever. A total of three dairy calves were infected, one being given ten per cent lung suspension from a field case of shipping fever intratracheally and Mycoplasma spp. intravenously (41) and the other two calves were given P.haemolytica, P.multocida and Mycoplasma spp. by the intratracheal route (96). In the latter experiment Pasteurella spp. and Mycoplasma were isolated from nasal swabs in life, but no lung lesions were found at post-mortem (Table 25).

Experimental models which used P.haemolytica and Chlamydia

A single experiment was described in which combined infections of P.haemolytica and Chlamydia were given simultaneously by the intratracheal route to a total of 15 beef calves (161). The Chlamydia used were Sporadic Bovine Encephalomyelitis agent (SBE), bovine enterovirus agent and YFV agent, these were isolated from the spleen of a clinical case of SBE, the faeces of cattle that had pyrexia, nasal exudate and coughing and from the faeces of healthy cattle respectively. A 12 hour broth culture of P.haemolytica, which had been isolated from the lungs of calves that had died from shipping fever, was used.

One calf inoculated with SBE and P.haemolytica became lethargic, dyspnoeic and fluid sounds could be heard on auscultation; at necropsy a bronchopneumonia with fibrinous pleurisy was present and P.haemolytica was re-isolated from the lungs in pure culture. The inoculation of YFV agent and P.haemolytica in two calves produced a pyrexia but no other clinical signs or pathology were described. Bovine enterovirus agent and P.haemolytica inoculated simultaneously failed to produce a clinical response (Table 26).

YEAR	AUTHOR(S)	ADMINISTRATION OF *Pasteurella haemolytica*			ADMINISTRATION OF CHLAMYDIA	EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGY		MICRO-ORGANISMS RECOVERED	COMMENTS
		CULTURE	ROUTE	DOSE		AGE	TYPE	NO.			G.	M.		
1959	Palotay & Christenson	12hr broth	i/t	5ml	Sporadic Bovine Encephalomyelitis i/t 5ml (3rd pass)	150kg	Beef	11	+	ND	+	ND	*P.haemolytica*	
1959	Palotay & Christenson	12hr broth	i/t	5ml	Bovine enterovirus 5ml i/t	150kg	Beef	2	-	ND	ND	ND	ND	
1959	Palotay & Christenson	12hr broth	i/t	5ml	YFV agent 5ml i/t	150kg	Beef	2	+	ND	ND	ND	ND	

Table 26. Experimental models which used *Pasteurella haemolytica* and Chlamydia.

Experimental models which used *Pasteurella* spp. and PI3 virus

The inclusion of PI3 virus in combined infections with *Pasteurella* spp. in attempts to reproduce shipping fever was the result of the discovery of PI3 virus in groups of calves with shipping fever (169) at a time in the late 1950s when experimental infections with *Pasteurella* spp. (43,78) were totally ineffective at producing clinical disease (78) or the results were equivocal because of pre-existing chronic pneumonia (43).

In 1957, Hoerlein and Marsh (105), following unsuccessful attempts to transmit shipping fever to susceptible calves by way of nasal exudates and blood from acute field cases, proposed the hypothesis for the aetiology of shipping fever that a virus, perhaps latent, was activated by the stress of shipment, and made a favourable environment for secondary bacteria. The same year an agent was isolated from field cases of shipping fever which agglutinated chicken and sheep erythrocytes and was thought to be a virus (174). In 1959 (169) SF_4 virus (later named PI3 virus) was isolated from field cases of shipping fever; antibodies to the virus were found to be widespread in feeder calves and significant increases in the haemagglutinating titres occurred within the first three weeks of arrival at the feedlot (104).

In his 1962 review article on shipping fever in cattle, Sinha (91) mentioned (without details) an experiment in which calves were infected with PI3 virus, *P.multocida* and *P.haemolytica*. Clinical signs, considered to be similar to those of shipping fever were produced, and although these were seen in all calves, trucking prior to inoculation increased their severity.

The first experimental model designed (Table 27) to investigate the role of PI3 virus and *Pasteurella* spp. in the aetiology of shipping fever was described in detail in 1962 (100) and involved eight dairy cross calves given PI3 virus either by aerosol or by intratracheal and

YEAR	AUTHOR(S)	ADMINISTRATION OF *Pasteurella* spp.			ADMINISTRATION OF PI_3	EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGY		MICROORGANISMS RECOVERED	
		CULTURE	ROUTE	DOSE		AGE	TYPE	NO.			G.	M.		
1962	Heddleston *et al*	18-24hr broth *P.multocida*	i/t & i/n	5ml i/t 5ml i/n	5ml aerosol i/t & i/n			2						
			-	24hrs post PI_3										
		P.multocida	"	5ml i/t 5ml i/n 8 days post PI3	"	6-8wks	Hol. X Fr.	2	+	+PI_3	ND	ND	ND	Clinical disease only mild
		P.haemolytica	"	5ml i/t 5ml i/n 24hrs post PI_3	"			2						
		P.haemolytica + *P.multocida*	"	5ml i/t 5ml i/n 24hrs post PI_3	"			2						
1963	Hamdy *et al*	6-8hr broth *P.haemolytica* + *P.multocida*	i/t & i/n	2ml 3ml	i/t & i/n 4-6hrs pre Pasteurella	3-4mths	Dairy	2	+	ND	+	+	*Pasteurella* spp.	Pathology in Trapp *et al.* 1966
1963	Hetrick *et al*	*P.multocida* Broth culture & 1 egg passage	i/t	5ml diluted allantoic fluid	Aerosol 5ml. i.e. $5x10^7$ $TCID_{50}$ 48hrs pre *P.multocida*	2-6wks	Hol. X Fr.	8	+	+ PI_3 P.m.	ND	ND	PI_3 *P.multocida*	Re-isolations from nasal swabs only
		"	"	"	Dose as above 48hrs post *P.multocida*	"	"	3	+	+ PI_3 P.m.	ND	ND	PI_3 *P.multocida*	
		"	"	"	Dose as above simultaneous with *P.multocida*	"	"	3	-	+ PI_3 P.m.	ND	ND	PI_3 *P.multocida*	
1964	Saunders & Berman	18hr agar *P.haemolytica*	i/t	10ml (10^9/ml)	Aerosol 5ml 10^7TCID_{50}/ml	6wks	Hol.	2	-	PI_3 +	ND	ND	*P.haemolytica* (nasal swabs)	
		18hr agar *P.multocida*	Aerosol	5ml (10^9/ml)	Aerosol 5ml 10^7TCID_{50}/ml	6mths	Hol.	4	-	PI_3 +	ND	ND	ND	
1964	Sorensen	*P.multocida*	Aerosol	?	Aerosol	?	Hol.X	3	+	ND	+	ND	ND	

YEAR	AUTHOR(S)	ADMINISTRATION OF *Pasteurella* spp			ADMINISTRATION OF PI_3	EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGY		MICROORGANISMS RECOVERED	
		CULTURE	ROUTE	DOSE		AGE	TYPE	NO.			G.	M.		
1966	Matsuoka *et al*	*P.multocida* + *P.haemolytica*	Aerosol + i/t	?	Aerosol	4-10wks	Dairy	14	+	PI_3+	+	+	Nasal swabs P.haemolytica	Stressed

intranasal inoculation at varying intervals from 24 hours to eight days prior to intratracheal and intranasal inoculation of P.multocida and/or P.haemolytica. All the calves became dull, depressed and pyrexic but there is no mention of clinical signs directly referable to respiratory disease. However, the disease was stated to be most severe in calves given P.multocida 24 hours after PI3 virus and least severe where there was an eight-day interval between viral and bacterial inoculation. Post-mortem studies were not carried out on these calves. In another experiment (96) PI3 virus and Pasteurella spp. were given to two calves as part of a large multifactorial experiment. Parainfluenza 3 virus and Pasteurella spp. (a mixture of equal volumes of P.haemolytica and P.multocida) cultures were both given by intratracheal and intranasal inoculation, the virus being given four to six hours prior to the bacterial culture. Both calves were pyrexic with coughing and nasal discharge. Pasteurella spp. were re-isolated from nasal swabs and from the lungs at necropsy and one calf had consolidation of the anterior lobes and fibrinous pleurisy. The other calf had abscesses within the lung parenchyma, with some pneumonic areas which were considered to be chronic (214).

The relationship between PI3 virus and P.multocida was further explored in an experiment where the time interval between inoculation of the agents and the sequence in which they were given was varied (103). The bacterium was initially cultured in broth but underwent a final egg passage to improve capsule formation and hence pathogenicity, and was then inoculated intratracheally 48 hours before, 48 hours after and at the same time as calves were exposed to an aerosol of PI3 virus. Clinical signs of pyrexia, coughing and nasal discharge were most severe in the calves given PI3 virus 48 hours prior to inoculation with P.multocida, but were also present in the calves inoculated with P.multocida 48 hours prior to infection with virus. The calves given both agents simultaneously experienced only a transient pyrexia. All

the calves had seroconverted to both PI3 virus and P.multocida by 28 days after inoculation and P.multocida was recovered from nasal swabs on the second to the tenth days post inoculation. Again, no pathology was recorded in this experiment.

A group of six calves that were exposed to an aerosol of PI3 virus and immediately inoculated intratracheally with P.haemolytica or exposed to an aerosol of P.multocida exhibited no clinical signs of pneumonia (177). Pasteurella haemolytica was the only microorganism reisolated from nasal swabs during the 14 days following infection. All the calves seroconverted to PI3 virus within 21 days after infection. Post-mortem examinations were carried out on only two calves, five weeks after inoculation and small areas of consolidation were found in the anterior lobes, the significance of which as evidence of bovine pneumonic pasteurellosis must be very doubtful.

Clinical signs of pneumonia, however, were seen in one of a group of three calves exposed to aerosols of PI3 virus and P.multocida (timing not stated) (197). The other calves in the group were pyrexic, coughed and had a nasal discharge. Scattered areas of lung consolidation were found in the most severely affected calf at necropsy, but no other calves were examined post-mortem. In another experiment, eight calves were exposed to an aerosol of PI3 virus followed up to 48 hours later by intratracheal inoculation of an eight hour broth culture of P.haemolytica. These calves developed clinical signs of pneumonia including inappetence, dullness, mucopurulent nasal discharge, hyperpnoea, tachypnoea and dry or fluid crackles on auscultation (21). Necropsy findings included widespread consolidation and the re-isolation of P.haemolytica in pure culture from lung tissue, but as only one calf, which had died 27 days after inoculation was examined there is little or no evidence that the clinical signs of pneumonia were related to lung lesions of bovine pneumonic pasteurellosis. All the calves

seroconverted to PI3 virus, and in the two calves in which IHA titres to P.haemolytica were measured, seroconversion to P.haemolytica also occurred within seven days of infection. However when the same infection regime was used in a later attempt to infect two calves which had recovered from experimental PI3 virus infection and had reciprocal serum IHA titres of 512 or greater no clinical disease was produced and no serological response to PI3 virus was elicited although the calves seroconverted to P.haemolytica. Reisolation of the infecting organisms was not attempted and no necropsies were performed.

Experimental models which used P.haemolytica and BHV-1

Four experimental models for the production of shipping fever are described in the literature and all were apparently successful. In the first description in 1960, Collier and his co-workers (50) exposed beef calves to an aerosol of BHV-1 three days before exposure to an aerosol of a 24 hour culture of P.haemolytica. Clinical signs of pyrexia, inappetence, dullness, dyspnoea, mucopurulent nasal discharge and coughing were produced and persisted longer in calves given both agents than in similar calves given either agent singly. Pasteurella haemolytica was recovered from nasal swabs but no serology or post-mortem investigations were carried out, so definite evidence that the disease was bovine pneumonic pasteurellosis and not infectious bovine rhinotracheitis was not available. (Table 28).

The other three descriptions were from the same group of research workers, who called the experimental disease bovine pneumonic pasteurellosis and were some of the first workers to specify the biotype and serotype of P.haemolytica used (117,119,201). The experimental designs were all essentially similar to that described above. Beef calves were exposed to an aerosol of BHV-1 on the day they were weaned, thereafter they were maintained in an environmental chamber and exposed to an aerosol of P.haemolytica A1 four

YEAR	AUTHOR(S)	ADMINISTRATION OF *P.haemolytica*			ADMINISTRATION OF BHV-1	EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGY		MICRO-ORGANISMS RECOVERED	COMMENTS
		CULTURE	ROUTE	DOSE		AGE	TYPE	NO.			G.	M.		
1960	Collier *et al*	24hr broth	Aerosol	1ml	3 days before *P.haemolytica* 2ml $10^{5.2}$TCID$_{50}$	150kg	Beef	4	+	ND	ND	ND	ND	
1976	Jericho *et al*	? *P.haemolytica* A1	Aerosol 4 days post BHV-1	$1x10^6$/ml	Aerosol $2x10^8$TCID$_{50}$/ml	200kg	Her.X Beef	5	+	ND	+	ND	ND	Weaned on day of BHV-1 aerosol. Maintained in environmental chamber.
1978	Jericho & Langford	*P.haemolytica* A1 18hr broth	Aerosol	10^6/calf	$5x10^5$/calf	4mths	Beef	44	+	BHV-1 neg. *Pasteurella* spp. ND	+	+	From lung BHV-1 *P.haemolytica* A1	Controlled climate. Variable time interval between BHV-1 aerosol and P.haemolytic A1 aerosol, four days appeared optimal
1979	Stockdale *et al*	*P.haemolytica* A1	Aerosol 4 days post BHV-1	10^6/calf	Aerosol $5x10^5$/calf	3mths	Beef	12	+	ND	+	ND	*P.haemolytica* A1	4 calves transported, 2 in environmental chamber. Transport stress reduced time to death but did not increase overall mortality.

Table 28. Experimental models which used *Pasteurella haemolytica* and BHV-1

days later. All the calves became pyrexic following exposure to the bacterial aerosol and two of the five calves were moribund three days later. Mention was not made of respiratory signs in life but post-mortem examination revealed extensive consolidation of the lungs with fibrinous pleurisy and pericarditis (117). Subsequent descriptions of this model involved varying the time interval between the viral and bacterial aerosols, concluding that exposure of the calves to the bacterial aerosol four days after exposure to the viral aerosol consistently produced severe pneumonic pasteurellosis as confirmed by the presence of lobar pneumonia and fibrinous pleurisy at necropsy and the isolation of BHV-1 and P.haemolytica from lung tissue (119). Serological studies carried out on these calves were restricted to BHV-1 but no serological response was detected. In a more recent description from this research group (201) 12 beef calves were exposed by the aerosol route to BHV-1 followed four days later by P.haemolytica A1 and the clinical signs were described as respiratory distress, dyspnoea and mucopurulent nasal discharge. These calves formed part of a complex experiment where a total of 24 calves in replicate groups were used to assess the effects of trucking on the experimental model. The mortality rate in both the trucked and non-trucked groups was the same but the calves that had been trucked died more rapidly after inoculation with P.haemolytica A1. In one of the sub-groups in this experiment, a fresh 24 hour culture of P.haemolytica A1 (containing 1.5×10^7 organisms/ml) was used rather than the frozen aliquots of 18 hour culture (1.25×10^5 organisms/ml) that had been used by these workers on previous occasions. This produced more dramatic clinical disease in both groups, even in calves previously vaccinated against BHV-1, a procedure which had previously been found to protect against the subsequent development of pneumonic pasteurellosis (117). To ensure that serological studies for BHV-1 could be completed some BHV-1 vaccinated calves were treated with tetracyclines to ensure their survival to the pre-arranged slaughter date.

Experimental models which used *Pasteurella* spp. and two or more additional microbiological or stress agents

Studies on the epidemiology of shipping fever in 1957 concluded that the disease was probably initiated by a virus, latent in the calves on the ranch but activated by the stress of shipment to feedlots, which then produced a suitable environment for the invasion of secondary bacteria (105). *Pasteurella* spp. had already been isolated from field cases of shipping fever since the 1930s (180), but experiments to reproduce the disease in experimental calves by inoculation of *Pasteurella* spp. into the respiratory tract had been largely unsuccessful (41). The discovery of a putative virus (174) followed by the isolation of PI3 virus from similar batches of purchased feedlot cattle (169) prompted the use of PI3 virus in combination with *Pasteurella* spp. in attempts to produce the disease experimentally (Table 29).

The addition of transport stress to the combined PI3 virus and *Pasteurella* spp. infection would have been a logical step in view of the natural occurrence of the disease in recently shipped cattle and this was first done experimentally in 1960 (191). An unstated number of calves were experimentally infected with PI3 virus and *Pasteurella* spp., and a proportion of these were transported for 48 hours in bad weather. Mild clinical signs (no details given) were seen in the control infected calves whereas the transported calves exhibited clinical signs which, according to the researcher, were similar to those seen in field cases of shipping fever. However, details of the clinical findings were not given and no microbiological or post-mortem examinations were described. The isolation of other agents from field cases of shipping fever e.g. *Mycoplasma* spp. (41), Chlamydia (161) and BHV-1 (116), and the lack of knowledge of their role, if any, in the aetiology of shipping fever led to the use of multiple infections of experimental calves which were often done in association with either temperature or transport stress (95,96,150,197,201).

YEAR	AUTHOR(S)	ADMINISTRATION OF *Pasteurella* spp.			OTHER AGENTS		STRESS	EXPERIMENTAL CATTLE			CLINICAL RESPONSE	SEROLOGICAL RESPONSE	PATHOLOGY		MICRO-ORGANISMS ISOLATED	COMMENTS
		CULTURE	ROUTE	DOSE				AGE	TYPE	NO.			G.	H.		
1963	Hamdy *et al*	6-8hr broth *P.haemolytica* + *P.multocida*	i/t i/n	2ml 3ml	PI_3 virus i/t & i/n	Mycoplasma i/t & i/n		6mths	Dairy	2	+	ND	+	ND	*Pasteurella* spp.	Reisolation from nasal swabs only
		"	"	"	PI_3 virus i/t & i/n		Temperature 104°F for 30min 34°F for 30min	4mths	Dairy	2	+	ND	+	ND	*P.multocida*	
		"	"	"		Mycoplasma i/t & i/n		4mths	Dairy	2	-	ND	-	ND	-	
		"	"	"	PI_3 virus i/t & i/n	Mycoplasma	Temperature (as above)	4mths	Dairy	4	+	ND	+	ND	*P.multocida* *P.haemolytica*	
1964	Hamdy *et al*	6-8hr broth *P.haemolytica* + *P.multocida*	i/t i/n	2ml 3ml	PI_3 i/t & i/n		Temperature 104°F for 30min 34°F for 30min	6mths	Dairy	2	+	PI_3 only	+	+	*Pasteurella* spp. PI_3	Pathology in Trapp *et al*, 1966 Reisolation from nasal swabs only
		"	"	"		Bovine Enterovirus (BEV) i/t & i/n	Temperature	6mths	Dairy	2	-	-	-	-	*Pasteurella* spp.	
		"	"	"		BHV-1 i/t & i/n	Temperature	6mths	Dairy	2	+	Virus only	+	+	*Pasteurella* spp. BHV-1	
		"	"	"		Chlamydia i/t & i/n	Temperature	6mths	Dairy	2	-	ND	-	-	*Pasteurella* spp. Chlamydia	
		"	"	"	PI_3 i/t & i/n	BEV i/t & i/n	Temperature	6mths	Dairy	2	-	PI_3 +	-	-	*Pasteurella* spp. PI_3	
		"	"	"	PI_3 i/t & i/n	BHV-1 i/t & i/n	Temperature	6mths	Dairy	2	+	PI_3 + BHV-1 +	+	+	*Pasteurella* spp. BHV-1	
		"	"	"	PI_3 i/t & i/n	Chlamydia i/t & i/n	Temperature	6mths	Dairy	2	+	PI_3 +	+	+	*Pasteurella* Chlamydia	
1964	Sorensen *et al*	?	Aero-sol	?	Aerosol PI_3		Cold stress 5-20°F for 72hrs pre-exposure	150kg	Hol-stein X	3	+	ND	+	ND	BVD virus	
1979	Stockdale *et al*	*P.haemolytica* A1 18hr broth	Aero-sol	10^6/ calf	Aerosol BHV-1 4 days pre-*P.haemolytica* $5x10^5$/calf		Transport stress on day of *P.haemolytica* inoculation and for next 3 days in inclement weather	3mths	Beef	4	+	ND	+	ND	*P.haemolytica* A1	

Table 29. Experimental models which used *Pasteurella* spp. and two or more additional microbiological or stress agents.

Two complex experiments were carried out by the same team of research workers in the early 1960s (95,96) and included combinations of all the microbiological agents mentioned above, and temperature stress. A total of 24 dairy type calves, aged between three and six months, were given the various microbiological agents by intratracheal and intranasal injection six hours before inoculation of the Pasteurella spp.. Eleven different combinations of agents were used, seven of which produced a clinical response and pathological lesions and from all of these Pasteurella spp. were reisolated from the lungs at post-mortem examination. Six of the seven successful combinations included hot and cold temperature stress and all contained either PI3 virus or BHV-1. Calves were usually exposed to the various combinations in groups of two, but for exposure to PI3 virus, Mycoplasma spp., Pasteurella spp. and temperature stress a group of four was used. The calves given the viral agents alone or in other combinations without the inoculation of Pasteurella spp. showed few if any clinical signs of respiratory disease. Severe clinical signs of pyrexia, dyspnoea and coughing were most often seen in calves which were stressed and then inoculated with a virus and Pasteurella spp.

Other multifactorial models have used the stress of either transport (201), or cold (197), or heat, transport and cold hosing (150) in addition to infection with PI3 virus (197), or BHV-1 (201). Calves exposed to an aerosol of PI3 virus and Pasteurella spp. and then chilled for 72 hours developed more severe and prolonged respiratory disease than calves that were similarly treated but not stressed (197). No clinical or pathological details were given, but lesions of pneumonia and BVD-MD virus infection were present at necropsy.

In the experiment where a total of 14 young (4-10 week old) dairy calves were kept at 38°C for 12 hours, trucked and cold hosed prior to infection with PI3 virus and a mixture of P.haemolytica and P.multocida all the calves were pyrexic within three days of inoculation

and four calves died between seven and 14 days post inoculation (150). Necropsy findings were consolidation, fibrin formation and oedema which confirmed the diagnosis of bovine pneumonic pasteurellosis in an animal that had died.

The effect of transport stress per se on a well established BHV-1 and P.haemolytica A1 model, was investigated using replicate groups of infected beef calves that were either transported or kept in an environmental chamber (201). The clinical signs of pyrexia, dyspnoea and recumbency were the same in both groups as was the mortality rate, but the calves that were transported died more rapidly. Fibrinous pneumonia with consolidation and pleurisy were seen in all the infected calves at necropsy.

2. Pneumonic pasteurellosis in other species

Sheep

In the early reports of the field disease from Iceland (66) and Wales (154) attempts were made by both groups of workers to reproduce the field disease in adult sheep by the inoculation of cultures of the organism (later identified as P.haemolytica) by a variety of routes. In Iceland (66) a nine hour broth culture was inoculated intratracheally and reproduced clinical signs and pathological lesions considered to be indistinguishable from the field disease. A 24 hour broth culture of the Welsh isolates of P.haemolytica produced no clinical signs or pathological lesions when inoculated intratracheally but produced a severe systemic illness without pneumonic lesions when inoculated intravenously or intraperitoneally (154). Later workers attributed this inability to consistently reproduce the field disease to the involvement of another agent, possibly a virus, in the initiation of the disease process (91).

In 1964, Smith (195) suggested that the organism suffered a reduction in pathogenicity on passage and storage. In a series of experiments frozen lung material was used either as a nine hour broth culture either direct or following 'pathogenicity enhancement' *via* an intermediate mouse culture. The reproduction of pneumonic pasteurellosis was successful in 13 month old and 21 month old sheep inoculated intrabronchially on one occasion with either culture. The group of 13 month old sheep given the broth culture (3.3×10^8 bacteria) became pyrexic and pneumonic and at post-mortem an anterior lobe pneumonia, with small red-centred grey "abscesses", was present and the infecting strain of *P.haemolytica* biotype A serotype 2 was reisolated from the lungs. In the experiment where 21 month old sheep were inoculated with a mouse culture of *P.haemolytica* the clinical signs and pathological lesions were shown to be dose related. All six animals given in excess of 5×10^{10} organisms died, only one of six animals given 8.8×10^9 organisms died and no animals given less than 10^9 organisms died. In the severe cases there was an acute fibrinous pneumonia with consolidation, pleurisy, pleural exudate and adhesions, and in the non-fatal cases circumscribed areas of fibrinous pneumonia were seen which had not been described in field cases. The author of this work suggests, correctly, that this was because no-one had examined pathologically non-fatal cases on a previous occasion. Large numbers of the infecting organism were isolated, often in excess of two hundred times the inoculated dose. Control animals given sterile broth or heat killed culture did not show clinical signs and no pathological lesions were present.

In three and four week old lambs inoculation of *P.haemolytica* biotype A by the intratracheal or intrabronchial route resulted in pneumonia and a systemic pasteurellosis (193).

Later workers attempted to reproduce pneumonic pasteurellosis using broth and mouse cultures but failed to produce convincing clinical disease or pathological

lesions (27). The reasons for the failure in this series of experiments may be that overnight broth cultures were used and the mouse culture method was used for a biotype T organism, whereas Smith (195) had used P.haemolytica A2 in both culture systems and his broth cultures were never more than nine hours old. This group of workers then used combinations of organisms including Streptococcus viridans, E.coli, S.aureus, Chlamydia, P.multocida and P.haemolytica in their attempts to reproduce enzootic pneumonia. Of a total of 55 experimental sheep, five were noticed to develop clinical signs, although the authors state that under the experimental conditions prevailing the clinical condition of the sheep was difficult to ascertain. One of these animals died following perforation of an abomasal ulcer, and of the remaining four sheep two had been infected with S.aureus (although P.haemolytica A2 was present in the respiratory tract) and two had been infected with P.haemolytica and Chlamydia. At post-mortem some consolidation, fibrinous pleurisy and dilatation of the interlobular septa was recorded and there was no difference in the appearance of the pneumonic lesions in animals inoculated with either A or T biotype. Inoculation of one sheep with an isolate of P.multocida recovered from a calf produced extensive lesions rather than the focal lesions previously seen after infection with P.haemolytica.

Following the isolation of PI3 virus from two to three month old intensively reared lambs (107), pneumonic lesions were produced experimentally in lambs in the absence of significant clinical disease using the same strain of virus (108). Subsequently, a number of groups of research workers investigated the potential of this virus in developing an experimental model for the production of pneumonic pasteurellosis (28,61,182). In a later examination of the respiratory tracts of clinically pneumonic sheep, PI3 virus was isolated from the lungs and nasal passages and this increased the support for its putative role in pneumonic pasteurellosis (109) despite the fact that P.haemolytica A2 and P.haemolytica A6 were

also isolated from the same pneumonic lungs. In a field survey for PI3 virus and any serological evidence to support its postulated role in the respiratory disease the virus was not isolated, and the serological findings did not indicate that PI3 virus was important in pneumonic pasteurellosis (27).

Inoculation of colostrum-deprived lambs with a bovine strain of PI3 virus produced severe clinical disease and pathological lesions in the absence of evidence of infection with P.haemolytica (108). Combined intrabronchial inoculations of PI3 virus followed three days later by P.haemolytica in four month old conventional or colostrum deprived lambs produced severe clinical disease and lesions of fibrinous pneumonia and pleurisy at post mortem (28). However, there was little difference in the clinical signs shown by lambs inoculated with either P.haemolytica alone or PI3 virus and P.haemolytica in combination except that deaths in the virus-bacterium inoculated group occurred 18 hours after the inoculation of the Pasteurella spp., whereas in the group given P.haemolytica alone deaths occurred after two days. The pathological lesions were most severe in the group given both PI3 virus and P.haemolytica. The inoculation of PI3 virus alone failed to produce any lesions in the conventional lambs.

The infecting isolate was P.haemolytica A5, a serotype rarely found in Britain, and this was re-isolated from the pneumonic lungs post-mortem. Although other strains of P.haemolytica were isolated from nasopharyngeal swabs both pre and post inoculation and from the lungs at post-mortem, the workers suggest that these other strains played no part in the development of pneumonia. However, they give no reasons for this and did not carry out immunofluorescence which may have supported this statement. There was no evidence of tissue invasion or bacterial multiplication following inoculation of PI3 virus.

Other workers have used similar experimental methods to reproduce pneumonic pasteurellosis with variable results (59,60,61). In one series of experiments 79% of conventional lambs given PI3 virus followed four to eight days later by an overnight culture of P.haemolytica developed severe pneumonia but none died (59). However 25% of the controls had pneumonic lesions compared with 21% and 12% of the experimentally infected lambs that had received either PI3 virus or P.haemolytica respectively.

The most successful and reproducible model was based on the inoculation of specific pathogen free lambs with intranasal PI3 virus followed either four or seven days later by an aerosol of an overnight culture of P.haemolytica A1 (182). Clinical signs were seen following the inoculation of PI3 virus but these increased in severity after the inoculation of P.haemolytica, resulting in 54% of the lambs dying or being killed in extremis as a result of pneumonic pasteurellosis. Clinical details were sparse but the pathology is well described (173). The early lesions consisted of widespread consolidation sometimes with gelatinous pleurisy, followed by the development of roughly spheroidal nodular lesions with dark red centres that later became encapsulated. However, even in the early cases no PI3 inclusion bodies were seen, and in the diagrammatic representation of the lung lesions, consolidation is shown in some lambs in the posterior portion of the caudal lung lobe, a site not described in the field disease. This disease model has been extensively used and described as a challenge system for vaccine evaluation (84,226) and serotypes other than A1 have been incorporated into the model.

More recently conventional sheep aged from three weeks to 16 months have shown signs of a febrile pneumonia following intravenous inoculation with agar followed by a 15 minute exposure to an aerosol of P.haemolytica A1 or A2 (82). However the clinical disease and the pathological lesions were not identical with those seen in the field

disease. This model has also been used in challenge experiments to evaluate new vaccines (83).

3. An appraisal of the literature relating to the experimental disease.

Some of the early workers produced fibrinous pneumonia in single calves using young cultures of P.haemolytica. However these results were not consistently produced and the success was attributed to the presence of pre-existing chronic pneumonia. Following the discovery of PI3 virus and the proposal of the multiple aetiology theory experiments became multifactorial with the use of bacteria, viruses, mycoplasma, hormonal and chemical agents and a variety of physical stresses e.g. transport, cold. Many of these experiments failed to reproduce pneumonic pasteurellosis consistently but one experimental model using BHV-1 and P.haemolytica A1 was successful and reproducible. Vaccination against BHV-1 protected against the experimental disease and a role for viruses in the field disease was assumed. Few, if any, workers used log phase cultures in their challenge systems, but in the BHV-1 and P.haemolytica model one group of calves was inoculated with a fresh young culture of P.haemolytica A1 because there was insufficient of the frozen overnight culture usually used. This group developed bovine pneumonic pasteurellosis but the result was dismissed by the research team without comment, as P.haemolytica was not considered to be a potential primary pathogen.

SECTION II

MATERIALS AND METHODS

Calves and management

In all experiments healthy weaned dairy or dairy cross calves, aged about four months, were used. Each experimental group (Tables 30 and 31) was housed separately in adjacent conventional looseboxes (14' x 14' approx.) in all instances except experiment five when the calves were housed in a row of five boxes, the relative positions being infected calves, environmental controls, feed store, sterile broth and killed culture. They were bedded on straw and fed good quality meadow hay and concentrates (190 calf pencils BOCm Silcock). Water was always available. In experiments four, five and six, the calves were selected on the basis of pre-inoculation reciprocal serum titres to P.haemolytica A1 of four or less. In experiment five the concentrates were available ad lib and daily concentrate intake was measured.

Inoculation routes and timing

In every experiment the microbiological agents were given by a combination of the intranasal and percutaneous intratracheal routes. The intratracheal inoculation was made using an 18g 1½" needle inserted between the tracheal rings in the mid-third of the trachea, ten ml of inoculum was injected slowly by this route. The intranasal inoculation was made using a plastic intranasal applicator, five ml of inoculum was trickled slowly into each nostril with the muzzle held high during, and for 30 seconds after, inoculation. Where repeated inoculations were given they were made at 1000 hours and 1600 hours each day. On days where only one inoculation was made it was carried out at 1000 hours. The first day of inoculation was designated day zero for each experiment.

Microbiological agents

Two isolates of P.haemolytica A1 were used in the experimental studies. The first isolate (M/C) was used in experiments one, two and six and was recovered from the lungs of a fatal case of bovine pneumonic pasteurellosis (Case No. 82541, Appendix 2) from an outbreak of transit fever in housed, weaned, single suckled calves.

The second isolate (S/C) was used in experiments three, four, five and six and was recovered from the lungs of a slaughtered case of bovine pneumonic pasteurellosis from a microbiologically and pathologically confirmed outbreak of the disease in purchased month-old bucket fed calves.

The isolates of P.haemolytica A1 were freeze dried for storage after three passages and were then grown in trypticase soy broth for inoculation either as an overnight (stationary-phase) culture (Experiments 1,2 and 6) or as a two and eight hour (log phase) culture (Experiments 3,4,5 and 6). In Experiment five a killed culture of P.haemolytica A1 was inoculated into one group of calves, this was an aliquot of the same culture given to the infected calves but had been heated at 56°C for 30 minutes to destroy any cells but retain th endotoxin present.

The isolate of PI3 virus was recovered from the lungs of a slaughtered case of PI3 virus pneumonia from a severe outbreak of the disease in weaned housed dairy and dairy cross calves. Foetal bovine lung cells were inoculated with a terminal dilution of the original viral isolate, and the resulting culture stored in aliquots at -70°C. The aliquots were thawed and used to inoculate calves.

Other agents

Chemical

In Experiment two, two groups of calves were treated with corticosteroids, specifically betamethasone injected intramuscularly at a dose rate of 4mg/50kg on days minus eight to minus four inclusive and dexamethasone (5mg/50kg) on day minus four. The other two groups of calves were injected intratracheally by the percutaneous route with 8% acetic acid on day minus one. In Experiment three, one group of calves were treated with 40% diethylcarbamazine citrate (2.5ml/50kg) by the intramuscular route on days -31, -30, -29.

Physical

In Experiment two, the calves that had received intratracheal acetic acid were hosed the same day. Hosing was with hot and cold water alternately, carried out on three occasions each of 30 minutes duration.

Nematodes

In Experiment three all calves were infected per os on day -46 with Dictyocaulus viviparus third stage larvae (L_3) at a dose rate of $50L_3$/kg bodyweight.

Experimental design

Six experiments were carried out in total. The first two experiments used a stationary phase culture of P.haemolytica A1 in conjunction with either PI3 virus infection, (experiment 1) or treatment with cortisone or hot and cold water hosing (experiment 2). The details of these experiments are shown in Table 30.

Pasteurella haemolytica A1 (S/C) in log phase culture was used to inoculate calves in experiments three, four and five. In experiment three inoculation followed lungworm (Dictyocaulus viviparus) infection, and in experiment four a five dose and a three dose inoculation regime using P.haemolytica A1 alone were compared. Experiment five evaluated the five dose regime using broth, killed culture and environmental controls to compare clinical parameters, food intake and to ensure that the disease seen in experiments three and four was not due to the effects of endotoxin.

In experiment six, stationary and log phase cultures of P.haemolytica A1 (S/C) and P.haemolytica A1 (M/C) respectively were compared on clinical, microbiological and pathological grounds.

The details of experiments three to six are shown in Table 31.

TABLE 30. Design of experiments using stationary phase cultures of P.haemolytica A1

Experiment	Group	No.of calves	Pasteurella haemolytica A1 (M/C)					Other agents						Post-mortem	
			No.of doses	Dose/ml	Volume	Route	Timing (days)	Agent	No.of doses	Dose/ml	Volume	Route	Timing (days)	No.of Calves	Day(s) killed
1	1	3	-	-	-	-	-	PI3virus	5	$10^{6.5}$TCID$_{50}$	10 ml 10 ml	i/n i/t	4,5,6	3	9,11,14
	2	3	5	$9x10^{12}$	10 ml 10 ml	i/n i/t	6,7,8	PI3virus	as above					3	11,14,20
	3	3	5	$9x10^{12}$	10 ml 10 ml	i/n	0,1,2	PI3virus	as above					3	11,14,20
	4	3	2x5	$9x10^{12}$	10 ml 10 ml	i/n i/t	0,1,2 6,7,8	PI3virus	as above					3	21
	5	2	-	-	-	-	-	-	-	-	-	-	-	2	14,20
2	1	2	-	-	-	-	-	bmsone dmsone	4 1	2 mg 3 mg	5 ml 5 ml	i/m i/m	-8 to -5 -4	1	8
	2	4	5	$2.6x10^{11}$	10 ml 10 ml	i/n i/t	0,1,2	as above						2	8
	3	4	as above					hosing CH_3COOH	multiple, hot and cold, body surface 1 i/t				-1 -1	0	-
	4	2	-	-	-	-	-	as above						0	-

bmsone - betamethasone
dmsone - dexamethasone

TABLE 31. Design of experiments using logarithmic phase cultures of P.haemolytica A1.

Experiment	Group	No.of calves	Pasteurella haemolytica A1 (S/C)					Other agents						Post-mortem	
			No.of doses	Dose/ml	Volume	Route	Timing (days)	Agent	No.of doses	Dose/ml	Volume	Route	Timing (days)	No.of calves	Day(s) killed
3	1	4	5	$8x10^8$ * $4x10^9$	10 ml 10 ml	i/n i/t	0,1,2	D.viviparus	1	$50L_3$/kg	bwt.	per os	-46	4	1,2,8,9
	2	3	as above					as above							
								DEC	3			i/m	-31,-30,-29	3	3,8,9
4	1	4	5	$4x10^8$ $9x10^9$	10 ml 10 ml	i/n i/t	0,1,2	-	-	-	-	-	-	4	2,3,8,9
	2	4	3	$4x10^8$ $9x10^9$	10 ml 10 ml	i/n i/t	1,2	-	-	-	-	-	-	4	2,3,8,9
5	1	4	5	$2x10^9$ $8x10^{11}$	10 ml 10 ml	i/n i/t	0,1,2	-	-	-	-	-	-	4	2,3,9,10
	2	4	-	-	-	-	-	Killed PhA1	5	$2x10^9$ $8x10^{11}$	10 ml 10 ml	i/n i/t	0,1,2	4	2,3,9,10
	3	4	-	-	-	-	-	Sterile broth	5	-	10 ml	i/n	0,1,2	4	2,3,9,10
	4	4	-	-	-	-	-	-	-	-	-	-	-	4	2,3,9,10
6	1	4	-	-	-	-	-	log-phase PhA1 M/C	5	$4x10^9$ $8x10^{10}$	10 ml 10 ml	i/n i/t	0,1,2	2 2	3 6
	2	4	-	-	-	-	-	Stat.phase PhA1 S/C	5	$10x10^{12}$	10 ml 10 ml	i/n i/t	0,1,2	2 2	3 6

D.viviparus - Dictyocaulus viviparus

PhA1 - P.haemolytica A1

DEC - Diethylcarbamazine

* where two bacterial counts appear they represent the 2 hr. and 8 hr. cultures respectively.

Clinical examination

Calves were observed at least once daily when demeanour, rectal temperature, respiration rate and character, presence or absence of cough, nasal and ocular discharge and any other relevant clinical details were recorded. The clinical terms used were described previously in Chapter 1, Section II. In some experiments these observations were made twice daily over the period following initial inoculation. Clinical examinations were always carried out before any sampling or inoculation took place.

In experiment five, the daily concentrate intake was measured for each group of calves at 09.00 h. each day. The amount eaten was expressed as kilograms of food eaten per 50 kg liveweight for the calves in that box and represented the intake over the previous 24 hours.

Microbiological examination (live calves)

Nasopharyngeal swabs were taken from all calves on several occasions prior to inoculation and at regular intervals thereafter throughout the experimental period. (App. 39 to 44).

Examination of the swabs for the presence of viruses, mycoplasma and bacteria was carried out as described previously (Chapter 1, Section II).

Serological examination

Blood samples were taken from all calves on at least one occasion prior to inoculation and on one or more occasions post-inoculation.

Samples were examined for the presence of antibodies to P.haemolytica A1, P.haemolytica A2, P.multocida, PI3 virus, BHV-1, RS virus and BVD-MD virus as described previously in Chapter 1, Section II.

Pathological examination (including microbiology)

Details of calf slaughter times for each experiment are shown in Tables 30 and 31: Calves were killed by stunning with a captive bolt pistol and exsanguination. Tissues were taken from nasal conchae (NC), trachea (Tr), right cranial lung lobe (RC), right middle lung lobe (RM), right caudal lung lobe (RD), tonsil (Ton) and bronchial lymph node (BrLN) aseptically for microbiological examination and from adjacent sites in 10% formol saline for processing by standard methods for histopathological examinations. Microbiological and immunofluorescent studies were carried out as described previously (Chapter 1, Section II).

SECTION III

RESULTS

The first two experiments were carried out using overnight (stationary phase) cultures of P.haemolytica A1 (M/C) in combination with either PI3 virus (experiment 1), and physical or hormonal stress (experiment 2). Neither experiment produced clinical signs or pathological lesions which could be considered similar to those seen in field cases of bovine pneumonic pasteurellosis. The following four experiments were carried out using two and eight hour (log phase) cultures of P.haemolytica A1. In the first of this series of experiments calves were infected in the post-patent phase of experimentally-produced D.viviparus infection. Clinical and pathological features consistent with those in field cases of bovine pneumonic pasteurellosis were seen in both the post-patent husk calves and in similar calves that had been treated with diethylcarbamazine in the prepatent phase of the disease, and which had few, if any, residual husk lesions. Pasteurella haemolytica A1 (S/C) was then used as the sole pathogen in subsequent experiments either to compare a five dose inoculation regime with a three dose regime, or to compare infected calves with sterile broth, killed culture and environmental control calves. The final experiment in this series compared log phase culture of P.haemolytica A1 (M/C), which had been used in stationary phase culture in experiments one and two, with stationary phase culture of P.haemolytica A1 (S/C), previously used in log phase culture in experiment three to five inclusive.

1. Experiments using stationary phase cultures of P.haemolytica A1

Pasteurella haemolytica A1 and PI3 virus

(Experiment 1, Appendix 39)

Clinical signs

In this experiment calves were infected with parainfluenza 3 virus and P.haemolytica A1 using different timings and combinations (Table 30). All the infected calves became dull and anorexic after infection with PI3 virus. Inoculation with P.haemolytica A1 alone did not produce dullness, and when inoculation followed viral infection there was no enhancement of the depression produced by the virus. There was some improvement in the demeanour of the calves by day 11, but they remained dull until the end of the experiment.

The clinical signs in all calves that were given PI3 virus were anorexia, pyrexia, tachypnoea, hyperpnoea and coughing. The mean group rectal temperatures for groups two, three and four which had received P.haemolytica A1 in combination with PI3 virus were higher than that for the PI3 virus only infected group between days five (24 hours post initial infection (p.i.i.) with PI3 virus) and day eight (Fig. 14). Individual maximum rectal temperatures were group one, 104.5°F, day eight; group two, 105.0°F, day ten; group three, 105.0°F, days five and eight; and group four, 104.8°F, on day seven. The rectal temperatures of the calves in the uninfected control group remained within the normal range throughout the experiment.

Group one (PI3 virus alone) had the highest mean respiratory rate (74/min) on day seven, although the mean respiratory rates for this group and group two are very similar (Fig. 15). Group three also showed an increase in respiratory rate but this was less marked than that in groups one and two. The mean respiratory rate for group four showed only a small increase over the normal range.

