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ANIMAL HEALTH AFTER 1992

ANIMAL HEALTH POST-1992

R N MARTIN*

Before examining the implications for animal health post-1992 it is useful to briefly outline the historical lead up to the Single European Act.

The European Communities Common Market was set up by the Treaty of Rome in 1957. It was designed to unlock the economic potential of the Community by promoting the free movement of goods, services, capital and persons. The free movement of goods is the most important at least from the animal health point of view since it includes animals and their products. The Treaty in principle prohibits all restrictions on trade. Fortunately and perhaps not unexpectedly there were exceptions laid down in Article 36. It provides inter alia that the overall prohibition shall not "preclude prohibitions or restrictions on imports or exports or goods in transit justified on grounds of..... the protection of health and life of humans, animals or plants..... . Such prohibitions or restrictions shall not however, contribute a means of arbitrary discrimination or a disguised restriction on trade between Member States". On initial reading of this Article it would appear that there is wide freedom for a Member State to protect itself. This is not so and case law at the European Court of Justice has interpreted and restricted its use in order to avoid abuse. The protection must not be arbitrary and the crucial test applied is a comparison between what is imposed on imports and that done domestically. The protection must be proved to be necessary and not disproportionate to the risk. This latter is important since the policy of zero risk for imports which for example my Department applied before the United Kingdom joined the Community is not acceptable. A further important aspect is that recourse cannot in general be made to Article 36 where the Community has harmonised rules by way of directives, regulations or decisions to provide for the measures to ensure protection of eg animals and public health.

In the animal health and public health sector over the years there has been built up a considerable amount of legislation - over 300 pieces of legislation are currently applicable. Many of these are modifying or qualifying acts. Simplistically directives are in force to control intra-community trade in cattle and pigs, fresh meat, poultry meat, meat products and heat treated milk. Apart from legislation on welfare and veterinary medicines the other main area of interest to veterinary epidemiologists is the harmonisation of national animal health policies eg in respect of Foot and Mouth Disease, Swine Fever, financing or eradication of tuberculosis, brucellosis and enzootic bovine leucosis (EBL).

Despite the exponential increase in the amount of legislation, progress was slow. In the author's view at least part of this was due to two main things. The first and most important was the requirement

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that Directives should be made by unanimous agreement (Article 100 of Treaty of Rome). With so many divergent views as to risk and methodology for controlling disease it was difficult and slow. This was compounded by the second reason which despite superficial denials to the contrary, was national protectionism.

In the early 1980s it was increasingly recognised that there had been a loss of momentum. Failure to complete harmonisation and promote the free movement of goods, services, capital and persons was costing Europe dearly in only partially unleashing the economic potential of the Community. A major cause identified was the cost generated by formalities at the Community's internal frontiers. Animal health, public health and plant health formalities and checks were a major component of this. The veterinary checks caused by divergent national standards were identified as the third most important delaying formality after controls by VAT and Excise rates and by the application of MCAs to farm products.

This realisation led to a report by the Commission to the Council in 1985. This was considered by the latter and resulted in The Single European Act. From the veterinary point of view two parts are worth quoting. First in Article 8A it is stated that "The Community shall adopt measures with the aim of progressively establishing the internal market over a period expiring on 31 December 1992" and "The internal market shall comprise an area without internal frontiers in which free movement of goods, persons, services and capital is ensured". The second was the insertion of a new Article 100A in the Treaty of Rome. As indicated earlier the existing Article 100 requires Directives to be adopted by unanimous vote. Article 100A provides for such measures to be adopted by qualified majority albeit with several safeguards.

UNIFIED MARKET IN THE VETERINARY SECTOR

A strategy was evolved and agreed in principle to allow the realisation of the free internal market in live animals, animal products and products of animal origin. At time of writing implementation measures are increasingly being agreed. It is hopefully sufficient to look at the principles of the strategy to allow conclusions to be drawn as to the implications on the animal health side.