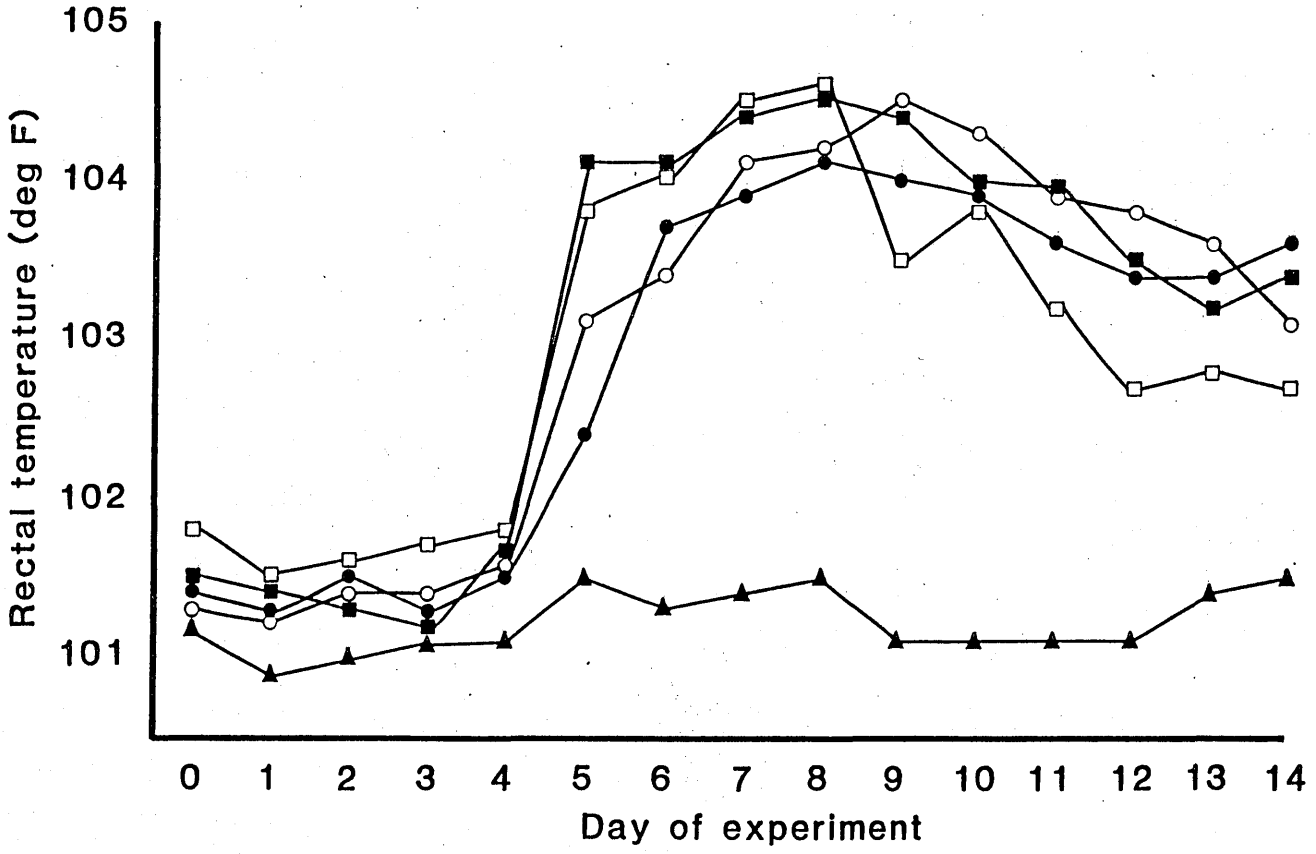

Figure 14

Experiment 1: PI3 virus and P.haemolytica A1 (stationary phase)
Rectal temperatures (group mean) of calves infected with PI3 virus (●—●), PI3 virus + P.haemolytica A1 (○—○), P.haemolytica A1 + PI3 virus (■—■), P.haemolytica A1 + PI3 virus + P.haemolytica A1 (□—□), and uninfected controls (▲—▲).

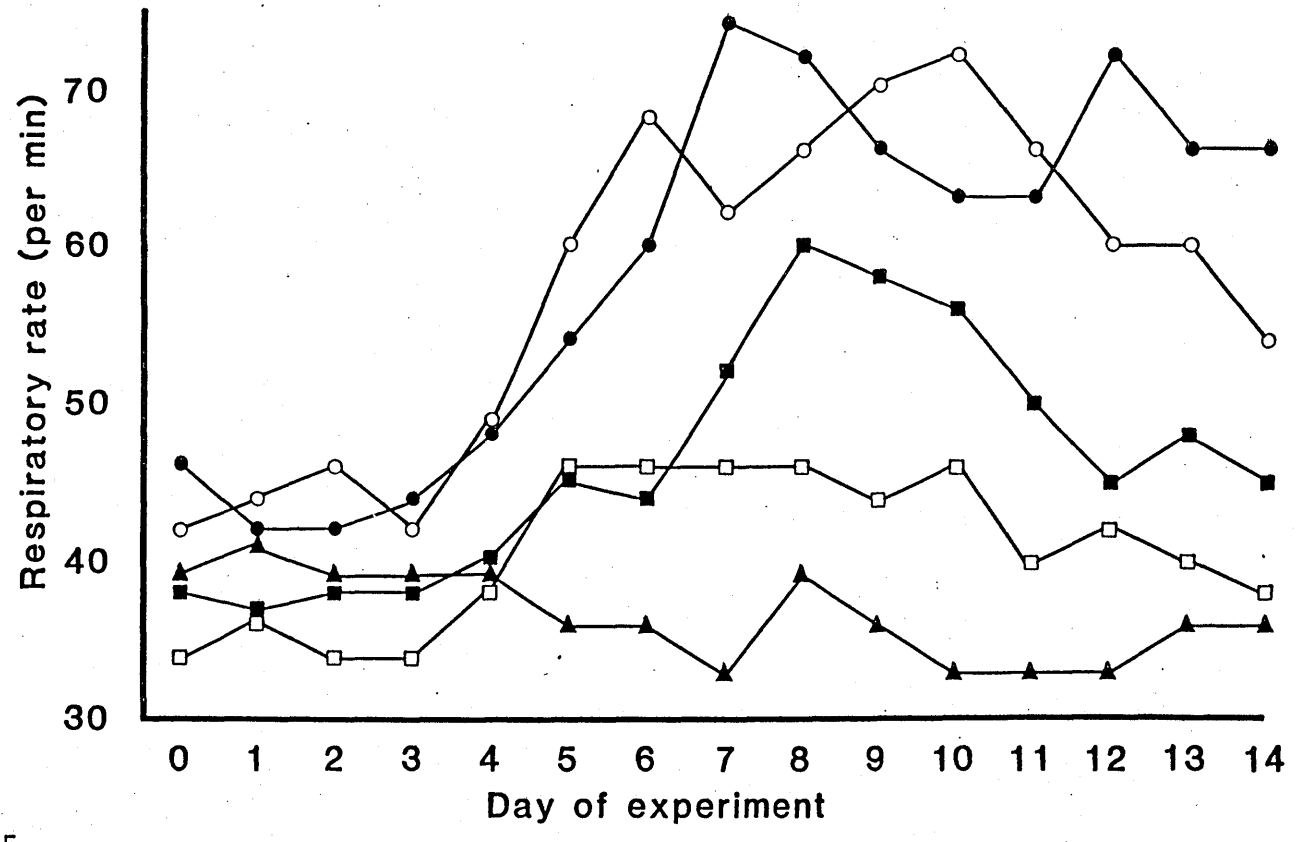

Figure 15
Experiment 1: PI3 virus and P.haemolytica A1 (stationary phase)
Respiratory rates (group mean) of calves infected with PI3 virus (●—●), PI3 virus + P.haemolytica AI (○—○), P.haemolytica A1 + PI3 virus (■—■), P.haemolytica A1 + PI3 virus + P.haemolytica A1 (□—□), and uninfected controls (▲—▲).

Individual maximum respiratory rates were group one, 78/min, day seven; group two, 78/min, day ten; group three, 66/min, days nine and ten; and group four, 48/min, on several occasions from days five to 14. The respiratory rates for the uninfected control calves remained within the normal range throughout the experiment.

All the infected groups coughed sporadically after infection with PI3 virus and a mucoid to mucopurulent nasal discharge was often present. There was no difference in the severity or frequency of these features between the infected groups.

Microbiology (live calves)

Pasteurella haemolytica A1 and PI3 virus were not isolated from the nasopharynx of the calves prior to the commencement of inoculation.

Parainfluenza 3 virus was isolated from nasopharyngeal swabs from all the calves in group one on day three.

Isolations of P.haemolytica A1 were made from one calf in each of groups three and four on day four, following inoculation on the previous three days with P.haemolytica A1, and further isolations were made from these groups on days seven and 14. Pasteurella haemolytica A1 was not isolated from any calves in group two, but single isolations were made from calves in group one (day 7) and group five (day 14).

Serology

Seroconversion to PI3 virus was widespread throughout the infected groups. Four of the 11 calves sampled had seroconverted by day eight (all of which had received P.haemolytica A1 and PI3 virus). By day 14, nine of the 10 sampled calves had seroconverted, the exception being the only calf sampled that had received PI3 virus alone. Some of the calves had seroconverted from pre-

inoculation reciprocal serum titres of 160, although the majority of titres at this time were between 10 and 40.

A wide range of reciprocal serum titres to P.haemolytica A1 were present in the calves at day zero of which the lowest was eight and the highest greater than 128. Three calves seroconverted, two from group two and one from group four, all of which had reciprocal serum titres of 16 at the start of the experiment.

Pathology (including microbiology)

Lesions consistent with PI3 virus infection (eosinophilic intracytoplasmic inclusion bodies, bronchiolar epithelial necrosis and alveolar epithelial hyperplasia) were seen in all the calves from group two killed within ten days post initial inoculation with PI3 virus. Parainfluenza 3 virus was isolated from one calf (40) in group one at post-mortem, where it was detected throughout the respiratory tract (but not the associated lymphoid tissue) by both isolation and immunofluorescence.

Fibrinous pneumonia was not present in any of the calves, but several calves in groups two, three and four had mild degree of septal dilatation with fibrin.

Pasteurella haemolytica A1 was not isolated at post-mortem but was demonstrated by immunofluorescence within the respiratory tract in calves from groups two, three and five.

Lesions of cuffing pneumonia were present in all calves with the exception of the calves in group four.

Pasteurella haemolytica A1 and stress
(Experiment 2, Appendix 40)

In this experiment calves were either treated with corticosteroids to reduce the immune response, or inoculated intratracheally with acetic acid and subjected to hot and cold water hosing before inoculation with P.haemolytica A1

(Table 30).

Clinical signs

None of the calves in this experiment became dull or anorexic at any time.

The calves, stressed by either method and inoculated with sterile broth, showed no change in rectal temperature throughout the experiment (Fig. 16). The rectal temperature changes seen in groups two and three, which were stressed and inoculated with P.haemolytica A1 showed an increase from days one to ten compared with the sterile broth groups. However, the group mean maxima were 103.2°F, day four, group 2; and 103.1°F, days two and three, group three, with individual maxima of 103.2°F and 103.8°F in groups two and three respectively.

An increase in respiratory rate was seen in all groups of calves from day one to the end of the experiment, this increase was most marked and persistent in the groups inoculated with P.haemolytica A1 (Fig. 17). Individual maximum respiratory rates were 60/min (group one), 78/min (group two), 72/min (group three) and 66/min (group four).

Microbiology (live calves)

Pasteurella haemolytica A1 was isolated from nasopharyngeal swabs from calves in groups one and two eight days before and six days p.i.i., and from one calf in group four six days p.i.i.

Serology

All the calves in group three (hosing and P.haemolytica A1) had seroconverted by ten days p.i.i. from pre-inoculation reciprocal titres of neat to 16, two calves in group two (cortisone and P.haemolytica A1) also seroconverted over this period from initial reciprocal titres of neat and four. No seroconversions were seen in groups one and four over this period, but both calves

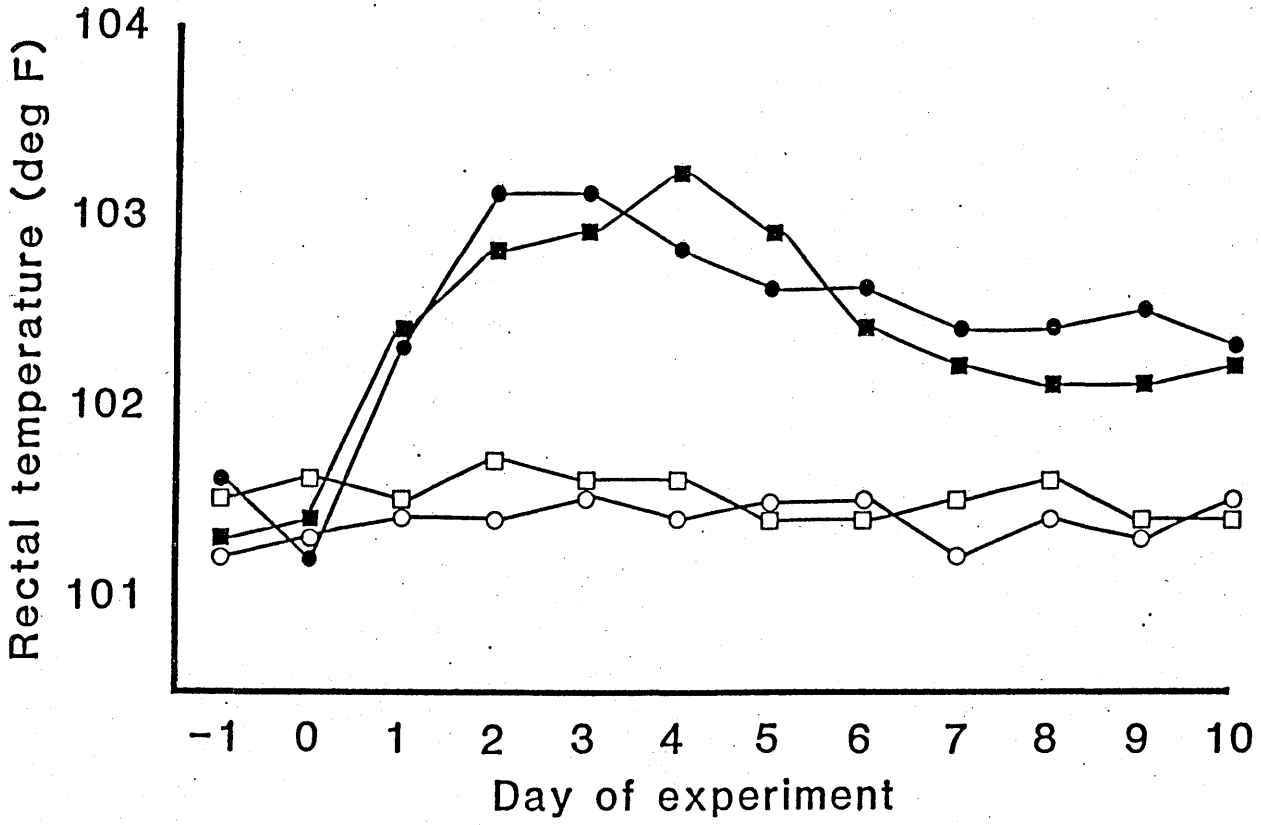

Figure 16

Experiment 2: P.haemolytica A1 (stationary phase) and stress

Rectal temperatures (group mean) of calves which were hosed and received P.haemolytica A1 (●—●), or sterile broth (○—○); or were given cortisone with either P.haemolytica A1 (■—■) or sterile broth (□—□).

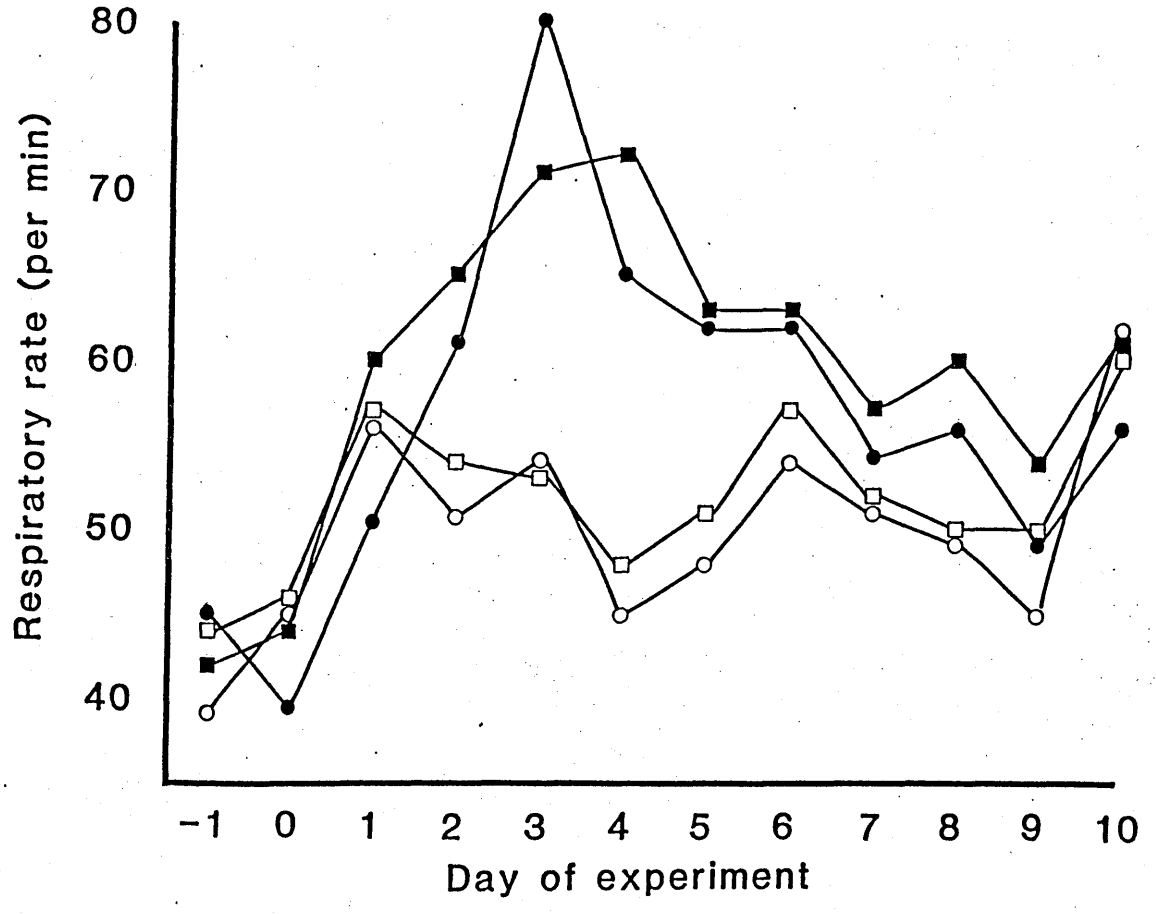

Figure 17

Experiment 2: P.haemolytica A1 (stationary phase) and stress.

Respiratory rates (group mean) of calves which were hosed and received P.haemolytica A1 (●—●) or sterile broth (○—○); or were given cortisone with either P.haemolytica A1 (■—■) or sterile broth (□—□).

in group four (hosing and sterile broth) seroconverted between 10 and 17 days p.i.i..

Pathology (including microbiology)

Three calves were killed on day seven, one from group one (cortisone and sterile broth) and two from group two (cortisone and P.haemolytica A1). No significant lesions were found in the calf from group one. In both of the calves from group two small foci of pneumonic consolidation were seen, and in addition one of these calves (68) had lesions of cuffing pneumonia together with an acute exudative reaction with minimal amounts of fibrin in the interlobular septa.

This latter calf was the only animal from which P.haemolytica A1 was recovered at post mortem; the single positive isolation site was the nasal conchae.

2. Experiments using log phase cultures of P.haemolytica A1

Pasteurella haemolytica A1 and Dictyocaulus viviparus (Experiment 3, Appendix 41)

The original aim of this experiment was to superimpose P.haemolytica A1 on the resolving post-patent phase of lungworm infection. However, 14 days after infection with Dictyocaulus viviparus three of the calves developed severe pneumonia. These three calves were treated with diethylcarbamazine. One of the untreated calves died from patent husk 40 days after infection with D.viviparus.

There were now two distinct groups of calves, one group which had shown all the clinical signs of patent husk, hyperpnoea, tachypnoea, coughing, crackles over the caudal lobes but had now entered the post-patent phase as judged by the reduction in severity of clinical signs and a low faecal larval output. The other group comprised the three calves that had been treated for prepatent husk, and had been clinically healthy for several weeks.

Clinical signs

Both groups of calves were fairly bright immediately before inoculation with P.haemolytica A1. The calves were between seven and eight months old at this time and were difficult to handle. After inoculation with P.haemolytica A1 all the calves became dull, depressed and inappetent, but towards the end of the experiment the surviving calves started to feed and appeared brighter.

The rectal temperatures of all calves were within the normal range prior to inoculation with P.haemolytica A1. The post-patent husk calves (Group 1) became pyrexic after one dose of P.haemolytica A1 and maintained this response until the last day of the experiment (Fig. 18). The calves which had been treated for prepatent husk were intermittently pyrexic, but two of the calves had rectal

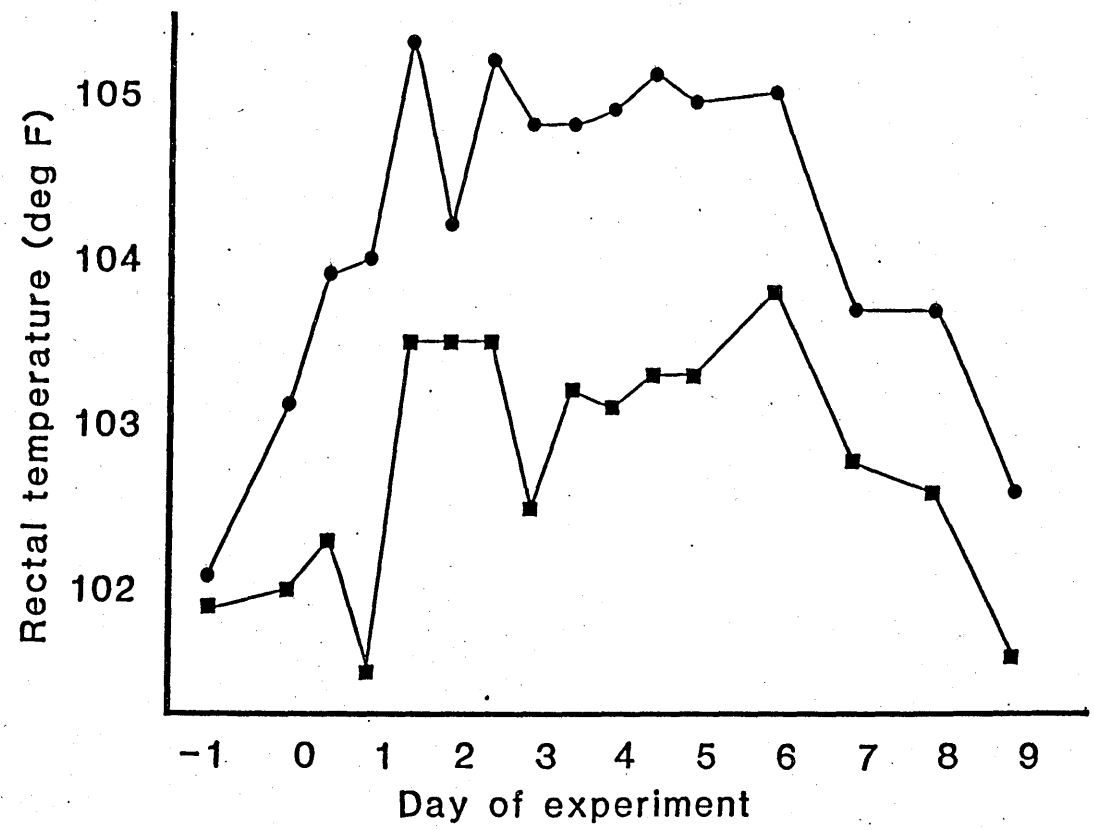

Figure 18

Experiment 3: P.haemolytica A1 (log phase) and D.viviparus.

Rectal temperatures (group mean) of calves given D.viviparus and P.haemolytica A1 (●—●), and calves given D.viviparus, diethylcarbamazine and P.haemolytica A1 (■—■).

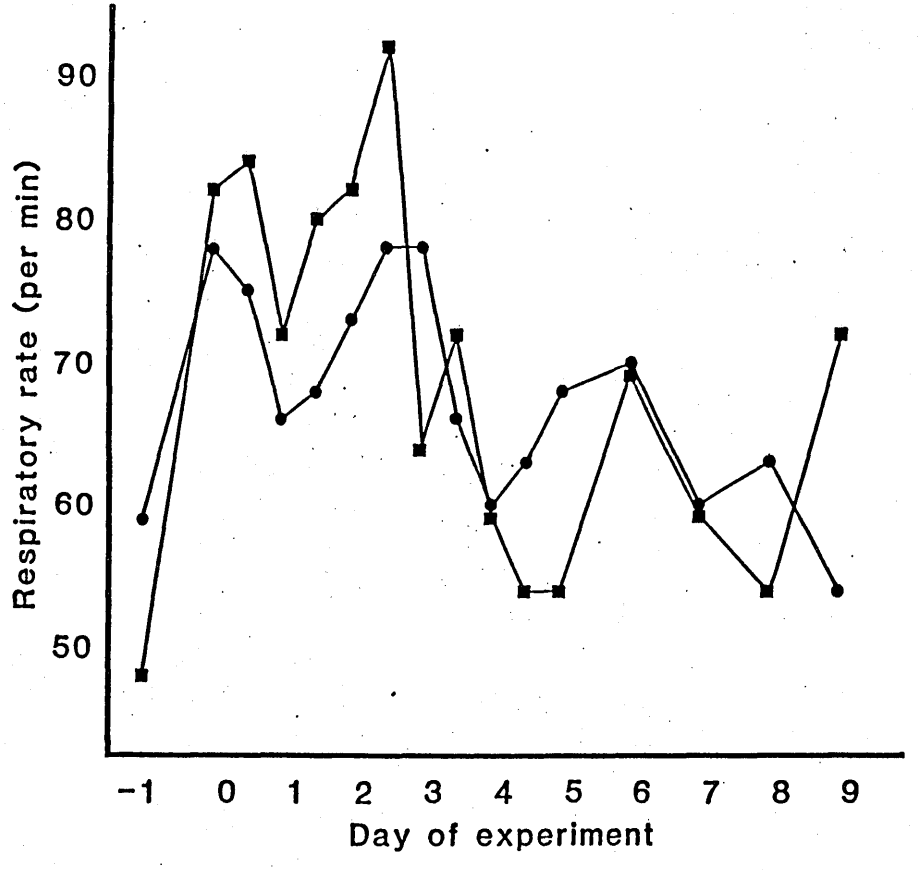

Figure 19

Experiment 3: P.haemolytica A1 (log phase) and D.viviparus.

Respiratory rates (group mean) of calves given D.viviparus and P.haemolytica A1 (●—●), and calves given D.viviparus, diethylcarbamazine and P.haemolytica A1 (■—■).

temperatures of 104°F or greater on days two and three. One calf in this group failed to become pyrexic at any time during the experiment. The respiratory rates of the calves in the post-patent husk group were 54 or 60 per minute on the day prior to inoculation, whereas the respiratory rates for all of the diethylcarbamazine treated group were 48 per minute. After infection with P.haemolytica A1 the mean group respiratory rates for both groups increased, some calves having an increased respiratory rate prior to inoculation probably associated with the stress of handling.

The pattern of increase in respiratory rates was similar in both groups, the early higher mean values for the diethylcarbamazine treated group being the result of one calf (88) with respiratory rates of 96, 120 and 132 per minute on days two and three (Fig. 19).

All the calves were heard to cough prior to inoculation with P.haemolytica A1, and the coughing was most severe in the untreated group. However, there was no change in the amount or severity of coughing in either group following inoculation of P.haemolytica A1.

A nasal discharge, which was mucoid or mucopurulent, was seen in all calves and this became more marked after inoculation with P.haemolytica A1.

Microbiology (live calves)

Pasteurella haemolytica A1 was not isolated from any of the calves in the period prior to experimental inoculation of the organism. Post-inoculation it was isolated from the nasopharynges of all the surviving calves on day four.

Serology

All the calves had reciprocal serum indirect haemagglutination titres to P.haemolytica A1 of 16 or less prior to inoculation. By day four, two of the four surviving calves (one in each group) had seroconverted, and

by day nine all four calves had seroconverted.

Serum titres were also measured to BHV-1, P13 virus and RS virus. No seroconversions were recorded.

Pathology (including microbiology)

Lesions typical of lungworm infection were found in the caudal lung lobes of all the calves in the untreated husk group and in two of the three calves from the treated group. Adult lungworms were present in the bronchi of three of the untreated husk cases.

Fibrinous pneumonia, fibrinous pleurisy, dilated interlobular septa and Pasteurella nodules were seen in all the calves infected with P.haemolytica A1, including the calves killed after only three doses of P.haemolytica A1. An acute exudative reaction in the lung tissue and the presence of fibrin in the lymphatics was recorded in six of the seven infected calves, both lesions being absent from one calf in the treated group.

Pasteurella haemolytica A1 was isolated from the lower respiratory tract of all calves at post mortem; from 12 of a possible 16 sites in the untreated husk calves and from seven of 12 sites in the treated group. Isolations of P.haemolytica A1 were made from the upper respiratory tract in three of the untreated husk calves and two of the treated calves.

Two calves in each group had mild lesions of either cuffing pneumonia or chronic suppurative pneumonia in the anterior lobes.

Pasteurella haemolytica A1 - five vs three inoculations (Experiment 4, Appendix 42)

Fibrinous pneumonia, Pasteurella nodules and fibrinous pleurisy, all lesions typical of bovine pneumonic pasteurellosis were produced in all the calves in the previous experiment, including those given three inoculations of P.haemolytica A1. This finding prompted

the comparison of the five inoculation regime used previously with a three inoculation regime.

Clinical signs

Both groups of calves became dull, depressed and anorexic within six hours of the first dose of P.haemolytica A1 and remained so until day six. From day seven onwards the demeanour of the calves improved and there was gradual increase in appetite, both these changes were more marked in the calves which received only three doses of P.haemolytica A1, compared with the five dose calves.

The rectal temperatures for both groups are shown in Fig. 20. All calves had temperatures within the normal range during the week prior to inoculation. The high mean group value for the three dose calves immediately pre-inoculation was because one calf had a rectal temperature of 105°F, the remaining calves were within the normal range. The mean group rectal temperatures of the five-dose group were higher (individual maximum 106.0°F) and the pyrexia persisted for longer (nine days) than in the three-dose group (individual maximum 106.2°F, pyrexic for seven days), and the temperature response within the five dose group was more consistent than in the three dose group. Individual calves in both groups were still pyrexic nine days p.i.i..

The respiratory rates of all calves were 42 per minute or less prior to inoculation. Within six hours of the first inoculation in both groups an increase in respiratory rate was seen. The group mean respiratory rate was higher (84/min) in the five-dose group than in the three-dose group. However, individual maxima were 96 per minute in both groups (Fig. 21).

Occasional coughing was heard in both groups after day five but it was not a prominent clinical feature. All calves developed a slight mucoid to mucopurulent nasal discharge on or around the fourth day after initial inoculation.

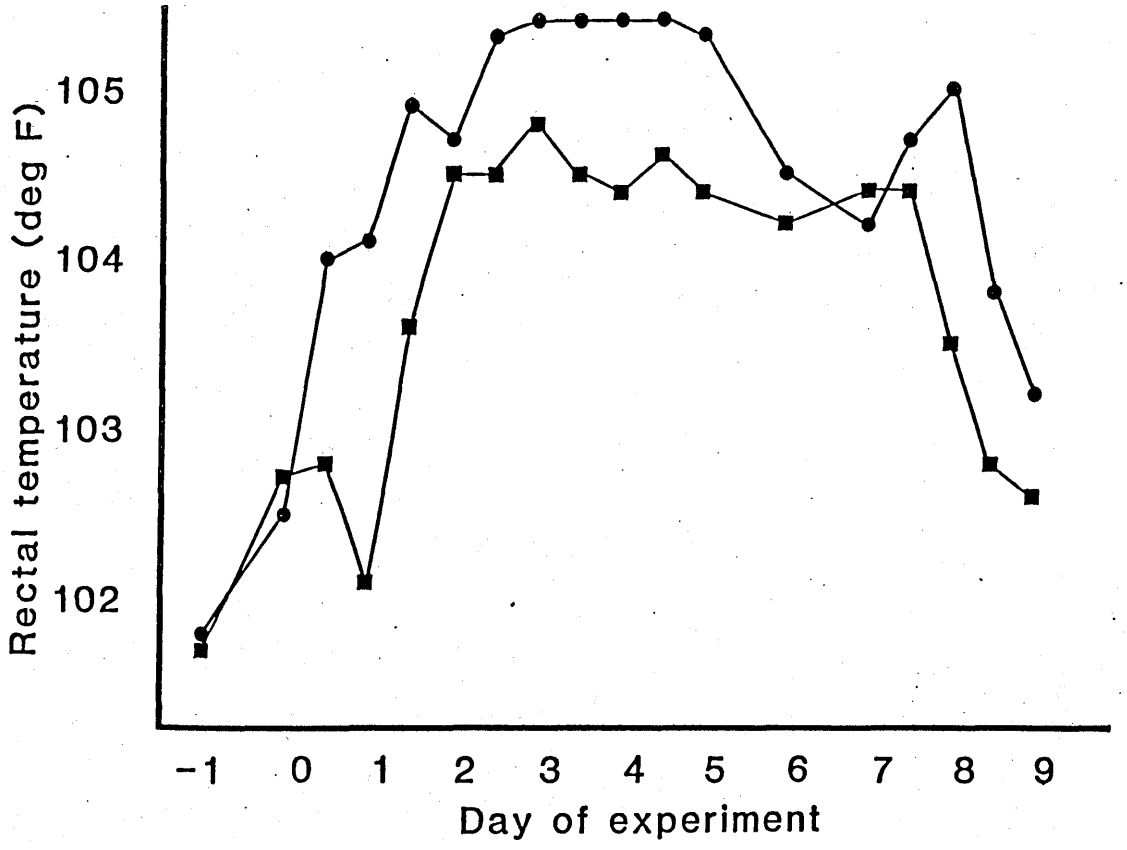

Figure 20

Experiment 4: P.haemolytica A1 (log phase). Five vs. three inoculations.
Rectal temperatures (group mean) of calves given five (●—●) or three (■—■) inoculations.

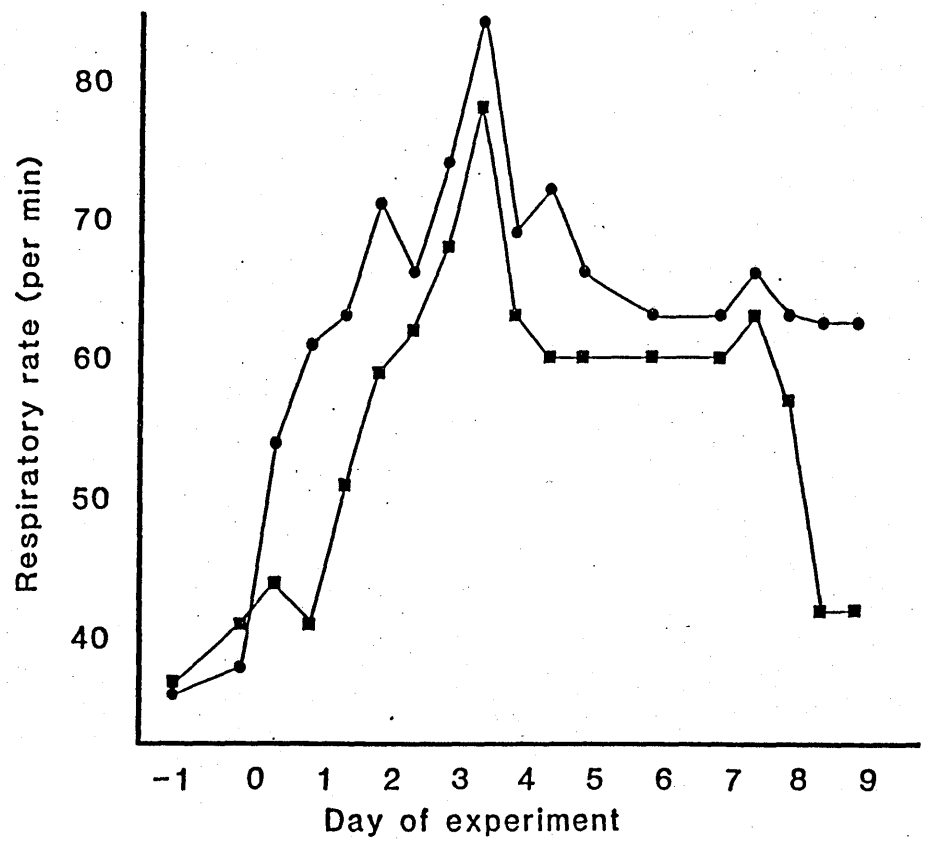

Figure 21

Experiment 4: P.haemolytica A1 (log phase). Five vs. three inoculations.
Respiratory rates (group mean) of calves given five (●—●) or three (■—■) inoculations.

Microbiology (live calves)

Pasteurella haemolytica A1 was not isolated from any calves prior to inoculation, but was isolated from all sampled calves, two, four and seven days p.i.i.. No other potential respiratory pathogens were isolated.

Serology

All calves had reciprocal serum titres of two or less prior to inoculation with P.haemolytica A1. Seroconversion occurred in the four surviving calves, two from each group, by day seven and the titres were maintained or had increased until slaughter on days eight and nine.

No seroconversions occurred to BHV-1, P13 virus or RS virus, and in the majority of calves titres to these microorganisms fell throughout the experimental period.

Pathology (including microbiology)

Fibrinous pneumonia and Pasteurella nodules were found in all calves from both groups at post-mortem examination. Fibrinous pleurisy was found in all the calves that received five doses of P.haemolytica A1 and in three of the four calves that received three doses. In both groups pleural adhesions were seen in all but one of the calves with fibrinous pleurisy. An acute exudative reaction was seen in three calves from each group, and all calves from both groups had dilated interlobular septa with fibrin. Vasculitis and arteritis was seen in one calf from each group, and one calf in the five-dose group had lesions of cuffing pneumonia.

Pasteurella haemolytica A1 was isolated from the upper and lower respiratory tracts of all calves irrespective of the number of inoculations. The organism was isolated from 19 out of a possible 20 sites in the respiratory tract and from seven of a possible 12 sites in the associated lymphatic tissue, from the calves in the five dose group. The comparable figures for the three dose group were 14 and four sites respectively.

No other potential respiratory pathogens were isolated.

Pasteurella haemolytica A1, comparison of infected calves with sterile broth, killed culture and environment controls.

(Experiment 5, Appendix 43)

The previous two experiments had indicated that inoculation of a log-phase culture of Pasteurella haemolytica A1 reproduced bovine pneumonic pasteurellosis. The experimental disease was indistinguishable from that seen in field cases on clinical, microbiological and pathological grounds.

Several other workers had suggested that endotoxin may be important in the pathogenesis of the disease, and this together with the need to investigate the effect of infection on food intakes prompted this experiment with several groups of control calves.

Clinical signs

All the calves were clinically normal before inoculation, and the calves which received only sterile broth remained bright and healthy throughout the experiment. The killed culture control group calves were all bright until day five when one calf became dull, but not inappetent, and remained so until day nine when it was slaughtered, the other three calves in the group remained normal throughout. Within six hours of the initial inoculation all the calves inoculated with P.haemolytica A1 were depressed, they stood dejectedly with drooping ears and failed to respond to gentle stimulation (Fig. 22). By 48 hours after the initial inoculation they were reluctant to move (Fig. 23), whereas the sterile broth controls by comparison were clinically normal (Fig. 24). The P.haemolytica A1 infected calves remained dull, although by the seventh day after inoculation they were more willing to rise and feed. The environmental control calves were all bright until day four after inoculation when the two surviving calves became dull and depressed, both remained

Fig. 22. Pasteurella haemolytica A1 infected calf, 6 hours after the initial inoculation.

Fig. 23. *Pasteurella haemolytica* A1 infected calves, 48 hours after the initial inoculation.

Fig. 24. Sterile broth control calves, 48 hours after the initial inoculation.

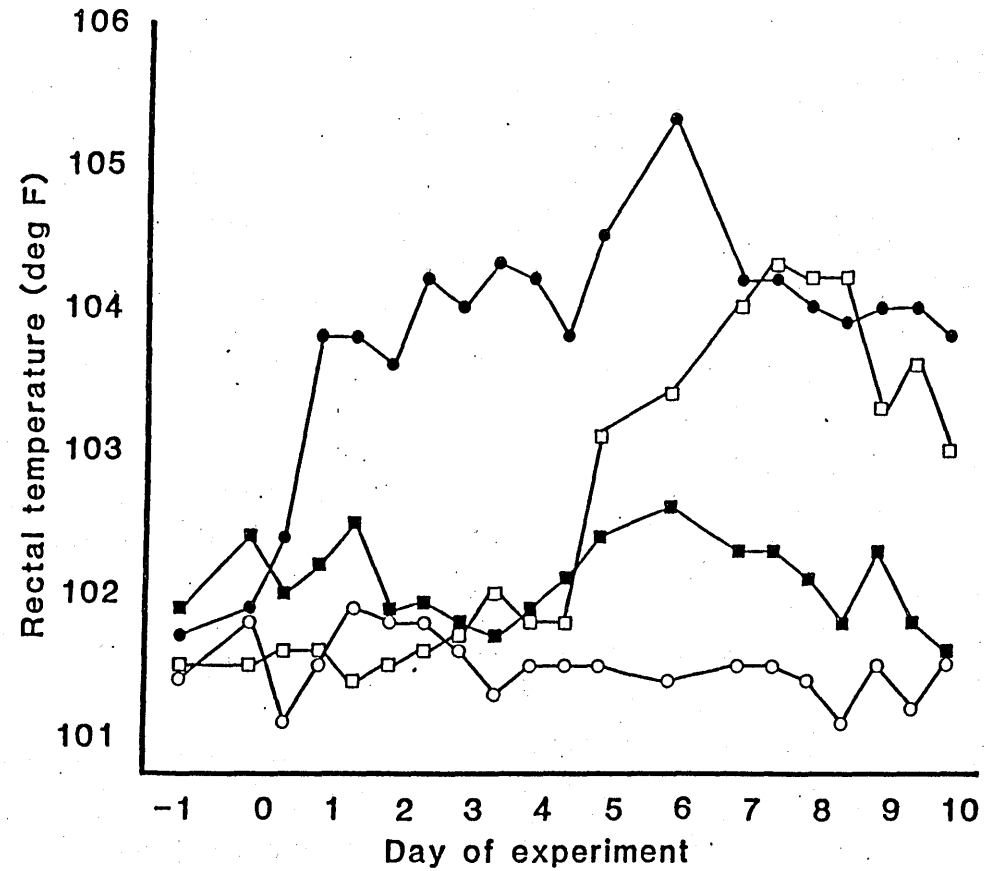

Figure 25

Experiment 5: P.haemolytica A1 (log phase) and control groups.