The overriding principle is that animal products should move freely within the Community unless subject to Community restrictions. In general frontier checks would disappear and be replaced by documentation where necessary guaranteeing the status of the animal or product issued at the place of origin and only random spot checks allowed at the place of destination. Specifically on the animal health side it is agreed that the principle objective is to achieve a high level of animal health throughout the Community before 1992. This obviously needs strong action to eradicate disease. Where this is not possible then Community action would be needed to restrict the spread of disease. This would be on an area basis for major diseases like Foot and Mouth Disease, Swine Fever etc or on a herd basis for diseases like Tuberculosis and Brucellosis. It would be implemented by Member States under Community supervision in order to safeguard not only other Member States but also the remainder of national territory.

Diseases are to be classified into 3 groups.

Group 1 Diseases are the compulsory notifiable diffusable epizootic diseases. These obviously include Foot and Mouth Disease, Classical and African Swine Fever for which Community control and eradication measures already exist to a considerable extent. But it would also include disease like Blue Tongue, African Horse Sickness, Vesicular Stomatitis, Newcastle Disease, Rinderpest, Peste des Petits Ruminants, Sheep and Goat Pox, Fowl Plague and Pleuropneumonia. Swine Vesicular Disease is to be looked at further by survey in the Community and then determination as to its inconclusion. As stated earlier these would be dealt with on an area or regional basis and the same restrictions would apply whether animals were for breeding or production or slaughter.

Group 2 diseases are contagious diseases, notifiable on a herd basis. Obviously Tuberculosis and Brucellosis fall into this category. Such diseases would be dealt with on the basis of herd restrictions although consideration would be given to establishing regional freedom eg in respect of EBL. They would require the development or redevelopment of eradication measures including rules for movement from a lower status to a higher status herd. Animals for slaughter would be in general exempt from control unless a human health risk existed eg Brucella melitensis.

Group 3 diseases should be declarable and eradicated from individual herds on a voluntary "health scheme" basis. The Standing Veterinary Committee would decide the parameters like test procedures, movement from lower to higher status, disposal of infected animals and maintenance of freedom. In general, rules would only apply to breeding herds or flocks which have achieved status and maintained it under official supervision. Herd owners would only be authorised to demand that animals came from equal or higher status herds.

This grouping is certainly agreed in principle. A real problem to be resolved is which diseases belong to which group particularly whether Group 2 or Group 3. Two examples of this cause particular difficulty within the United Kingdom. Almost certainly EBL will be Group 2. Northern Ireland is free of disease and very shortly will be establishing Community-accepted regional freedom. Great Britain will have to consider measures for its control or eradication. Conversely Great Britain has eradicated Aujeszky's Disease and it has probably been accepted that this disease will now go in Group 2 also. This will cause considerable problems and expense in Northern Ireland in having to eradicate it in the situation where there is currently little clinical disease but extensive serological evidence. Furthermore from Northern Ireland's point of view particularly, import controls have been applied in the past in respect of diseases like Johne's Disease, Infectious Bovine Rhinotracheitis, Scrapie, Jaagsziekte, Maedi-Visna etc etc. The problem which has to be resolved is will these diseases fall into Group 2 or Group 3 or indeed any Group at all.

Bovine Spongiform Encephalopathy (BSE) became of significance only after the principles of the Unified Market were established. The Community controls being applied particularly in respect of live animals seem to be contrary to at least some of the principles. The question that has to be solved is it a Group 1 or Group 2 disease? It does not fit easily into either.

IMPLICATIONS FOR THE UNIFIED MARKET FOR ANIMAL HEALTH

In the last section a start was made to look at some of the specific detailed problems. Even more importantly it is pertinent to look at the wider implications. By no means exclusive but the following are of significance.

Free movement

The potential and overriding advantages of free trade are widely accepted by economists and politicians. Veterinarians tend to be more apprehensive. As long ago as the early 1860s Professor Gamgee of Edinburgh was convinced that the increase of transport by rail and ships together with free trade would result sooner rather than later in cattle plague being imported into the United Kingdom. He warned and advised but was ignored. By 1865 cattle were dying all over Britain from cattle plague! It can be argued that things are much better now. As outlined earlier no movement will be allowed out of areas or regions with epizootic disease or out of herds with notifiable contagious disease. Decisive action is being taken. The incidence for example of Foot and Mouth Disease has been reduced massively since the United Kingdom joined the Community. To the extent indeed that the Community is going to stop vaccination against this disease except in an emergency. It helps to allay fears somewhat but apprehension remains. Veterinarians and particularly veterinary epidemiologists are only too aware of the dangers of movement, particularly of animals. The most important vector of disease is an animal. Practically every veterinarian is convinced of the necessity ideally for a "closed herd" policy. It is right therefore to be apprehensive. However in light of the political direction and instruction the ideal is not acceptable and veterinarians need to examine the potential risks and devise measures based on sound epidemiological knowledge of the most important diseases to minimise the risk.