Rectal temperatures (group mean) of P.haemolytica A1 infected (●—●), sterile broth (○—○), killed culture (■—■) and environmental control (□—□) calves.

so until slaughter on days nine and 10.

The rectal temperatures of all calves were within the normal range for the 14 days prior to the commencement of the experiment, and the rectal temperatures of all calves in the sterile broth control group remained so throughout the experiment (Fig. 25).

Two of the calves inoculated with a heat-killed culture of P.haemolytica A1 had rectal temperatures that remained within the normal range throughout the experiment. Of the two other calves in this group one was pyrexic (104.2°F) immediately prior to the first inoculation and remained so until the afternoon of day two when its temperature returned to normal, the other became pyrexic (103.6°F) on day six and remained so until day eight when its temperature returned to normal.

All the calves infected with P.haemolytica A1 were pyrexic (>103.2°F) within 30 hours of the initial inoculation, and all had rectal temperatures of 104.0°F or above by 54 hours after the initial inoculation. All calves in this group remained pyrexic for the duration of the experiment and individual maximum temperatures were 104.5°F and 104.2°F for the animals killed on days two and three and 105.7°F and 104.8°F for calves killed on days nine and 10.

The rectal temperatures of the calves within the environmental control group were within the normal range until day five when one of the two surviving calves became pyrexic (103.6°F); the other calf became pyrexic on day seven (104.0°F); both remained febrile until slaughter.

In the pre-infection period all but one of the calves had respiratory rates within the normal range (25-40/min). The other calf had a consistently higher respiratory rate (50-60/min) slight hyperpnoea and coughed occasionally when raised. Following inoculation of sterile broth none of the calves in that group showed any change in respiratory rate, this included the calf

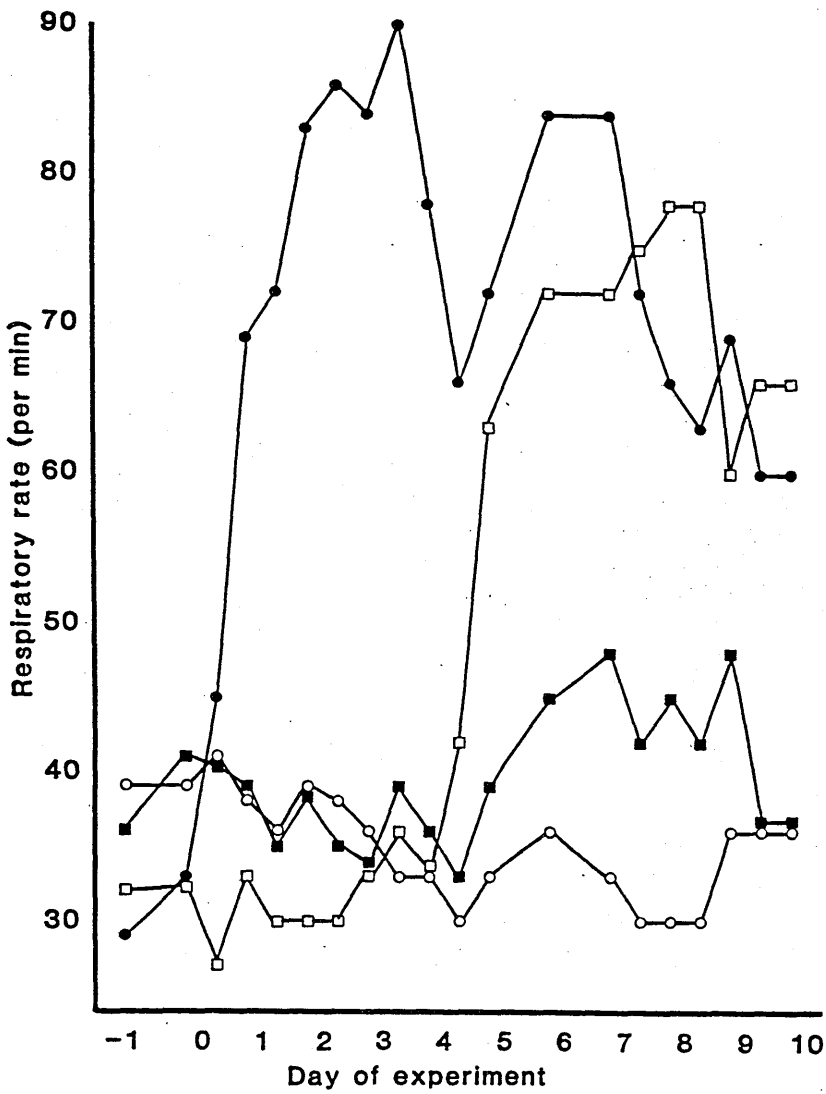

Figure 26

Experiment 5: P.haemolytica A1 (log phase) and control groups.

Respiratory rates (group mean) of P.haemolytica A1 infected (●—●), sterile broth (○—○), killed culture (■—■) and environmental control (□—□) calves.

mentioned above with the high respiratory rate whose condition remained unchanged (Fig. 26). Two of the killed culture control calves had normal respiratory rates until slaughter; a third calf developed a slight tachypnoea (never in excess of 50/min) which coincided with its pyrexic episodes but it was clinically normal in all other respects. The fourth killed culture control calf became tachypnoeic (50/min) on day five and remained so until slaughter, the tachypnoea and previously mentioned pyrexia tended to be concurrent. This calf also showed an increasing amount of hyperpnoea.

By 24 hours after the initial inoculation of P.haemolytica A1 all four calves in the group were tachypnoeic (40-84/min); respiratory rates continued to rise such that by 48 hours after initial inoculation the rates were between 70 and 100 per minute. This degree of tachypnoea was maintained by all calves throughout the experimental period. The highest respiratory rate recorded was 100 per minute and several calves attained this figure on several occasions between days one and six.

Coughing was never a major clinical feature, and was recorded only occasionally from day four onwards. By day three after inoculation the surviving P.haemolytica A1 infected calves had a bilateral nasal discharge, clear with purulent flecks, which was present in small amounts for the rest of the experimental period (Fig.27). On auscultation of the infected group harsh respiratory sounds were detected anteroventrally from day two onwards, but no adventitious sounds were heard.

The respiratory rates of the environmental controls were within the normal range until the afternoon of day four when a slight tachypnoea (40/min) was recorded in the two surviving calves. Thereafter both calves became increasingly tachypnoeic reaching maximum rates of 84 per minute on days six and seven respectively. Occasional coughing and the presence of a clear nasal discharge with purulent flecks was noted in both calves from day six onwards.

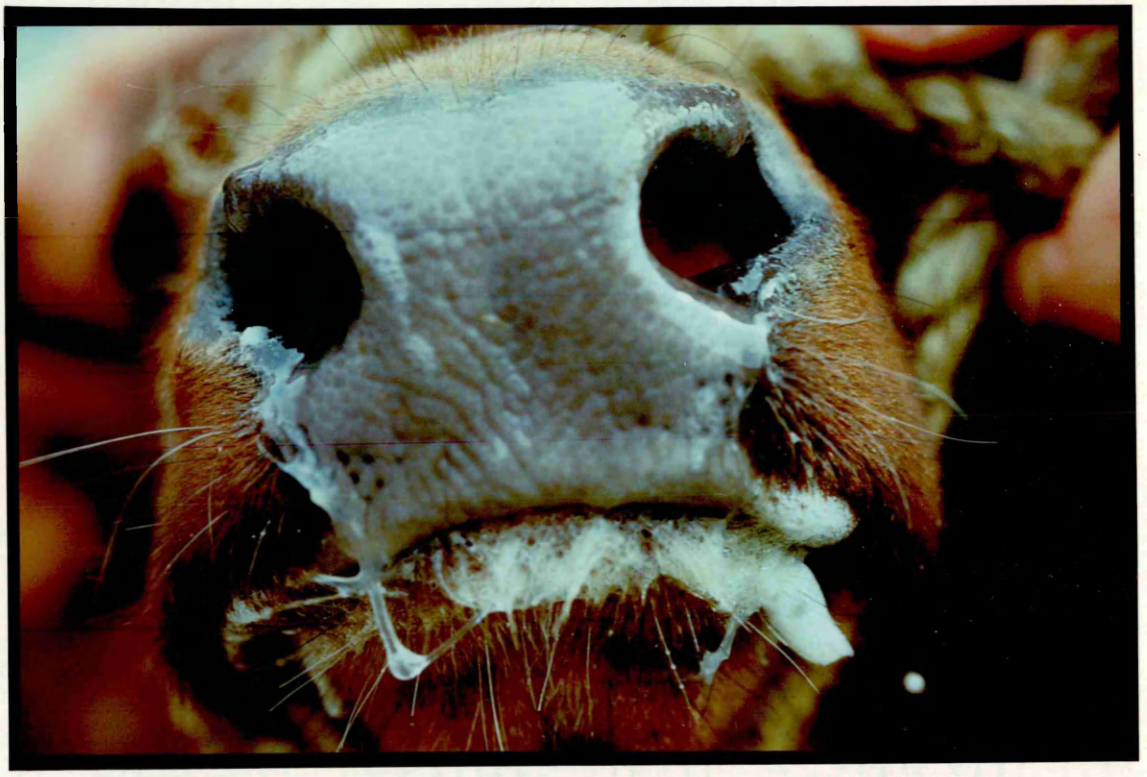

Fig. 27. Nasal discharge seen in P.haemolytica A1 infected calves.

The mean daily food intakes for each group are shown in Fig.28; these indicate the feed consumption over the previous 24 hours, thus the intake for day one represents the feed intake during the 24 hours previous to 0900 hours on that day.

All calves were gradually introduced to ad libitum concentrate feeding during the 14 days prior to infection, and their stabilised intake on the day immediately preceding initial inoculation was in the order of two kg of concentrate eaten per 50 kg liveweight of calf.

The sterile broth controls showed a slight fall in food intake during the first two days after initial inoculation but had regained their pre-inoculation level of intake by day three and were eating three kg of concentrate per 50 kg liveweight by the end of the experimental period.

The killed culture controls demonstrated a similar slight fall in food intake followed by a return to normal by day three. However a subsequent fall in intake was seen between days five and nine which coincided with the period of dullness, fever and respiratory signs in calf one. The other surviving calf in this group had a normal food intake.

The food intake of the calves inoculated with P.haemolytica A1 fell from 2.25 kg per 50 kg liveweight for the 24 hour period immediately pre-inoculation to 0.99 kg per 50 kg liveweight for the equivalent period ending on day one; thereafter the food intake remained severely depressed for the remaining experimental period.

The environmental controls did not show any significant reduction in food intake over the first four days after inoculation. However, on day five, the food intake fell from 1.75 kg per 50 kg liveweight the previous day to 1.36 kg per 50 kg liveweight; this decrease coincided with the onset of dullness, fever and respiratory signs in the surviving calves. Their food intake then returned to within the expected range by day nine.

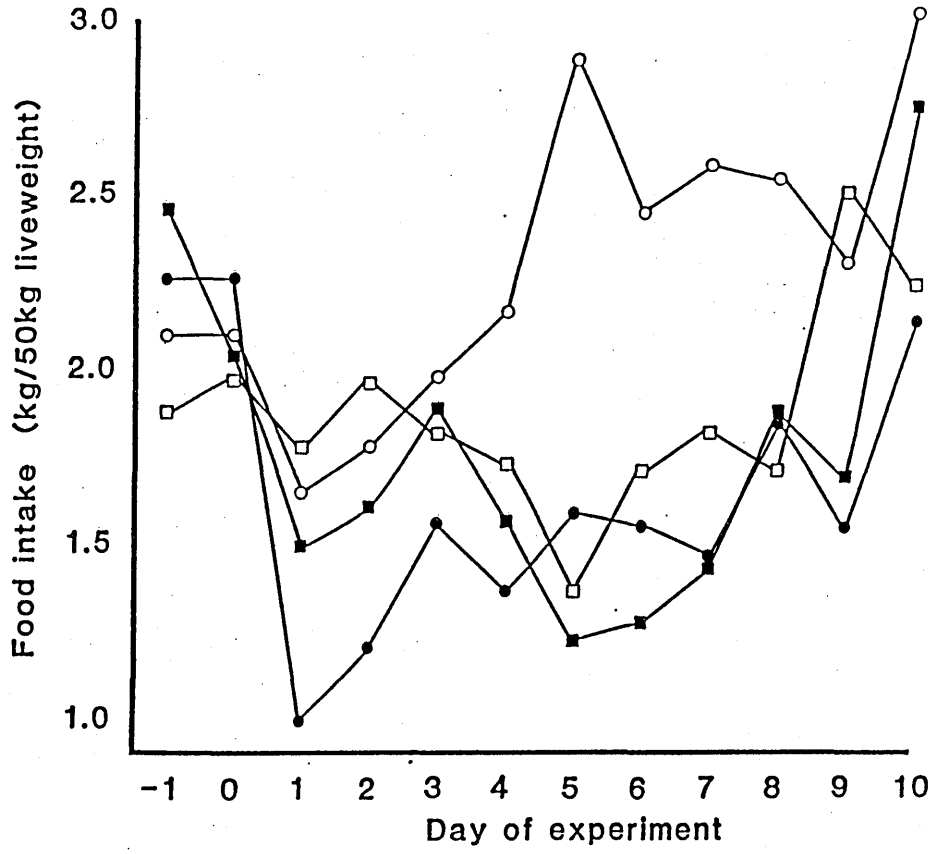

Figure 28

Experiment 5: P.haemolytica A1 (log phase) and control groups.

Food intake (group mean) of P.haemolytica A1 infected (●—●), sterile broth (○—○), killed culture (■—■) and environmental control (□—□) calves.

Microbiology (live calves)

Pasteurella haemolytica A1 was not isolated from the nasopharyngeal swabs taken from any of the calves during the 14 days before infection, and no other serotypes of P.haemolytica were isolated. Pasteurella multocida type A was isolated from four calves on one occasion seven days before inoculation, and a single isolation of Mycoplasma bovis was made pre-inoculation on day zero. Pasteurella haemolytica A1 was never isolated from any calf in the sterile broth or killed culture control groups. Other potential respiratory pathogens were not isolated either pre- or post-inoculation from any of the calves using nasopharyngeal swabs.

Pasteurella haemolytica A1 was consistently isolated in large numbers from nasopharyngeal swabs taken from all the calves inoculated with log-phase culture of P.haemolytica A1 from six hours after the last inoculation until day eight of the experiment.

No significant respiratory pathogens were isolated from swabs taken from the two environmental control calves killed on days two and three, and which remained clinically normal; but P.haemolytica A1 was isolated on day four and day seven respectively and consistently thereafter from the two surviving calves which became dull, febrile and pneumonic.

Serology

Highly significant seroconversions occurred in the calves inoculated with P.haemolytica A1 with reciprocal titres increasing from four or less immediately pre-inoculation to greater than 128 within five to eight days and reaching 256 immediately prior to slaughter.

An increase in titre also occurred in the two environmental control calves which became dull and pneumonic from day four onwards as a result of infection with P.haemolytica A1, probably by horizontal transmission.

None of the calves seroconverted to P.haemolytica A2, P.multocida type A, Mycoplasma bovis, BHV-1, PI3 virus or BVD-MD virus during the experimental period. All the calves were seropositive for RS virus on at least one occasion during the experimental period but, although several showed an increase in titre, only one calf had seroconverted by day nine.

Pathology (including microbiology)

Only two of the calves inoculated with sterile broth were found to have macroscopic pulmonary lesions at post-mortem; one calf slaughtered on day two had mild lesions of cuffing pneumonia in the anterior lobes, and the other, slaughtered on day three had a few areas of acute exudative pneumonia. Three of the calves inoculated with killed culture had lesions of pneumonia; two had moderately severe areas of grey/fawn firm pulmonary consolidation, microscopically a proliferative bronchiolitis and alveolitis with a moderately severe exudative reaction, and the other calf had mild lesions of cuffing pneumonia.

Significant bacteria, mycoplasmas and viruses were not isolated from any respiratory tract tissues of calves inoculated with either sterile broth or killed culture and tissues from all animals in both groups were negative for PI3 virus, RS virus and P.haemolytica A1 by immunofluorescence.

In the P.haemolytica A1 infected group of calves, the lesions seen in the two calves slaughtered on days two and three of the experiment were similar, involving approximately 70 per cent of the anterior lobes (Fig.29); the lesions varied from greyish purple to deep reddish purple, and the pleura and interlobular septa were slightly thickened and gelatinous. On section the lesions were firm and oedematous, and many areas were more solid and haemorrhagic with pale centres, these latter areas were often lobular in distribution. Microscopically there was a severe acute inflammatory reaction with flooding of the alveoli with oedema, neutrophils, macrophages, (Fig.30) and

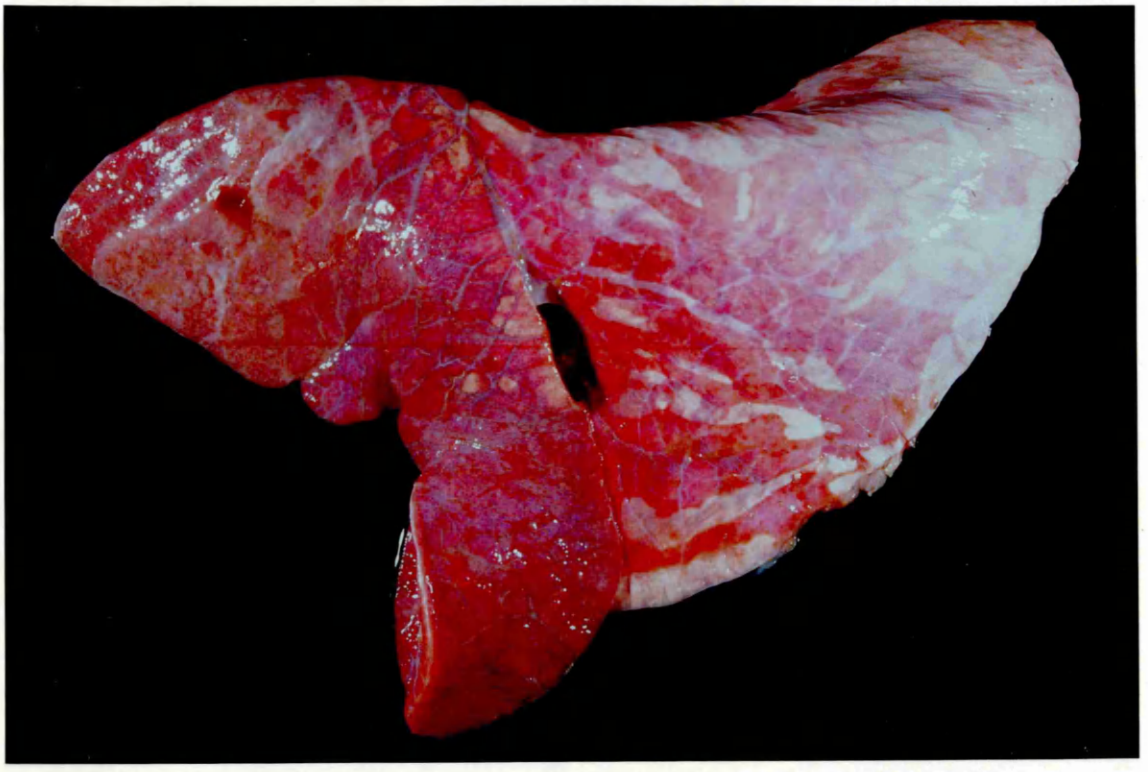

Fig. 29. Lungs from P.haemolytica A1 infected calf slaughtered on day three, showing consolidation and dilatation of interlobular septa.

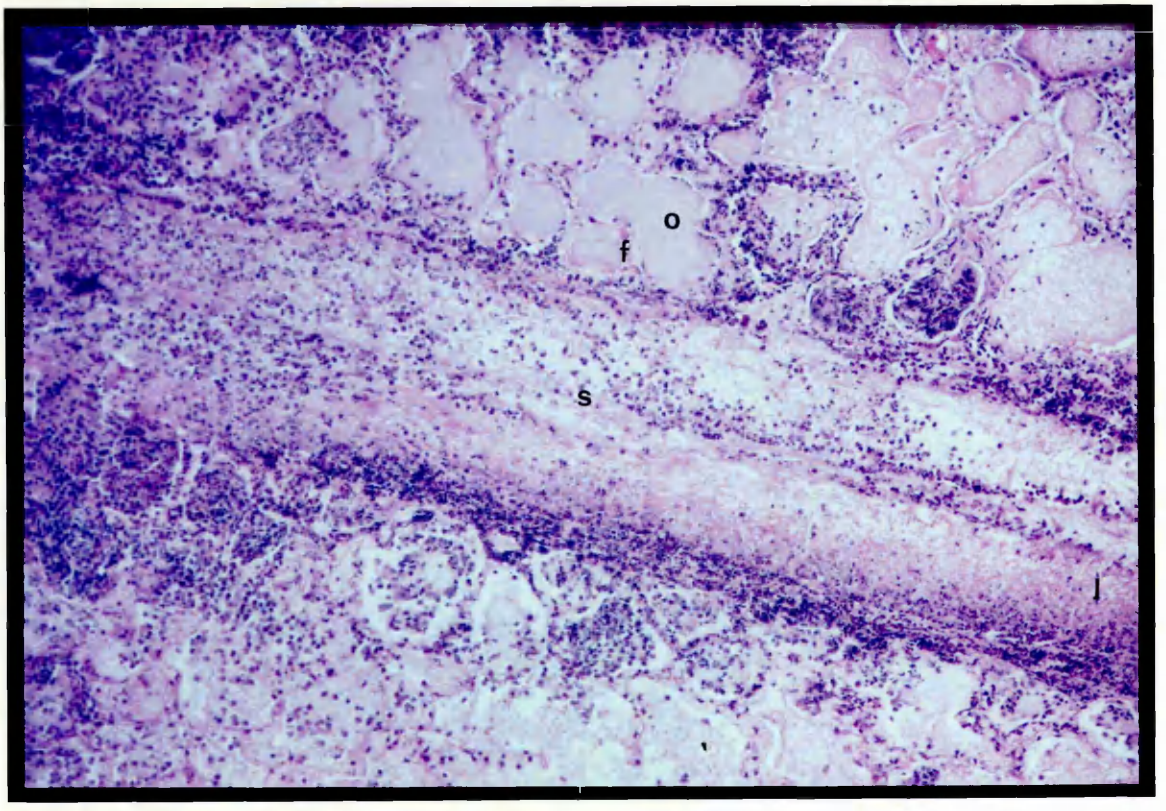

Fig. 30. Flooding of alveoli with oedema[o] and fibrin[f] and associated septal reaction[s], P.haemolytica A1 infected calf killed day three.
(Haematoxylin and eosin x 100)

intraalveolar haemorrhage. Classical fibrinous pneumonia was seen in many lobules, with alveoli filled with oedema and networks of fibrin, whilst other alveoli contained a mixture of neutrophils and macrophages, many of which could be described as oat cells, and which were prevalent in alveoli close to interlobular septa. Many bronchioles were plugged with exudate and there were often foci of epithelial necrosis. The interlobular septa and lymphatics were dilated with oedema and clots of fibrin.

The lungs of the calves examined on day nine and day ten after inoculation were similar with lesions involving about 60% of the anterior lobes. The affected areas were nodular (Fig. 31) because of the presence of hard, gritty lumps covered by thickened pleura. Some nodules had an overlying fibrinous pleurisy and many were present within non-pneumonic tissue. On section the nodules were dry and crumbly with extensive tissue necrosis and enclosed within a fibrous capsule. The associated interlobular septa were dilated and filled with thick gelatinous exudate. Microscopically the nodules were foci of well-defined fibrinous pneumonia (Fig. 32) surrounded by a thick layer of fibrous tissue. Immunofluorescent staining indicated that P.haemolytica A1 was usually confined to the nodules, especially when these nodules were within non-pneumonic tissue.

Tissues from all four calves in this group were negative for PI3 virus and RS virus by immunofluorescence.

Large numbers of P.haemolytica A1 were isolated from all but one of the respiratory tract sites in both of the calves killed on days two and three; the calves killed on days nine and ten had large numbers of the organism in the right cranial and right middle lobes, and one of these calves also had large numbers in the right caudal lobe. No other significant respiratory pathogens were isolated from these calves.

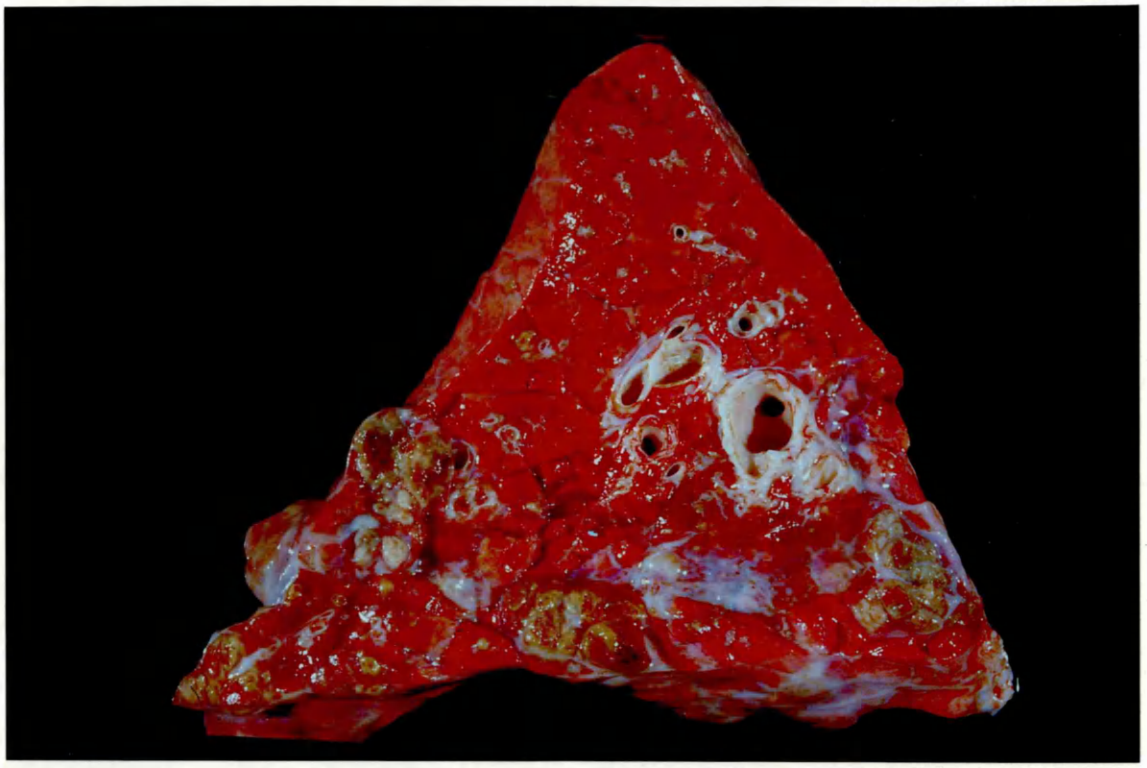

Fig. 31. Transverse section of lung from P.haemolytica A1 infected calf killed day nine with multiple Pasteurella nodules

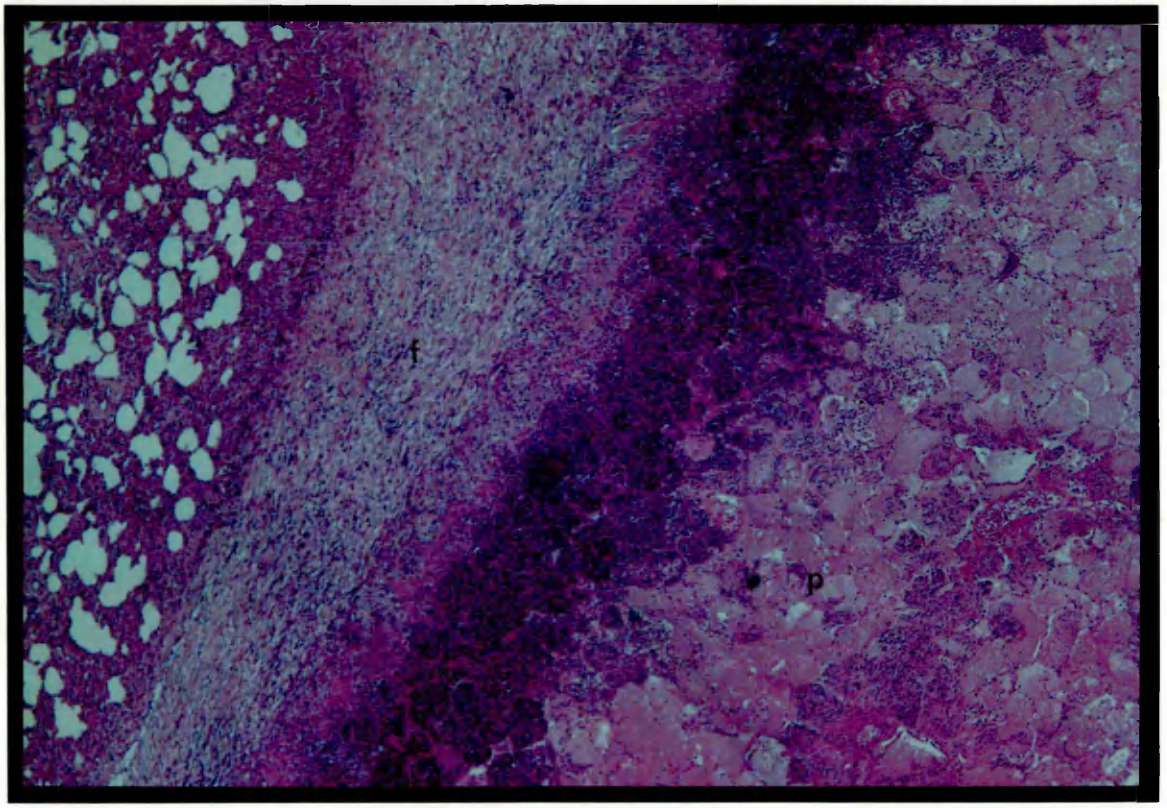

Fig. 32. Section at margin of nodule from P.haemolytica A1 infected calf killed day nine; focus of fibrinous pneumonia[p] with peripheral cellular[c] and fibrous reaction[f]

The two calves from the environmental control group slaughtered on days two and three had only a few consolidated lung lobules, which were shown microscopically to be mild lesions of cuffing pneumonia. The calf from this group killed on day nine had severe anterior lobe consolidation with fibrinous pleurisy, fibrinous pneumonia and several well defined nodules, the other calf, killed on day ten had fibrinous pneumonia but no nodular lesions were detected.

The calves from this group killed on days two and three were negative for P.haemolytica A1, PI3 virus and RS virus by immunofluorescence, and P.haemolytica A1 was not isolated from the respiratory tract. In contrast the two calves killed on days nine and 10 had large numbers of P.haemolytica A1 cultured from their respiratory tracts, and both were positive by immunofluorescence. However, both calves were negative for PI3 virus and RS virus by immunofluorescence.

No other potential respiratory pathogens were isolated from any of the calves in this group.

Pasteurella haemolytica A1: a comparison of strain M/C in log-phase culture with strain S/C in stationary phase culture

(Experiment 6, Appendix 44)

This experiment was conducted to ascertain whether the isolate of P.haemolytica A1 used experimentally in stationary phase culture in the first two experiments, where it produced only minimal clinical signs and pathological lesions, could produce overt disease and pathology when inoculated in log-phase culture. Similarly the effect on pathogenicity of the second isolate by using it in stationary phase culture was assessed.

Clinical signs

Within six hours of inoculation the calves inoculated with a log-phase culture of P.haemolytica A1 (M/C) were dull, depressed and reluctant to feed, and all

remained so for the duration of the experiment. In contrast the calves inoculated with a stationary phase culture of P.haemolytica A1 (S/C) showed only a slight degree of dullness post-inoculation and continued to feed throughout the experiment.

The rectal temperatures of both groups of calves had increased by six hours after the initial inoculation, to group mean values of 103.7°F for the log-phase culture and 104.4°F for the stationary phase culture. After a small overnight fall, rectal temperatures of both groups continued to increase, peaking on day four for the log-phase group (105.4°F) and on days three and four (105.7°F) for the stationary phase group (Fig. 33). Individual maxima were 106.6°F for both the log-phase and stationary phase culture groups. The temperature response in both groups was similar in pattern, the stationary phase group attaining slightly higher values.

The respiratory response of the two groups, however, was markedly different. The log-phase culture group showed an increase in group mean respiratory rate from 38 per minute immediately pre-inoculation to 57 per minute by six hours after inoculation and continued to increase to 75 per minute, 24 hours after the initial inoculation. The group maximum mean respiratory rate was 87 per minute, 48 hours after the initial inoculation, the maximum individual calf respiratory rate was 96 per minute. The calves in this group remained tachypnoeic for the duration of the experiment (Fig. 34).

The calves inoculated with a stationary phase culture showed only a slight increase in respiratory rate from 24 hours to five days after the initial inoculation. The maximum mean value for this group was 48 per minute on days two and four with individual maxima of 48 on several days post inoculation.

Only occasional coughs were heard from both groups of calves and a low-grade mucoid to mucopurulent nasal

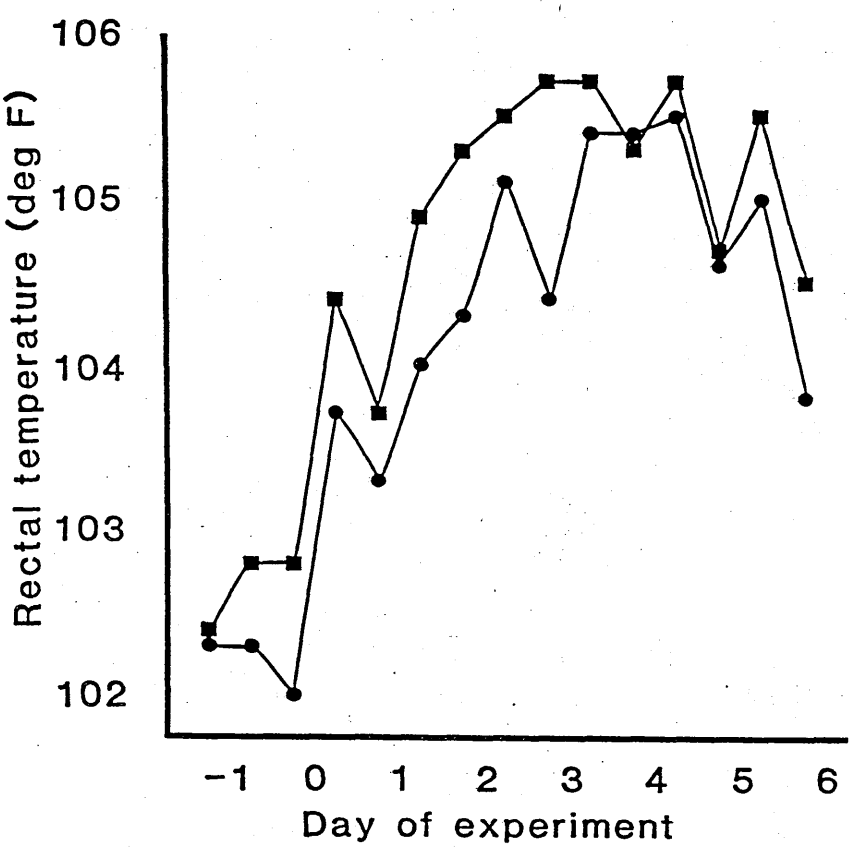

Figure 33.

Experiment 6: P.haemolytica A1, comparison of log phase M/C with stationary phase S/C.

Rectal temperatures (group mean) of calves infected with log phase M/C (●—●) and stationary phase S/C (■—■).

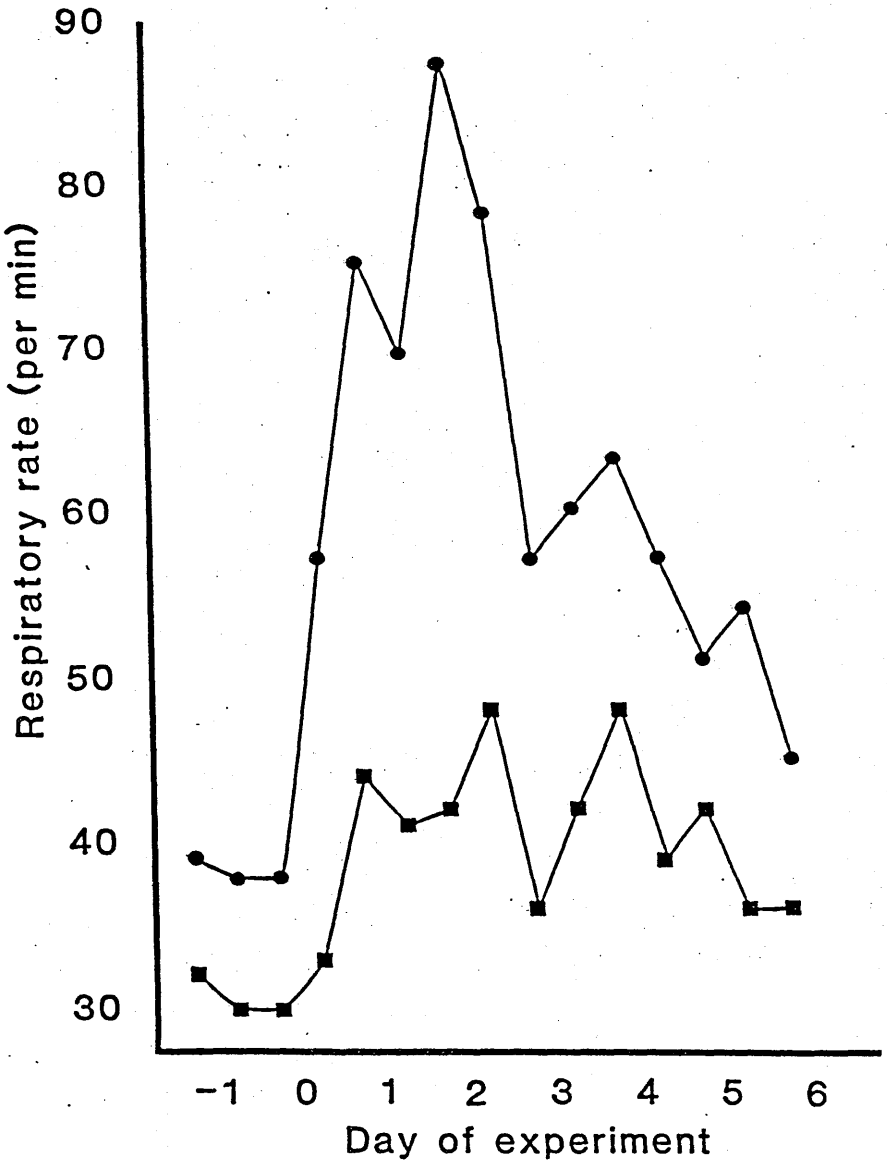

Figure 34

Experiment 6: P.haemolytica A1, comparison of log phase M/C with stationary phase S/C.

Respiratory rates (group mean) of calves infected with log phase M/C (●—●) and stationary phase S/C (■—■).

discharge was seen in both groups, the log-phase culture group was most commonly affected.

Microbiology (live calves)

Pasteurella haemolytica A1 was not isolated from any of the eight calves prior to inoculation with either log-phase or stationary phase culture, but the respective inoculum strain was isolated from nasopharyngeal swabs from all surviving calves on two or more occasions on three samplings over days three, four and five.

No other significant pathogens were isolated from nasopharyngeal swabs.

Serology

All calves, from both groups, killed on day six had seroconverted to P.haemolytica A1.

Pathology (including microbiology)

Two calves that had been inoculated with stationary phase culture were killed on day three; both had lesions of fibrinous pneumonia but these were only focal in distribution, the interlobular septa showed only mild dilatation, and only one of the calves had an acute exudative reaction. The two comparable calves inoculated with log-phase culture both had widespread fibrinous pneumonia, marked dilatation of the interlobular septa and an acute exudative reaction. One of these log-phase calves also had nodules.

Of the stationary phase culture calves killed on day six, one had widespread fibrinous pneumonia with septa dilatation and an acute exudative reaction, whilst in the other calf the lesions were restricted to nodules of fibrinous pneumonia. The two log-phase culture calves killed at this time both had nodules present.

Fibrinous pleurisy was seen in one of the stationary phase (day 6) and two of the log-phase culture calves (days 3 and 6). Oat cells and vasculitis were seen once in calves killed on day six after inoculation with stationary phase culture and cuffing pneumonia was present in three calves in this group and two calves in the log-phase group.

The respective inoculating strains of P.haemolytica A1 were isolated from the upper and lower respiratory tracts of all calves with the exception of one calf in the stationary phase group. However, the isolations were more widespread, numerous and consistent from the respiratory tracts of the log-phase culture calves.

SECTION IV

DISCUSSION

The aim of the above experimental studies was to develop a model for the disease described in North America as shipping fever and in Britain as transit fever. Most previous models were based on the theory of Hoerlein and Marsh (105) that, although the final and fatal lesion was that of bovine pneumonic pasteurellosis, predisposing factors such as infections, viral or otherwise, and stressors either physical or chemical, were essential for the development of the disease.

This hypothesis of multiple aetiology was followed in the design of the first three experiments undertaken in this study of experimental bovine pneumonic pasteurellosis when a virus, parainfluenza 3 (isolated from a pathologically confirmed incident of PI3 pneumonia in weaned dairy calves), hormonal and physical stress, and a nematode, Dictyocaulus viviparus were used in combination with P.haemolytica A1. Stationary phase cultures of P.haemolytica A1 were used in the first two of these three experiments and a log-phase culture in the third experiment.

In the first experiment a strain of PI3 virus, known to produce clinical respiratory disease under experimental conditions, was given alone and in various combinations with P.haemolytica A1. The calves which were inoculated with both PI3 virus and P.haemolytica A1 showed marginally higher rectal temperatures and respiratory rates than those calves given PI3 virus alone, but there was no dramatic difference in clinical signs. No classical pathology associated with pneumonic pasteurellosis (i.e. fibrinous pneumonia) was seen at post-mortem although occasional calves given both agents had a mild degree of septal dilatation.

In experiment two, the use of a stress model was investigated. The method using intratracheal acetic acid and alternate hot and cold hosing was described in an evaluation of a tetracycline formulation as treatment for pneumonic pasteurellosis following stressing and inoculation of P.multocida (34). This was compared with a hormonally-induced stress model using injected corticosteroids (betamethasone and dexamethasone) used in a regime similar to that described by Saunders and Berman (177). Increases in rectal temperature and respiratory rate were seen in both groups that were inoculated with P.haemolytica A1 irrespective of the stressors used. However, although the group mean respiratory rates increased significantly, the increase in rectal temperatures did not rank as significant pyrexia and the calves were never dull. Calves were killed from the groups that received corticosteroids plus either sterile broth or a stationary phase culture of P.haemolytica A1. No lesions were present in the lungs of the calf that received the sterile broth, but both calves that received P.haemolytica A1 had small foci of pneumonic consolidation, and one had, in addition, small amounts of fibrin in the interlobular septa. However, once again the experiment failed to produce a disease that resembled pneumonic pasteurellosis on either clinical or pathological grounds.

The attempted reproduction of the disease with a known pathogenic strain of PI3 virus and stationary phase culture of P.haemolytica A1 isolated from farm two, where PI3 virus was also thought to be involved, had been unsuccessful, as had attempts with the stress model. Reports of pneumonic pasteurellosis in sheep, where PI3 virus appeared to be an essential component in the experimental reproduction of the disease, indicated that evidence of concomitant viral infection in field cases was lacking (27).

Evidence gathered at this stage from field investigations indicated that pneumonic pasteurellosis was a distinct disease entity characterised by severe febrile

pneumonia and extensive and distinctive associated pathology. An outbreak of pneumonic pasteurellosis in bucket fed month-old dairy calves was investigated and P.haemolytica A1 was isolated from the lungs of several affected calves that had lesions of fibrinous pneumonia and pleurisy. Soon after this disease outbreak Baluyat and others (22) published a description of cytotoxin production by P.haemolytica during the log-phase of the growth cycle. This cytotoxin was capable of killing neutrophils, a property of P.haemolytica that had been demonstrated earlier (24), and mononuclear leucocytes (183), and had also been shown to be toxic for alveolar macrophages (144). In view of this report of cytotoxin production and the hypothesis that it may be responsible for the pathogenic effects of P.haemolytica in cattle, the decision was taken to use log phase cultures in experiments in the future. The recent isolation of what appeared to be a highly pathogenic strain, on clinical and pathological grounds, from the bucket-reared calves produced the ideal P.haemolytica A1 isolate to test the log-phase cytotoxin theory. This isolate was then used in log-phase culture for the subsequent experiments.

Experiment three compared the effects of inoculation of a log-phase culture on calves that had been infected experimentally with Dictyocaulus viviparus third stage larvae and had either entered the post-patent phase of the disease or had been treated with diethylcarbamazine in the prepatent phase of the disease. Clinical signs were seen in both groups of calves, pyrexia was more marked in the untreated calves, but the increase in respiratory rate was greater in the calves that had been treated. All the calves were dull, depressed and anorexic after the inoculation of P.haemolytica A1. At post-mortem examination fibrinous pneumonia, fibrinous pleurisy and nodules were found in all the calves inoculated with P.haemolytica A1, irrespective of whether they had been treated with anthelminthic or not. The infecting strain of P.haemolytica A1 was recovered from the lower respiratory tract of all calves at post-mortem, 75% of

sites in the untreated calves and 58% of the diethylcarbamazine treated group. All the calves killed nine days after the initial inoculation of P.haemolytica A1 had seroconverted to P.haemolytica A1. Some of the calves in this experiment were killed after only three doses of P.haemolytica A1, and were clinically pneumonic and had lesions of fibrinous pneumonia at post-mortem.

Thus pneumonic pasteurellosis had been successfully reproduced using P.haemolytica A1 alone, in log-phase culture, inoculated into conventional weaned dairy and dairy cross calves (aged three months) with reciprocal serum titres (using an IHA test) to P.haemolytica A1 of 16 or less.

Experiment four was conducted to compare a dosage regime of five doses with a three dose regime, as one possible reason for the success of the model could be the large numbers of P.haemolytica A1 inoculated and any reduction in challenge would be a refinement of the model. The five dose model delivers a total possible dose of $4x10^{13}$ bacteria and because of the routes of inoculation a substantial proportion of this is probably lost by being coughed up and swallowed. For this experiment calves were selected with pre-inoculation reciprocal serum titres of 4 or less as an attempt to standardise the experimental infection.

Clinical signs consistent with those of bovine pneumonic pasteurellosis were seen and fibrinous pneumonia was demonstrated at post-mortem in all the calves that had received either three or five infecting doses of P.haemolytica A1. However, the clinical response and the pathological lesions were more consistent in the five dose group than the three dose group. All calves in both groups had seroconverted by the seventh day after the initial inoculation of P.haemolytica A1. In addition the inoculated strain of P.haemolytica A1 was consistently isolated from nasopharyngeal swabs post-inoculation and from the tissues of the upper and lower respiratory tract post-mortem. The

use of this isolate of P.haemolytica A1 in an experimental situation was fortuitous as it had an unusual antibacterial sensitivity pattern and could therefore be readily re-identified as the infecting strain of organism and not a contaminating field strain.

Once the experimental reproduction of bovine pneumonic pasteurellosis had been established a fully controlled experiment was carried out in order to compare the clinical and pathological features of the P.haemolytica A1 infected calves with those that received equivalent inoculations of killed culture, sterile broth and environmental controls. The clinical signs of dullness, anorexia, pyrexia and pneumonia were seen in the P.haemolytica A1 infected calves and fibrinous pneumonia, sometimes with pleurisy and nodules, was found at post-mortem examination. No clinical signs attributable to bovine pneumonic pasteurellosis were seen in either the sterile broth or killed culture control calves. The sterile broth calves remained normal throughout but occasional calves in the killed culture control group were pyrexic (one before initial inoculation) and tachypnoeic. However, these calves were never dull and could not be mistaken on clinical examination for cases of pneumonic pasteurellosis.

The calves were housed in a row of five conventional looseboxes, one group per loosebox; the relative positions being infected calves, environmental controls, feed store, sterile broth and killed culture. On day five one of the two surviving environmental control calves became pyrexic and went on to develop the classical clinical signs of bovine pneumonic pasteurellosis, and its pen-mate did likewise. At post-mortem pneumonic pasteurellosis was confirmed and the strain of P.haemolytica A1 isolated in life from nasopharyngeal swabs and post-mortem from the tissues of the respiratory tract was identical to that used to inoculate the infected calves in the adjacent loosebox. The experimentally infected calves were always handled last and strict hygiene was observed so it would be unlikely

that direct transfer of infection by personnel, buckets etc. had occurred, as any breakdown should have resulted in the spread of infection to other groups. Therefore it seemed likely that infection had spread between the two adjacent looseboxes through a common ventilating airspace at the ridge.

All the experimentally infected calves had seroconverted by day four after the initial inoculation and had high reciprocal titres (256) by days nine and ten. The naturally infected calves also seroconverted by days seven and ten respectively.

The spread of infection of the same, identified, strain of P.haemolytica A1 to environmental controls by horizontal transmission indicated that the infecting strain of P.haemolytica A1 was capable of producing severe pneumonic pasteurellosis in calves, satisfying rigorous clinical, pathological, microbiological and serological criteria, by air-borne transmission without the need for experimental inoculation. This finding invalidated the implied criticism of other workers (242) that pneumonic pasteurellosis was being produced by the inoculation method because of the large numbers of organisms involved and not because P.haemolytica A1 is a potent pathogen in its own right.

Experiment six was conducted to compare the effect of log-phase culture of isolate M/C used in experiments one and two (where it was used, unsuccessfully, in stationary phase) with a stationary phase culture of the isolate S/C used in experiments three to five (where it was used in log phase culture). The log phase culture of the M/C isolate behaved in a similar manner to log-phase culture of S/C by reproducing clinical disease (dullness, pyrexia and pneumonia), pathology (fibrinous pneumonia, pleurisy and nodules), seroconversions and recovery of the organism from the upper and lower respiratory tract at post-mortem. In contrast, the stationary phase culture of S/C produced a different response to that seen either

itself as log-phase culture or as M/C in stationary phase culture. The calves inoculated with stationary phase culture of S/C had a temperature response similar to log-phase S/C and log-phase M/C but remained bright and did not demonstrate any marked increase in respiratory rate. Despite this low-grade clinical response, lesions of fibrinous pneumonia, pleurisy and nodules were demonstrated at post-mortem and the organism was isolated from sites throughout the respiratory tract.

There are several possible reasons for the discrepancies in clinical response and pathological findings between the different isolates in different phases of culture. The M/C strain in stationary phase culture was isolated from an outbreak of bovine pneumonic pasteurellosis in which P13 virus was also implicated, whereas the S/C strain was isolated from an incident where no other respiratory pathogens were involved. It is probable that there are differences in the innate pathogenicity of these strains, possibly related to cytotoxin production or other as yet unrecognised pathogenic markers which are responsible for the difference in calf response, which has been noted in this and other studies (231). However, the stationary phase S/C strain did not produce dullness or a significant increase in respiratory rate so different factors may be involved in the pyrogenic and pneumonic response. The reason for the maintenance of a respiratory rate within the normal range in calves which had fibrinous pneumonia at post-mortem is not immediately apparent. The pyrexia could be explained as the effect of endotoxin, but in experiment five no pyrexia could be attributed to endotoxin in the killed culture group. Bacteria from the stationary phase culture entering log-phase culture themselves within the lung with associated cytotoxin production could explain the fibrinous pneumonia but it would be expected that a concomitant increase in dullness and respiratory rate would also occur.

The cytotoxin neutralising ability of serum has been demonstrated in feedlot cattle in Ontario (186) a value which would appear to be independent of serum indirect haemagglutinating ability. It may be that in the calves given a stationary phase culture of a high cytotoxin producing strain of P.haemolytica, the log-phase of the cycle is reached in the lungs by only low numbers of bacteria at various times after infection. This gradual increase in cytotoxin production may produce an immune response to cytotoxin which reduces the clinical response but still produces fibrinous pneumonia which is localised in distribution. This would explain the localised lesions seen in the S/C calves killed on day three, whereas one of the calves killed on day six had widespread lesions of severe fibrinous pneumonia, which would be expected earlier in the disease rather than the nodules usually seen in calves killed at this stage.

The endotoxin produced by P.haemolytica has been shown to have haemodynamic properties (126), and a single intravenous inoculation of log-phase culture of P.haemolytica A1 S/C produced fatal endotoxin shock within six hours in one calf (unpublished observations). Whether there is any relationship between endotoxin and cytotoxin production in individual strains of P.haemolytica is not known, although cytotoxin production has been shown to vary between individual strains of all the different serotypes of P.haemolytica (185) it is not established how, if at all, this affects pathogenicity.

There can be no doubt from the experimental work described that bovine pneumonic pasteurellosis can be produced experimentally using log-phase cultures of P.haemolytica A1 alone without the need of other stressor or infectious agents. The disease produced was identical to that seen in the field on clinical, pathological and microbiological grounds.

Quite apart from the use of log-phase cultures another reason for success was the careful selection of calves. These were selected on the basis of negative serology and the failure to isolate P.haemolytica from repeated nasopharyngeal swabs. Although the failure to isolate P.haemolytica on repeated nasopharyngeal swabbing cannot be guaranteed (164), it would appear that, for the experiments described above, the method was successful as no other strains of P.haemolytica were isolated from the lungs at post-mortem examination. The use of nasopharyngeal swabs was preferred because the tonsil and nasopharynx are well recognised sites for potential respiratory pathogens in cattle (70,164,228), sheep (85), dog (196) and humans (203), and the likelihood of isolation of significant organisms is greater than using nasal swabs where contamination rates are usually high. This repeated swabbing throughout the 14 day pre-inoculation period was apparently effective in identifying calves that were free from infection with P.haemolytica as judged by the failure to demonstrate P.haemolytica, other than the infecting strain, in nasopharyngeal swabs post-inoculation or in tissues at post-mortem by either isolation or immunofluorescence.

More recently bovine pneumonic pasteurellosis has been reproduced using log-phase cultures of four further isolates of P.haemolytica A1 (231). These isolates were all carefully selected from clinicopathologically confirmed cases of pneumonic pasteurellosis, where the organism was present in large numbers throughout the respiratory tract in an untreated slaughtered animal, but it was noted that there were slight differences in the clinical signs and pathology between the strains.

It was thought that the satisfaction of these criteria was probably also important in the successful reproduction of the disease. However in experiment six, bovine pneumonic pasteurellosis was reproduced using an isolate from a treated calf that had been found dead in an outbreak where there was evidence that PI3 virus may also

have been involved. On the experimental evidence, even in this incident, Koch's postulates were satisfied by P.haemolytica A1 alone, PI3 virus was probably of only limited importance.

In summary, poor results were obtained in the early experiments designed to reproduce pneumonic pasteurellosis using a stationary-phase culture of P.haemolytica A1 in two multifactorial models, PI3 and stress. Subsequent experiments were successful and this was attributed to several factors relating to both the bacteria inoculated and the calves used in the experiments. The change from using stationary-phase culture to log-phase cultures in the later experiments together with the careful selection of strains of P.haemolytica A1 was undoubtedly important in the successful reproduction of the disease. At the same time experimental calf selection procedures were made more stringent, with repeated pre-inoculation swabbings and more insistence on low pre-inoculation serum titres. However, the previous insistence on using isolates from untreated cattle is probably over-cautious, as described above, but the need for clinicopathological confirmation of the disease and the widespread presence of large numbers of the organism throughout the respiratory tract remains essential.

To date, pneumonic pasteurellosis has been reproduced with isolates of P.haemolytica A1, usually given in log-phase culture, although one strain (S/C) produced the characteristic lesions of pneumonic pasteurellosis when inoculated in stationary-phase culture, which emphasises the probable variation in potential pathogenicity between strains. However the use of log-phase cultures of all the isolates tried so far in the five dose experimental model has reproduced clinical signs and pathological lesions of pneumonic pasteurellosis. This again confirms the view that P.haemolytica A1 can act as a primary pathogen in the bovine respiratory tract and subsequently the search for evidence of viral involvement in the pathogenesis of bovine pneumonic pasteurellosis is unnecessary.

CHAPTER 3

GENERAL DISCUSSION AND CONCLUSIONS

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In North America, the disease seen after range calves are shipped, often over vast distances, to feedlots, is known as shipping fever and has traditionally been considered to be a pneumonic pasteurellosis occurring secondary to viral infections with predisposing factors such as stress playing a significant part (105).

The disease, as seen in Britain which is usually, but not exclusively, encountered in recently housed weaned suckled calves and known as transit fever, was the subject of a combined clinical and pathological investigation into field incidents and was shown to be a primary pneumonic pasteurellosis. While there is evidence from North America that weaned calves are often exposed to viruses, especially Pl3, on entry to feedlots there is no hard field evidence to support the theory that viruses are directly involved in the pathogenesis of bovine pneumonic pasteurellosis. Clinical investigations on feedlots are often merely a numbers exercise, the numbers involved being based on "pulling rate" (i.e. the number of sick calves removed or "pulled" from the normal pens to hospital pens by the feedlot cowboys). The decision to treat is made by the cowboys and treatment is with a pre-determined sequence of antibacterials, determined by response to treatment, rather than by the clinical condition of the animal (151). All calves treated within one month of arrival at the feedlot are considered to be suffering from shipping fever, and few, if any, are seen let alone examined by the feedlot veterinarians. Similarly, pathological studies have been conducted on fatal cases of shipping fever, often following unsuccessful antibacterial treatment, so the pathological diagnosis and possibility of incriminating other respiratory pathogens in the disease is ruled out because of the extent of pneumonic pasteurellosis and post-mortem change in the available case material. Thus, to have any chance of assessing

whether or not viruses do in fact play any part in the pathogenesis, it is essential to kill cattle either early in the severe, potentially fatal, form of the disease or when suffering from a milder, non-fatal, form of the disease, before evidence of possible viral infection is obscured by the pathology of pneumonic pasteurellosis. In the above investigations early untreated cases were examined clinically, microbiologically and pathologically; there was no consistent evidence to implicate viruses in the development of the disease, and in only one outbreak was there evidence of concurrent infection with a virus (P13).

In the groups of in-contact calves there was often evidence of viral activity as judged by the seroconversions seen, usually to PI3 virus and RS virus, without any evidence of associated clinical disease based on clinical examination and response to treatment. Furthermore, similar levels of viral activity were seen in monitor groups of calves in which no clinical respiratory disease occurred. Similarly, there was also evidence of infection with P.haemolytica A1 in both in-contact calves in affected groups and in calves from unaffected groups on the basis of isolation from nasopharyngeal swabs and seroconversions. It therefore follows that microbiological examination of nasopharyngeal swabs and paired serology must be interpreted with care and are of only limited value in diagnosing pneumonic pasteurellosis. Equally high isolation and seroconversion rates can be seen in groups of calves not suffering from respiratory disease as in those in which pneumonic pasteurellosis is confirmed. Diagnosis of pneumonic pasteurellosis can be made on clinical and epidemiological findings and confirmed by gross pathology. A similar philosophy must also be adopted in relation to seroconversions to viral pathogens unless confirmatory pathology is available, because even if viruses are isolated or serological evidence of viral infection is forthcoming the presence of the virus and concurrent pneumonic pasteurellosis may be purely fortuitous and merely reflect the presence of several infectious agents circulating within that group of cattle.

In Britain, P.haemolytica A1 is usually sensitive to the penicillin, oxytetracycline, the potentiated sulphonamides and chloramphenicol (9), and treatment with antibacterials, often oxytetracycline, is successful in the majority of cases. This is in marked contrast to the situation in the United States where multi-resistant strains of P.haemolytica are widespread and frequent (11) and where annual losses from shipping fever are often in excess of 350,000 head of cattle in spite of antibacterial treatment and other control measures aimed at diminishing the frequency and severity of the disease.

In North America, a means of effective control of shipping fever is considered to be a high-priority research commitment (18). A variety of pre-conditioning programmes have been investigated where range calves were subjected to procedures such as castration and vaccination prior to transit and were weaned and introduced to a feedlot-style diet on the farm of origin. The aim was to reduce the stress and reduction in appetite associated with arrival at the feedlot. However, in one study of these calves (234) no difference was demonstrated between conditioned and non-conditioned calves with regard to morbidity and mortality from shipping fever but the conditioned calves had an improved weight gain in the first few weeks on the feedlot, and the value of such an expensive pre-conditioning programme was considered questionable.

The use of vaccines has been widespread, either Pasteurella spp. bacterins or viral vaccines, although early reports on the use of bacterins indicated that their use increased mortality. Recent studies on the efficacy of vaccine use indicated that they not only had no effect on weight gain (146) but may even increase the probability of pneumonic pasteurellosis occurring in individual animals (149).

In recent developments on the use of vaccines for the control of pneumonic pasteurellosis several different approaches have been considered, many of which involve the

use of live vaccines. The problem with killed vaccine would appear to result from the production of opsonising antibody. Antibody opsonises the bacteria within the lung to facilitate and maximise the phagocytosis of the organism by alveolar macrophages and neutrophils. Unfortunately this mechanism, which in most bacterial diseases is advantageous to the infected host animal, is likely to be disastrous for the host in the case of infections with P.haemolytica, as the increased numbers of P.haemolytica phagocytosed produce increased amounts of cytotoxin. This cytotoxin causes breakdown of macrophages and neutrophils which in turn results in the activation of complement and a pyrogenic response, a procedure which results in the development of the fibrinous pneumonia, septal dilatation and fever seen in pneumonic pasteurellosis. Thus, the opsonisation of the bacteria increases the speed and severity of damage to the macrophages and neutrophils and the subsequent onset of clinical disease.

As cytotoxin production is now considered to be central to the pathogenic ability of P.haemolytica and the development of pneumonic pasteurellosis in cattle and sheep, any effective vaccine should probably be directed at neutralising the cytotoxin rather than killing bacteria by cellular mechanisms. The possible methods by which this could be achieved are either by administering purified cytotoxin alone, or administering small numbers of P.haemolytica A1 by the respiratory route to multiply within the respiratory tract and induce cytotoxin neutralising antibody (183). Purified cytotoxin may be difficult to prepare at present as extraction from log-phase cultures may not be practical on a large, i.e. industrial, scale but developments in molecular biology could solve this problem. The question also arises as to whether cytotoxin is identical irrespective of the strain of P.haemolytica A1, as there appears to be a difference between serotypes (185).

Administration of an aerosol of a live culture of P.haemolytica A1 would appear to be protective against subsequent challenge by the same organism irrespective of whether the vaccinating "dose" is a log or stationary phase culture (53). However, live vaccines of field strains of P.haemolytica A1 administered to feedlot cattle with the aim of the organisms multiplying within the respiratory tract to induce cytotoxin neutralising antibody, might not be ideal under field conditions quite apart from the almost inevitable rejection by the regulatory authorities. Any attenuation of the organism that may be demanded by the authorities would almost certainly reduce the potential efficacy of the vaccine as cytotoxin production is almost certainly related to pathogenicity.

In conclusion, the investigations of incidents of transit (or shipping) fever in weaned and sucking single suckled calves showed the disease to be a primary pneumonic pasteurellosis, usually the result of infection with P.haemolytica A1. Although there was evidence of viral activity within groups of calves, there was no indication that they were significantly involved in the pathogenesis of the disease. A primary role for P.haemolytica A1 has been confirmed by the development of an experimental model in conventional weaned calves which produced a disease which was indistinguishable from the field disease on clinical, microbiological and pathological grounds. The model used log-phase culture of P.haemolytica A1 inoculated by the intranasal and percutaneous intratracheal routes alone with no other infectious or stressor agents.

In Britain, the disease responds well to antibacterial therapy but effective treatment depends on good stockmanship and a means of preventing the disease would be useful. In North America, multi-resistant strains of P.haemolytica are widespread and treatment is less successful, and in this situation a satisfactory means of preventing the disease is a high research priority. The successful development of an experimental model provides the ideal opportunity to evaluate potential vaccines and

therapeutic agents for use in pneumonic pasteurellosis and on which a future control programme could be based.

APPENDICES

Appendix 1 Sheet A - Farm and group background details.

Farm reference no: 1 Location: Maybole, Ayrshire.

Farmer's veterinary surgeon: Robertson and Orr, Maybole.

Date of first contact with Veterinary Surgeon: October 26, 1980.

Date of first visit to farm: October 29, 1980

Farm background: Beef rearing unit. Buys in 60-80 weaned calves every year, both bucket fed and single suckled, to finish. Rears some on the bucket himself. Has never had transit fever before.

Present (farmer's) complaint: A group of 28 weaned single suckled calves were purchased in market on October 21, kept indoors and turned out to grass on October 24. On October 26 several calves were not feeding, coughed and were tachypnoeic. Eight calves were severely affected with marked pyrexia (106°F), respiratory rate 80+/minute and coughing.

Action taken/prescribed prior to visit:

Six of the 8 calves were treated with Oxytetracycline $^{i}/_{m}$. The 2 untreated calves were purchased for examination at G.U.V.H. The group was housed in a well-ventilated shed to facilitate detection of new clinical cases and treatment.

Author's assessment of 1. Cattle operation:

Good, excellent handling facilities.

2. Affected group:

Mixed group of calves from a variety of sources.
Coughing widespread and at least 50% of the group had infectious bovine keratoconjunctivitis.

Author's advice:

Treatment of all calves in group with oxytetracycline $^{i}/_{m}$.

Follow-up comments:

Improved rapidly with no further clinical cases, coughing disappeared within a few days and calves were obviously gaining weight by November 27.

Appendix 1 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 1 Location: Maybole, Ayrshire.

Case reference no: 82392

Clinical Signs:

Dull, reluctant to feed, pyrexic (106°F), tachypnoeic (84/minute), occasional coughing and mucoid nasal discharge.

Pathology and Microbiology:

Extensive consolidation anterior lung lobes. Multiple hard gritty lumps which were pale grey, often with a red centre on section and a fibrous capsule. These nodules were encapsulated foci of fibrinous pneumonia. Acute fibrinous pneumonia was found outwith the nodules.

Pasteurella haemolytica A2	NC
Corynebacterium pyogenes	NC
Listeria monocytogenes	Tr
Streptococcus bovis	Tr
Mycoplasma bovirhinis	RC

Serology: ND

Appendix 1 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 1 Location: Maybole, Ayrshire.

Case reference no: 82412

Clinical Signs:

Dull, inappetent, pyrexic (104°F), coughing, tachypnoeic (66/minute) and hyperpnoeic.
Harsh lung sounds on auscultation.

Pathology and Microbiology:

Purulent bronchiolitis with pale epithelial cells. Alveolar reaction with macrophages and some collapse, and a little alveolar epithelial hyperplasia.

Micrococcus sp.	NC
Aerococcus viridans	Tr, RC, RM
Mycoplasma bovirhinis	RC

Serology: ND

Appendix 1

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 1 Location: Maybole, Ayrshire.

First Sampling Date: October 29, 1980

Total number of calves in group: 26

Number of calves sampled: 7

Organism	No. of calves positive	Individual calf reference nos.
Neisseria pharyngis	1	1
Neisseria flavescens	1	4
Moraxella bovis	2	2,3
Corynebacterium bovis	1	4
Corynebacterium pyogenes	1	6
Flavobacterium meningosepticum	1	5
Micrococcus sp.	1	5
Listeria monocytogenes	2	6,7
Mycoplasma bovirhinis	4	1,4,5,7
Mycoplasma bovis.	1	4

Second Sampling. Date: ND No. of calves sampled:

Organism	No. of calves positive	Individual calf reference nos.

Appendix Sheet D - Serological findings in Affected Group.

Farm reference no: 1 Location: Maybole, Ayrshire.

Date of first sampling: October 29, 1980 Date of second sampling: December 2, 1980 No. of calves in group: 26

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
2	32	32	128	8	ND	ND	-	4	-	-	160	H*	>5120	4786	<10	<10
3	64	128	128	8	ND	ND	-	-	4	2	80	320	1819	724	<10	160
6	128	32	8	8	ND	ND	-	-	-	-	80	320	4168	1318	<10	<10
8	128	128	128	8	ND	ND	-	-	-	-	160	640	1318	1819	<10	<10
9	128	128	128	8	ND	ND	-	2	-	-	1280	160	4786	912	<10	<10

* haemolysed red blood cells

Appendix 2 Sheet A - Farm and group background details.

Farm reference no: 2 Location: Tarbolton, Ayrshire.

Farmer's veterinary surgeon: Barr and McMillan, Mauchline.

Date of first contact with Veterinary Surgeon: November 10, 1980

Date of first visit to farm: November 11, 1980

Farm background:

Retired farmer, buys in 25-30 weaned, single suckled calves per year. Had incident of transit fever 3 years ago.

Present (farmer's) complaint:

Bought calves in Ayr market October 21, wormed group with fenbendazole on November 4 when 1 calf was noticed to be ill; cough, nasal discharge and tachypnoea. This calf responded to treatment with oxytetracycline, but 4 further calves in the group were noticed to be ill, with similar clinical signs on November 8.

Action taken/prescribed prior to visit:

Treatment of affected animals with oxytetracycline $^{1}/_{m}$ for 3 days.

Author's assessment of

1. Cattle operation: Good, excellent stockman but getting old. Slatted floor house where calves were housed has poor ventilation.

2. Affected group: 25 cattle were purchased on October 21, but all the clinical cases are in a group of 10 that all came from the same farm.

Author's advice:

Treat remaining calves in group with oxytetracycline, as one further calf pyrexic on November 11.

Follow-up comments:

Revisited December 4, all calves feeding well and growing. No coughing. One calf has severe ringworm.

Appendix 2 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 2 Location: Tarbolton, Ayrshire.

Case reference no: 82541

Clinical Signs:

Reduced appetite, coughing, mucopurulent nasal discharge and tachypnoea in November 8. Treated with oxytetracycline by i/m injection. Died overnight November 10/11.

Pathology and Microbiology: P.M. November 11, 1980.

Widespread lung consolidation, congested tracheal mucosa with flecks of purulent exudate. Microscopically an acute exudative interstitial fibrinous pneumonia.

Pasteurella haemolytica A1	NC, Tr, RC, RM and RD
Mycoplasma bovis	RD
Mycoplasma bovirhinis	Tr, RC
PI_3 virus	NC, Tr, RD.

Serology: ND

Appendix 2

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 2 Location: Tarbolton, Ayrshire.

First Sampling Date: November 11, 1980

Total number of calves in group: 10

Number of calves sampled: 9

Calves treated:

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	4	1,5,6,7
Neisseria catarrhalis	3	2,4,9
Bacillus coagulans	1	3
Acinetobacter lwoffi	1	8
Mycoplasma bovis	2	1,8
Mycoplasma bovirhinis	6	2,3,5,7,8,9
PI_3 virus	1	(not known, lab. error)

Second Sampling. Date: ND No. of calves sampled:

Organism	No. of calves positive	Individual calf reference nos.

Appendix 2 Sheet D - Serological findings in Affected Group.

Farm reference no: 2 Location: Tarbolton, Ayrshire.

Date of first sampling: November 11, 1980 Date of second sampling: December 4, 1980 No. of calves in group: 9

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	128	64	32	8	-	-	2	-	Samples contaminated at laboratory. Unsuitable for assay.		80	320	436	295	<10	<10
2	128	128	64	64	n	n	-	-			10	80	1584	234	<10	<10
3	128	128	128	32	-	-	-	-			<10	640	691	1445	<10	<10
4	128	128	32	16	-	-	-	-			<10	80	5495	1258	<10	<10
5	128	128	64	64	n	n	-	-			<10	80	158	114	<10	<10
6	128	128	64	64	-	n	-	-			<10	80	331	144	<10	<10
7	128	64	8	8	-	-	-	-			<10	80	660	602	<10	<10
8	128	128	64	64	-	-	-	-			80	40	537	891	<10	<10
9	128	128	64	64	-	n	-	-			20	80	758	178	<10	<10

Appendix 3 Sheet A - Farm and group background details.

Farm reference no: 3 Location: Milngavie, Dunbartonshire.

Farmer's veterinary surgeon: Ross and Bickerton, Bishopbriggs.

Date of first contact with Veterinary Surgeon: September 1982

Date of first visit to farm: October 6, 1982

Farm background: Ex. dairy farmer. Buys in weaned suckled calves (approx. 200) each autumn, usually in batches of about 20 from markets. Over past 6 years (since he gave up dairying) has had at least 1 case of transit fever per year, and occasionally as many as 12 cases.

Present (farmer's) complaint:

Group of calves bought in September 29, one calf noticed dull and pneumonic October 2, treated and improved. Three others noticed dull October 3, treated and improved. More calves purchased October 5 and added to September 29 calves, total calves in group, 13.

Action taken/prescribed prior to visit:

Sick calves treated with trimethoprim/sulphadoxine.
All calves wormed with fenbendazole on arrival.

Author's assessment of 1. Cattle operation: Cattle kept on slats (100) which are kept through next summer and finished indoors the following winter, and 100 other cattle kept in straw yards and sold as stores. Good handling facilities and housing.

2. Affected group: Mainly Hereford and Galloway X calves as farmer separates out Charolais and keeps them together.

Author's advice:

Follow-up comments:

Sick calf of October 2 relapsed October 6, treated oxytetracycline. Some improvement in appetite but remained hyperpnoeic and tachypnoeic until purchased for slaughter October 14.
Total ill for season 13.

Appendix 3 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 3 Location: Milngavie, Dunbartonshire.

Case reference no: 89421

Clinical Signs:

Dullness, inappetence initially (October 2) which responded to antibacterial (trimethoprim/sulphadoxine) therapy, relapsed Ocgober 6, treated oxytetracycline but although brighter remained hyperpnoeic and tachypnoeic (RR. 60/minute), and still empty looking. Temperature 103°F, mucopurulent nasal discharge.

Pathology and Microbiology: P.M. October 15.

Arteritis in all lung lobes with bronchiolar reaction in anterior lobes.

Pasteurella haemolytica A1	Tr, RC, Tonsil
Streptococcus bovis	NC, RC, RM
Moraxella nonliquefaciens	Tr
Bacillus coagulans	Thymus

Serology:

Pasteurella haemolytica A1	8
Pasteurella haemolytica A2	16
Mycoplasma bovis	4

Appendix 3

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 3 Location: Milngavie, Dunbartonshire.

First Sampling Date: October 6, 1982

Total number of calves in group: 38

Number of calves sampled: 14

Calves treated: 3,4

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella sp.	1	9
Acinetobacter anitratum	1	8
Acinetobacter lwoffi	1	1
Corynebacterium pyogenes	1	2
Nocardia sp.	2	3,11
Micrococcus luteus	1	12
Micrococcus sp.	5	3,6,7,13,14
Bacillus coagulans	1	5
Flavobacterium sp.	1	10
Mycoplasma dispar	1	10
Acholeplasma laidlawii	4	3,6,9,13

Second Sampling. Date: October 21 No. of calves sampled: 16

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella multocida	1	16
Bacillus alvei	7	1,2,3,4,7,12,15
Micrococcus sp.	6	2,5,6,8,11,16
Acinetobacter anitratum	1	3
Corynebacterium bovis	3	4,5,14
Corynebacterium pyogenes	1	6
Aerococcus viridans	3	7,9,13
Mycoplasma bovis	2	9,13
Mycoplasma bovirhinis	5	1,3,4,5,16
Acholeplasma laidlawii	4	4,5,6,7

Appendix 3 (1) Sheet D - Serological findings in Affected Group.

Farm reference no: 3 Location: Milngavie, Dunbartonshire.

Date of first sampling: October 6 1982 Date of second sampling: October 21 1982 No. of calves in group: 38

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	n	2	-	2	ND	ND	-	2	.10	.11	.21	.42	.66	.52	ND	ND
2	2	2	n	4	ND	ND	-	-	0	0	0	0	0	.16	ND	ND
3	2	8	n	8	ND	ND	-	-	0	.01	.09	.21	0	.56	ND	ND
4	n	2	-	2	ND	ND	4	-	.12	.14	.91	.94	.38	1.03	ND	ND
5	n	2	n	4	ND	ND	-	-	0	0	.68	.82	.10	.89	ND	ND
6	n	4	n	2	ND	ND	-	-	.10	.07	.23	.26	.02	.19	ND	ND
7	2	n	-	n	ND	ND	-	2	0	0	.24	.09	0	.56	ND	ND
8	n	n	-	n	ND	ND	-	-	.38	.31	.40	.38	.02	.55	ND	ND
9	2	2	2	2	ND	ND	-	-	.04	.05	.04	.74	.82	.85	ND	ND
10	n	2	-	-	ND	ND	-	8	.11	.11	.12	.16	.01	.71	ND	ND

Appendix 3 Sheet D(2) - Serological findings in Affected Group.

Farm reference no: 3 Location: Milngavie, Dunbartonshire.

Date of first sampling: October 6 1982 Date of second sampling: October 21 1982 No. of calves in group: 38

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
11	n	4	n	n	ND	ND	-	4	.09	.08	.45	.44	.52	.63	ND	ND
12	n	n	-	n	ND	ND	-	-	.03	.03	.30	.45	.05	1.10	ND	ND
13	n	2	4	2	ND	ND	-	-	.06	.06	.27	.37	0	.57	ND	ND
14	n	2	n	n	ND	ND	-	-	.10	.10	.95	.84	.37	1.04	ND	ND
15	16	NS	n	NS	ND	ND	-	NS	ND	NS	ND	NS	ND	NS	ND	ND
16	NS	2	NS	2	ND	ND	ND	-	NS	ND	NS	ND	NS	ND	ND	ND

Appendix 4 Sheet A - Farm and group background details.

Farm reference no: 4 Location: Douglas Water, Lanarkshire

Farmer's veterinary surgeon: G.U.L.P. Lanark

Date of first contact with Veterinary Surgeon: September 1982

Date of first visit to farm: October 29, 1982

Farm background:

One of two farms run by brothers. Traditional upland farm but only rears beef, no commercial breeding cattle. Buys in weaned suckled calves every autumn and has occasionally had a case of "transit fever" but not every year.

Present (farmer's) complaint:

39 calves purchased at market October 19, all wormed (fenbendazole) October 20, 2 ill (dull, pyrexic, tachypnoeic) October 27, another ill October 28.

Action taken/prescribed prior to visit:

Three sick calves treated with oxytetracycline (^{i}/m)

Author's assessment of 1. Cattle operation: Traditional yarded cattle fed silage and barley. Calves kept in groups of about 12 each in various buildings. Stockmanship good.

2. Affected group: Mainly Hereford X calves, several dull-looking including the treated animals which farmer says have improved. One calf pyrexic for first time when sampled, left untreated and purchased by G.U.V.H.

Author's advice:

If more cases develop, treat all group with oxytetracycline. (^{i}/m)

Follow-up comments:

Group were all treated because 2 further cases developed over next few days. After that no further problems, all fit on 2nd visit.

Appendix 4 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 4 Location: Douglas Water, Lanarkshire

Case reference no: 89612

Clinical Signs:

Dull, pyrexic (104.5°F), respiratory rate 72/minute, hyperpnoeic, slight mucoid nasal discharge. Harsh lung sounds on auscultation.

Pathology and Microbiology: P.M. October 29.

Fibrinous pneumonia with pleurisy.
Dilated septa, lymphatics plugged with fibrin.

Pasteurella haemolytica A1	NC, Tr, RC, RM, BrLN, Thymus
Bacillus coagulans	RD
Aerococcus viridans	Tonsil
Mycoplasma bovirhinis	Tr, RM

Serology:

Pasteurella haemolytica A1	16
Pasteurella haemolytica A2	8
Mycoplasma bovis	-

Appendix 4

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 4 Location: Douglas Water, Lanarkshire.
First Sampling Date: October 29 1982
Total number of calves in group: 39
Number of calves sampled: 11
Calves treated: 5 Treatment: oxytetracycline.

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	4	1,2,3,4
Bacillus licheniformis	6	5,6,7,8,10,11
Actinobacillus lignieresi	4	7,9,10,11
Mycoplasma bovirhinis	7	1,4,5,7,8,9,11
Acholeplasma laidlawii	2	6,7

Second Sampling. Date: November 23 1982 No. of calves sampled: 10

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	1	1
Bacillus coagulans	8	3,4,5,6,8,9,10,11
Moraxella nonliquefaciens	3	1,5,11
Bacillus circulans	3	6,7,9
Micrococcus sp.	1	8
Aerococcus sp.	1	3
Actinobacillus lignieresi	3	6,7,9
Acinetobacter anitratum	1	8
Acinetobacter lwoffi	1	10
Mycoplasma bovis	9	1,3,4,5,6,7,8,9,10
Mycoplasma bovirhinis	1	11
Acholeplasma laidlawii	6	1,5,6,7,9,10

Appendix 4 Sheet D - Serological findings in Affected Group.

Farm reference no: 4 Location: Douglas Water, Lanarkshire.

Date of first sampling: October 29 1982 Date of second sampling: November 23 1982 No. of calves in group: 39

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	4	32	2	2	ND	ND	-	-	0	.08	.13	.24	.09	.13	ND	ND
2 *	8	ND	2	ND	ND	ND	-	ND	.09	ND	.74	ND	.11	ND	ND	ND
3	n	8	n	n	ND	ND	-	-	.12	.20	.67	.89	.08	.87	ND	ND
4	4	64	n	n	ND	ND	-	-	.11	.41	.09	.27	.05	.19	ND	ND
5	32	64	2	2	ND	ND	-	-	.09	.15	.10	.16	.03	.10	ND	ND
6	8	4	n	n	ND	ND	-	-	.12	.13	.13	.39	.15	.15	ND	ND
7	2	16	2	n	ND	ND	-	-	.06	.09	.07	.31	.04	.26	ND	ND
8	32	64	2	2	ND	ND	-	-	.11	.14	.87	1.17	.11	.15	ND	ND
9	n	8	-	-	ND	ND	2	-	.10	.11	.19	.19	.06	.18	ND	ND
10	2	8	n	n	ND	ND	-	-	.10	.12	.10	.75	.12	.15	ND	ND
11	-	2	-	n	ND	ND	-	-	.09	.11	0	.63	.01	.09	ND	ND

* calf purchased and slaughtered.

Appendix 5 Sheet A - Farm and group background details.

Farm reference no: 5 Location: Blairdrummond, Stirlingshire

Farmer's veterinary surgeon: Chapman, Kippen.

Date of first contact with Veterinary Surgeon: September, 1982

Date of first visit to farm: November 1, 1982

Farm background: Owned by Insurance Company, which also owns large tracts of land in Ardnamurchan where cows and calves are kept. Calves (210 in number) are weaned and moved down to Perthshire unit. Pen-housed on slats, all calves wormed with benzimidazole and given 10 ml Long Acting Penicillin at time of housing.

Present (farmer's) complaint:

Group of calves moved in from Ardnamurchan November 1; this was group being monitored, sick calf came from another group also housed November 1 in same accommodation.

Action taken/prescribed prior to visit:

None.

Author's assessment of 1. Cattle operation: Well handled by observant, conscientious, competent stockmen.

2. Affected group: Wild, fit calves.

Author's advice:

Follow-up comments:

A total of 27 calves were treated for pneumonia in 1982.

Appendix 5 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 5 Location: Blairdrummond, Stirlingshire.

Case reference no: 89839

Clinical Signs:

Housed November 1, first seen ill November 11 (dull, pneumonic), treated trimethoprim/sulphonamide November 11-13, penicillin November 14.

Relapsed 17 November - not retreated.

Pathology and Microbiology: P.M. November 18.

Fibrinous pneumonia with early encapsulation.

Pasteurella haemolytica A1	NC,Tr,RC,RM,RD,BrLN,Tonsil
Proteus sp.	Tonsil
Mycoplasma bovirhinis	Tr

Serology:

Pasteurella haemolytica A1	64
Pasteurella haemolytica A2	n
Mycoplasma bovis	-

Appendix 5 Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 5 Location: Blairdrummond, Stirlingshire.
First Sampling Date: November 1 1982
Total number of calves in group: 44
Number of calves sampled: 22
Calves treated: none

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	1	33
Acinetobacter lwoffi	8	1,2,4,7,8,9,34,39
Bacillus coagulans	3	3,5,6
Micrococcus sp.	6	7,10,11,35,38,40
Actinobacillus lignieresi	3	12,32,33
Corynebacterium bovis	1	32
Neisseria pharyngis	1	37
Mycoplasma bovirhinis	4	1,3,33,37
Acholeplasma laidlawii	1	7

Second Sampling. Date: November 25 1982 No. of calves sampled: 25

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella multocida	1	39
Flavobacterium sp.	4	1,4,32,33
Actinobacillus lignieresi	1	2
Aerococcus viridans	1	2
Acinetobacter anitratum	1	6
Acinetobacter lwoffi	2	3,41
Bacillus coagulans	3	3,40,41
Micrococcus sp.	11	5,7,8,9,11,12,32, 34,37,43,44
Proteus sp.	5	10,31,35,36,38
Neisseria pharyngis	1	40
Mycoplasma bovis	5	4,8,32,39,40
Mycoplasma bovirhinis	7	9,10,11,31,35,38,40
Acholeplasma laidlawii	16	1,2,3,4,5,6,7,9,10, 11,32,34,36,37,39,41

Appendix 5 Sheet D (1) - Serological findings in Affected Group.

Farm reference no: 5 Location: Blairdrummond, Stirlingshire.

Date of first sampling: November 1 1982 Date of second sampling: November 25 1982 No. of calves in group: 44

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	2	8	n	2	ND	ND	-	-	.03	.09	.13	.33	.02	.24	ND	ND
2	16	8	128	64	ND	ND	-	2	0	.05	.10	.11	.40	.39	ND	ND
3	2	8	64	16	ND	ND	-	8	.37	.44	0	.09	.04	.21	ND	ND
4	16	8	8	64	ND	ND	-	-	.09	.22	0	.12	.06	.29	ND	ND
5	4	4	-	2	ND	ND	-	-	.09	.10	0	.02	.16	.22	ND	ND
6	4	2	n	8	ND	ND	2	-	.17	.05	0	0	.03	.13	ND	ND
7	16	8	32	16	ND	ND	8	8	.05	.09	0	.36	0	.27	ND	ND
8	16	32	4	16	ND	ND	-	8	.17	.01	.04	.09	.02	.10	ND	ND
9	16	32	8	8	ND	ND	-	4	0	0	0	0	0	0	ND	ND
10	n	16	n	2	ND	ND	-	4	.10	0	0	0	0	.24	ND	ND
11	2	4	4	16	ND	ND	-	-	.04	0	0	0	0	.02	ND	ND

Appendix 5 Sheet D(2) - Serological findings in Affected Group.