Specific Disease Risk

The strategy of the unified market in the veterinary sector is based quite rightly and necessarily on the objective of a high level of animal health throughout the Community. The question of significance is: can it be achieved in time? As already indicated progress is being made in respect of Foot and Mouth Disease. Similarly the position in respect of Swine Fever has greatly improved although the recent epizootic in Belgium causes concern as does the continued outbreaks in Germany with a reservoir in the wild pig population. The reappearance of Pleuropneumonia in Italy after some 90 years is disturbing. More importantly perhaps, the continuing presence of African Swine Fever and African Horse Sickness in the Iberian Peninsula does alarm. A concerted effort to reduce if not eradicate by the end of 1992 is imperative. This is going on and there is the protection of regional restrictions both now and post-1992. But quarantine and frontier checks will have disappeared by 1 January 1993 and only spot checks at place of destination will remain. The veterinarian in private practice will increasingly be the first line (or is it the last?) line of defence. The necessity is paramount for him (and his colleagues in veterinary laboratories) to be aware of the risk and be knowledgeable about the symptoms and epidemiology of epizootic diseases which have never occurred in the British Isles or last occurred over a generation or generations ago.

Turning to the Group 2 and 3 diseases two aspects are worthy of particular attention. As for the epizootic diseases there are diseases elsewhere in the Community that we do not have or never had had. Brucella melitensis is probably a good example. Again veterinarians in the British Isles will have to be knowledgeable and aware. The second aspect is that in order to obtain protection Member States like the United Kingdom will have to prove their freedom. This could be expensive and time consuming. It is a two-edged weapon that State Veterinarians are having to live with. On the one hand the risk of importation of a disease from a Member State which has or has had a particular disease pressurises towards requesting 100% guarantees of freedom. On the other hand proving our own freedom needs to be achieved at minimum expenditure. A balance has to be drawn. In the case of Northern Ireland despite having a monitoring programme running for EBL since 1972 and a case never having been detected, it accepted the necessity to test every bovine animal over 2 years of age in order that other regions or Member States which have had the disease would either have to do at least the same or provide acceptable guarantees of herd and animal freedom.

Competence of Veterinary Services

Part of the last problem stems from an underlying and often publicly unstated (for diplomatic reasons) lack of confidence in other Member States' veterinary services. Far more importantly the whole principles of the unified market depend on competent veterinary services. Eradication of disease, knowledge of what is going on at field level, supplying the guarantees at point of origin etc require veterinary services which are effective and dependable and have the necessary resources, legislation, Government support and ethical attitudes. This is currently being addressed in the Community by an initial pilot study of the veterinary services in 2 Member States. Ultimately it may result in some subordination to an overriding Community Veterinary Service and/or the Standing Veterinary Committee (SVC) but this is a subject of considerable political debate. It is already existent to some extent in the now regular inspection of EC Approved Meat Plants by Commission experts and by decisions of the SVC in respect of epizootic disease control. On balance it may prove necessary to be subordinate to the Commission and the SVC to some extent in order to ensure that animal health control is applied effectively and equally in all Member States.

External Factors

The Unified/Single European market cannot be looked at totally in isolation. Two external factors are particularly significant and likely to influence the situation. The first is that even the European Community cannot live in isolation. From the veterinary point of view it might be ideal to erect and maintain a protective barrier round the community. But it does live and trade in the world and thus increasingly will be controlled by the General Agreement of Tariffs and Trade and thus the standards set by Office International des Epizooties. This aspect is being dealt with by the next paper at this Conference.

The second factor is that barriers between Eastern and Western Europe are coming down. Few, certainly in the veterinary world, envisaged for example the speed with which Germany would be reunited. Despite all the efforts to avoid trouble the number of herds breaking down with EBL in Western Europe as a consequence again causes apprehension. Thus not only is there a need to assess the effects on animal health post 1992 as a result of the Single European Act but the external factors which will influence it.