Farm reference no: 5 Location: Blairdrummond, Stirlingshire.

Date of first sampling: November 1, 1982 Date of second sampling: November 25, 1982 No. of calves in group: 44

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
12	8	32	2	16	ND	ND	-	n	.02	.05	.04	.18	0	.33	ND	ND
13	2	2	8	32	ND	ND	8	2	0	0	0	.16	0	.17	ND	ND
14	2	32	8	16	ND	ND	-	-	0	0	.12	.05	.07	.29	ND	ND
15	8	8	64	16	ND	ND	-	2	0	0	0	.01	0	.03	ND	ND
16	8	2	n	32	ND	ND	-	2	0	.13	0	.03	0	.24	ND	ND
17	32	16	8	32	ND	ND	-	-	.08	0	.13	.14	.06	.24	ND	ND
18	16	64	8	4	ND	ND	8	n	.03	.04	.01	.41	0	.17	ND	ND
19	64	8	8	4	ND	ND	-	4	.03	.07	0	.15	0	.27	ND	ND
20	4	2	16	16	ND	ND	-	n	.01	.03	0	0	0	.07	ND	ND
21	16	8	2	8	ND	ND	4	8	.13	.02	0	.09	0	.16	ND	ND
22	n	32	16	4	ND	ND	-	n	.01	0	0	0	.14	.32	ND	ND

Appendix 5 Sheet D(3) - Serological findings in Affected Group.

Farm reference no: 5 Location: Blairdrummond, Stirlingshire

Date of first sampling: November 1, 1982 Date of second sampling: November 25, 1982 No. of calves in group:

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
23	64	32	32	16	ND	ND	-	-	0	.06	0	.14	0	.09	ND	ND
24	2	2	n	n	ND	ND	-	2	.01	.03	0	.25	0	.23	ND	ND
25	16	16	8	32	ND	ND	2	-	.03	.06	.05	.34	0	.24	ND	ND
26	2	4	4	16	ND	ND	4	4	.07	.05	.02	.49	0	.14	ND	ND
27	16	4	4	2	ND	ND	2	-	.04	.05	.03	.07	.12	.11	ND	ND
28	4	32	2	4	ND	ND	4	-	.07	.03	.03	.10	.15	.18	ND	ND
29	2	2	4	32	ND	ND	-	-	.10	.08	.03	.20	.03	.24	ND	ND
30	8	4	n	8	ND	ND	-	2	.03	.02	.01	.08	0	.17	ND	ND
31	4	2	n	n	ND	ND	-	8	.08	.05	.05	.06	.09	.10	ND	ND
32	2	4	-	2	ND	ND	-	8	.05	.05	.05	.11	.01	.07	ND	ND
33	4	4	n	32	ND	ND	4	4	.04	.05	.01	.10	.01	.09	ND	ND

Appendix 5 Sheet D (4) - Serological findings in Affected Group.

Farm reference no: 5 Location: Blairdrummond, Stirlingshire.

Date of first sampling: November 1, 1982 Date of second sampling: November 25, 1982 No. of calves in group: 44

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
34	2	32	2	4	ND	ND	-	8	.06	.08	.04	.11	.01	.06	ND	ND
35	4	4	4	16	ND	ND	-	8	.07	.06	.02	.08	.02	.05	ND	ND
36	32	>128	8	64	ND	ND	n	-	.03	.03	0	.08	0	.12	ND	ND
37	4	4	n	8	ND	ND	-	n	.01	.02	0	.02	.02	.08	ND	ND
38	8	8	8	8	ND	ND	n	-	.07	.09	.01	.10	.06	.15	ND	ND
39	8	64	16	16	ND	ND	-	-	.05	0	0	.03	0	.04	ND	ND
40	8	64	-	n	ND	ND	2	4	.05	.05	0	.09	0	.18	ND	ND
41	16	16	4	8	ND	ND	-	-	.03	0	0	0	0	0	ND	ND
42	2	8	2	8	ND	ND	8	-	0	0	0	0	0	0	ND	ND
43	2	4	4	8	ND	ND	-	4	.03	.02	0	.05	0	.12	ND	ND
44	2	2	4	4	ND	ND	-	n	.18	0	0	.04	.18	.26	ND	ND

Appendix 6 Sheet A - Farm and group background details.

Farm reference no: 6 Location: New Deer, Aberdeenshire.

Farmer's veterinary surgeon: Corrie, Imray and Maclean, Strichen.

Date of first contact with Veterinary Surgeon: October 20, 1982

Date of first visit to farm: Not visited.

Farm background:

About 120 weaned suckled calves purchased each year; in previous years has had 3-5 cases of transit fever and widespread IBR infection. Now vaccinates against IBR, and purchases in smaller groups. All doses with anthelminthic on arrival.

Present (farmer's) complaint:

Group of 25 heifers purchased October 14, noticed to be anorexic and dull October 17 but not treated. Tachypnoeic, coughing, T.106°F October 18 when treated with penicillin/streptomycin/ betamethasone i/m. October 19 T.104°F but respiratory signs worse, treated with chloramphenicol and oxytetracycline.

Action taken/prescribed prior to visit:

Admitted to G.U.V.H. October 20.

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments:

21 other cases of transit fever treated from October 26 to December 31. Total cattle bought in over the period October 14 to December 31 was 120.

Appendix 6 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 6 Location: New Deer, Aberdeenshire.

Case reference no: 89481

Clinical Signs:

7 month old heifer in good condition. Dull, inappetent, rectal temperature 102°F, heart rate 120/minute, respiratory rate 24/minute, markedly hyperpnoeic with a respiratory grunt. Bilateral mucopurulent nasal discharge with crusting.

Pathology and Microbiology:

Proliferative alveolitis.

Pasteurella haemolytica A1	NC, RD, BrLN, Tonsil and Thymus
Actinobacillus lignieresi	NC, BrLN
Escherichia coli	Tr
Shigella sp	Tr
Moraxella osloensis	RC, RD
Mycoplasma bovirhinis	Tr, RC

Serology:

Pasteurella haemolytica A1	16
Pasteurella haemolytica A2	32
Mycoplasma bovirhinis	-

Appendix 7 Sheet A - Farm and group background details.

Farm reference no: 7 Location: Crieff, Perthshire.

Farmer's veterinary surgeon: Ashworth and Rodger, Crieff.

Date of first contact with Veterinary Surgeon: September, 1982

Date of first visit to farm: not visited

Farm background:

Ex dairy farm, bought in weaned suckled calves for first year in 1981, and treated 25 calves for pneumonia that year. Bought in 107 calves this year, 5 treated for pneumonia. No IBR.

Present (farmer's) complaint:

Group of weaned suckled calves purchased in market September 24. One calf noticed dull October 8, left untreated and purchased by G.U.V.H. Many other calves coughing but no further cases pf pneumonia.

Action taken/prescribed prior to visit:

All calves given ivermectin and implanted with oestradiol 17B at housing.

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments:

Appendix 7 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 7 Location: Crieff, Perthshire.

Case reference no: 89328

Clinical Signs:

8 month old Charolais X bullock. Good condition. Alert, easily caught. Rectal temperature October 8 (Friday) 103°F, October 9 (Saturday) 102.6°F. Occasional cough. Respiratory rate 70/minute. Hyperpnoeic, mucopurulent nasal discharge. Untreated. Softish crackles anteroventrally (R). Diarrhoeic.

Pathology and Microbiology: P.M. October 9.

Fibrinous pneumonia with early evidence of nodule formation i.e. encapsulation.

Pasteurella haemolytica A1	NC,Tr,RC,RM,RD,BrLN
Micrococcus sp.	NC
Corynebacterium pyogenes	RC,RM
Bacillus megatherium	Tonsil
Bacillus circulans	Thymus
Mycoplasma bovirhinis	RC

Serology:

Pasteurella haemolytica A1	64
Pasteurella haemolytica A2	n
Mycoplasma bovis	4

Appendix 8 Sheet A - Farm and group background details.

Farm reference no: 8 Location: Parkgate, Dumfriesshire.

Farmer's veterinary surgeon: Miller, Lockerbie.

Date of first contact with Veterinary Surgeon: 1981

Date of first visit to farm: 1981 (IBR incident)

Farm background:

Large beef rearing unit, buys in around 600 weaned suckled calves per year. Sells off about 400 at end of winter and keeps rest at grass to sell at end of summer. All calves kept on slats with "hospital" yards.

Present (farmer's) complaint:

None, recognises early cases, keen to supply sick animals.

Action taken/prescribed prior to visit:

All purchased cattle receive live IBR vaccine on arrival at farm, and are dosed with fenbendazole.

Author's assessment of 1. Cattle operation: Excellent stockmanship. All cases recognised early, treated promptly and effectively.

2. Affected group:

Author's advice:

Follow-up comments: In current season (1982), 520 cattle purchased, 41 treated, no deaths.

Appendix 8 Sheet B (1) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 8 Location: Parkgate, Dumfriesshire.

Case reference no: 89490

Clinical Signs:

Purchased in market September 23, first seen to be "pneumonic" October 1. Treated with trimethoprim/sulphadoxine October 1-5, little response. Treated oxytetracycline October 6-10, some slight improvement but relapsed. Admitted G.U.V.H., October 21. Quiet, rectal temperature 102.4°F, respiratory rate 60/min, hyperpnoeic, slight mucopurulent nasal discharge, occasional cough. Harsh respiration on auscultation.

Pathology and Microbiology:

P.M. October 22. Widespread consolidation with slightly dilated fibrinous septa, many Pasteurella nodules and some abscessation. Adhesions between lobes. Mild bronchiolitis obliterans and proliferative alveolitis. Thrombosed blood vessels and lymphatics plugged with fibrin.

Pasteurella haemolytica A1	NC, Tr, RD
Pasteurella multocida	Tonsil
Micrococcus sp.	RM, Tonsil
Flavobacterium meningosepticum	NC
Neisseria catarrhalis	RM
Mycoplasma bovirhinis	Tr, RC.

Serology:

Pasteurella haemolytica A1	64
Pasteurella haemolytica A2	n
Mycoplasma bovis	2

Appendix 8 Sheet B(2) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 8 Location: Parkgate, Dumfriesshire.

Case reference no: 89599

Clinical Signs:

Purchased October 14 in market, noticed to be inappetent and quiet October 21, treated trimethoprim/sulphadoxine October 21-25, in owner's opinion "not going to do". Admitted G.U.V.H. October 28. Dull, rectal temperature 103°F, respiratory rate 66/min, hyperpnoeic, slight serous nasal discharge and an occasional cough.
Harsh lung sounds on auscultation.

Pathology and Microbiology: P.M. October 31

Pasteurella "nodules" in all lung lobes and foci of consolidation in caudal lobes. No evidence of lungworm. Bronchiolitis obliterans and some peribronchiolar infiltration by lymphocytes and plasma cells. "Streaming" of macrophages in alveolar and bronchiolar spaces.

Pasteurella haemolytica A1	RC, Tonsil
Micrococcus sp.	NC, Tr, RM, Tonsil
Pseudomonas putida	Tr
Mycoplasma bovirhinis	Tr
Mycoplasma dispar	RM

Serology:

Pasteurella haemolytica A1	>128
Pasteurella haemolytica A2	-
Mycoplasma bovis	4

Appendix 9 Sheet A - Farm and group background details.

Farm reference no: 9 Location: Lochwinnoch, Renfrewshire.

Farmer's veterinary surgeon: Andrew, Allardice and Love, Paisley.

Date of first contact with Veterinary Surgeon: October 26, 1982

Date of first visit to farm: October 27, 1982

Farm background:

Hill farm, mainly Scottish Blackface Sheep but with a few beef cows, spring calving; regularly buys in about 20 weaned single suckled calves.

Present (farmer's) complaint:

Group of 6 calves arrived home from Highland Markets October 14 and put outside with home-bred calves. All calves housed October 22. Two calves (one homebred, one purchased) were noticed to be pneumonic October 22, both treated but one (homebred) died October 25. Rest of calves noticed to be inappetent and possibly pneumonic October 23. V.S. treated rest of group.

Action taken/prescribed prior to visit:

First two calves ill given long-acting oxytetracycline by farmer. Rest of purchased calves given parenteral neomycin October 23.

Author's assessment of 1. Cattle operation: Very secondary to sheep enterprise.

2. Affected group: Small weaned suckled calves (spring born), home-bred calves back on hill at time of visit.

Author's advice:

Follow-up comments: All 6 calves from market purchased for examination. Further calves bought in by farmer in subsequent weeks, no problems.

Appendix Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 9 Location: Lochwinnoch, Renfrewshire.

Case reference no: 89545

Clinical Signs:

Seen by farmer to be inappetent and pneumonic, treated oxytetracycline, died 2 days later.

Pathology and Microbiology:

Only piece of lung submitted by V.S. October 26.
Acute exudative fibrinous pneumonia with pleurisy

Pasteurella multocida isolated

Serology: ND

Appendix 9 Sheet B (2) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 9 Location: Lochwinnoch, Renfrewshire.

Case reference no: 89573

Clinical Signs:

Temperature 102.4°F. Respiratory Rate 72/minute, hyperpnoeic. Quiet, no nasal discharge.

Pathology and Microbiology: P.M. October 28.

Small lobular areas of consolidation in R.C. with occasional peribronchiolar lymphoid aggregates and neutrophilic exudation.

Pasteurella haemolytica A1	BrLN, Thymus, Tonsil
Streptococcus bovis	Tr, RC, RM, RD.
Bacillus coagulans	NC, Tr.

Serology:

Pasteurella haemolytica A1	2
Pasteurella haemolytica A2	32
Mycoplasma bovis	-

Appendix 9 Sheet B(3) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 9 Location: Lochwinnoch, Renfrewshire.
Case reference no: 89574

Clinical Signs:

Quiet, alert, temperature 103.1°F, respiratory rate 45/minute, hyperpnoeic, slight mucoid nasal discharge.

Pathology and Microbiology: P.M. October 28

Deep red purple lesions in all lobes which were bronchiolar reaction with severe epithelial necrosis and bacterial colonies visible. Necrotic area in RC surrounded by septa with "streaming" of necrotic macrophages and neutrophils.

Pasteurella haemolytica A1	NC, Tonsil
Pasteurella multocida	Tr, RM, RD, BrLN
Klebsiella oxytoca	Tr, RC, RM, BrLN
Streptococcus bovis	RD
Streptococcus bovis var. liquefaciens	Tonsil
Mycoplasma bovis	RM
Mycoplasma bovirhinis	Tr

Serology:

Pasteurella haemolytica A1	8
Pasteurella haemolytica A2	-
Mycoplasma bovis	4

Appendix 9 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 9 Location: Lochwinnoch, Renfrewshire.

Case reference no: 89575

Clinical Signs:

Fairly bright, temperature 101.8°F, respiratory rate 50/minute, hyperpnoeic, occasional dry cough, mucoid nasal discharge and purulent ocular discharge.
Harsh lung sounds on auscultation.

Pathology and Microbiology: P.M. October 28.

Widespread deep red-purple oedematous areas in the lungs with gelatinous septa and pleura. Extensive bronchiolar epithelial necrosis and mild peribronchiolar reaction. Small blood vessels with thickened walls.

Pasteurella multocida	NC
Streptococcus bovis	NC, Tr, RD, BrLN
Micrococcus sp.	BrLN
Bacillus coagulans	Thymus
Klebsiella aerogenes	Tonsil
Gamella haemolysans	Tr

Serology:

Pasteurella haemolytica A1	n
Pasteurella haemolytica A2	-
Mycoplasma bovis	-

Appendix 9 Sheet B (5) Clinical, pathological and microbiological details of individual cases.

Farm reference no: 9 Location: Lochwinnoch, Renfrewshire.

Case reference no: 89576

Clinical Signs:

Quiet.
Temperature 103.1°F, respiratory rate 50/minute, hyperpnoeic.
Mucoid nasal and ocular discharges. Occasional dry cough.
Harsh respiration on auscultation.

Pathology and Microbiology: P.M. October 28.

Dilated interlobular septa, fibrinous pneumonia, fibrinous pleurisy and numerous Pasteurella nodules throughout all lobes.

Pasteurella haemolytica A1	RC, Tonsil
Bacillus circulans	NC, Tr
Micrococcus sp.	NC, Tr, RM, RD
Proteus sp.	Thymus
Mycoplasma dispar	RM
Mycoplasma bovirhinis	Tr, RC.

Serology:

Pasteurella haemolytica A1	64
Pasteurella haemolytica A2	-
Mycoplasma bovis	4

Appendix 9 Sheet B (6) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 9 Location: Lochwinnoch, Renfrewshire

Case reference no: 89577

Clinical Signs:

Dull, temperature 102.6°F, respiratory rate 75/minute, hyperpnoeic. Occasional cough. Mucoid nasal discharge. Harsh lung sounds on auscultation.

Pathology and Microbiology: P.M. October 28.

Moderate amounts of consolidation with some mild bronchiolar epithelial necrosis.

Pasteurella haemolytica A1	NC, RM, RD, Tonsil
Streptococcus bovis	Tr
Acinetobacter anitratum	RC
Mycoplasma bovirhinis	Tr, RM.

Serology:

Pasteurella haemolytica A1	2
Pasteurella haemolytica A2	64
Mycoplasma bovis	-

Appendix 9 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 9 Location: Lochwinnoch, Renfrewshire

Case reference no: 89578

Clinical Signs:

Bright, temperature 102.2°F, respiratory rate 40/minute, slight mucoid nasal discharge. Occasional cough.

Pathology and Microbiology: P.M. October 28.

Several firm dark grey-fawn lesions throughout lungs, which were foci of collapse with macrophages; some peribronchiolar lymphoid accumulations, and slight bronchiolar epithelial necrosis. Some thickened blood vessels.

Pasteurella haemolytica A1	Tr, RC, RM, BrLN, Tonsil
Bacillus coagulans	NC, Tr
Bacillus laterosporus	NC
Streptococcus bovis	RC, RM, RD, BrLN, Thymus
Mycoplasma bovirhinis	Tr

Serology:

Pasteurella haemolytica A1	8
Pasteurella haemolytica A2	>128
Mycoplasma bovis	-

Appendix 9

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 9 Location: Lochwinnoch, Renfrewshire.

First Sampling Date: October 28, 1982

Total number of calves in group: 6

Number of calves sampled: 6

Calves treated: 73,74,75,76,77,78. Treatment: Oxytetracycline 75, rest neomycin.

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	2	77,78
Bacillus circulans	1	77
Bacillus coagulans	1	76
Micrococcus luteus	1	73
Micrococcus sp.	1	74
Acinetobacter lwoffi	1	74

Group slaughtered after first sample.

Second Sampling. Date: No. of calves sampled:

Organism	No. of calves positive	Individual calf reference nos.

Appendix 10 Sheet A - Farm and group background details.

Farm reference no: 10 Location: Aberfoyle, Perthshire.

Farmer's veterinary surgeon: Chapman, Kippen.

Date of first contact with Veterinary Surgeon: September, 1982

Date of first visit to farm: October 19, 1982

Farm background:

Main enterprise is fattening bought-in weaned suckled calves - also has a lambing flock of cross-bred ewes.

Approximately 200 calves are purchased each year in batches of about 20-30. The calves are dosed with oxyclozamide/levamisole at housing.

Present (farmer's) complaint:

Two groups of weaned suckled calves, bought in market October 30 and November 5. One calf (from first group) noticed ill November 22 (not feeding, tachypnoeic) treated oxytetracycline for 3 days, second calf (from November 5 purchase) with similar signs seen November 23.

Action taken/prescribed prior to visit:

Second calf left untreated (at our request)

Author's assessment of 1. Cattle operation: Disorganised.

2. Affected group: A mixed batch of breeds and sizes.

Author's advice:

Treat any further cases with high doses of oxytetracycline.

Follow-up comments:

Had IBR in later group in 1982 and again in 1983 (Appendix 21)

In 1982, 184 purchased, 12 treated, 1 death.

Appendix 10 Sheet B (1) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 10 Location: Aberfoyle, Perthshire.

Case reference no: 89906

Clinical Signs:

Purchased November 5, noticed sick November 23. Untreated. Dull, thin, temperature 107.6°F, respiratory rate 60/minute. Mild hyperpnoea, no cough. Mucoid nasal discharge, serous ocular discharge with slight conjunctivitis. Lungs sound solid.

Pathology and Microbiology: P.M. November 24, 1982

Fibrinous pneumonia.

Pasteurella haemolytica A1	NC, Tr, RC, RM, RD, BrLN
Mycoplasma bovirhinis	Tr, RM

Serology:

Pasteurella haemolytica A1	2
Pasteurella haemolytica A2	16
Mycoplasma bovis	16

Appendix 10 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 10 Location: Aberfoyle, Perthshire.

Case reference no: 89938

Clinical Signs:

Purchased October 30.
Noticed sick November 22, treated oxytetracycline November 22-24.
Dull, rectal temperature 106.0°F, respiratory rate 66/minute.
No cough or nasal discharge. Harsh respirations but no adventitious sounds.

Pathology and Microbiology: P.M. November 29, 1982 (died).

Fibrinous pneumonia.

Pasteurella haemolytica A1	NC,Tr,RC,RM,RD,BrLN,Thymus,Tonsil
Mycoplasma bovirhinis	Tr,RC,RM

Serology:

Appendix 10

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group (not group from which bodies came, but in-contact group)

Farm reference no: 10

First Sampling Date: October 19, 1982

Total number of calves in group: 21 Location: Aberfoyle, Perthshire.

Number of calves sampled: 21

Calves treated: not known

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	5	6,7,10,17,18
Pasteurella haemolytica A2	1	13
Corynebacterium pyogenes	1	12
Corynebacterium bovis	3	1,18,19
Bacillus megatherium	9	1,3,5,9,12,13,15,17,19.
Micrococcus sp.	6	2,5,14,15,16,21
Aerococcus viridans	3	3,10,11
Acinetobacter lwoffi	1	8
Flavobacterium meningosepticum	1	11
Neisseria catarrhalis	1	20
Mycoplasma bovis	6	2,7,9,14,16,17
Mycoplasma bovirhinis	6	1,4,5,10,13,15
Acholeplasma laidlawii	12	1,3,6,7,8,11,12,17,18, 19,20,21

Second Sampling. Date: November 15 1982 No. of calves sampled: 21

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	3	5,12,16
Pasteurella haemolytica A2	3	1,13,20
Micrococcus sp.	8	2,4,5,11,13,14,18,19
Bacillus coagulans	1	6
Bacillus licheniformis	3	14,15,16
Moraxella nonliquefaciens	4	9,11,15,18
Acinetobacter anitratum	2	6,21
Actinobacillus lignieresi	2	8,10
Mycoplasma bovirhinis	7	2,8,9,10,11,12,14
Acholeplasma laidlawii	8	5,6,8,13,18,19,20,21

Appendix 10 Sheet D (1) - Serological findings in Affected Group (in-contact with group that bodies came from

Farm reference no: 10 Location: Aberfoyle, Perthshire.

Date of first sampling: October 19 , 1982 Date of second sampling: November 15, 1982 No. of calves in group: 21

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	n	2	16	32	ND	ND	-	-	0	.03	0	.09	0	.03	ND	ND
2	64	64	n	>128	ND	ND	-	-	.10	.14	.10	.54	.14	.25	ND	ND
3	2	NS	8	NS	ND	ND	n	NS	.28	NS	.83	NS	0	NS	ND	ND
4	128	64	2	4	ND	ND	-	-	.03	0	.11	.33	.25	.09	ND	ND
5	8	32	2	64	ND	ND	-	4	.11	.12	.44	.69	.33	.27	ND	ND
6	32	16	2	4	ND	ND	-	-	.04	.03	.64	.53	.49	.28	ND	ND
7	n	NS	2	NS	ND	ND	-	NS	0	NS	0	NS	.08	NS	ND	ND
8	n	8	2	16	ND	ND	-	-	.03	.03	.07	.17	.10	.12	ND	ND
9	8	8	>128	64	ND	ND	-	-	.05	.08	.01	.19	0	.24	ND	ND
10	n	64	32	32	ND	ND	-	-	.10	.02	.56	.62	.08	.01	ND	ND
11	>128	>128	n	n	ND	ND	-	2	.13	.11	.43	.85	.44	.27	ND	ND

Appendix 10 Sheet D (2) - Serological findings in Affected Group.

Farm reference no: 10 Location: Aberfoyle, Perthshire.

Date of first sampling: October 19, 1982 Date of second sampling: November 15, 1982 No. of calves in group:

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
12	n	4	8	2	ND	ND	16	-	.16	.16	.32	.96	.33	.27	ND	ND
13	16	8	-	8	ND	ND	4	2	.16	.17	.22	.39	.10	.26	ND	ND
14	4	2	32	>128	ND	ND	2	4	.09	.11	.14	.70	.30	.31	ND	ND
15	2	64	n	2	ND	ND	-	4	.10	.12	.32	.82	.44	.52	ND	ND
16	n	8	8	4	ND	ND	-	-	.09	.09	.15	.33	.22	.22	ND	ND
17	8	8	8	128	ND	ND	-	4	.12	.16	.20	.62	.21	.24	ND	ND
18	8	64	n	2	ND	ND	-	-	.06	.08	0	.08	.10	.15	ND	ND
19	4	4	n	16	ND	ND	-	-	0	.19	0	.54	0	.35	ND	ND
20	16	32	16	64	ND	ND	4	-	.12	.09	.02	.23	.10	.09	ND	ND
21	16	16	16	32	ND	ND	-	-	.20	.05	.23	.34	.12	.14	ND	ND

Appendix 11 Sheet A - Farm and group background details.

Farm reference no: 11 Location: Langside, Aberdeenshire.

Farmer's veterinary surgeon: Corrie, Imray & Maclean, Strichen.

Date of first contact with Veterinary Surgeon: September, 1982

Date of arrival of case at G.U.V.H.: November 24, 1982

Farm background:

Cattle fattening unit, producing 500 fat cattle per year.

Present (farmer's) complaint:

Group of 60 (30 big, 30 small) weaned single suckled calves purchased from Orkney, and arrived on farm October 30 after delayed sea crossing. 1st calf ill 13th Nov., dull, anorexic, tachypnoeic, pyrexic. Case noticed to be ill on November 22, T. 106°F, not treated.

Action taken/prescribed prior to visit: None

IBR vaccination.
No anthelmintic.

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments: Of the 60 purchased, 16 ill, 1 death.

Appendix 11 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 11 Location: Langside, Aberdeenshire.

Case reference no: 89884

Clinical Signs:

Alert but quiet, T.105.1°F ⟶ T.104°F, RR 40/minute. Dried ocular discharge. No conjunctivitis. Profuse mucopurulent nasal discharge. No plaques. Occasional cough. On auscultation bubbles and high pitched squeaks, occasional crackles but solid.

Pathology and Microbiology: 24.11.82

Fibrinous pneumonia and pleurisy.

Pasteurella haemolytica A1	Tr, RC, Tonsil
Acinetobacter anitratum	RM, RD
Flavobacterium sp.	Thymus
Corynebacterium pyogenes	NC, Thymus
Mycoplasma bovis	Tr, RC, RM.

Serology:

Pasteurella haemolytica A1	64
Pasteureila haemolytica A2	16
Mycoplasma bovis	-

Appendix 12 Sheet A - Farm and group background details.

Farm reference no: 12 Location: Crieff, Perthshire.

Farmer's veterinary surgeon: Ashworth and Rodger, Crieff.

Date of first contact with Veterinary Surgeon: October 9, 1982

Date of first visit to farm: October 26, 1982

Farm background:

Large farming enterprise, sheep orientated.
70 single suckler cows, the calves from which are fattened.
90 weaned single suckled calves bought in market.

Present (farmer's) complaint:

Has had 'transit fever' every year, usually in bought-in calves. Group of 61 calves purchased on September 27 and housed. Dehorned etc. on September 29, one calf found dead October 5. Five calves ill with 'transit fever' over next 3 days, all from same sub-group of Simmental X calves.

Action taken/prescribed prior to visit:

No vaccines.
Fenbendazole at housing.

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments: In 1982, 90 purchased, 12 treated, 1 death.

Appendix 12 Sheet B (1) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 12 Location: Crieff, Perthshire.

Case reference no: 89329

Clinical Signs:

Purchased in a group of 61 on September 27 and housed. Dehorned September 30. First seen ill October 8. Alert but quiet. Temperature 104.4°F, respiratory rate 50/minute. Occasional cough. Mucopurulent nasal discharge. No adventitious sounds on auscultation. Not treated.

Pathology and Microbiology: P.M. October 9 1982

Fibrinous pneumonia.

Pasteurella haemolytica A1	NC,Tr,RC,RM,RD,BrLN,Tonsil,Thymus.
Mycoplasma bovirhinis	RC,RM.

Serology:

Pasteurella haemolytica A1	2
Pasteurella haemolytica A2	2
Mycoplasma bovis	2

Appendix 12 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 12 Location: Crieff, Perthshire.

Case reference no: 89776

Clinical Signs:

Admitted November 11. Temperature 106°F. Alert, difficult to catch. No cough. Eyes OK. Serous nasal discharge. Respiratory rate 90/minute but agitated. Harsh respiratory sounds on auscultation with occasional whistles.

Pathology and Microbiology: P.M. November 12, 1982

Fibrinous pneumonia.

Pasteurella haemolytica A1	NC,Tr,RC,RM,RD
Staphylococcus sp.	Thymus
Actinobacillus lignieresi	Tonsil
Mycoplasma bovirhinis	RC,RM

Serology: ND

Appendix 12

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group (in-contact)

Farm reference no: 12 Location: Crieff, Perthshire.

First Sampling Date: October 26, 1982

Total number of calves in group: 16 (purchased 25/10)

Number of calves sampled: 16

Calves treated: not known

Organism	No. of calves positive	Individual calf reference nos.
Bacillus coagulans	5	4,10,11,12,14
Bacillus laterosporus	2	4,9
Corynebacterium xerosis	2	1,3
Micrococcus sp.	4	2,6,9,16
Mycoplasma bovis	1	5
Mycoplasma dispar	1	16
Acholeplasma laidlawii	4	2,6,12,14

Second Sampling. Date: Not done No. of calves sampled:

Organism	No. of calves positive	Individual calf reference nos.

Appendix 13 Sheet A - Farm and group background details.

Farm reference no: 13 Location: Slamannan, Stirlingshire.

Farmer's veterinary surgeon: Newlands, Falkirk.

Date of first contact with Veterinary Surgeon: September, 1982

Date of first visit to farm: not visited

Farm background:

Part-time farmer.
Buys and sells beef calves. Calves purchased in autumn are given oxyclozamide/levamisole at housing.

Present (farmer's) complaint:

Group of 20 weaned suckled calves purchased from market on October 21. One calf noticed to be inappetent and tachypnoeic on October 27.

Action taken/prescribed prior to visit:

Treated with amoxycillin by intramuscular injection. Good early response to treatment but relapsed. Purchased for examination.

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments:

Of the 20 purchased, 2 were treated, no deaths.

Appendix 13 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 13 Location: Slamannan, Stirlingshire.

Case reference no: 89717

Clinical Signs:

8 month old Hereford X
First noticed to be ill on 27.10.82. Roaring, T. 105°F, Dull, and tachypnoeic. Treated with amoxycillin 3 days; improved but appetite remained depressed. Relapsed and not retreated.
Admitted to G.U.V.H. 8.11.82. Alert, thin, easily caught. Ataxic, rolled eyes. Hyperpnoeic, respiratory rate 80/minute. No cough. T.105.6°F. No adventitious sounds on auscultation, lungs solid.

Pathology and Microbiology: P.M. 8.11.82

Fibrinous pneumonia and nodules.

Pasteurella haemolytica A1	NC, Tr, RC, RM, RD, BrLN, Tonsil
Streptococcus bovis	Tonsil

Serology:

Pasteurella haemolytica A1	4
Pasteurella haemolytica A2	-
Mycoplasma bovis	2

Appendix 14 Sheet A - Farm and group background details.

Farm reference no: 14 Location: Duns, Berwickshire.

Farmer's veterinary surgeon: Peek, Duns.

Date of first contact with Veterinary Surgeon: September, 1982

Date of first visit to farm: not visited

Farm background:

Arable - potatoes and barley
Livestock - fattens cattle and sheep
Annual purchase of about 220 head of weaned suckled calves; 40 privately, rest through markets over a 2 week period.

Present (farmer's) complaint:

Group of calves purchased in market October 12.
One calf noticed ill (dull, pneumonic) October 27, left untreated and purchased by G.U.V.H.

Action taken/prescribed prior to visit: Ivermectin two days after housing.

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments: In 1982; 223 purchased, 22 ill, no deaths.

Appendix 14 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 14 Location: Duns, Berwickshire.

Case reference no: 89600

Clinical Signs:

Autumn born, Hereford X yearling, one of a group of 10 bought privately on October 12.
First noticed to be ill on October 27. T.105°F. Not treated, admitted to G.U.V.H. October 28.
Excellent body condition. T.103°F. Quiet, still alert. Mild conjunctivitis, mucoid nasal discharge. Not heard to cough, no response to percussion. Respiratory rate 90/minute. Hyperpnoeic. On auscultation soft crackles were heard antero-ventrally on the right with squeaks and high pitched bubbling sounds audible on the left side.

Pathology and Microbiology: P.M. October 29, 1982.

Fibrinous pneumonia.

Pasteurella multocida	NC, Tr, RC, RM, RD, BrLN, Tonsil
Aerococcus viridans	NC
Streptococcus faecalis	NC
Actinobacillus lignieresi	Thymus, tonsil
Mycoplasma bovirhinis	Tr, RC, RM

Serology:

Pasteurella haemolytica A1	16
Pasteurella haemolytica A2	64
Mycoplasma bovis	-

Appendix 15 Sheet A - Farm and group background details.

Farm reference no: 15 Location: Crocketford, Kirkcudbrightshire.

Farmer's veterinary surgeon: Allison and Murchie, Dumfries.

Date of first contact with Veterinary Surgeon: September, 1982

Date of first visit to farm: November 17, 1982.

Farm background:

Family run farm with 59 spring-calving beef cows and calves at foot. No cattle purchased recently. Also has commercial sheep flock. Cows and calves yarded together in autumn. Had "pneumonia" problem last year, one calf died, rest responded to antibiotics.

Present (farmer's) complaint:

59 cows and calves housed (with access to uncovered yard) on November 3, and vaccinated against PI3 and IBR and wormed (fenbendazole) when housed. One calf noticed to be dyspnoeic November 14. On examination of rest of group a further 11 were noticed to be dull, hyperpnoeic and tachypnoeic. V.S. was called and all were treated. By November 16, 21 calves were being treated.

Action taken/prescribed prior to visit:

Calves were all injected with tylosin, severe cases were given trimethoprim/sulphadiazine and the markedly hyperpnoeic calves were given betamethasone.

Author's assessment of 1. Cattle operation: Traditional beef and sheep farm, preventive medicine fair, but not very observant.

2. Affected group: The majority of calves are tachypnoeic and many are dull and empty. Charolais-cross calves, but some are small because of several old cows present in herd.

Author's advice:

Treat all further cases with oxytetracycline, and do not use tylosin or betamethasone. Consider 'blanket treatment'.

Follow-up comments:

No further cases after oxytetracycline treatment of all calves. At second visit only two calves still hyperpnoeic and tachypnoeic, these gradually improved over next few months.

Appendix 15 Sheet B (1) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 15 Location: Crocketford, Kirkcudbrightshire.

Case reference no: 89807

Clinical Signs:

Dyspnoeic calf of November 14, treated tylosin, trimethoprim sulphadiazine and betamethasone. Found dead November 15.

Pathology and Microbiology: P.M. November 17, 1982.

Severe fibrinous pneumonia with pleurisy.

Actinobacillus lignieresi RC, RM.

Serology:

Appendix 15 Sheet B(2) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 15 Location: Crocketford, Kirkcudbrightshire.

Case reference no: 89861

Clinical Signs:

Quiet but alert. Temperature 102.6°F, respiratory rate 50/minute, no nasal discharge, treated with tylosin and trimethoprim/sulphadiazine for 3 days. Harsh respiratory sounds.

Pathology and Microbiology: P.M. November 18, 1982

Severe fibrinous pneumonia with pleurisy.

P.haemolytica A1	Tr, RC, RM, LC, BrLN
Actinobacillus lignieresi	Thymus, tonsil
Flavobacterium sp.	NC, RD
Mycoplasma bovirhinis	Tr, RC.

Serology:

P.haemolytica A1	2
P.haemolytica A2	-
Mycoplasma bovis	-

Appendix 15

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 15 Location: Crocketford, Kirkcudbrightshire
First Sampling Date: November 17, 1982
Total number of calves in group: 58
Number of calves sampled: 10
Calves treated: 2,3,4,5,6,8,9

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella multocida	1	1
Klebsiella oxytoca	3	1,4,5
Acinetobacter lwoffi	1	1
Corynebacterium bovis	6	2,3,6,8,9,10
Aerococcus viridans	3	3,6,10
Mycoplasma bovirhinis	2	4,8

Second Sampling. Date: December 9,1982 No. of calves sampled: 10

Organism	No. of calves positive	Individual calf reference nos.
Bacillus coagulans	6	1,2,3,7,8,9
Bacillus lichenformis	3	2,5,9
Neisseria catarrhalis	3	1,4,5
Corynebacterium bovis	1	3
Micrococcus sp.	3	3,4,6
Kurthia sp.	1	9
A-D Group	1	10
Aerococcus sp.	1	10
Mycoplasma bovis	7	2,3,5,6,8,9,10
Mycoplasma bovirhinis	1	2
Acholeplasma laidlawii	1	9

Appendix 15 Sheet D - Serological findings in Affected Group.

Farm reference no: 15 Location: Crocketford, Kirkcudbrightshire.

Date of first sampling: November 17 1982 Date of second sampling: December 9 1982 No. of calves in group: 58

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	2	8	-	-	ND	ND	2	2	.20	.41	.03	.08	.22	.23	ND	ND
2	64	>128	4	16	ND	ND	-	-	.06	.20	0	.06	.09	.07	ND	ND
3	32	16	-	-	ND	ND	-	-	.41	.40	0	.19	.09	.10	ND	ND
4	8	8	-	-	ND	ND	-	n	.17	.22	.04	0	.09	.09	ND	ND
5	16	16	-	-	ND	ND	-	-	.36	.39	.15	.53	.21	.20	ND	ND
6	16	64	-	-	ND	ND	-	-	.25	.20	.01	.09	.19	.15	ND	ND
7	4	8	4	4	ND	ND	-	-	.08	.07	0	.03	.13	.11	ND	ND
8	8	32	n	4	ND	ND	-	-	.63	.57	.09	.35	.13	.13	ND	ND
9	n	32	-	-	ND	ND	-	-	.21	.30	.05	0	.09	.09	ND	ND
10	32	32	-	2	ND	ND	-	-	.18	.17	.01	.09	.11	.08	ND	ND

Appendix 16 Sheet A - Farm and group background details.

Farm reference no: 16 Location: Catrine, Ayrshire.

Farmer's veterinary surgeon: Barr and McMillan, Mauchline.

Date of first contact with Veterinary Surgeon: October 12, 1982

Date of first visit to farm: October 13, 1982

Farm background:

Small dairy farm, rears bought-in cattle as subsidiary enterprise.

Present (farmer's) complaint:

Group of 7 home bred bucket reared calves been at grass all summer, two weaned suckled calves purchased in market 14 days ago and added to group which were housed 10 days ago. Three days later 2 calves became ill, inappetent and pneumonic, little response to treatment. Calves not pyrexic but frequent, spontaneous coughing throughout the group.

Action taken/prescribed prior to visit:

2 sick calves treated with long-acting oxytetracycline.

Author's assessment of

1. Cattle operation: Good farmer all-round; good stockmanship.

2. Affected group: Inadvisable to mix home-reared and bought-in calves, but both groups well grown. Calves 3 and 5 are the purchased animals.

Author's advice: 1 further calf ill at time of visit. Advise blanket treatment of all group with long acting oxytetracycline at high dose rate.

Follow-up comments:

No further clinical cases. All made excellent rapid recovery.

Appendix 16 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 16 Location: Catrine, Ayrshire.

Case reference no: 89362

Clinical Signs:

Slight dullness but feeding. Temperature 102.8°F, respiratory rate 80/minute, hyperpnoeic, mucoid nasal discharge and fairly frequent cough.

Pathology and Microbiology:

Cuffing pneumonia.

Moraxella nonliquefaciens	NC, RM, RD.
Acinetobacter anitratum	Tr.
Actinobacillus lignieresi	RC, RM.
Micrococcus spp.	Thymus.
Bacillus licheniformis	Thymus, Tonsil.
Mycoplasma bovis	Tr, RC, RM.
Acholeplasma laidlawii	RM.

Serology:

Pasteurella haemolytica A1	2
Pasteurella haemolytica A2	2
Mycoplasma bovis	n

Appendix 16

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 16 Location: Catrine, Ayrshire.
First Sampling Date: October 13, 1982
Total number of calves in group: 8
Number of calves sampled: 8
Calves treated: 1 (1) Treatment oxytetracycline.

Organism	No. of calves positive	Individual calf reference nos.
Bacillus megatherium	7	1,2,3,4,5,6,7
Aerococcus viridans	4	2,6,7,8
Micrococcus sp.	2	3,4
Bacillus licheniformis	1	8
Flavobacterium sp.	1	1
Mycoplasma bovis	3	2,4,6
Mycoplasma bovirhinis	2	5,6

Second Sampling. Date: November 4 No. of calves sampled: 8

Organism	No. of calves positive	Individual calf reference nos.
Acinetobacter lwoffi	4	2,3,4,5
Micrococcus sp.	2	1,3
Corynebacterium bovis	4	4,5,6,7
Neisseria pharyngis	1	7
Streptococcus faecium	1	8
Bacillus coagulans	1	8
	3	3,4,6
	3	2,3,5

Appendix 16 Sheet D - Serological findings in Affected Group.

Farm reference no: 16 Location: Catrine, Ayrshire.

Date of first sampling: October 13, 1982 Date of second sampling: November 4, 1982 No. of calves in group: 8

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	NS	4	NS	16	ND	ND	NS	8	NS	0	NS	.37	NS	.07	ND	ND
2	8	8	16	32	ND	ND	-	16	.10	.13	.39	.76	.06	.34	ND	ND
3	16	16	4	32	ND	ND	>32	>32	.13	.22	.44	.68	.25	.20	ND	ND
4	8	4	64	32	ND	ND	-	-	.10	.07	.15	.22	.03	.01	ND	ND
5	32	32	64	32	ND	ND	-	16	0	0	.05	.21	0	0	ND	ND
6	8	4	16	16	ND	ND	-	8	.09	.22	.10	.54	.06	.35	ND	ND
7	8	2	64	64	ND	ND	-	4	.03	.10	.38	.16	.13	.10	ND	ND
8	4	4	64	64	ND	ND	-	-	.03	.08	.11	.96	.03	.22	ND	ND

NS - sample lost in laboratory

Appendix 17 Sheet A - Farm and group background details.

Farm reference no: 17 Location: Douglas Water, Lanarkshire.

Farmer's veterinary surgeon: G.U.L.P. Lanark.

Date of first contact with Veterinary Surgeon: September, 1982

Date of first visit to farm: October 12, 1982.

Farm background:

Has herd of beef cows (run with Charolais bull) and breeding sheep. Weaned suckled calves bought in for past few years. No previous problems.

Present (farmer's) complaint:

36 calves purchased in N. Ireland October 9 and 11, then shipped to Stranraer then by road to Douglas Water; arrived on farm late on October 12.
October 15, 10 calves noticed to be inappetent, dull and coughing. This group separated from others.

Action taken/prescribed prior to visit:

One calf treated with amoxycillin and bromhexine.
Farmer told by V.S. to inject remaining 9 in sick group with sulphamethylphenazole.

Author's assessment of 1. Cattle operation: Good handling facilities for one man operation as farm manager works the unit alone. Efficient small farm, good stockmanship.

2. Affected group: Good even group of bullocks but all very quiet and easy to handle. In addition to the "sick" group of 10 first seen ill, 14 of the 26 "well" calves are dull, have a mucoid nasal discharge and are pyrexic.

Author's advice: Acute IBR outbreak.

Treat all group with long acting antibacterial. Vaccinate rest of cattle on farm with intranasal IBR vaccine.

Follow-up comments:

Group recovered well.
Vaccination not carried out on practising V.S. advice.

Appendix 17

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 17 Location: Douglas Water, Lanarkshire.

First Sampling Date: October 15, 1982

Total number of calves in group: 36

Number of calves sampled: 10 (all "sick" group)

Calves treated: 7 Amoxycillin.

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	2	6,8
Bacillus licheniformis	8	1,2,4,6,7,8,9,10
Corynebacterium bovis	4	2,3,5,7
Micrococcus sp.	2	1,2
Aerococcus viridans	2	3,9
Corynebacterium haemolytica	1	4
Klebsiella aerogenes	1	10
Mycoplasma bovirhinis	2	2,4
Acholeplasma laidlawii	1	5
BHV-1	4	1,4,6,7

Second Sampling. Date: November 5 1982 No. of calves sampled: 10

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella multocida	3	1,5,7
Streptococcus sp.	1	2
Alcaligenes faecalis	1	3
Mycoplasma bovis	1	1
Mycoplasma bovirhinis	2	6,8
Acholeplasma laidlawii	8	1,2,3,4,7,8,9,10

Appendix 17 Sheet D - Serological findings in Affected Group.

Farm reference no: 17 Location: Douglas Water, Lanarkshire.

Date of first sampling: October 15, 1982 Date of second sampling: November 5, 1982 No. of calves in group: 36

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	128	128	n	8	ND	ND	-	4	.06	.06	.05	.35	0	.14	ND	ND
2	>128	>128	>128	>128	ND	ND	-	-	.02	.04	.07	.13	0	.03	ND	ND
3	>128	16	n	4	ND	ND	-	2	0	.01	0	.36	0	.11	ND	ND
4	128	>128	64	64	ND	ND	-	-	.02	.07	.03	.22	0	.17	ND	ND
5	128	>128	8	32	ND	ND	-	2	.05	0	.04	.17	.02	.22	ND	ND
6	128	>128	8	>128	ND	ND	-	-	0	0	0	.63	0	.22	ND	ND
7	64	>128	8	64	ND	ND	n	-	.04	.10	.06	.85	.45	.79	ND	ND
8	>128	>128	8	16	ND	ND	-	8	.03	.05	.03	.28	.03	.14	ND	ND
9	128	>128	8	>128	ND	ND	-	-	.07	.11	.09	1.08	.24	.56	ND	ND
10	4	>128	4	32	ND	ND	-	-	0	0	0	.57	0	.21	ND	ND

Appendix 18 Sheet A - Farm and group background details.

Farm reference no: 18 Location: Aberfoyle, Perthshire.

Farmer's veterinary surgeon: McKenzie, Croftamie.

Date of first contact with Veterinary Surgeon: September, 1982

Date of first visit to farm: Not visited

Farm background:

All home bred, spring calving herd. Also buys cull cows and implants them. 200 cows and calves (Charolais and Charolais X). Heifers all put to Limousin bull. All respiratory problems in slatted floor house. Had severe IBR in 1978.
All calves dosed with Ivermectin when housed with dams.

Present (farmer's) complaint:

208 calves at foot with dams, respiratory disease problem, 4 deaths. 48 calves treated.

Action taken/prescribed prior to visit:

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments:

Appendix 18 (1) Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 18 Location: Aberfoyle, Perthshire.

Case reference no: 89902

Clinical Signs:

Hereford X heifer.
Housed November 2 with dam. First seen ill November 20, treated trimethoprim/sulphonamide and chloramphenicol November 20-22, no clinical response.
Admitted 23 November. Alert. Temperature 101.8°F. Respiratory rate 30/minute. Hyperpnoeic, slight serous nasal discharge. Squeaks anteroventrally. Right solid anteroventral squeaks.

Pathology and Microbiology: P.M. November 24.

Fibrinous pneumonia and nodules.

Aerococcus viridans	NC, Tr, RC
Acinetobacter lwoffi	RM
Actinobacillus lignieresi	Tonsil
Mycoplasma bovis	RM
Mycoplasma bovirhinis	Tr, RM.

Serology:

Pasteurella haemolytica A1	4
Pasteurella haemolytica A2	16
Mycoplasma bovis	-

Appendix 18 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 18 Location: Aberfoyle, Perthshire.

Case reference no: 90122

Clinical Signs:

Limousin X bullock. Housed November 2 (with dam). First seen ill November 14, treated trimethoprim/sulphonamide plus chloramphenicol November 14-17, apparently recovered. Relapsed December 3, antibacterial treatment as before for 1 day only, improved but relapsed again December 11, treatment as before December 11 and 12. Respiratory rate 80-100/minute. Dull. Hyperpnoeic. Occasional cough. Temperature 102.8°F. Very harsh on auscultation, crackles anteroventrally (R).

Pathology and Microbiology: P.M. December 13.

Acute interstitial pneumonia (AIP)

Pasteurella haemolytica	Tonsil
Haemophilus sp.	NC
Acinetobacter anitratum	NC, TR
Moraxella nonliquefaciens	RC, RM, RD, BrLN
Aerococcus viridans	RC, RM, RD, BrLN
Mycoplasma bovis	Tr, RC, RM

Serology: ND

Appendix 18 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 18 Location: Aberfoyle, Perthshire.

Case reference no: 90172

Clinical Signs:

Housed (with dam) November 2. No previous history of illness. Found mouth-breathing and died December 18. Not treated.

Pathology and Microbiology: P.M. December 19

Fibrinous pneumonia.

Escherichia coli	Tr, RC, RM, RD
Alcaligenes bronchiseptica	BrLN
Corynebacterium murium	Tonsil
Mycoplasma bovirhinis	Tr, RC
Mycoplasma bovis	Tr, RM

Serology:

ND

Appendix 19 Sheet A Farm and group background details.

Farm reference no. 19 Location: Canonbie, Dumfriesshire

Farmer's Veterinary Surgeon: Miller and Partners, Lockerbie.

Date of first contact with Veterinary Surgeon: October 1982

Date of first visit to farm: October 20 1982

Farm background:

Retired veterinary surgeon with small pedigree Charolais herd and 30 commercial suckler cows, many of which carry embryo transplants. Persistent respiratory disease problems in single suckled calves at foot, with a high (25%+) mortality rate.

Author's assessment of 1. Cattle operation Unusual method of rearing one calf per cow for four months, weaning it and fostering a second calf onto the same cow for the remainder of her lactation.

2. Affected group Poor group of calves, several respiratory cripples in recently weaned group. Problems start when calves are still sucking, but are only allowed access to dam twice daily. Sampled group are younger but are showing signs of respiratory disease.

Follow-up comments:

Farmer persuaded to allow calves to run with their dams constantly and dissuaded from buying in the "foster" calves. "Ovip st" (Hoechst) sheep pasteurellosis vaccine used in 1983, which together with improved management resulted in better calves, fewer cases of respiratory disease and no deaths.

In 1982, 45 calves at risk, 18 ill, 8 deaths.

Appendix 19 Sheet B(1) Clinical, pathological and microbiological details of individual cases.

Farm reference no: 19 Location: Canonbie, Dumfriesshire.

Case reference no: 89491

Clinical Signs:

3 month old Limousin heifer.
Chronic respiratory cripple, thin, coughing, respiratory rate 66/min, rectal temperature 103.8°F. Harsh respiratory sounds, occasional squeaks anteroventrally. Treated with chloramphenicol, oxytetracycline and trimethoprim/sulphonamide with little effect.

Pathology and Microbiology: P.M. October 22, 1982

Chronic nonsuppurative pneumonia with bronchiolitis obliterans.

Actinobacillus lignieresi	NC, Tr, RC, RM, RD, BrLN
Mycoplasma bovirhinis	Tr.

Serology: ND

Appendix 19 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 19 Location: Canonbie, Dumfriesshire.

Case reference no: 89492

Clinical Signs:

4 month old Simmental heifer.
Respiratory cripple. Rectal temperature 102.8°F, respiratory rate 60/min. Cough. Marked weight loss. Harsh respiratory sounds with squeaks anteroventrally. Treated with chloramphenicol, oxytetracycline and potentiated sulphonamides without success.

Pathology and Microbiology: P.M. October 22, 1982.

Chronic non-suppurative pneumonia with bronchiolitis obliterans.

Actinobacillus lignieresi	NC, Tr, RC, RM, RD, BrLN
Acinetobacter anitratum	Thymus, Tonsil
Staphylococcus aureus	Thymus, Tonsil
Mycoplasma bovis	Tr, RM.

Serology: ND

Appendix 19 Sheet B(3) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 19 Location: Canonbie, Dumfriesshire.

Case reference no: 89638

Clinical Signs:

3 month old Charolais heifer.
Rectal temperature 103.2°F, respiratory rate 60/minute.
Dull, weight loss, occasional cough. Poor response to antibiotics.

Pathology and Microbiology: P.M. November 4, 1982

Chronic non-suppurative pneumonia with some Pasteurella nodules.

Pasteurella haemolytica A1	NC, Nodule in RD
Acinetobacter anitratum	Tr,RC,RM,RD,BrLN,Tonsil
Actinobacillus lignieresi	NC
Moraxella nonliquefaciens	Thymus
Klebsiella oxytoca	Tonsil
Flavobacterium sp.	Nodule in RC
Mycoplasma bovis	RC,RM
Mycoplasma bovirhinis	RC,RM
Acholeplasma laidlawii	Tr

Serology: ND

Appendix 19 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 19 Location: Canonbie, Dumfriesshire.

Case reference no: 89988

Clinical Signs:

10 week old Limousin calf.
Found dead, no previous clinical signs noticed.

Pathology and Microbiology: P.M. December 1, 1982

Extensive lung consolidation with few dilated septa.
Severe bronchiolar reaction with alveolitis.

Haemophilus somnus	Tr, RC, RM, RD, BrLN
Acinetobacter anitratum	RC, RM, BrLN
Actinobacillus lignieresi	Tr
Corynebacterium pyogenes	Tr
Mycoplasma bovis	RC
Mycoplasma bovirhinis	Tr, RC, RM

Serology: ND

Appendix 19

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 19 Location: Canonbie, Dumfriesshire.

First Sampling Date: October 20, 1982

Total number of calves in group: 15

Number of calves sampled: 10

Calves treated:

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	7	1,2,4,5,6,8,10
Pasteurella sp.	1	9
Bacillus alvei	6	1,2,3,4,5,7
Micrococcus sp.	1	3
Staphylococcus aureus	2	4,7
Acinetobacter anitratum	3	6,8,10
Mycoplasma bovis	3	2,3,4
Mycoplasma bovirhinis	10	1,2,3,4,5,6,7,8,9,10
Acholeplasma laidlawii	1	10

Second Sampling. Date: November 12, 1982 No. of calves sampled: 9

Organism	No. of calves positive	Individual calf reference nos.
Acinetobacter anitratum	1	9
Acinetobacter lwoffi	7	2,4,5,6,7,8,10
Actinobacillus lignieresi	1	9
Bacillus licheniformis	3	2,4,7
Mycoplasma bovis	4	2,7,8,10
Mycoplasma bovirhinis	8	2,3,5,6,7,8,9,10

Appendix 19 Sheet D - Serological findings in Affected Group.

Farm reference no: 19 Location: Canonbie, Dumfriesshire.

Date of first sampling: October 20,1982 Date of second sampling: November 12,1982 No. of calves in group: 15

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	-	NS	-	NS	ND	ND	n	NS	0.09	NS	0.45	NS	0.04	NS	ND	ND
2	16	8	-	-	ND	ND	-	4	0.09	0.12	0.12	0.10	0.05	0.05	ND	ND
3	4	n	-	-	ND	ND	-	2	0.00	0.00	1.05	0.93	0.56	0.42	ND	ND
4	4	16	-	-	ND	ND	-	-	0.28	0.09	0.26	0.11	0.27	0.11	ND	ND
5	8	16	-	-	ND	ND	-	-	0.30	0.16	0.10	0.08	0.04	0.03	ND	ND
6	4	4	-	-	ND	ND	8	2	1.40	0.77	0.73	0.34	0.25	0.11	ND	ND
7	n	n	-	-	ND	ND	-	n	0.02	0.06	0.44	0.22	0.05	0.06	ND	ND
8	-	2	-	-	ND	ND	-	-	0.25	0.14	0.47	0.24	0.20	0.10	ND	ND
9	2	16	-	n	ND	ND	2	4	0.46	0.30	0.24	0.13	0.11	0.13	ND	ND
10	4	8	-	n	ND	ND	-	-	0.16	0.06	0.17	0.09	0.04	0.03	ND	ND

Appendix 20 Sheet A Farm and group background details.

Farm reference no. 20 Location: Duns, Berwickshire.

Farmer's Veterinary Surgeon: Peek, Duns.

Date of first contact with Veterinary Surgeon: 1982

Date of first visit to farm: Not visited.

Farm background:

See Appendix 14.

123 weaned, single suckled calves bought in and housed over 4 week period.
All treated with Ivermectin and given IBR vaccine on arrival.

Author's assessment of 1. Cattle operation

2. Affected group

Follow-up comments:

In 1983; 123 purchased, 13 treated, no deaths.

Appendix 20 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 20 Location: Duns, Berwickshire

Case reference no: 93094

Clinical Signs:

Purchased October 17, in a group of we weaned single suckled calves. First noticed to be ill on October 27. Slightly dull but in good condition. Rectal temperature 106.5°F, respiratory rate 72/minute.
Not treated.

Pathology and Microbiology: P.M. October 28, 1983.

Foci of fibrinous pneumonia with oat cells. Dilated oedematous interlobular septa.

Pasteurella haemolytica A1	NC, Tr, RC, RM, RD, BrLN
Escherichia coli	Tonsil
Mycoplasma bovirhinis	RM

Serology: ND

(1)

Appendix 21 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm details, see Appendix 10. In 1983, 3 of 220 calves treated.

Farm reference no: 21 Location: Aberfoyle, Perthshire.

Case reference no: 93267

Clinical Signs:

14 month old Charolais X. Purchased mid June, at grass and housed September 29. First seen ill November 8. Alert. Rectal temperature 104.5°F. Respiratory rate 40/minute. Harsh respiratory sounds. Cough. Profuse nasal discharge with plaques, IBR diagnosed with associated pneumonia. Treated with oxytetracycline and betamethasone.

Pathology and Microbiology: P.M. 10 November 1983.

IBR + pneumonia (some dilation of interlobular septa).

Haemophilus sp.	RC
Neisseria catarrhalis	NC, BrLN
Proteus sp.	Tr, Tonsil
Micrococcus sp.	Tr
Actinobacillus lignieresi	Tonsil
Acholeplasma laidlawii	Tr, RC, RM
BHV-1	Tr

Serology: ND

Appendix 21 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 21 Location: Aberfoyle, Perthshire.

Case reference no: 93268

Clinical Signs:

Bought in October 29, first seen ill November 6.
Dull. Rectal temperature 108°F. Respiratory rate 30/minute.
Dyspnoeic, hyperpnoeic, mouth breathing. No nose lesions.
Mucopurulent nasal discharge. Crackles on auscultation.
Not treated.

Pathology and Microbiology:

IBR + fibrinous pneumonia, interstitial emphysema and fibrinous tags on the pleura.

Pasteurella haemolytica A1	NC, RC, RM
Actinobacillus lignieresi	RD
Micrococcus sp.	NC
Proteus sp.	Tr, Tonsil
Mycoplasma bovirhinis	Tr, RC, RM
Acholeplasma laidlawii	Tr
BHV-1 .	NC

Serology: ND

Appendix 22 Sheet A - Farm and group background details.

Farm reference no: 22 Location: Fraserburgh, Aberdeenshire.

Farmer's veterinary surgeon: Corrie, Imray and Maclean, Strichen.

Date of first contact with Veterinary Surgeon: October 1983.

Date of first visit to farm: November 17, 1983.

Farm background:

Buys in about 500 weaned single suckled calves each year for fattening. On arrival calves are wormed, given IBR vaccine and castrated. Of the 500 calves, half are usually autumn born and half spring born.

Present (farmer's) complaint:

240 large calves arrived October 31. Within 10 days of arrival 30 calves were treated for pneumonia and 2 died, but no post-mortems were carried out.
The second group of 240 spring-born calves arrived on November 7, the first pneumonia cases were noticed on November 14 and 27 calves were treated subsequently. 2 calves died on November 16. Coughing and oculonasal discharge were widespread.

Action taken/prescribed prior to visit:

Pneumonic calves were treated with penicillin/streptomycin and later with chloramphenicol if thought necessary. Several calves were lame with swollen joints because of poor slat design. These were treated with trimethoprim sulphadoxine.

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments:

In 1983; 480 purchased, 73 treated, 4 deaths.

Appendix 22 Sheet B (1) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 22 Location: Fraserburgh, Aberdeenshire.

Case reference no: 93378

Clinical Signs:

Set of lungs from calf that died November 16.

Pathology and Microbiology: P.M. November 18. Fibrinous pneumonia.

Pasteurella haemolytica A1	RC, RM, RD.
Corynebacterium haemolyticum	RM.
Acinetobacter anitratum	RD.
Acholeplasma laidlawii	RM, RD.

Serology: ND

(2)

Appendix 22 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 22 Location: Fraserburgh, Aberdeenshire.

Case reference no: 93379

Clinical Signs:

Wild blue-grey heifer. Rectal temperature 103.5°F.
No cough. Respiratory rate 70/minute. Hyperpnoeic.
Harsh respirations with squeaks and crackles anteroventrally, especially on the right lung field.
Slight serous nasal discharge. Conjunctivitis.
Not treated.

Pathology and Microbiology: P.M. November 18.

Proliferative bronchiolitis and alveolitis with degenerating cells and minimal fibrinous reaction.

Acinetobacter anitratum	Tr, RC, RM
Bacillus coagulans	BrLN
Escherichia coli	Tonsil
Mycoplasma bovis	RM
Mycoplasma bovirhinis	Tr, RC, RM
Acholeplasma laidlawii	Tr, RC

Serology: ND

Appendix 22 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 22 Location: Fraserburgh, Aberdeenshire.

Case reference no: 93380

Clinical Signs:

Slightly dull, Limousin cross steer.

Rectal temperature 103°F. Respiratory rate 50/minute. Harsh respiration, no adventitious sounds. Occasional cough. Mucopurulent nasal discharge. No eye lesions.

Pathology and Microbiology: P.M. November 18.

Proliferative bronchiolitis and alveolitis with degenerating cells and foci of fibrinous pneumonia.

Acinetobacter anitratum	RC, RM, RD
Acinetobacter lwoffi	Tonsil
Corynebacterium bovis	NC
Neisseria catarrhalis	NC, Tr, RM, RD, BrLN
Micrococcus sp.	Tonsil
Mycoplasma bovis	Tr, RC
Mycoplasma bovirhinis	Tr
Acholeplasma laidlawii	RM

Serology: ND

Appendix 22

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 22 Location: Fraserburgh, Aberdeenshire.

First Sampling Date: November 17, 1983.

Total number of calves in group: 20

Number of calves sampled: 13

Calves treated: not known

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	1	8

Second Sampling. Date: Not done No. of calves sampled:

Organism	No. of calves positive	Individual calf reference nos.

Appendix 23 Sheet A - Farm and group background details.

Farm reference no: 23 Location: Auchterarder, Perthshire.

Farmer's veterinary surgeon: Ashworth and Rodger, Crieff.

Date of first contact with Veterinary Surgeon: November 15, 1983

Date of first visit to farm: December 12, 1983

Farm background:

Weaned single suckled calves purchased from market and from a brother, and fattened.

Present (farmer's) complaint: 47 calves arrived on unit on October 17 (23 from market, 24 from brother) mixed and split into 2 groups. 2 calves from this batch seen to be pneumonic on days 8 and 9 after purchase, treated with long-acting penicillin and recovered. 51 smaller calves arrived from brother on October 19, widespread cough and mucopurulent nasal discharge on October 25, still coughing on November 15.

Action taken/prescribed prior to visit:

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments:

No further cases of "Transit fever" after the calf admitted to G.U.V.H.

Appendix 23 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 23 Location: Auchterarder, Perthshire.

Case reference no: 93350

Clinical Signs:

One of group of 51 calves which arrived at farm on October 19, widespread coughing and mucopurulent nasal discharge in group on October 25. No calves treated until this calf was seen to be anorexic and dull on November 10, treated with long-acting Penicillin on two occasions. On admission to G.U.V.H. the calf was a 7 month old Aberdeen Angus cross in fair condition but dull. Rectal temperature 103.6°F, respiratory rate 70/minute with marked hyperpnoea. Harsh respiration and anteroventral squeaks. No cough. No nasal or ocular discharge.

Pathology and Microbiology: P.M. November 16, 1983.

Fibrinous pneumonia, dilated interlobular septa. Bronchiolitis, proliferative alveolitis.

Pasteurella haemolytica A1	Tr, RC, LC
Actinobacillus lignieresi	NC
Acinetobacter anitratum	RC, RM
Bacillus coagulans	Tr
Escherichia coli	Tonsil
Mycoplasma bovirhinis	Tr, RC, RM

Serology: ND

Appendix 23

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 23 Location: Auchterarder, Perthshire

First Sampling Date: December 12, 1983

Total number of calves in group: 51

Number of calves sampled: 26

Calves treated: not known

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	11	1,5,6,9,10,12,15, 17,20,22,25
Pasteurella haemolytica A2	1	14

Second Sampling. Date: Not done No. of calves sampled:

Organism	No. of calves positive	Individual calf reference nos.

Appendix 24 Sheet A - Farm and group background details.

Farm reference no: 24 Location: Skelmorlie, Ayrshire.

Farmer's veterinary surgeon: Kennedy, W. Kilbride.

Date of first contact with Veterinary Surgeon: November 30, 1983

Date of first visit to farm: December 21, 1983

Farm background:

90 suckler cows, kept in 2 groups. All calves reared and fattened. About 50 additional calves purchased. Homebred calves are Charolais X, bought-in calves are of various breeds.

Present (farmer's) complaint:

Widespread coughing especially in home-bred calves (which are separate from bought-in calves). Two home-bred calves have died. Many calves are anorexic, tachypnoeic and have a mucopurulent nasal discharge.

Action taken/prescribed prior to visit:

Author's assessment of 1. Cattle operation: Poor housing conditions and general management.

2. Affected group:

Author's advice:

Follow-up comments:

A total of 37 calves were treated for respiratory disease. Two yearlings died.
Calves still running with cows.

Appendix 24 Sheet B(1) Clinical, pathological and microbiological details of individual cases.

Farm reference no: 24 Location: Skelmorlie, Ayrshire.

Case reference no: 93509

Clinical Signs:

Home-bred calf aged 5 months, still running with dam. Housed late October. Off legs November 11, treated with chloramphenicol, tripelennamine and dexamethasone for 2 weeks, recovered and relapsed November 29.

Pathology and Microbiology: P.M. November 30, 1983.

Bronchiolitis obliterans, occasional foci of fibrinous pneumonia.

Corynebacterium bovis	RC, RM, RD, BrLN, Brain
Acinetobacter anitratum	NC, Tonsil
Actinobacillus lignieresi	Tr
Escherichia coli	Tonsil
Bacillus coagulans	RtLN
Flavobacterium sp.	NC
Mycoplasma bovirhinis	Tr, RC

Serology: ND

Appendix 24 Sheet B(2) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 24 Location: Skelmorlie, Ayrshire.

Case reference no: 93510

Clinical Signs:

Home-bred calf, aged 5 months still running with dam. Same group as 93509. First noticed to be pneumonic November 17, treated with chloramphenicol, dexamethasone and tripelennamine on several occasions. Developed subcutaneous emphysema on November 29.

Pathology and Microbiology: P.M. November 30, 1983.

Classical early fibrinous pneumonia with septal involvement, proliferative bronchiolitis.

Pasteurella multocida	RC, RM, RD, LC.
Flavobacterium sp.	NC, Tr
Bacillus coagulans	Tonsil
Staphylococcus aureus	RtLN
Mycoplasma bovirhinis	Tr, RC
Acholeplasma laidlawii	RM

Serology: ND

Appendix 24 Sheet B (3) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 24 Location: Skelmorlie, Ayrshire.

Case reference no: 93679

Clinical Signs:

Lungs only, from large yearling.

Pathology and Microbiology: December 14, 1983.

Pasteurella haemolytica T10 RC, RM

Serology: ND

Appendix 24 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 24 Location: Skelmorlie, Ayrshire.

Case reference no: 93680

Clinical Signs:

D.O.A. - large yearling.

Pathology and Microbiology: P.M. December 14, 1983.

Proliferative bronchiolitis and alveolitis, bronchiolitis obliterans with lesions of atypical interstitial pneumonia in caudal lobes.

Pasteurella haemolytica T10 RC, RM

Serology: ND

Appendix 24

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 24 Location: Skelmorlie, Ayrshire.

First Sampling Date: December 21, 1983

Total number of calves in group: 45

Number of calves sampled: 15

Calves treated: not known

Organism	No. of calves positive	Individual calf reference nos.

Pasteurella sp. were not isolated.

Second Sampling. Date: ND No. of calves sampled:

Organism	No. of calves positive	Individual calf reference nos.

Appendix 25 Sheet A - Farm and group background details.

Farm reference no: 25 Location: Markinch, Fife.

Farmer's veterinary surgeon: Wilson, Cupar, Fife.

Date of first contact with Veterinary Surgeon: 1983

Date of first visit to farm: November 7, 1983

Farm background:

45 weaned single suckled calves purchased on 14th October in Dalmally. 60 larger calves still on farm from last year. Calves housed on arrival at farm, but can run out into yards. Given ivermectin and implanted with zeranol at housing.

Present (farmer's) complaint:

Group purchased October 14, one calf noticed to be dull on October 28.

Action taken/prescribed prior to visit:

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments:

Two further calves treated in group of recently purchased animals.

Appendix 25 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 25 Location: Markinch, Fife.

Case reference no: 93114

Clinical Signs:

Purchased October 14, noticed to be dull October 28. Hereford X heifer, alert, rectal temperature 102°F. Serous nasal discharge. Respiratory rate 40/minute. No cough. No adventitious sounds on auscultation. Not treated.

Pathology and Microbiology: P.M. October 29, 1983

Proliferative bronchiolitis and alveolitis, epithelial necrosis, interstitial emphysema.

Bacillus coagulans	NC, RD
Bacillus licheniformis	Tr, RM
Acinetobacter lwoffi	RC
Acinetobacter sp.	BrLN
Streptococcus pyogenes	RD
Actinobacillus lignieresi	Tonsil

Serology: ND

Appendix 25

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 25 Location: Markinch, Fife.

First Sampling Date: November 7, 1983

Total number of calves in group: 45

Number of calves sampled: 18

Calves treated: not known

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	1	48
Pasteurella haemolytica A2	1	49

Second Sampling. Date: December 14,1983 No. of calves sampled: 18

Organism	No. of calves positive	Individual calf reference nos.

Pasteurella sp. were not isolated

Appendix 25 Sheet D - Serological findings in Affected Group.

Farm reference no: 25 Location: Markinch, Fife.

Date of first sampling: November 7, 1983 Date of second sampling: December 14, 1983 No. of calves in group: 45

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
43	64	64	4	>128	ND	ND	8	16	0.01	0.09	1.10	1.62	0.28	0.33	ND	ND
44	64	64	4	>128	ND	ND	16	16	0.04	0.09	0.83	1.66	0.96	0.54	ND	ND
45	64	64	64	128	ND	ND	16	16	0.02	0.05	0.87	1.64	0.16	0.18	ND	ND
46	64	64	16	32	ND	ND	2	16	0.14	0.17	0.47	1.34	1.51	1.50	ND	ND
47	64	64	4	>128	ND	ND	16	8	0.09	0.06	0.19	1.66	0.45	0.18	ND	ND
48	64	64	>128	>128	ND	ND	-	-	0.05	0.38	1.11	1.09	0.33	0.50	ND	ND
49	64	64	128	>128	ND	ND	-	-	0.02	0.17	1.48	1.23	1.40	1.05	ND	ND
50	64	64	64	>128	ND	ND	-	-	0.00	0.04	1.37	1.50	0.39	0.36	ND	ND
51	64	64	64	>128	ND	ND	-	-	0.10	0.05	0.43	0.65	0.79	0.43	ND	ND
52	64	64	64	>128	ND	ND	-	-	0.07	0.21	1.30	0.33	0.12	0.00	ND	ND
53	64	64	8	8	ND	ND	-	-	0.19	0.22	1.70	1.71	1.41	1.24	ND	ND
54	64	64	16	32	ND	ND	-	-	0.03	0.03	0.19	0.52	1.25	0.81	ND	ND

Appendix 25 Sheet D - Serological findings in Affected Group.

Farm reference no: 25 Location: Markinch, Fife.

Date of first sampling: November 7, 1983 Date of second sampling: December 14, 1983 No. of calves in group: 45

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
55	8	64	128	>128	ND	ND	-	-	0.03	0.07	0.52	0.94	1.05	0.66	ND	ND
56	16	64	32	>128	ND	ND	-	-	0.00	0.17	1.49	1.09	0.74	0.31	ND	ND
57	8	64	32	>128	ND	ND	-	-	0.09	0.06	0.35	1.52	0.16	0.00	ND	ND
58	32	32	128	64	ND	ND	-	-	0.49	0.43	1.11	1.11	0.35	0.43	ND	ND
59	64	64	16	>128	ND	ND	-	-	0.00	0.09	1.65	1.63	1.05	0.76	ND	ND
60	32	64	>128	64	ND	ND	-	-	0.02	0.01	0.37	1.04	0.66	0.28	ND	ND

Appendix 26 Sheet A - Farm and group background details.

Farm reference no: 26 Location: Comrie, Fife.

Farmer's veterinary surgeon: Wilson, Cupar.

Date of first contact with Veterinary Surgeon: 1983

Date of first visit to farm: November 7, 1983

Farm background:

Hill farm with 80 suckler cows and fattens all home-bred calves which are spring-born.

Present (farmer's) complaint: Group of 80 calves weaned, castrated and dehorned on September 29th and left outside. Two calves noticed to be ill on October 11, both treated with oxytetracycline, one further calf noticed to be ill on October 12 and treated similarly. Occasional coughing was heard from the group of calves. All calves housed on October 14 and dosed with anthelminthic, on 15th October one of the calves that had been ill outside relapsed and was re-treated. Two further calves were treated on October 17 when many calves were noticed to have a serous nasal discharge.

Action taken/prescribed prior to visit:

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments:

A total of 10 calves were treated (including the calf admitted to G.U.V.H.). Subsequently all the calves were given chlortetracycline in-feed.

Appendix 26 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 26 Location: Comrie, Fife.

Case reference no: 93116

Clinical Signs:

Treated on two occasions for pneumonia. First seen to be ill on October 22, treated for 3 days with oxytetracycline but relapsed on October 28 and treated again, this time with trimethoprim/sulphadoxine.

7 month old Hereford X heifer. Thin, slightly dull. Rectal temperature 102.2°F. Respiratory Rate 30/minute. No nasal discharge. No cough. "Wheezy" sounds on auscultation of right lung field.

Pathology and Microbiology: P.M. October 30, 1983

Fibrinous pneumonia and pleurisy.

Pasteurella haemolytica A1	NC, RC, RM, RD, BrLN, Tonsil
Staphylococcus aureus	Tr
Mycoplasma bovirhinis	Tr, RC, RM

Serology: ND

Appendix 26

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 26 Location: Comrie, Fife.
First Sampling Date: November 7, 1983
Total number of calves in group: 80
Number of calves sampled: 12
Calves treated: not known

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella sp. were not isolated		

Second Sampling. Date: December 7, 1983 No. of calves sampled:

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	2	11,12

Appendix 26 Sheet D - Serological findings in Affected Group.

Farm reference no: 26 Location: Comrie, Fife.

Date of first sampling: November 7, 1983 Date of second sampling: December 7, 1983 No. of calves in group: 80

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	64	32	32	16	ND	ND	-	4	0.00	0.00	0.02	0.01	0.00	0.00	ND	ND
2	64	32	>128	>128	ND	ND	n	-	0.00	0.00	0.00	0.06	0.00	0.00	ND	ND
3	8	16	128	128	ND	ND	2	8	0.48	0.23	0.03	0.02	0.00	0.00	ND	ND
4	32	32	64	64	ND	ND	8	n	0.00	0.00	0.00	0.00	0.00	0.00	ND	ND
5	32	32	32	>128	ND	ND	n	2	0.15	0.08	0.00	0.00	0.00	0.00	ND	ND
6	32	32	32	>128	ND	ND	-	-	0.00	0.00	0.00	0.11	0.00	0.00	ND	ND
7	32	32	64	32	ND	ND	-	-	0.03	0.02	0.02	0.00	0.00	0.00	ND	ND
8	32	32	>128	>128	ND	ND	-	-	0.00	0.00	0.00	0.10	0.00	0.00	ND	ND
9	32	32	>128	>128	ND	ND	-	-	0.00	0.00	0.01	0.00	0.00	0.00	ND	ND
10	32	16	>128	>128	ND	ND	4	-	0.00	0.00	0.05	0.07	0.00	0.00	ND	ND
11	32	128	>128	>128	ND	ND	2	4	0.05	0.02	0.08	0.15	0.00	0.00	ND	ND
12	32	128	32	>128	ND	ND	2	-	0.09	0.10	0.10	0.14	0.06	0.00	ND	ND

Appendix 27 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm details, see Appendix 5. In 1983, 40 of 210 calves treated.

Farm reference no: 27 Location: Blairdrummond, Stirlingshire.

Case reference no: 93240

Clinical Signs:

Housed October 27. First seen ill November 8.

Alert. Rectal temperature 104°F. Respiratory rate 75/min. Mucoid nasal discharge. No cough or adventitious sounds on auscultation. Untreated.

Pathology and Microbiology: P.M. November 9, 1983

Pasteurella haemolytica A1	NC, Tr, RC, RM, RD, BrLN, Tonsil
Mycoplasma bovirhinis	Tr.

Serology: ND

Appendix 27 Sheet C - Microbiological findings (from nasopharyngeal swabs) in Monitor Group

Farm reference no: 27 Location: Blairdrummond, Stirlingshire.

First Sampling Date: October 27, 1983

Total number of calves in group: 40

Number of calves sampled: 40

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	4	6,19,21,22

Second Sampling. Date: December 6, 1983 No. of calves sampled: 40

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	4	13,17,30,38

Appendix 27 Sheet D - Serological findings in Monitor group.

Farm reference no: 27 Location: Blairdrummond, Stirlingshire

Date of first sampling: October 27, 1983 Date of second sampling: December 6, 1983 No. of calves in group: 40

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	16	>128	4	16	ND	ND	-	-	0.00	0.10	0.21	0.48	0.24	0.74	ND	ND
2	8	>128	4	16	ND	ND	-	-	0.00	0.00	0.17	0.29	0.16	0.56	ND	ND
3	8	>128	64	128	ND	ND	-	-	0.09	0.23	0.38	0.76	0.25	0.75	ND	ND
4	16	64	4	2	ND	ND	-	4	0.00	0.05	0.25	0.52	0.21	0.40	ND	ND
5	>128	>128	128	64	ND	ND	-	-	0.13	0.30	0.33	0.71	0.29	0.10	ND	ND
6	16	>128	8	64	ND	ND	-	-	0.15	0.26	0.22	0.68	0.17	0.55	ND	ND
7	32	>128	2	16	ND	ND	-	-	0.19	0.34	0.41	0.34	0.23	0.53	ND	ND
8	8	>128	4	8	ND	ND	-	-	0.09	0.25	0.20	0.66	0.20	0.64	ND	ND
9	16	>128	4	8	ND	ND	-	-	0.01	0.05	0.15	0.45	0.17	0.49	ND	ND
10	32	>128	2	8	ND	ND	-	n	0.10	0.09	0.38	0.77	0.21	0.86	ND	ND

Appendix 27 Sheet D - Serological findings in Monitor Group.

Farm reference no: 27 Location: Blairdrummond, Stirlingshire.

Date of first sampling: October 27, 1983 Date of second sampling: December 6, 1983 No. of calves in group: 40

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
11	16	>128	128	64	ND	ND	-	-	0.00	0.04	0.26	0.54	0.20	0.92	ND	ND
12	32	32	128	64	ND	ND	-	-	0.06	0.20	0.14	0.52	0.19	0.56	ND	ND
13	8	>128	128	64	ND	ND	-	-	0.00	0.00	0.15	0.29	0.29	0.86	ND	ND
14	4	>128	4	8	ND	ND	-	-	0.13	0.19	0.18	0.25	0.18	0.74	ND	ND
15	8	>128	8	32	ND	ND	-	-	0.00	0.04	0.28	0.50	0.43	0.64	ND	ND
16	8	8	64	64	ND	ND	-	4	0.00	0.07	0.21	0.51	0.21	0.37	ND	ND
17	8	8	32	64	ND	ND	-	-	0.00	0.00	0.17	1.30	0.25	0.60	ND	ND
18	4	8	64	64	ND	ND	-	-	0.13	0.13	0.14	0.69	0.31	0.51	ND	ND
19	4	NS	n	NS	ND	ND	-	NS	ND	ND	ND	ND	ND	ND	ND	ND
20	4	64	32	64	ND	ND	n	n	0.01	0.00	0.37	1.39	0.18	0.54	ND	ND

Appendix 27 Sheet D - Serological findings in Monitor Group.

Farm reference no: 27 Location: Blairdrummond, Stirlingshire.

Date of first sampling: October 27, 1983 Date of second sampling: December 6, 1983 No. of calves in group: 40

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
21	4	>128	4	2	ND	ND	2	4	0.00	0.06	0.09	0.39	0.26	0.79	ND	ND
22	64	64	128	128	ND	ND	n	4	0.00	0.05	2.29	2.07	0.18	0.65	ND	ND
23	64	64	16	8	ND	ND	-	4	0.01	0.00	0.49	0.84	0.00	0.86	ND	ND
24	8	64	4	32	ND	ND	-	n	0.00	0.05	0.08	0.30	0.08	0.75	ND	ND
25	32	>128	4	64	ND	ND	-	2	0.02	0.00	0.10	0.50	0.32	0.70	ND	ND
26	8	>128	32	128	ND	ND	-	-	0.00	0.05	0.00	0.24	0.07	0.99	ND	ND
27	16	>128	4	32	ND	ND	-	-	0.00	0.01	0.07	0.31	0.00	0.25	ND	ND
28	32	>128	32	16	ND	ND	-	-	0.05	0.03	0.21	0.74	0.12	1.04	ND	ND
29	64	64	8	64	ND	ND	-	-	0.05	0.01	1.48	1.76	0.24	0.61	ND	ND
30	32	>128	8	32	ND	ND	-	-	0.00	0.07	0.06	0.22	0.18	0.46	ND	ND

Appendix 27 Sheet D - Serological findings in Monitor Group.

Farm reference no: 27 Location: Blairdrummond, Stirlingshire.

Date of first sampling: October 27, 1983 Date of second sampling: December 6, 1983 No. of calves in group: 40

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
31	32	>128	32	64	ND	ND	-	-	0.11	0.06	0.74	0.72	0.00	0.59	ND	ND
32	64	>128	4	64	ND	ND	-	-	0.00	0.06	0.55	1.15	0.15	0.88	ND	ND
33	32	>128	16	128	ND	ND	-	n	0.05	0.04	0.88	1.98	0.00	0.76	ND	ND
34	32	>128	128	128	ND	ND	-	n	0.03	0.12	0.08	0.90	0.29	0.65	ND	ND
35	32	>128	128	64	ND	ND	8	-	0.06	0.00	0.08	0.41	0.36	1.30	ND	ND
36	32	>128	128	64	ND	ND	4	2	0.00	0.00	0.00	0.38	0.23	1.05	ND	ND
37	32	>128	2	32	ND	ND	-	-	0.02	0.00	0.07	0.50	0.37	0.36	ND	ND
38	64	64	2	32	ND	ND	-	-	0.00	0.00	0.05	0.72	0.38	0.99	ND	ND
39	64	64	2	32	ND	ND	2	4	0.05	0.08	0.02	0.83	0.38	0.42	ND	ND
40	32	>128	64	128	ND	ND	n	-	0.00	0.00	0.05	0.48	0.45	2.73	ND	ND

Appendix 28 Sheet A - Farm and group background details.

Farm reference no: 28 Location: Maybole, Ayrshire.

Farmer's veterinary surgeon: Robertson and Orr, Maybole.

Date of first contact with Veterinary Surgeon: November 30, 1983.

Date of first visit to farm: December 1, 1983.

Farm background:

Hill farm, 34 suckler cows (mixed breed) run with Limousin bull,and blackface sheep.
Calving July/August, housed early November, weaned in February.
All cows and calves treated with ivermectin at housing.
Cows and calves housed together November 9, calves creep fed.

Present (farmer's) complaint:

Bout of coughing in calves 10 days ago.
1 calf found dead November 30, 4 others found to be pyrexic and pneumonic.

Action taken/prescribed prior to visit:

2 of 4 sick calves treated with tetracyclines and betamethasone November 30, 2 left untreated and admitted to G.U.V.H. November 30.

Author's assessment of 1. Cattle operation: Traditional, family run farm.

2. Affected group: Uneven group of calves, some had diarrhoea earlier in summer. A lot of coughing, all look empty and slow to come for barley in creep. Majority RR >60 /minute, mucopurulent nasal discharge. Several calves have ringworm which is unusual.

Author's advice:

Treat all of group with long acting tetracyclines.

Follow-up comments:

All well grown and clinically normal at second sampling on January 10, 1984, apart from 1 calf which is a respiratory cripple.

Appendix 28 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 28 Location: Maybole, Ayrshire

Case reference no: 93523

Clinical Signs:

Found dead November 30, 1983.

Pathology and Microbiology: P.M. November 30, 1983.

Fibrinous pneumonia and nodules

Acinetobacter anitratum RC, RM, RD

Serology: ND

Appendix 28 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 28 Location: Maybole, Ayrshire.

Case reference no: 93524

Clinical Signs:

Pyrexic and pneumonic November 30, 1983.

Rectal temperature 104.8°F, dull, respiratory rate 60/min, cyanotic. Harsh lung sounds on auscultation, no adventitious sounds. Treated oxytetracycline and betamethasone.

Pathology and Microbiology: November 30, 1983.

Pasteurella haemolytica A1	NC
Pasteurella haemolytica T10	Tr, RC, RM, RD, BrLN, Tonsil, RTLN
Micrococcus sp.	NC

Serology: ND

Appendix 28 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 28 Location: Maybole, Ayrshire.

Case reference no: 93527

Clinical Signs:

Pyrexic and pneumonic November 30, 1983.

Rectal temperature 103.4°F, dull, respiratory rate 60/min.
Mucoid nasal discharge, occasional cough, conjunctivitis.
No adventitious sounds on auscultation.
Not treated.