CONCLUSION

This paper presents a high level view of the strategy being followed and its effect on animal control post-1992 due to the Single European Act. A lot of the detail is not yet known and thus the specific consequences in respect of individual diseases are difficult as yet to assess. By outlining and examining the main principles however a number of conclusions can be drawn -

1. The political and economic pressures to achieve a Unified Market are inescapable and despite the strategy adopted by the Community in the veterinary sector the resultant freer and greater volume of trade will increase the risks of introduction of disease.

2. Veterinarians in practice will become the first line of defence and they need to be aware of the risks and acquire the knowledge to recognise quickly and effectively exotic disease - both epizootic and contagious notifiable disease. The increase in risk and thus threat to the industry can also be viewed as an oportunity for veterinarians.

3. Effective and dependable state veterinary services are vital if the Unified Market is going to succeed in the animal health sector.

4. Both the Single European Act and external factors such as GATT and the breakdown of barriers between Eastern and Western Europe will result in rapidly evolving change and all veterinarians will have to develop the capability and the expertise to adapt rapidly and effectively.

EVOLUTION OF THE VETERINARY ROLE IN INTERNATIONAL TRADE IN THE 1990s

K. J. DUNN*

Animals and animal products traditionally comprise one of the largest commodity groups traded between and within countries. A well known history of animal disease movement associated with international trade in these commodities threads through the millennia. The ancient Greek and Roman societies recognized the necessity to develop and apply quarantine and slaughter practices to effect animal disease control.

Since the genesis of modern veterinary science in Lyon in 1762, veterinarians have been invested by governments with official responsibilities for the control of animal diseases and from the late 1800s for the safeguarding of food hygiene in animal products destined for human consumption. One major element of these responsibilities continues to be prevention of disease entry in imported commodities.

The arsenal of control measures available to veterinary officials regulating trade is already comprehensive. It contains techniques which can ensure that international trade in most commodities can occur safely from an animal disease standpoint. Yet in reality, animal diseases are still moving between nations and continents. A "no risk" import policy is an abstract ideal. In the last five years we have seen African horse sickness, contagious bovine pleuropneumonia, screw worm fly, swine fever and several other significant diseases appear in countries which had been free of those diseases for long periods. (Anon., 1990a; Kouba and Velloso, 1987)

VETERINARY ROLES IN TRADE

Import laws in most countries contain broad powers which permit controls to be exercised over imports of animals and

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animal products to safeguard animal and public health in the importing country. These controls are usually spelt out in subordinate legislation or administrative rules. They describe the technical specifications relating to animal or public health which must be met by imported animals and animal products to enable them to qualify for importation.

These technical restrictions are drawn up after scientific analysis of the threat posed by the disease agents or pests which be could present in the various types of goods from given exporting countries. In determining import requirements veterinary officials must analyse and apply a diverse range of scientific, technical and legal information in order to ensure that consistency and objectivity sustain their decision making.

It is hardly surprising that there are several weaknesses in the information banks to which Veterinary Services refer in this process. As in the case of other forms of biological study, veterinary science itself contains deficits in the knowledge and understanding of most animal diseases. This holds true in veterinary epidemiology - a branch of the science which has been receiving its due share of recognition only in recent years and one whose application predominates in the area of import and quarantine regulation.

Looking at some of the information requirements in this field we can begin to understand the situation better. Details of prevalence and incidence of diseases known to be present in an exporting country are fundamental in assessing risks and developing the response by import officials to those risks. Yet information is unavailable in sufficient detail or precision in many countries - leaving doubts about the grounds for objective analysis. This also leads to the question of the capability of Veterinary Services in the exporting country to obtain and provide detailed knowledge of the national disease status. Assessment of the Veterinary Services of another country remains a relatively subjective exercise. Procedures for this are under international study at present.

Differentiation among product categories of the probabilities of infection or contamination also has to be done for the diseases identified as significant in given circumstances. This should be based on more than empirical or anecdotal data but in many cases specific scientific reference data is lacking. Simple examples can highlight this such as do imported goats pose identical risks as sheep for given exotic diseases?

Control measures based on a number of approaches are applied to veterinary regulation of trade in animals and animal products. Inspection and certification to attest to disease free origin of commodities, isolation of animals or products, testing, treatment and quarantine are the types of control measures which are applied singularly or combined.