Pathology and Microbiology: P.M. November 30, 1983.

P.haemolytica T10	RC, RM, RD, BrLN, RTLN.
Acinetobacter anitratum	NC, Tr, Tonsil.
Acinetobacter lwoffi	RC, RM, RD, Tonsil.

Serology: ND

Appendix 28

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 28 Location: Maybole, Ayrshire.

First Sampling Date: December 1, 1983

Total number of calves in group: 31

Number of calves sampled: 10

Calves treated:

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	1	3
Acinetobacter anitratum	8	1,2,4,6,7,8,9,10
Micrococcus sp.	6	2,4,5,6,7,10

Second Sampling. Date: January 10,1984 No. of calves sampled: 10

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	1	4
Pasteurella haemolytica A2	1	6

Appendix 28 Sheet D - Serological findings in Affected Group.

Farm reference no: 28 Location: Maybole, Ayrshire.

Date of first sampling: December 1, 1983 Date of second sampling: January 10, 1984 No. of calves in group: 31

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	2	2	2	n	ND	ND	-	-	0.07	0.15	0.07	0.17	0.02	0.00	ND	ND
2	2	16	n	n	ND	ND	-	-	0.29	0.04	0.39	0.25	0.08	0.00	ND	ND
3	2	64	2	n	ND	ND	-	2	0.14	0.23	0.40	0.36	0.00	0.00	ND	ND
4	n	32	2	n	ND	ND	n	-	0.27	0.14	0.12	0.15	0.22	0.18	ND	ND
5	n	128	n	n	ND	ND	-	*IS	0.04	0.00	0.12	0.52	0.00	1.81	ND	ND
6	2	16	n	n	ND	ND	-	IS	0.04	0.00	0.19	0.30	0.38	0.57	ND	ND
7	2	128	n	n	ND	ND	-	-	0.10	0.03	0.60	0.33	0.05	0.00	ND	ND
8	2	32	n	n	ND	ND	n	n	0.00	0.06	0.39	0.21	0.00	0.00	ND	ND
9	2	32	-	n	ND	ND	-	IS	0.05	0.00	0.11	0.18	0.00	0.24	ND	ND
10	2	32	-	n	ND	ND	IS	IS	0.10	0.00	0.46	0.14	0.30	0.00	ND	ND

IS insufficient sample

Appendix 29 Sheet A - Farm and group background details.

Farm reference no: 29 Location: Milngavie, Dunbartonshire.
Farmer's veterinary surgeon: Ross and Bickerton, Bishopbriggs.
Date of first contact with Veterinary Surgeon: 1982
Date of first visit to farm: December 2, 1983
Farm background:

For details see Appendix 3.

Present (farmer's) complaint:

Agreed to act as monitor farm in 1983, one bought in calf found dead during monitor period.

Action taken/prescribed prior to visit:

All calves dosed with fenbendazole at housing.

Author's assessment of 1. Cattle operation:

2. Affected group:

Author's advice:

Follow-up comments:

Total of 280 calves purchased, 13 treated, 1 death.
All treated calves recovered.
Calf 8 in sampled group treated with trimethoprim/sulphadoxine on three occasions.

Appendix 29 Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 29 Location: Milngavie, Dunbartonshire.

Case reference no: 93593

Clinical Signs:

Purchased October 30 and put outside. Housed December 2, one of a group of 67, and dosed with fenbendazole. Not seen to be ill, found dead December 5.

Pathology and Microbiology: P.M. December 5, 1983

Extensive anterior lobe pneumonia, congestion, oedema and fibrinous reaction in septa and pleura. Intra-alveolar haemorrhage, oedema and mild alveolar epithelial hyperplasia. Widespread bacterial colonisation especially of small blood vessels in lungs but also in liver and lymph nodes.

Serology: ND

Appendix 29

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 29 Location: Milngavie, Dunbartonshire.

First Sampling Date: December 2, 1983

Total number of calves in group: 67

Number of calves sampled: 10

Calves treated:

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	4	2,4,7,9

Second Sampling. Date: January 9,1984 No. of calves sampled: 10

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella sp.	0	

Appendix 29 Sheet D - Serological findings in Affected Group.

Farm reference no: Location: Milngavie, Dunbartonshire.

Date of first sampling: December 2,1983 Date of second sampling: January 9,1984 No. of calves in group: 67

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
2	16	16	2	4	ND	ND	n	-	0.00	0.00	0.67	0.49	0.00	0.00	ND	ND
3	128	128	2	2	ND	ND	-	-	0.00	0.00	0.30	0.40	0.00	0.00	ND	ND
4	32	32	2	2	ND	ND	-	-	0.00	0.00	0.62	1.20	0.00	0.77	ND	ND
5	64	>128	2	n	ND	ND	-	-	0.03	0.00	0.49	0.36	0.00	0.19	ND	ND
6	8	16	2	2	ND	ND	2	-	0.00	0.00	0.09	0.33	1.19	1.27	ND	ND
7	16	128	4	2	ND	ND	-	-	0.00	0.00	0.93	0.78	0.51	0.00	ND	ND
8	64	128	4	2	ND	ND	-	-	0.00	0.00	0.00	0.09	0.00	0.43	ND	ND
9	>128	>128	n	2	ND	ND	-	-	0.00	0.00	0.74	1.00	0.00	0.14	ND	ND
10	>128	>128	128	>128	ND	ND	-	-	0.00	0.00	1.24	1.11	0.00	1.09	ND	ND
11	64	>128	128	>128	ND	ND	2	2	0.00	0.00	0.54	0.52	0.00	0.00	ND	ND

Appendix 30 Sheet A - Farm and group background details.

Farm reference no: 30 Location: Parkgate, Dumfriesshire.

Farmer's veterinary surgeon: Miller and Partners, Lockerbie.

Date of first contact with Veterinary Surgeon: 1981

Date of first visit to farm: November 1, 1983

Farm background:

Large rearing and fattening unit, buys in about 700 weaned single suckled calves each autumn. Calves bought in and yarded for a week until put on slats.

Present (farmer's) complaint:

Has had 25 cases of transit fever so far this year, 23 of whom have responded to treatment with oxytetracycline - 2 cases keep relapsing. One new case purchased on October 24 and first seen ill November 1 left untreated.

Action taken/prescribed prior to visit:

All calves are given IBR vaccine, long acting penicillin and ivermectin on arrival at the unit.

Author's assessment of 1. Cattle operation: Excellent.

2. Affected group:

Author's advice:

Follow-up comments:

Total of 640 purchased, 85 treated, no deaths.

Appendix 30 (1) Sheet B - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 30 Location: Parkgate, Dumfriesshire.

Case reference no: 93151

Clinical Signs:

Purchased October 24, first seen ill November 1.
Rectal temperature 105.2°F, respiratory rate 72/minute, dull, reluctant to rise but in good condition. No cough. No nasal discharge. Harsh respiratory sounds but no adventitious sounds. Not treated.

Pathology and Microbiology: P.M. November 1. 1983

Peribronchiolar and perivascular lymphocytic cuffs, mild bronchitis and mild diffuse eosinophilia. Blood vessels have oedematous walls and enlarged nuclei in endothelial cells. Tonsillitis.

Pasteurella haemolytica A1	NC, TR
Actinobacillus lignieresi	RC, Tonsil
Listeria monocytogenes	BrLN
M.bovirhinis	Tr.

Serology: ND

Appendix 30 Sheet B (2) - Clinical, pathological and microbiological details of individual cases.

Farm reference no: 30 Location: Parkgate, Dumfriesshire.

Case reference no: 94545

Clinical Signs:

Purchased March 6, first seen ill with respiratory disease on March 13, treated with oxytetracycline for 1 day with no response, so treated with trimethoprim/sulphadoxine for 3 days but little improvement.
Very dull, distressed, rectal temperature 100.8°F, respiratory rate 65/minute. No cough. No nasal discharge. Fawn coloured diarrhoea. Subcutaneous emphysema over shoulders, squeaks on left side half-way up chest wall, lungs sound solid.

Pathology and Microbiology: P.M. March 17. 1984

Fibrinous pneumonia with fibrinous pleurisy and pericarditis. Evidence of early nodule formation.

Pasteurella haemolytica A1	NC,Tr,RC,RM,RD,BrLN,RTLN
Escherichia coli	Tonsil
Acholeplasma laidlawii	RC

Serology: ND

Appendix 31 Sheet A Farm and group background details.

Farm reference no. 31 Location: Paisley, Renfrewshire.

Farmer's Veterinary Surgeon: Andrew, Allardice and Love, Paisley.

Date of first contact with Veterinary Surgeon: 1980

Date of first visit to farm: October 12, 1982

Farm background:

One of several large beef units that buy in weaned suckled calves. Had severe IBR 1980. Total 600 calves, 200 of own stock, 400 market purchased.

Author's assessment of 1. Cattle operation, no good handling facilities, overall stockmanship poor, obviously sick cattle are not noticed.

2. Affected group

Follow-up comments:

One death, six calves treated for pneumonia and two calves not eating (but not treated). On visits to the unit, many more sick calves could be identified than the number said to have been treated.

Appendix 31 Sheet C - Microbiological findings (from nasopharyngeal swabs) in Monitor Group

Farm reference no: 31 Location: Paisley, Renfrewshire.

First Sampling Date: October 12. 1982

Total number of calves in group: 13

Number of calves sampled: 13

Organism	No. of calves positive	Individual calf reference nos.
Moraxella nonliquefaciens	1	1
Neisseria catarrhalis	3	1,2,3
Neisseria pharyngis	2	12,13
Bacillus coagulans	5	2,4,5,6,7
Aeromonas sp.	1	5
Chromobacterium violaceum	4	6,7,8,10
Actinobacillus lignieresi	2	8,9
Flavobacterium meningosepticum	1	11
Acinetobacter anitratum	1	11

Second Sampling. Date: October 20, 1982 No. of calves sampled: 25
(for Pasteurella spp. only, different group of calves)

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	2	11,25
Pasteurella haemolytica A2	2	7,16
Pasteurella haemolytica A6	1	3

Appendix 32 Sheet A Farm and group background details.

Farm reference no. 32 Location: Crieff, Perthshire.

Farmer's Veterinary Surgeon: Ashworth and Rodger, Crieff.

Date of first contact with Veterinary Surgeon: October 1982

Date of first visit to farm: November 9, 1983

Farm background: Details in Appendix 12.

Pneumonic pasteurellosis diagnosed in 1982.
Monitor group of weaned single suckled calves purchased in Market October 26 1983 and housed immediately.

Author's assessment of 1. Cattle operation

2. Affected group

Follow-up comments:

One monitor calf (13) treated for "Transit Fever".

131 calves housed (73 purchased, 58 homebred) of which 18 were treated (7 purchased, 11 homebred).

Appendix 32 Sheet C - Microbiological findings (from nasopharyngeal swabs) in Monitor Group

Farm reference no: 32 Location: Crieff, Perthshire.

First Sampling Date: November 9, 1983

Total number of calves in group: 21

Number of calves sampled: 21

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	1	9

Second Sampling. Date: November 25, 1983 No. of calves sampled: 20

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	5	7,12,18,20,21

Appendix 32 Sheet D - Serological findings in Monitor Group.

Farm reference no: 32 Location: Crieff, Perthshire.

Date of first sampling: November 9, 1983 Date of second sampling: November 25, 1983 No. of calves in group: 21

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	n	4	128	64	ND	ND	-	-	0.05	0.01	1.10	1.36	0.07	0.00	ND	ND
2	4	16	8	64	ND	ND	-	-	0.01	0.10	0.32	0.27	0.12	0.03	ND	ND
3	2	64	8	64	ND	ND	-	-	0.10	0.12	0.12	0.19	0.06	0.02	ND	ND
4	4	16	128	64	ND	ND	4	-	0.22	0.26	0.24	0.30	0.00	0.37	ND	ND
5	2	4	64	64	ND	ND	-	-	0.13	0.41	0.25	0.42	0.00	0.00	ND	ND
6	4	64	32	64	ND	ND	-	n	0.05	0.22	0.14	0.25	0.36	0.22	ND	ND
7	4	32	64	32	ND	ND	4	-	0.11	0.16	0.10	0.49	0.00	0.00	ND	ND
8	n	32	64	64	ND	ND	-	-	0.11	0.09	0.36	0.37	0.00	0.20	ND	ND
9	4	32	64	32	ND	ND	-	-	0.08	0.09	0.12	0.10	0.00	0.00	ND	ND
10	16	64	32	64	ND	ND	-	-	0.13	0.09	0.23	0.83	0.58	0.34	ND	ND
11	8	4	32	128	ND	ND	-	-	0.14	0.32	0.49	1.20	0.00	0.02	ND	ND

Appendix 32 Sheet D - Serological findings in Monitor Group.

Farm reference no: 30 Location: Crieff, Perthshire.

Date of first sampling: November 9, 1983 Date of second sampling: November 25, 1983 No. of calves in group: 21

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
12	8	4	32	32	ND	ND		2	0.54	0.67	0.16	0.21	0.00	0.00	ND	ND
13	4	8	32	32	ND	ND	n	-	0.00	0.00	0.18	0.38	0.06	0.00	ND	ND
14	4	ns	8	ns	ND	ND	ND	NS	ND	NS	ND	NS	ND	NS	ND	ND
15	4	128	32	64	ND	ND	-	-	0.09	0.04	0.20	0.45	0.22	0.00	ND	ND
16	2	32	8	64	ND	ND	2	-	0.24	0.12	0.60	0.61	1.21	1.16	ND	ND
17	2	4	32	32	ND	ND	-	2	0.04	0.18	0.58	0.88	0.00	0.20	ND	ND
18	2	32	32	32	ND	ND	-	n	0.13	0.03	0.28	0.54	0.06	0.27	ND	ND
19	16	64	64	32	ND	ND	-	-	0.08	0.20	0.11	0.14	0.00	0.32	ND	ND
20	4	64	64	32	ND	ND	n	-	0.12	0.12	0.13	0.22	1.03	1.35	ND	ND
21	4	16	64	32	ND	ND	-	-	0.07	0.12	0.45	0.51	0.00	0.00	ND	ND

Appendix 33 Sheet A (M) Farm and group background details.

Farm reference no. 33 Location: St. Monans, Fife.

Farmer's Veterinary Surgeon: Cowan Wilson, Cupar.

Date of first contact with Veterinary Surgeon:

Date of first visit to farm: October 20, 1983

Farm background:

Fattens cattle on own account and keeps cattle for shorter periods of time on behalf of a cattle dealer. Also grows potatoes and vegetables.
Total of 140 cattle including 21 weaned single suckled calves.
Calves sampled at housing and given anthelminthic (Systamex or Ivomec) and implanted with anabolic steroid (Finaplix)

Author's assessment of 1. Cattle operation

2. Affected group

Follow-up comments:

No calves treated for "Transit fever" in 1983.

Appendix 33 Sheet C - Microbiological findings (from nasopharyngeal swabs) in Monitor Group

Farm reference no: 33 Location: St. Monans, Fife.
First Sampling Date: October 20, 1983
Total number of calves in group: 21
Number of calves sampled: 21

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	4	1,7,10,14
Acinetobacter anitratum	5	2,4,8,16,17
Staphylococcus aureus	9	2,6,9,11,13,14,18 19,20
Aerococcus viridans	1	1
Corynebacterium bovis	3	4,9,15
Corynebacterium pyogenes	1	5
Mycoplasma bovirhinis	3	7,10,18
Acholeplasma laidlawii	1	9

Second Sampling. Date: December 7, 1983 No. of calves sampled: 19

Organism	No. of calves positive	Individual calf reference nos.
Staphylococcus aureus	17	1,2,3,5,6,7,8,9,10,11, 13,14,15,16,18,19,20
Acinetobacter anitratum	3	4,7,19
Acinetobacter lwoffi	1	16
Corynebacterium bovis	2	10,13
Corynebacterium pyogenes	1	15
Flavobacterium sp.	1	4
Bacillus lentus	1	8
Bacillus coagulans	1	11
Neisseria pharyngis	1	6
Alcaligenes faecalis	1	17
Micrococcus sp.	2	17,20

Appendix 33 Sheet D (M) - Serological findings in Monitor Group.

Farm reference no: 33 Location: St. Monans, Fife.

Date of first sampling: October 20, 1983 Date of second sampling: December 12, 1983 No. of calves in group: 21

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	128	64	>128	>128	ND	ND	-	n	0.42	0.13	0.21	1.11	0.13	1.49	ND	ND
2	64	64	16	>128	ND	ND	-	-	0.00	0.02	0.89	0.98	1.82	1.28	ND	ND
3	32	ns	64	ns			SAMPLE LOST AT LABORATORY									
4	32	64	16	>128	ND	ND	-	2	0.08	0.08	0.57	0.80	0.76	0.28	ND	ND
5	32	32	64	>128	ND	ND	-	-	0.43	0.34	0.41	0.71	1.55	1.46	ND	ND
6	32	32	32	32	ND	ND	-	n	0.08	0.08	1.02	1.07	1.20	1.23	ND	ND
7	32	32	32	128	ND	ND	-	-	0.04	0.11	0.61	0.71	1.74	1.45	ND	ND
8	32	32	32	128	ND	ND	-	-	0.01	0.02	1.14	1.22	0.91	0.90	ND	ND
9	32	128	64	8	ND	ND	-	-	0.11	0.04	1.60	1.57	0.51	0.54	ND	ND
10	16	64	64	64	ND	ND	n	-	0.00	0.07	1.07	1.60	1.67	1.11	ND	ND
11	32	64	64	>128	ND	ND	-	-	0.09	0.05	0.96	0.76	1.54	1.63	ND	ND

Appendix 33 Sheet D (M) - Serological findings in Monitor Group.

Farm reference no: 33 Location: St. Monans, Fife.

Date of first sampling: October 20, 1983 Date of second sampling: December 12, 1983 No. of calves in group: 21

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
12	32	64	32	>128	ND	ND	-	-	0.00	0.05	0.82	1.46	1.58	1.11	ND	ND
13	64	64	64	>128	ND	ND	n	-	0.02	0.01	0.72	1.17	1.01	0.91	ND	ND
14	64	64	64	>128	ND	ND	-	-	0.01	0.02	0.62	0.99	1.41	0.73	ND	ND
15	64	64	64	>128	ND	ND	-	n	0.04	0.03	0.59	0.54	1.15	0.96	ND	ND
16	64	128	64	>128	ND	ND	n	-	1.29	1.35	0.55	1.08	0.82	0.59	ND	ND
17	64	128	64	8	ND	ND	-	-	0.01	0.09	0.65	0.62	1.27	0.87	ND	ND
18	64	128	128	64	ND	ND	2	-	0.01	0.03	0.69	1.41	1.69	1.69	ND	ND
19	64	128	64	>128	ND	ND	n	2	0.03	0.04	0.47	1.20	1.12	0.68	ND	ND
20	64	128	32	>128	ND	ND	-	n	0.01	0.02	0.47	0.57	1.60	1.10	ND	ND
21	64	128	64	>128	ND	ND	2	n	0.09	0.10	1.27	1.59	1.77	1.73	ND	ND

Appendix 34 Sheet A Farm and group background details.

Farm reference no. 34 Location: Douglas Water, Lanarkshire

Farmer's Veterinary Surgeon: G.U.L.P., Lanark.

Date of first contact with Veterinary Surgeon: 1982

Date of first visit to farm: October 13, 1983

Farm background:

Pneumonic pasteurellosis diagnosed in 1982 (see Appendix 4)

Monitor group purchased in market October 5, 1983. Housed October 12.

Author's assessment of 1. Cattle operation

2. Affected group

Follow-up comments:

No animals treated for "Transit Fever" in 1983. (87 purchased)

Appendix 34. Sheet C - Microbiological findings (from nasopharyngeal swabs) in Monitor Group

Farm reference no: 32 Location: Douglas Water, Lanarkshire.

First Sampling Date: October 13, 1983

Total number of calves in group: 21

Number of calves sampled: 10

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	7	1,2,3,6,8,9,10
Pasteurella haemolytica A2	3	4,5,7
Actinobacillus lignieresi	1	4
Moraxella sp.	1	5
Neisseria pharyngis	1	10
Mycoplasma bovirhinis	3	1,6,7

Second Sampling. Date: November 4, 1983 No. of calves sampled: 10

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	2	7,8
Pasteurella haemolytica A2	2	1,3
Acinetobacter anitratum	1	10
Acinetobacter lwoffi	2	2,9
Actinobacillus lignieresi	1	5
Micrococcus sp.	3	3,4,6
Flavobacterium meningosepticum	1	5
Mycoplasma bovirhinis	6	2,3,4,5,7,8
Acholeplasma laidlawii	3	6,9,10

Appendix 34 Sheet D (M) - Serological findings in Monitor Group.

Farm reference no: 34 Location: Douglas Water, Lanarkshire.

Date of first sampling: October 13, 1983 Date of second sampling: November 4, 1983 No. of calves in group: 21

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		* IBR		* PI_3		* RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	2	>128	n	16	ND	ND	4	8	0.01	0.03	0.10	0.60	0.01	1.11	ND	ND
2	4	64	128	128	ND	ND	4	n	0.01	0.01	0.08	1.33	0.12	0.99	ND	ND
3	4	32	2	32	ND	ND	2	-	0.33	0.03	0.67	0.61	0.02	0.76	ND	ND
4	2	64	2	16	ND	ND	4	n	0.08	0.11	0.02	0.56	0.31	0.35	ND	ND
5	n	16	2	16	ND	ND	-	-	0.01	0.05	0.10	0.14	0.14	0.09	ND	ND
6	8	16	128	64	ND	ND	n	-	0.04	0.00	1.22	1.05	0.30	0.44	ND	ND
7	8	8	64	64	ND	ND	2	-	0.01	0.03	0.49	2.01	0.55	1.43	ND	ND
8	2	>128	2	16	ND	ND	-	n	0.07	0.00	0.08	0.91	0.11	0.53	ND	ND
9	32	8	2	8	ND	ND	-	-	0.27	0.02	0.01	0.57	0.02	0.50	ND	ND
10	4	64	4	8	ND	ND	-	-	0.04	0.00	0.03	0.67	0.26	0.33	ND	ND

Appendix 35 Sheet A - Farm and group background details.

Farm reference no: 35 Location: Douglas Water, Lanarkshire

Farmer's veterinary surgeon: G.U.L.P. Lanark

Date of first contact with Veterinary Surgeon: October 1982

Date of first visit to farm: October 18, 1983

Farm background: See Appendix 17, ref. 17

Had severe IBR in 1982. This year did not buy in weaned single suckled calves. Group of 60 mixed breed suckler cows, calving May/June to Charolais bull, calves weaned at housing and available for monitoring. Housed October 16, 1983.

Present (farmer's) complaint:

Action taken/prescribed prior to visit:

Author's assessment of 1. Cattle operation: Good handling facilities. Moderate cattle operation.

2. Affected group: Good, well grown calves. All dosed with Panacur at housing.

Author's advice:

Follow-up comments:

No widespread respiratory disease in any cattle.
1 calf found dead in December.

Appendix 35 Sheet C - Microbiological findings (from nasopharyngeal swabs) in Monitor Group

Farm reference no: 35 Location: Douglas Water, Lanarkshire.
First Sampling Date: October 18, 1983
Total number of calves in group: 60
Number of calves sampled: 10

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	1	6
Pasteurella haemolytica A2	2	3,9
Corynebacterium pyogenes	4	1,2,6,7
Corynebacterium xerosis	1	4
Actinobacillus lignieresi	3	8,9,10
Bacillus coagulans	1	7
Aerococcus viridans	4	1,2,3,4
Micrococcus sp.	1	5
Mycoplasma bovirhinis	2	4,9
BHV-1	1	8

Second Sampling. Date: November 8,1983 No. of calves sampled: 10

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	1	4
Corynebacterium pyogenes	3	2,3,8
Corynebacterium bovis	1	5
Bacillus licheniformis	1	2
Acinetobacter anitratum	2	1,7
Neisseria catarrhalis	3	6,9,10
Mycoplasma bovirhinis	3	1,3,4
Acholeplasma laidlawii	4	2,5,7,9

Appendix 35 Sheet D - Serological findings in Monitor Group.

Farm reference no: 35 Location: Douglas Water, Lanarkshire.

Date of first sampling: October 17, 1983 Date of second sampling: November 8, 1983 No. of calves in group: 60

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	4	8	8	32	ND	ND	-	-	0.09	0.01	0.00	0.20	0.10	0.24	ND	ND
2	4	8	8	32	ND	ND	-	-	0.04	0.12	0.05	0.19	0.21	0.57	ND	ND
3	32	4	8	32	ND	ND	-	-	0.01	0.11	0.02	0.48	0.14	0.53	ND	ND
4	4	4	8	8	ND	ND	-	-	0.00	0.01	0.01	0.89	0.52	0.61	ND	ND
5	4	8	4	8	ND	ND	2	-	0.07	0.03	0.27	1.15	0.22	0.59	ND	ND
6	16	16	8	32	ND	ND	-	-	0.03	0.02	0.02	0.21	0.20	0.68	ND	ND
7	8	16	8	8	ND	ND	-	4	0.02	0.05	0.01	0.24	0.12	0.33	ND	ND
8	4	8	8	4	ND	ND	-	n	0.03	0.00	0.04	0.44	0.11	0.65	ND	ND
9	8	32	8	8	ND	ND	n	-	0.02	0.01	0.14	0.95	0.07	0.61	ND	ND
10	2	>128	8	8	ND	ND	n	2	0.02	0.03	0.03	0.26	0.19	0.79	ND	ND

Appendix 36 Sheet A Farm and group background details.

Farm reference no. 36 Location: Aberfoyle, Perthshire.

Farmer's Veterinary Surgeon: Chapman, Kippen.

Date of first contact with Veterinary Surgeon: 1982

Date of first visit to farm: October 24, 1983

Farm background: (see Appendix 18)

Group of single-suckled calves at foot. Housed 2 days before sampling, and dosed with levamisole and a killed Pasteurella spp. vaccine (Carovax, Wellcome).
(IBR diagnosed in another group of cattle)

Author's assessment of 1. Cattle operation

2. Affected group

Follow-up comments:

13 of 120 calves at risk treated in first three months of housing period.

Appendix 36 Sheet C - Microbiological findings (from nasopharyngeal swabs) in Monitor Group

Farm reference no: 36 Location: Aberfoyle, Perthshire.

First Sampling Date: October 24, 1983

Total number of calves in group: 30

Number of calves sampled: 30

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A2	2	23, 26

Second Sampling. Date: December 12, 1983 No. of calves sampled: 30

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	1	25

Appendix 36 Sheet D - Serological findings in Monitor Group.

Farm reference no: 36 Location: Aberfoyle, Perthshire.

Date of first sampling: October 24, 1983 Date of second sampling: December 13, 1983 No. of calves in group: 120

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	4	>128	8	32	ND	ND	n	-	0.10	0.14	0.52	1.01	0.19	0.47	ND	ND
2	4	4	32	16	ND	ND	-	-	0.04	0.15	0.69	0.88	0.20	0.19	ND	ND
3	16	64	4	16	ND	ND	n	-	0.17	0.17	0.25	0.52	0.16	0.64	ND	ND
4	4	64	64	16	ND	ND	n	n	0.03	0.10	0.44	1.35	0.13	0.89	ND	ND
5	4	64	2	16	ND	ND	-	-	0.29	0.08	0.60	0.38	0.23	0.16	ND	ND
6	16	64	2	16	ND	ND	-	-	0.07	0.05	0.18	1.01	0.15	0.47	ND	ND
7	16	>128	2	64	ND	ND	-	-	0.11	0.06	0.83	1.07	0.15	0.36	ND	ND
8	2	64	16	64	ND	ND	n	-	0.11	0.04	0.42	0.97	0.15	0.17	ND	ND
9	8	64	8	32	ND	ND	2	-	0.03	0.01	0.96	1.57	0.18	0.90	ND	ND
10	2	NS	2	NS	ND	ND	-	NS	ND	NS	ND	NS	ND	NS	ND	ND

Appendix 36 Sheet D - Serological findings in Monitor Group.

Farm reference no: 36 Location: Aberfoyle, Perthshire

Date of first sampling: October 24, 1983 Date of second sampling: December 13, 1983 No. of calves in group: 120

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
11	16	>128	4	16	ND	ND	-	-	0.20	0.12	0.52	0.37	0.16	0.40	ND	ND
12	8	16	2	16	ND	ND	-	n	0.13	0.07	0.95	1.13	0.12	0.39	ND	ND
13	8	>128	2	16	ND	ND	-	-	0.10	0.03	0.51	0.60	0.11	0.29	ND	ND
14	4	>128	2	16	ND	ND	-	-	0.05	0.02	0.85	1.51	0.12	0.15	ND	ND
15	4	32	8	4	ND	ND	-	-	0.18	0.10	0.57	0.47	0.12	0.29	ND	ND
16	8	>128	8	4	ND	ND	-	-	0.04	0.06	0.91	0.69	0.08	0.56	ND	ND
17	2	NS	2	NS	ND	ND	n	NS	ND	NS	ND	NS	ND	NS	ND	ND
18	2	16	4	8	ND	ND	-	-	0.07	0.02	0.64	1.13	0.06	0.37	ND	ND
19	2	8	4	2	ND	ND	-	-	0.08	0.04	0.11	0.51	0.10	0.16	ND	ND
20	4	64	128	16	ND	ND	-	-	0.05	0.03	0.18	0.49	0.18	1.90	ND	ND

Appendix 36 Sheet D - Serological findings in Monitor Group.

Farm reference no: 36 Location: Aberfoyle, Perthshire

Date of first sampling: October 24, 1983 Date of second sampling: December 13, 1983 No. of calves in group: 120

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
21	64	128	128	16	ND	ND	-	-	0.02	0.02	0.09	0.80	0.09	0.93	ND	ND
22	4	128	4	16	ND	ND	-	-	0.06	0.06	0.63	0.24	0.54	0.20	ND	ND
23	4	128	2	64	ND	ND	-	-	0.09	0.13	0.08	0.65	0.09	0.63	ND	ND
24	8	>128	2	64	ND	ND	-	-	0.32	0.05	0.81	0.75	0.17	0.22	ND	ND
25	2	64	4	8	ND	ND	-	-	0.13	0.22	0.14	0.15	0.10	0.20	ND	ND
26	2	64	4	8	ND	ND	-	-	0.15	0.10	0.23	0.58	0.14	0.38	ND	ND
27	8	128	64	4	ND	ND	-	-	0.09	0.09	0.19	0.70	0.14	0.24	ND	ND
28	64	128	2	4	ND	ND	-	n	0.11	0.12	0.25	0.55	0.08	0.52	ND	ND
29	64	>128	128	32	ND	ND	-	-	ND	ND	ND	ND	ND	ND	ND	ND
30	64	>128	128	32			n	n	ND	ND	ND	ND	ND	ND	ND	ND

Appendix 37 Sheet A Farm and group background details.

Farm reference no. 37 Location: Crocketford, Kirkcudbrightshire.

Farmer's Veterinary Surgeon: Allison and Murchie, Dumfries.

Date of first contact with Veterinary Surgeon: 1982

Date of first visit to farm: December 6, 1983

Farm background:

Severe pneumonic pasteurellosis in single-suckled calves at foot in November 1982 (P.haemolytica A1) (Appendix 15). Housed and weaned November 8, 1983. Vaccinated with IBR and PI3 vaccines.

Author's assessment of 1. Cattle operation Traditional, 60 cow single suckler herd, mixed females, Charolais bull. Cows culled on poor calf performance on regular basis.

2. Affected group Spring born calves, well grown, no respiratory problems. Vaccinated PI3 and IBR (Imuresp, Smith Kline Animal Health) and wormed (benzimidazole).

Follow-up comments:

Severe IBK at resampling.
No respiratory problems.

Appendix 37 Sheet C - Microbiological findings (from nasopharyngeal swabs) in Monitor Group

Farm reference no: 37 Location: Crocketford

First Sampling Date: December 6, 1983

Total number of calves in group: 60

Number of calves sampled: 11

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella sp.	0	

Second Sampling. Date: January 19,1984 No. of calves sampled:

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella sp.	0	

Appendix 37 Sheet D - Serological findings in Monitor Group.

Farm reference no: 37 Location: Crocketford, Kirkcudbrightshire.

Date of first sampling: December 6, 1983 Date of second sampling: January 19, 1984 No. of calves in group: 60

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	16	128	16	8	ND	ND	4	IS	0.00	0.00	0.68	0.94	0.00	0.00	ND	ND
2	4	32	-	-	ND	ND	8	IS	0.02	0.24	0.32	0.35	0.00	0.02	ND	ND
3	16	NS	-	NS	ND	ND	ND	NS	ND	NS	ND	NS	ND	NS	ND	ND
4	32	16	4	4	ND	ND	-	n	0.02	0.00	0.51	0.52	0.00	0.00	ND	ND
5	128	16	-	4	ND	ND	NS	n	0.26	0.28	0.52	0.63	0.00	0.01	ND	ND
6	64	32	4	8	ND	ND	-	2	0.07	0.15	0.48	0.78	0.00	0.00	ND	ND
7	8	64	4	4	ND	ND	4	2	0.19	0.05	0.52	0.23	0.00	0.00	ND	ND
8	128	>128	4	4	ND	ND	-	2	0.36	0.39	0.60	0.68	0.00	0.17	ND	ND
9	32	NS	-	NS	ND	ND	ND	NS	ND	NS	ND	NS	ND	NS	ND	ND
10	32	16	4	8	ND	ND	4	2	0.21	0.37	0.28	0.58	0.00	0.38	ND	ND
11	32	16	2	8	ND	ND	-	4	0.00	0.21	0.53	0.61	0.00	0.00	ND	ND

NS - no sample IS - insufficient sample ND - not done

Appendix 38 Sheet A - Farm and group background details.

Farm reference no: 38 Location: Canonbie, Dumfriesshire.

Farmer's veterinary surgeon: Miller, Lockerbie.

Date of first contact with Veterinary Surgeon: 1982

Date of first visit to farm: November 1, 1983

Farm background:

Retired veterinary surgeon has pedigree Charolais cattle onto which he fosters an additional calf when first calf about one month old. Pneumonic pasteurellosis 1982/83 (Appendix 19). Vaccinated Ovipast (Hoechst) autumn 1983.

Present (farmer's) complaint:

Group of 7 vaccinated calves, still at foot, housed October 20. 12 days later (November 1), all had mucopurulent nasal discharge and one was dull, pyrexic and inappetent and treated with chloramphenicol. Vaccinated with IBR vaccine September 28.

Action taken/prescribed prior to visit:

Author's assessment of 1. Cattle operation:

2. Affected group: Calves in better condition than 1982.

Many fat lambs also have mucopurulent nasal discharge 7 were sampled, 5 Pasteurella haemolytica A2 positive.

Author's advice:

Follow-up comments:

Appendix 38

Sheet C - Microbiological findings (from nasopharyngeal swabs) in Affected Group

Farm reference no: 38 Location: Canonbie, Dumfriesshire.

First Sampling Date: November 1, 1983

Total number of calves in group: 7

Number of calves sampled: 7

Calves treated:

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A2	1	1
Acinetobacter anitratus	3	2,6,7
Actinobacillus lignieresi	1	7
Corynebacterium bovis	2	2,3
Staphylococcus sp.	1	5
Listeria sp.	1	4
Flavobacterium meningosepticum	1	3

Second Sampling. Date: November 25,1983 No. of calves sampled: 7

Organism	No. of calves positive	Individual calf reference nos.
Pasteurella haemolytica A1	1	2
Pasteurella haemolytica A2	1	7
Bacillus coagulans	5	1,2,3,4,5
Bacillus licheniformis	4	1,2,4,5
Flavobacterium sp.	5	1,3,4,5,6
Klebsiella oxytoca	1	4
Actinobacillus lignieresi	1	7
Acinetobacter lwoffi	1	7
Staphylococcus aureus	1	7

Appendix 38 Sheet D - Serological findings in Affected Group.

Farm reference no: 38 Location: Canonbie, Dumfriesshire.

Date of first sampling: November 1, 1983 Date of second sampling: November 24, 1983 No. of calves in group: 7

Calf No.	P. haemolytica A1		P. haemolytica A2		P. multocida		M. bovis		IBR		PI_3		RSV		BVD	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	8	16	8	8	ND	ND	-	4	0.00	0.00	0.00	0.00	0.00	0.00	ND	ND
2	16	16	-	-	ND	ND	2	2	0.89	0.39	0.33	0.21	0.00	0.00	ND	ND
3	4	8	-	n	ND	ND	-	-	0.43	0.20	0.00	0.00	0.00	0.00	ND	ND
4	2	4	-	n	ND	ND	-	-	1.09	0.40	0.05	0.00	0.00	0.00	ND	ND
5	2	4	-	4	ND	ND	-	n	0.36	0.15	0.50	0.29	0.00	0.00	ND	ND
6	2	8	8	8	ND	ND	-	-	0.02	0.00	0.00	0.00	0.00	0.00	ND	ND
7	16	8	8	8	ND	ND	-	-	0.00	0.00	0.00	0.00	0.00	0.00	ND	ND

APPENDIX 39.

PASTEURELLA HAEMOLYTICA A1 and PARAINFLUENZA 3 VIRUS

EXPERIMENT 1.

Rectal temperatures (°F)

GROUP	CALF	DAY OF EXPERIMENT														
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	40	101.2	101.4	101.6	101.3	101.4	101.4	103.8	104.0	103.6	104.0	KILLED				
	51	101.4	101.2	101.2	101.3	101.4	102.8	103.4	103.8	104.5	104.0	104.2	103.5	KILLED		
	96	101.7	101.4	101.6	101.2	101.6	103.0	104.0	103.8	104.2	104.0	103.5	103.7	103.4	103.4	103.6
2	31	101.4	101.6	101.5	101.6	101.6	103.0	102.8	104.0	104.4	104.2	104.0	104.0	103.8	104.0	103.6
	64	101.6	101.4	101.4	101.5	101.6	103.4	104.0	104.2	104.2	104.6	104.0	104.2	KILLED		
	82	100.8	101.0	101.2	101.0	101.2	102.8	103.4	104.2	104.0	104.8	105.0	103.6	103.8	103.2	102.6
3	74	101.0	100.8	101.2	101.0	101.2	103.8	103.6	104.0	104.4	103.8	104.0	103.2	103.4	102.8	103.0
	95	101.4	101.2	101.0	101.2	101.4	103.6	104.0	104.4	105.0	104.8	104.0	104.2	103.6	103.6	103.8
	99	101.8	102.2	102.0	101.8	102.2	105.0	104.8	104.8	104.2	104.5	104.0	104.2	KILLED		
4	60	101.8	101.4	101.4	101.6	101.8	104.4	104.2	104.8	104.6	103.4	103.6	103.0	102.0	102.2	101.8
	65	101.8	101.6	101.4	101.6	101.6	103.6	104.2	104.6	104.2	103.4	103.6	103.2	103.2	103.4	103.0
	87	101.8	101.6	101.6	101.8	102.0	103.4	104.0	104.2	104.6	103.8	104.2	103.4	103.0	102.8	103.2
5	52	101.4	100.8	101.0	101.2	101.2	101.6	101.4	101.6	101.6	101.2	101.0	101.2	101.2	101.4	101.2
	53	101.2	101.0	101.0	101.2	101.0	101.4	101.2	101.2	101.4	101.0	101.2	101.0	101.0	101.4	101.8

Group 1 P13 virus (days 4, 5 & 6)
Group 2 P13 virus (days 4, 5 & 6), P.haemolytica A1 (days 6, 7 & 8)
Group 3 P.haemolytica A1 (days 0, 1 & 2), + P13 virus (days 4, 5 & 6)
Group 4 P.haemolytica A1 (days 0, 1 & 2), + P13 virus (days 4, 5 & 6), + P.haemolytica A1 (days 6, 7 & 8)
Group 5 Broth controls

APPENDIX 39.

PASTEURELLA HAEMOLYTICA A1 and PARAINFLUENZA 3 VIRUS

EXPERIMENT 1.

Respiratory Rates (per min)

GROUP	CALF	DAY OF EXPERIMENT 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	40	48	42	42	42	48	60	60	72	72	66	KILLED				
	51	48	42	42	42	48	54	54	72	72	60	66	60			
	96	42	42	42	48	48	48	66	78	72	72	60	66	72	66	66
2	31	42	48	42	42	48	60	66	60	72	66	72	60	60	60	60
	64	42	42	48	42	48	60	72	66	60	72	66	66	KILLED		
	82	42	42	48	42	48	60	66	60	66	72	78	72	60	60	48
3	74	42	36	42	42	42	48	42	54	60	48	42	42	36	36	42
	95	36	42	36	36	42	48	42	54	60	60	66	48	54	60	48
	99	36	30	36	36	36	42	48	48	60	66	60	60	KILLED		
4	60	30	36	36	30	36	48	48	48	42	48	42	36	42	36	30
	65	36	42	36	36	42	48	48	42	48	42	36	36	42	42	36
	87	36	30	30	36	36	42	42	48	48	42	60	48	42	42	48
5	52	42	42	36	42	42	36	36	36	42	36	30	36	36	30	30
	53	36	42	42	36	36	36	36	30	36	36	36	30	30	42	42

Group 1 P13 virus (days 4, 5 & 6)
Group 2 P13 virus (days 4, 5 & 6), P.haemolytica A1 (days 6, 7 & 8)
Group 3 P.haemolytica A1 (days 0, 1 & 2), + P13 virus (days 4, 5 & 6)
Group 4 P.haemolytica A1 (days 0, 1 & 2), + P13 virus (days 4, 5 & 6), + P.haemolytica A1 (days 6, 7 & 8)
Group 5 Broth controls

APPENDIX 39. PASTEURELLA HAEMOLYTICA A1 and PARAINFLUENZA 3 VIRUS

EXPERIMENT 1. Isolation of P13 virus and P.haemolytica A1 from nasopharyngeal swabs

GROUP	CALF No.	P13 Day of Experiment 0	7	14	P.haemolytica A1 Day of Experiment 0	4	7	14
1	40	-	+	NS	-	ND	+	ND
	51	-	+	NS	-	ND	-	ND
	96	-	+	NS	-	ND	-	ND
2	31	-	-	-	-	ND	-	ND
	64	-	-	-	-	ND	-	ND
	82	-	-	-	-	ND	-	-
3	74	-	-	-	-	-	-	ND
	95	-	-	-	-	-	+	+
	99	-	-	-	-	+	+	ND
4	60	-	-	-	-	-	-	+
	65	-	-	-	-	-	+	-
	87	-	-	-	-	+	-	+
5	52	-	-	-	-	ND	-	-
	53	-	-	-	-	ND	-	+

NS = no sample ND = not done

Group 1 P13 virus (days 4,5 and 6)

Group 2 P13 virus (days 4,5 and 6), P.haemolytica A1 (days 6,7 and 8)

Group 3 P.haemolytica A1 (days 0,1 and 2), + P13 virus (days 4,5 and 6)

Group 4 P.haemolytica A1 (days 0,1 and 2), + P13 virus (days 4,5 and 6), + P.haemolytica A1 (days 6,7 and 8)

Group 5 Broth controls

APPENDIX 39. PASTEURELLA HAEMOLYTICA A1 and PARAINFLUENZA 3 VIRUS

EXPERIMENT 1. Post-mortem isolations and immunofluorescence

GROUP	CALF No.	DAY KILLED	P13 virus							P.haemolytica A1						
			NC	Tr	RC	RM	RD	BrLN	RTLN	NC	Tr	RC	RM	RD	BrLN	RTLN
1	40	9	I	IF	IF	IF	IF	-	-	-	-	-	-	-	-	-
	51	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	96	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	31	14	-	-	-	-	-	-	-	-	-	-	F	F	-	-
	64	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	82	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	74	14	-	-	-	-	-	-	-	-	-	F	-	-	-	-
	95	20	-	-	-	-	-	-	-	-	-	-	F	-	-	-
	99	11	-	-	-	-	-	-	-	-	F	-	-	-	-	-
4	60	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	65	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	87	21	-	-	-	-	-	-	-	- (m)	-	-	-	-	-	- (m)
5	52	14	-	-	-	-	-	-	-	F	-	-	F	-	-	-
	53	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-

I = micro-organism isolated
F = micro-organism demonstrated by immunofluorescence
(m) P.multocida isolated

Group 1 P13 virus (days 4,5 and 6)
Group 2 P13 virus (days 4,5 and 6), P.haemolytica A1 (days 6,7 and 8)
Group 3 P.haemolytica A1 (days 0,1 and 2), + P13 virus (days 4,5 and 6)
Group 4 P.haemolytica A1 (days 0,1 and 2), + P13 virus (days 4,5 and 6), + P.haemolytica A1 (days 6,7 and 8)
Group 5 Broth controls

APPENDIX 39. PASTEURELLA HAEMOLYTICA A1 and PARAINFLUENZA 3 VIRUS

EXPERIMENT 1. Pathological findings

GROUP	1			2			3			4			5	
CALF No.	40	51	96	31	64	82	74	95	99	60	65	87	52	53
DAY KILLED	9	11	14	14	11	20	14	20	11	21	21	21	14	20
Mucopus in airways	+	+	+	-	+	-	-	-	+	-	-	-	-	+
Haemorrhagic lymph nodes	+	-	+	+	+	+	+	+	-	-	+	-	-	-
Pleural reaction	-	-	-	+	-	+	+	+	+	+	+	+	-	+
Pulmonary abscessation	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Consolidation	-	-	-	-	+	-	-	-	+	-	-	-	-	+
Rhinitis and tracheitis	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Loss of cilia	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Eosinophilic intracytoplasmic inclusion bodies	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Bronchial and bronchiolar epithelial necrosis	+	-	+	-	-	-	-	-	-	-	-	-	-	-
Airways plugged with inflammatory exudate	+	+	+	-	-	-	-	-	-	+	-	-	-	+
Alveolar epithelial hyperplasia	+	+	+	+	+	-	-	-	-	-	-	-	-	-
Foci of cuffing pneumonia	+	+	-	+	+	-	-	+	+	-	-	-	+	+
Septal dilatation with fibrin	-	-	-	+	-	-	-	+	+	+	-	+	-	-

Group 1 P13 virus (days 4, 5 & 6)
Group 2 P13 virus (days 4, 5 & 6), P.haemolytica A1 (days 6, 7 & 8)
Group 3 P.haemolytica A1 (days 0, 1 & 2), + P13 virus (days 4, 5 & 6)
Group 4 P.haemolytica A1 (days 0, 1 & 2), + P13 virus (days 4, 5 & 6), + P.haemolytica A1 (days 6, 7 & 8)
Group 5 Broth controls

APPENDIX 39. PASTEURELLA HAEMOLYTICA A1 and PARAINFLUENZA 3 VIRUS

EXPERIMENT 1. Reciprocal serum titres to P13 virus and P.haemolytica A1

GROUP	CALF No.	P13 virus Day of Experiment -72	0	+8	+14	P.haemolytica A1 Day of Experiment -72	0	+8	+14
1	40	ND	<10	<10	ND	ND	32	32	16
	51	ND	<10	<10	ND	ND	8	16	8
	96	ND	10	10	20	ND	16	16	16
2	31	<10	40	10	2560	16	16	32	>128
	64	20	20	10	2560	128	64	128	128
	82	10	10	160	2560	8	16	32	64
3	74	10	10	40	2560	32	128	>128	>128
	95	10	160	160	2560	16	64	64	>128
	99	10	10	160	2560	32	128	>128	>128
4	60	10	10	640	2560	8	16	32	64
	65	10	40	20	2560	8	64	128	64
	87	10	20	ND	320	>128	>128	>128	>128
5	52	ND	10	10	10	ND	8	8	16
	53	ND	10	10	10	ND	32	64	32

ND = not done

Group 1 P13 virus (days 4,5 and 6)
Group 2 P13 virus (days 4,5 and 6), P.haemolytica A1 (days 6,7 and 8)
Group 3 P.haemolytica A1 (days 0, 1 and 2), + P13 virus (days 4,5 and 6)
Group 4 P.haemolytica A1 (days 0, 1 and 2), + P13 virus (days 4,5 and 6) + P.haemolytica A1 (days 6,7 and 8)
Group 5 Broth controls

APPENDIX 40.

PASTEURELLA HAEMOLYTICA A1 and STRESS

EXPERIMENT 2.

Rectal temperatures of calves

GROUP	CALF	DAY -8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
1	64	101.0	101.6	101.2	101.2	101.4	101.2	101.2	101.6	101.6	101.4	101.6	101.4	101.4	101.2	101.4	101.4	101.6	101.4	101.4
	86	101.4	101.6	101.6	101.5	101.6	101.2	101.2	101.4	101.6	101.6	101.8	101.8	101.6	101.4	101.4	101.6	KILLED		
2	60	102.0	101.2	101.8	101.6	101.6	101.4	101.4	101.8	101.6	103.0	102.8	102.8	103.2	103.0	102.4	102.0	101.8	102.0	102.0
	61	101.0	100.8	101.0	101.2	101.2	101.0	101.2	101.2	101.4	102.6	102.8	103.0	103.2	102.6	102.4	102.2	KILLED		
	68	100.6	100.8	100.8	101.0	101.2	101.0	101.2	101.0	101.4	102.2	102.8	102.6	103.2	103.0	102.4	102.4	KILLED		
	87	101.0	100.8	101.2	101.0	101.0	101.2	101.2	100.8	101.0	101.8	102.6	103.2	103.2	103.0	102.4	102.2	102.4	102.2	102.4
3	65	100.8	100.8	101.0	101.0	100.8	100.8	100.8	101.0	100.8	102.0	103.0	102.8	103.0	102.6	102.6	102.4	102.6	102.2	102.2
	74	100.8	101.4	101.2	101.2	101.0	101.4	101.2	101.4	101.0	102.2	103.4	103.8	103.0	102.4	102.6	102.4	102.2	102.4	102.0
	95	101.2	101.4	101.2	101.2	101.4	101.2	101.2	101.4	101.2	102.6	103.0	103.2	102.8	102.8	102.6	102.4	102.2	102.6	102.6
	99	101.2	101.6	102.0	101.8	101.8	101.6	101.8	102.0	101.8	102.4	102.8	102.6	102.4	102.6	102.4	102.4	102.6	102.8	102.4
4	31	101.6	101.0	101.2	101.2	101.0	101.4	101.4	101.2	101.4	101.6	101.6	101.4	101.4	101.6	101.6	101.4	101.6	101.2	101.4
	82	101.0	100.8	101.2	101.0	101.2	101.2	101.0	101.2	101.4	101.4	101.2	101.6	101.4	101.2	101.4	101.0	101.2	101.6	101.6

Group 1 Cortisone (days -8 to -4 inclusive) + sterile broth (days 0, 1 and 2)

Group 2 Cortisone (days -8 to -4 inclusive) + P.haemolytica A1 (days 0, 1 and 2)

Group 3 Acetic acid and hosing (day -1) + P.haemolytica A1 (days 0, 1 and 2)

Group 4 Acetic acid and hosing (day -1) + sterile broth (days 0, 1 and 2)

APPENDIX 40. PASTEURELLA HAEMOLYTICA A1 and STRESS

EXPERIMENT 2. Respiratory rates of calves (Stress and P.haemolytica A1)

GROUP	CALF	DAY	-8	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
1	64		48	48	40	42	42	36	40	40	42	54	48	54	48	48	54	48	48	48	60
	86		42	48	48	42	42	42	42	48	48	60	60	54	48	54	60	54	KILLED		
2	60		42	42	48	48	48	42	42	48	48	66	66	72	72	60	66	54	60	54	60
	61		42	36	42	42	48	42	36	42	48	66	48	66	78	60	60	60	KILLED		
	68		36	36	42	36	42	42	36	36	36	54	78	72	66	72	60	54	KILLED		
	87		36	42	42	42	42	36	42	42	42	54	66	72	72	60	66	60	60	54	66
3	65		36	36	42	36	42	42	42	48	36	42	60	66	60	72	66	60	60	54	60
	74		48	42	42	48	36	36	42	36	36	54	72	72	72	60	60	54	54	48	60
	95		42	42	42	48	48	42	42	48	42	54	60	72	72	60	60	48	54	42	42
	99		42	42	48	48	48	42	48	48	42	54	54	48	54	54	60	54	54	48	60
4	31		42	40	36	40	40	36	36	36	42	58	54	54	48	54	54	48	48	42	60
	82		48	48	48	42	48	42	42	42	48	54	48	54	42	42	54	54	48	48	66

Group 1 Cortisone (days -8 to -4 inclusive) + sterile broth (days 0, 1 and 2)

Group 2 Cortisone (days -8 to -4 inclusive) + P.haemolytica A1 (days 0, 1 and 2)

Group 3 Acetic acid and hosing (day -1) + P.haemolytica A1 (days 0, 1 and 2)

Group 4 Acetic acid and hosing (day -1) + sterile broth (days 0, 1 and 2)

APPENDIX 40. PASTEURELLA HAEMOLYTICA A1 and STRESS

EXPERIMENT 2. Pasteurella haemolytica A1 - isolations and serology

GROUP	CALF	Isolation of P.haemolytica A1				Reciprocal serum titre (IHA to P.haemolytica A1)			
		Nasopharyngeal swabs			Post Mortem				
		DAY -8	DAY 0	DAY 6	DAY 7	DAY -8	DAY 0	DAY 10	DAY 17
1	64	+	-	-	ND	32	32	64	64
	86	-	-	+	-	8	8	8	NS
2	60	-	-	+	ND	NS	n	8	64
	61	-	-	-	-	8	8	16	NS
	68	+	-	+	NC	2	8	16	NS
	87	-	-	+	ND	8	4	64	16
3	65	-	-	-	ND	2	n	64	>128
	74	-	-	-	ND	4	2	>128	NS
	95	-	-	-	ND	4	16	>128	64
	99	-	-	-	ND	8	8	64	16
4	31	-	-	+	ND	NS	8	8	32
	82	-	-	-	ND	2	4	2	128

ND - not done NC - nasal conchae NS - no sample n - neat

Group 1 Cortisone (days -8 to -4 inclusive) + sterile broth (days 0, 1 and 2)
Group 2 Cortisone (days -8 to -4 inclusive) + P.haemolytica A1 (days 0, 1 and 2)
Group 3 Acetic acid and hosing (day -1) + P.haemolytica A1 (days 0, 1 and 2)
Group 4 Acetic acid and hosing (day -1) + sterile broth (as above)

APPENDIX 40. PASTEURELLA HAEMOLYTICA A1 and STRESS

EXPERIMENT 2. Pathological lesions

Group	1	2	
Calf no.	86	61	68
Day of slaughter	7	7	7
Small foci of pneumonic consolidation	-	+	+
Cuffing pneumonia	-	-	+
Acute exudative reaction	-	-	+
Presence of fibrin in interlobular septa	-	-	±

± minimal reaction

No calves were killed from groups 3 and 4.
Group 1 Cortisone (days -8 to -4 inclusive) + sterile broth (days 0,1 and 2)
Group 2 Cortisone (days -8 to -4 inclusive) + P.haemolytica A1 (days 0, 1 and 2)

APPENDIX 41. PASTEURELLA HAEMOLYTICA A1 and DICTYOCAULUS VIVIPARUS

EXPERIMENT 3. Rectal temperatures of calves (°F)

GROUP	CALF	DAY -1	0		1		2		3		4		5	6	7	8	9
		am	am	pm	am	pm	am	pm	am	pm	am	pm	am	am	am	am	am
1	23	102.4	103.8	103.4	102.4	KILLED											
	25	102.2	102.4	103.6	105.4	104.8	104.6	KILLED									
	29	102.2	102.4	105.0	103.4	105.4	103.8	105.0	104.6	104.8	104.8	105.0	104.8	104.8	102.8	102.6	102.6
	30	102.0	103.6	103.4	104.8	105.6	104.2	105.4	105.0	104.8	105.0	105.2	105.0	105.2	104.6	104.8	KILLED
2	26	102.0	102.0	104.0	101.0	102.0	101.6	102.0	101.6	102.6	101.6	101.8	101.8	102.6	101.6	101.4	101.6
	27	102.0	102.0	101.8	102.0	103.6	103.8	104.2	104.0	103.8	104.6	104.8	104.8	105.0	104.0	103.8	KILLED
	88	101.8	102.0	101.0	101.6	104.8	105.0	104.2	101.8	KILLED							

Group 1 D.viviparus (day -46) + P.haemolytica A1 (days 0, 1 and 2)

Group 2 as Group 1 plus diethylcarbamazine citrate on days (-31, -30, -29)

APPENDIX 41. PASTEURELLA HAEMOLYTICA A1 and DICTYOCAULUS VIVIPARUS

EXPERIMENT 3. Respiratory rates of calves (per min)

GROUP	CALF	DAY -1	0	1	2	3	4	5	6	7	8	9
1	23	54	48 78	60 KILLED								
	25	60	96 72	72 72	84 KILLED							
	29	60	72 72	72 72	64 84	84 60	66 66	64	68	48	54	54
	30	60	96 78	60 60	72 72	72 72	54 60	72	72	72	72	KILLED
2	26	48	78 84	72 72	72 72	72 72	54 48	48	76	60	48	72
	27	48	72 96	72 72	54 72	60 72	66 60	60	64	60	60	KILLED
	88	48	96 72	72 96	120 132	60 KILLED						

Group 1 D.viviparus (day -46) + P.haemolytica A1 (days 0, 1 and 2)

Group 2 as Group 1 plus diethylcarbamazine citrate on days (-31, -30, -29)

APPENDIX 41. PASTEURELLA HAEMOLYTICA A1 and DICTYOCAULUS VIVIPARUS

EXPERIMENT 3. Isolation of Pasteurella haemolytica A1 from nasopharyngeal swabs and at post mortem

GROUP	CALF	DAY KILLED	DAY	-24	-11	-3	0	+4	Site	NC	Tr	RC	RM	RD	LN
1	23	1		-	-	-	-	ND		+	+	+	+	+	+
	25	2		-	-	-	-	ND		+	+	+	+	+	+
	29	9		-	-	-	-	+		-	-	+	-	+	-
	30	8		-	-	-	-	+		+	+	+	+	-	-
2	26	9		-	-	-	-	+		-	-	+	-	-	-
	27	8		-	-	-	-	+		+	-	+	+	+	+
	88	3		-	-	-	-	ND		+	+	+	+	-	-

ND not done

Group 1 D.viviparus (day -46) + P.haemolytica A1 (days 0, 1 and 2)

Group 2 as Group 1 plus diethylcarbamazine citrate on days (-31, -30, -29)

APPENDIX 41. PASTEURELLA HAEMOLYTICA A1 and DICTYOCAULUS VIVIPARUS

EXPERIMENT 3. Pathological findings

GROUP	1				2			
CALF	23	25	29	30	26	27	88	28
DAY OF SLAUGHTER	1	2	9	8	9	8	3	-6
Husk lesions - caudal lobes	+	+	+	+	+	+	-	+
Lungworms	+	+	-	+	-	-	-	+
Interstitial emphysema	+	-	-	-	-	-	-	+
Fibrinous pneumonia	+	+	+	+	+	+	+	-
Fibrinous pleurisy	+	+	+	+	+	+	+	-
Dilated interlobular septa	+	+	+	+	+	+	+	-
Fibrin in lymphatics	+	+	+	+	+	-	+	-
Pasteurella nodules	+	+	+	+	+	+	+	-
Oat cells	+	-	-	-	-	-	-	-
"Streaming" of necrotic inflammatory cells	+	-	-	-	-	-	-	-
Acute exudative reaction	+	+	+	+	+	-	+	-
Intraalveolar haemorrhage	-	+	-	-	-	-	+	-
Bronchiolitis obliterans	-	-	-	-	-	-	-	-
Bronchiolar epithelial necrosis	+	-	-	-	-	-	-	-
Chronic suppurative pneumonia/abscess	-	-	+	+	-	-	-	-
Cuffing pneumonia	-	-	-	-	+	-	+	-

Group 1 D.viviparus (day -46) + P.haemolytica A1 (days 0, 1 and 2)
Group 2 as Group 1 plus diethylcarbamazine citrate on days (-31, -30, -29)

APPENDIX 41. PASTEURELLA HAEMOLYTICA A1 and DICTYOCAULUS VIVIPARUS

EXPERIMENT 3. Reciprocal serum antibody titres to Pasteurella haemolytica A1

GROUP	CALF	DAY -46	-26	-11	-4	0	+2	+4	+9
1	23	2	2	2	2	8	4	KILLED	
	25	2	4	2	2	2	2	KILLED	
	29	2	2	2	2	2	NS	8	>128
	30	2	2	16	16	16	NS	16	>128
2	26	n	n	2	2	2	NS	4	128
	27	2	4	2	2	2	NS	8	>128
	88	2	8	8	8	8	4	KILLED	

NS = No sample n = neat

Group 1 D.viviparus (day -46) + P.haemolytica A1 (days 0, 1 and 2)

Group 2 as Group 1 plus diethylcarbamazine citrate on days (31, -30, -29)

APPENDIX 41. PASTEURELLA HAEMOLYTICA A1 and DICTYOCAULUS VIVIPARUS

EXPERIMENT 3. Serum titres (ELISA) to BHV-1, Pl_3 and RSV

GROUP	CALF	BHV-1						Pl_3						RSV					
	DAY	-46	-26	-11	-4	0	+7	-46	-26	-11	-4	0	+7	-46	-26	-11	-4	0	+7
1	23	.03	.02	.05	.04	.06	NS	.10	.04	.06	.07	.07	NS	.02	.02	.05	.06	.05	NS
	25	0	0	0	.01	0	NS	0	.02	0	0	.01	NS	.45	.42	.35	.24	.17	NS
	29	.03	.06	.05	.07	.06	0	.05	.07	.04	.07	.04	0	.03	.05	.04	.03	0	0
	30	.03	.01	.02	.04	.09	.49	.03	.01	.01	.02	0	0	.09	.08	.08	.08	.07	.04
2	26	.04	.02	0	.04	.03	.03	.02	.03	.01	.03	0	0	.06	.08	.03	.05	.03	0
	27	.01	.03	0	0	0	.02	0	0	0	0	0	0	.14	.18	.08	.04	.05	.09
	88	.27	.26	.31	.31	.32	NS	.02	.01	0	0	.02	NS	1.43	1.15	1.05	.97	.69	NS
	28	.01	.05	.11	DIED			.03	.04	.05	DIED			.08	.11	.08	DIED		

NS no sample

Group 1 D.viviparus (day -46) + P.haemolytica A1 (days 0, 1 and 2)

Group 2 as Group 1 plus diethylcarbamazine citrate on days (-31, -30, -29)

APPENDIX 42. PASTEURELLA HAEMOLYTICA A1 : FIVE VS. THREE INOCULATIONS

EXPERIMENT 4. Rectal temperatures (°F)

GROUP	CALF	DAY -1	DAY 0		DAY +1		DAY +2		DAY +3		DAY +4		DAY +5	DAY +6	DAY +7		DAY +8		DAY +9
		am	am	pm	am	pm	am	pm	am	pm	am	pm	am	am	am	pm	am	pm	am
1	2	102.2	103.2	105.4	105.2	105.6	103.6	105.6	104.8	KILLED									
	5	101.4	101.8	103.6	105.6	105.4	105.0	105.2	KILLED										
	12	101.8	102.2	104.2	103.6	104.6	106.0	105.4	105.4	105.8	105.6	105.0	105.2	104.8	105.8	105.6	106.0	KILLED	
	25	101.6	102.6	102.6	102.0	104.0	104.0	105.0	106.0	105.0	105.2	105.8	105.4	104.2	102.6	103.8	104.0	103.8	103.2
2	7	101.6	102.0	102.2	101.4	103.2	105.8	104.2	KILLED										
	8	101.6	102.0	102.8	101.8	102.2	104.0	104.0	105.2	KILLED									
	10	101.8	105.0	104.0	102.6	105.0	105.2	105.6	106.2	105.0	105.2	105.4	104.8	104.6	105.8	105.6	104.4	KILLED	
	66	101.8	102.0	102.6	102.4	104.0	103.0	104.0	103.0	104.0	103.6	103.8	104.0	103.8	103.2	103.2	102.6	102.8	102.6

NS no sample

Group 1 P.haemolytica A1 on days 0, 1 and 2 (five doses)
Group 2 P.haemolytica A1 on days 1 and 2 (three doses)

APPENDIX 42. PASTEURELLA HAEMOLYTICA A1: FIVE vs. THREE INOCULATIONS

EXPERIMENT 4. Respiratory rates (per min.)

GROUP	CALF	DAY -1	DAY 0	DAY +1	DAY +2	DAY +3		DAY +4	DAY +5	DAY +6	DAY +7	DAY +8		DAY +9
		am	am pm	am pm	am pm	am	pm	am pm	am	am	am pm	am	pm	am
1	2	36	36 60	52 66	60 66	66	KILLED							
	5	36	36 48	72 66	96 66	KILLED								
	12	36	36 48	60 60	54 60	72	84	72 72	66	66	66 66	60	KILLED	
	25	36	42 60	60 60	72 72	84	84	66 72	66	60	60 66	66	60	60
2	7	36	42 48	42 48	60 60	KILLED								
	8	36	42 42	42 48	48 60	66	KILLED							
	10	36	42 42	36 48	66 66	54	60	66 60	54	60	66 72	66	KILLED	
	66	36	36 42	42 60	60 60	84	96	60 60	66	60	54 54	48	42	42

Group 1 P.haemolytica A1 on days 0, 1 and 2 (five doses)

Group 2 P.haemolytica A1 on days 1 and 2 (three doses)

APPENDIX 42. PASTEURELLA HAEMOLYTICA A1 : FIVE vs. THREE INOCULATIONS

EXPERIMENT 4. Isolation of P.haemolytica A1 from nasopharyngeal swabs and tissues

GROUP	CALF	DAY KILLED	DAY -10	-5	0	2	4	7	NC	Tr	RC	RM	RD	BrLN	RTLN	Ton
1	2	3	-	-	-	+	NS	NS	+	+	+	+	+	+	+	+
	5	2	-	-	-	NS	NS	NS	+	+	+	+	+	+	+	+
	12	8	-	-	-	+	+	+	+	+	+	+	-	+	-	-
	25	9	-	-	-	+	+	+	+	+	+	+	+	-	-	-
2	7	2	-	-	-	NS	NS	NS	+	+	+	+	+	+	-	-
	8	3	-	-	-	+	NS	NS	-	+	-	+	-	-	+	+
	10	8	-	-	-	+	+	+	+	+	+	+	+	-	-	-
	66	9	-	-	-	+	+	+	+	-	+	-	-	-	-	+

NS - no sample

Group 1 P.haemolytica A1 on days 0, 1 and 2 (five doses)

Group 2 P.haemolytica A1 on days 1 and 2 (three doses)

APPENDIX 42. PASTEURELLA HAEMOLYTICA A1 : FIVE vs. THREE INOCULATIONS

EXPERIMENT 4. Pathological lesions

GROUP	1				2			
CALF	2	5	12	25	7	8	10	66
DAY OF EXPERIMENT WHEN KILLED	+3	+2	+8	+9	+2	+3	+8	+9
DAYS AFTER INITIAL INOCULATION	3	2	8	9	1	2	7	8
DAYS AFTER FINAL INOCULATION	1	6/24	6	7	6/24	1	6	7
Widespread consolidation	+	+	-	-	+	-	-	-
Fibrinous pneumonia	+	+	+	+	+	+	+	+
Fibrinous pleurisy	+	+	+	+	+	-	+	+
Pleural adhesions	+	-	+	+	-	-	+	+
'Pasteurella' nodules	+	+	+	+	+	+	+	+
Dilated interlobular septa	+	+	+	+	+	+	+	+
Fibrin in interlobular septa	+	+	+	+	+	+	+	+
Acute exudative pneumonia	+	-	+	+	+	+	+	-
Thrombosis of small blood vessels	-	+	-	-	-	-	+	-
Vasculitis/arteritis	-	+	-	-	-	+	-	-
Cuffing pneumonia	-	-	+	-	-	-	-	-

Group 1 - P.haemolytica A1 on days 0, 1 and 2 (five doses)

Group 2 - P.haemolytica A1 on days 1 and 2 (three doses)

APPENDIX 42. PASTEURELLA HAEMOLYTICA A1 : FIVE vs. THREE INOCULATIONS

EXPERIMENT 4. Serological response to Pasteurella haemolytica A1

GROUP	CALF	DAY 0	+2	+3	+4	+7	+8	+9
1	2	2	2	2	KILLED			
	5	n	2	KILLED				
	12	n	n	ND	4	32	64	KILLED
	25	2	2	ND	4	64	32	64
2	7	n	2	KILLED				
	8	-	-	2	KILLED			
	10	2	2	ND	2	32	64	KILLED
	66	2	2	ND	2	32	32	32

n = neat ND = not done

Group 1 P.haemolytica A1 on days 0, 1 and 2 (five doses)
Group 2 P.haemolytica A1 on days 1 and 2 (three doses)

APPENDIX 42. PASTEURELLA HAEMOLYTICA A1 : FIVE vs. THREE INOCULATIONS

EXPERIMENT 4. Serum titres (ELISA) to BHV-1, Pl_3 and RSV

GROUP	CALF	BHV-1						Pl_3						RSV					
	DAY	-10	-5	0	+2	+4	+7	-10	-5	0	+2	+4	+7	-10	-5	0	+2	+4	+7
1	2	.10	.09	.10	.07	NS	NS	.09	.08	.08	.07	NS	NS	.04	.05	.07	.04	NS	NS
	5	.25	.22	.18	.17	NS	NS	.47	.47	.39	.32	NS	NS	.19	.20	.15	.11	NS	NS
	12	.13	.12	.11	.09	.09	.07	.13	.16	.14	.11	.11	.09	.51	.40	.36	.20	.16	.17
	25	.07	.08	0	.06	.05	.04	.11	.12	.08	.13	.10	.10	0	.01	0	.02	.01	.01
2	7	.15	.10	.09	.04	NS	NS	.18	.12	.13	.07	NS	NS	0	0	.01	0	NS	NS
	8	.20	.21	.17	.13	NS	NS	.09	.10	.08	.06	NS	NS	.06	.07	.07	.05	NS	NS
	10	.04	.04	.02	.10	.05	.08	.38	.39	.34	.34	.30	.31	.16	.06	.04	.07	.05	.07
	66	.24	.24	.19	.19	.18	.16	.29	.28	.24	.24	.22	.21	.16	.16	.11	.11	.09	.08

NS no sample

Group 1 P.haemolytica A1 on days 0, 1 and 2 (five doses)
Group 2 P.haemolytica A1 on days 1 and 2 (three doses)

APPENDIX 43.

PASTEURELLA HAEMOLYTICA A1

EXPERIMENT 5.

Rectal temperatures (°F)

GROUP	CALF	DAY -1	DAY 0		DAY +1		DAY +2		DAY +3		DAY +4		DAY +5	DAY +6	DAY +7		DAY +8		DAY +9		DAY +10
		am	am	pm	am	pm	am	pm	am	pm	am	pm	am	am	am	pm	am	pm	am	pm	am
1	4	101.4	102.0	102.6	102.2	103.2	103.8	104.0	104.2	KILLED											
	10	101.6	101.8	102.2	104.8	104.6	103.2	104.0	103.8	104.4	104.6	104.0	105.0	105.7	104.2	104.6	104.0	104.2	103.8	KILLED	
	11	102.0	102.4	103.5	103.8	103.4	102.8	104.6	104.0	104.2	103.8	103.5	104.0	104.8	104.2	103.8	104.0	103.5	104.2	104.0	103.8
	15	101.4	101.2	101.2	104.2	104.0	104.5	104.0	KILLED												
2	1	101.6	101.0	100.6	101.8	101.4	101.2	102.0	102.2	102.0	102.2	102.2	103.0	103.6	103.0	103.2	102.8	102.2	102.6	KILLED	
	5	102.2	104.2	103.8	103.8	104.6	103.5	102.4	KILLED												
	7	102.0	102.2	101.8	101.4	102.2	101.4	101.8	101.6	101.4	101.4	102.0	101.8	101.6	101.6	101.4	101.4	101.6	102.0	101.8	101.6
	13	101.6	102.0	101.6	101.6	101.8	101.2	101.4	101.4	KILLED											
3	2	101.2	101.8	101.4	101.6	101.8	102.0	102.0	101.6	KILLED											
	6	101.4	102.0	100.4	101.2	102.2	101.2	101.8	101.4	101.0	101.4	101.8	101.4	101.4	101.2	101.6	101.4	101.0	101.4	KILLED	
	8	101.5	102.0	101.5	101.3	101.4	102.0	101.6	101.8	101.5	101.6	101.2	101.5	101.4	101.7	101.4	101.4	101.2	101.6	101.2	101.6
	16	101.6	101.4	101.2	101.8	102.2	101.8	101.6	KILLED												
4	3	101.2	101.2	101.5	101.4	101.4	101.2	101.4	101.4	KILLED											
	9	101.7	101.8	101.4	101.6	101.2	101.5	101.5	101.8	102.0	102.0	101.8	103.6	104.4	104.0	103.8	104.5	104.0	103.5	KILLED	
	12	101.6	102.0	102.2	101.8	101.6	102.0	102.0	101.8	102.0	101.5	101.8	102.5	102.4	104.0	104.8	103.8	104.4	103.0	103.6	103.0
	14	101.6	101.0	101.2	101.6	101.2	101.4	101.6	KILLED												

Group 1 Pasteurella haemolytica A1 log-phase culture

Group 2 Pasteurella haemolytica A1 killed culture

Group 3 Sterile broth

Group 4 Environmental controls

APPENDIX 43. PASTEURELLA HAEMOLYTICA A1

EXPERIMENT 5. Isolation of Pasteurella haemolytica A1

GROUP	CALF	DAY KILLED	NASOPHARYNGEAL SWABS											POST-MORTEM						
			DAY -14	-7	-4	0	+2	4	5	6	7	8	9	NC	Tr	RC	RM	RD	LN	Ton
1	4	+3	-	-	-	-	+	KILLED						+	+	+	+	+	-	+
	10	+9	-	-	-	-	+	+	+	+	+	-	KILLED	-	-	+	+	+	+	-
	11	+10	-	-	-	-	+	+	+	+	+	+	-	-	-	+	+	-	-	-
	15	+2	-	-	-	-	KILLED							-	+	+	+	+	+	+
2	1	+9	-	-	-	-	-	-	ND	ND	-	-	KILLED	-	-	-	-	-	-	-
	5	+2	-	-	-	-	KILLED							-	-	-	-	-	-	-
	7	+10	-	-	-	-	-	-	ND	ND	-	-	-	-	-	-	-	-	-	-
	13	+3	-	-	-	-	-	KILLED						-	-	-	-	-	-	-
3	2	+3	-	-	-	-	-	KILLED						-	-	-	-	-	-	-
	6	+9	-	-	-	-	-	-	ND	ND	-	-	KILLED	-	-	-	-	-	-	-
	8	+10	-	-	-	-	-	-	ND	ND	-	-	-	-	-	-	-	-	-	-
	16	+2	-	-	-	-	KILLED							-	-	-	-	-	-	-
4	3	+3	-	-	-	-	-	KILLED						-	-	-	-	-	-	-
	9	+9	-	-	-	-	-	+	ND	ND	+	-	KILLED	+	+	-	+	-	+	+
	12	+10	-	-	-	-	-	-	ND	ND	+	+	-	+	-	+	-	-	-	-
	14	+2	-	-	-	-	KILLED							-	-	-	-	-	-	-

ND not done

Group 1 Pasteurella haemolytica A1 log-phase culture
Group 2 Pasteurella haemolytica A1 killed culture
Group 3 Sterile broth
Group 4 Environmental controls

APPENDIX 43. PASTEURELLA HAEMOLYTICA A1

EXPERIMENT 5. Reciprocal serum titres to Pasteurella haemolytica A1

GROUP	CALF	DAY -14	-7	0	+2	+3	+4	+5	+6	+7	+8	+9	+10
1	4	2	4	4	8	4	KILLED						
	10	0	2	2	0	NS	16	128	128	128	256	256	KILLED
	11	2	2	2	2	NS	16	64	64	64	128	256	256
	15	0	0	0	0	KILLED							
2	1	4	4	4	8	NS	8	NS	NS	8	2	8	KILLED
	5	4	4	4	8	KILLED							
	7	2	4	4	2	NS	4	NS	NS	8	4	8	8
	13	4	2	4	4	4	KILLED						
3	2	0	2	2	2	2	KILLED						
	6	0	2	4	4	NS	8	NS	NS	16	4	8	KILLED
	8	0	4	4	4	NS	8	NS	NS	8	4	16	8
	16	4	4	4	4	KILLED							
4	3	2	4	4	8	2	KILLED						
	9	2	4	4	2	NS	4	NS	NS	64	64	256	KILLED
	12	2	2	2	2	NS	2	NS	NS	2	8	8	32
	14	0	0	0	0	KILLED							

NS no sample

Group 1 Pasteurella haemolytica A1 log-phase culture
Group 2 Pasteurella haemolytica A1 killed culture
Group 3 Sterile broth
Group 4 Environmental controls

APPENDIX 43. PASTEURELLA HAEMOLYTICA A1

EXPERIMENT 5. Serum (ELISA) titres to BHV-1, P13, RS and BVD viruses

GROUP	CALF	BHV-1				P13				RSV				BVD			
		DAY-14	-7	0	+7	-14	-7	0	+7	-14	-7	0	+7	-14	-7	0	+7
1	4	.02	.04	.03	NS	.02	.05	.03	NS	0	.03	.03	NS	<10	<10	<10	NS
	10	.27	.21	.20	.17	.20	.16	.18	.18	.09	.14	.15	.39	190	48	28	17
	11	.17	.11	.11	.07	.17	.18	.27	.39	.07	.08	.11	.31	17	<10	<10	<10
	15	.03	.03	.01	NS	.12	.06	.04	NS	.06	.05	.11	NS	<10	<10	<10	NS
2	1	0	.03	.06	.05	.03	.04	.07	.04	.02	.03	.02	.03	<10	<10	<10	<10
	5	.02	0	0	NS	.01	.02	.01	NS	.02	.02	.01	NS	<10	<10	<10	NS
	7	.08	.08	.02	.03	.11	.10	.05	.16	.09	.09	.02	.22	57	28	14	<10
	13	.16	.11	.07	NS	.05	.04	0	NS	.06	.04	0	NS	14	<10	<10	NS
3	2	.02	.01	0	NS	.03	.02	.01	NS	.02	.02	.01	NS	<10	<10	<10	NS
	6	.10	.11	.06	.08	.04	.08	.06	.08	.03	.04	.05	.25	<10	<10	<10	<10
	8	.15	.16	.08	.06	.28	.26	.15	.12	.17	.21	.11	.12	40	17	14	14
	16	.31	.23	.17	NS	.17	.11	.09	NS	.07	.07	.04	NS	57	34	12	NS
4	3	.02	.03	.04	NS	.01	.02	.02	NS	.01	.02	.03	NS	<10	<10	<10	NS
	9	.11	.08	.08	.37	.36	.28	.28	.06	.06	.06	.06	.81	<10	<10	<10	<10
	12	.13	.08	.05	.08	.14	.18	.24	.35	.18	.19	.16	.34	<10	<10	<10	<10
	14	.03	.03	.03	NS	.04	.04	.05	NS	.06	.06	.09	NS	<10	<10	<10	NS

NS - no sample

Group 1 Pasteurella haemolytica A1 log-phase culture
Group 2 Pasteurella haemolytica A1 killed culture
Group 3 Sterile broth
Group 4 Environmental controls

APPENDIX 43.

PASTEURELLA HAEMOLYTICA A1

EXPERIMENT 5.

Pathological lesions

GROUP	1				2				3				4			
CALF	4	10	11	15	1	5	7	13	2	6	8	16	3	9	12	14
DAY SLAUGHTERED	+3	+9	+10	+2	+9	+2	+10	+3	+3	+9	+10	+2	+3	+9	+10	+2
Widespread pulmonary consolidation	+	+	+	+	+	±	-	-	-	-	-	-	±	+	+	-
Fibrinous pneumonia	+	+	+	+	-	-	-	-	-	-	-	-	-	+	+	-
Fibrinous pleurisy	+	+	+	+	-	-	-	-	-	-	-	-	-	+	+	-
Pasteurella nodules	+	+	+	+	-	-	-	-	-	-	-	-	-	+	-	-
Dilated interlobular septa	+	+	+	+	+	-	-	-	-	-	-	-	-	+	+	-
Fibrin in interlobular septa	+	+	+	+	-	-	-	-	-	-	-	-	-	+	+	-
"Oat" cells	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Acute exudative pneumonia	+	+	-	-	+	-	-	-	+	-	-	-	-	+	+	-
Vasculitis	+	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-
Bronchitis	-	-	-	-	-	+	-	-	+	-	-	+	+	-	-	-
Proliferative bronchiolitis/alveolitis	-	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-
Bronchiolar epithelial necrosis	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-
Peribronchiolar lymphoid accumulations	-	-	-	+	+	-	-	+	+	+	+	+	+	-	-	+

Group 1 Pasteurella haemolytica A1 log-phase culture
Group 2 Pasteurella haemolytica A1 killed culture
Group 3 Sterile broth
Group 4 Environmental controls

APPENDIX 44. PASTEURELLA HAEMOLYTICA A1 : COMPARISON OF LOG AND STATIONARY PHASE CULTURES

EXPERIMENT 6.

Rectal temperatures (°F)

GROUP	CALF	DAY -1		DAY 0		DAY +1		DAY +2		DAY +3		DAY +4		DAY +5		DAY +6
		am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am
1	30	102.4	102.7	102.2	102.2	104.2	104.0	106.0	106.4	105.6	105.8	106.6	106.4	104.0	105.2	104.8
	31	102.0	102.7	102.6	103.8	103.0	104.4	104.4	104.2	106.6	105.6	104.0	105.0	105.2	105.8	104.2
	32	102.6	103.6	103.6	104.8	104.0	105.0	104.8	104.6	105.8	KILLED					
	33	102.2	102.4	102.6	106.6	105.6	106.0	105.8	106.6	104.8	KILLED					
2	39	101.8	102.0	101.6	105.6	103.2	104.2	105.4	106.2	105.6	KILLED					
	41	102.8	102.5	102.4	104.0	104.6	104.8	105.0	106.6	104.0	105.0	105.8	105.6	105.8	106.0	104.0
	42	102.5	102.2	101.8	103.5	102.5	103.5	103.6	103.8	103.5	KILLED					
	43	102.0	102.4	102.0	101.5	103.0	103.4	103.2	103.8	104.5	105.8	105.0	105.6	103.4	104.0	103.5

Group 1 P.haemolytica A1 (S/C) stationary phase culture

Group 2 P.haemolytica A1 (M/C) log phase culture

APPENDIX 44. PASTEURELLA HAEMOLYTICA A1 : COMPARISON OF LOG AND STATIONARY PHASE CULTURES

EXPERIMENT 6. Respiratory rates (per min)

GROUP	CALF	DAY -1		DAY 0		DAY +1		DAY +2		DAY +3		DAY +4		DAY +5		DAY +6
		am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am
1	30	30	28	24	24	42	42	42	36	36	42	48	36	48	36	42
	31	30	28	30	36	42	36	42	48	42	42	48	42	36	36	30
	32	36	32	36	30	42	42	36	42	30	KILLED					
	33	30	32	30	42	48	42	48	66	36	KILLED					
2	39	42	42	42	48	90	72	96	82	48	KILLED					
	41	36	42	36	72	72	66	96	90	72	60	66	60	54	54	42
	42	36	30	36	72	66	66	84	78	72	KILLED					
	43	42	36	36	36	72	72	72	60	36	60	60	54	48	54	48

Group 1 P.haemolytica A1 (S/C) stationary phase culture

Group 2 P.haemolytica A1 (M/C) log phase culture

APPENDIX 44. PASTEURELLA HAEMOLYTICA A1 : COMPARISON OF LOG AND STATIONARY PHASE CULTURES

EXPERIMENT 6. Isolation of Pasteurella haemolytica A1

GROUP	CALF	DAY KILLED	NASOPHARYNGEAL SWABS						POST MORTEM						
			-7	-4	0	+3	+4	+5	NC	Tr	RC	RM	RD	LN	Ton
1	30	+6	-	-	-	+	+	+	+	+	-	+	+	-	+
	31	+6	-	-	-	-	+	+	+	+	-	-	-	-	-
	32	+3	-	-	-	KILLED			+	+	+	+	-	+	-
	33	+3	-	-	-	KILLED			+	+	+	+	-	-	+
2	39	+3	-	-	-	KILLED			-	+	+	+	+	+	-
	41	+6	-	-	-	+	+	+	+	-	+	+	+	+	-
	42	+3	-	-	-	KILLED			+	+	+	+	+	+	+
	43	+6	-	-	-	+	+	+	+	+	+	+	-	-	+

Group 1 P.haemolytica A1 (S/C) stationary phase culture

Group 2 P.haemolytica A1 (M/C) log phase culture

APPENDIX 44. PASTEURELLA HAEMOLYTICA A1 : COMPARISON OF LOG AND STATIONARY PHASE CULTURES

EXPERIMENT 6. Pathological lesions

GROUP	1				2			
CALF	30	31	32	33	39	41	42	43
DAY KILLED	+6	+6	+3	+3	+3	+6	+3	+6
Fibrinous pleurisy	+	-	-	-	-	+	+	-
Dilated interlobular septa	+	-	±	±	+	-	+	-
Fibrinous pneumonia widespread	+	-	-	-	+	-	+	-
focal	-	-	+	+	-	-	-	-
nodular	-	+	-	-	-	+	+	+
Acute exudative reaction	+	-	-	+	+	-	+	±
Presence of "oat" cells	-	+	-	-	-	-	-	-
Vasculitis	+	-	-	-	-	-	-	-
Cuffing pneumonia	-	+	+	+	+	-	-	±

± denotes only a mild reaction

Group 1 P.haemolytica A1 (S/C) stationary phase culture

Group 2 P.haemolytica A1 (M/C) log phase culture

APPENDIX 44. PASTEURELLA HAEMOLYTICA A1 : COMPARISON OF LOG AND STATIONARY PHASE CULTURES

EXPERIMENT 6. Serum (IHA) titres to Pasteurella haemolytica A1

GROUP	CALF	DAY -7	DAY 0	DAY +3	DAY +4	DAY +5	DAY +6
1	30	-	n	n	n	NS	4
	31	-	-	n	2	NS	4
	32	2	n	n	NS	NS	NS
	33	2	n	n	NS	NS	NS
2	39	2	n	n	NS	NS	NS
	41	2	2	n	16	>128	>128
	42	2	n	n	NS	NS	NS
	43	-	2	n	16	64	>128

n = neat NS = no sample

Group 1 P.haemolytica A1 (S/C) stationary phase culture
Group 2 P.haemolytica A1 (M/C) log phase culture

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