Within each of these elements there are detailed techniques available. As with any form of applied technology these are continually being modernised and refined. For example, in the certification area the use of national electronic information systems is streamlining and improving the accuracy of health certification in some countries. International electronic data transfer of meat certification is under trial between Australia and USA and this procedure may offer future advantages in global trade.

It is in the area of testing for diseases that the 1990s promises most development of direct benefit to the veterinary role in regulating international trade. Import/export testing needs diagnostic support which can demonstrate freedom from infection in clinically healthy individual animals (and the absence of specific contamination in animal products) instead of requiring the more customary diagnostic end-point, namely confirming the presence of specific disease in an animal or herd. This difference is often overlooked and can be significant.

Sensitivity and specificity in tests for many diseases have to be further improved. Some well known diseases serve as examples in this regard viz. bovine tuberculosis and Johne's disease. Applied biotechnology offers the potential to achieve these developments in the next few years. We look forward to diagnostic advances over and above those achieved using such significant new tools as monoclonal antibodies in the 1980s through the application of nucleic acid based technologies in this new decade. Developments in antigen detection at low infection levels are needed to help offset the limitations of antibody testing in live animals in international trade. Interpretation difficulties associated with low level reactions and the inability of serum antibody testing to show the "real-time" status of infection of the animal are two examples of these limitations.

Many import restrictions which are applied are criticised as being excessive in the degree of security they seek to achieve. These are often justified on the basis of insufficient knowledge of the epidemiology of a disease. Restrictions applied by countries on beef or bovine semen and embryos from BSE affected countries would fit this category. The development of a reliable diagnostic test to show freedom of BSE or scrapie in the live animal would greatly facilitate trade in ruminants and their genetic material from affected countries.

At this point it should be possible to understand the dilemma often faced by official Veterinary Services who must ensure that safeguards are met but not at the expense of unnecessary (and very often politically unacceptable) technical impediments to international trade.

GATT

During the last four years, the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) has concentrated on establishing disciplines to facilitate greater freedom in international trade. The application of animal and plant health restrictions in import/export trade has not escaped focus by the GATT.

There has been a lot of concern among veterinary officials that this process has been designed to sacrifice the animal disease security of individual countries on the altar of free trade. This is not so although there will be need for watchful oversight of developments. In essence, the GATT fully acknowledges the need for animal and public health trade restrictions but seeks to ensure that these are fair and justified. Regulatory veterinarians may have to defend their policies to other officials of their own or trading partner nations more frequently as a result.

One of the many aims of the Uruguay Round has been to set down agreed rules relating to the GATT provision which recognizes the right for countries to set import restrictions for domestic protection of human, animal and plant life and health. These rules would serve to minimise the number of arbitrary or unjustified restrictions in the process of protecting life and health. The potential for a country to misuse veterinary restrictions as non-tariff trade barriers to commercially protect local industries is undeniable. This has been practised by most countries at some time - although often not by calculated intention. Local livestock industries facing damaging competition from cheap imports are renowned for the zealousness which they can show in calling for stricter national veterinary import restrictions in the name of enhanced disease security.

A special working group comprising delegates from many countries has recently completed nearly two years activity to produce a draft GATT agreement on rules to apply to veterinary and phytosanitary trading restrictions. The future of this agreement is tied to the outcome of the Uruguay Round.

There has been a wide agreement among the countries which have chosen to participate in these talks that international harmonisation of veterinary import restrictions is fundamental to the establishment of GATT discipline in this field. That is to say, individual countries should recognize international animal health and public health standards and apply them in their own veterinary requirements for importation of animals and animal products. Presently this is not the case with most countries.

Correspondingly, there has been a recognition in GATT that current international standards or guidelines may be not up to date, not effective enough or may not exist for certain diseases or commodities. It has also accepted that there will be many situations where an importing country is justified in applying more stringent import restrictions than those of international standard. This would be acceptable provided there are sound scientific bases to justify the requirements.

OIE

The Paris-based international animal health body, the Office International des Epizooties (OIE), has been recognized by GATT as the authoritative organisation for standards, recommendations and guidelines on animal health. This is logical and appropriate. Since 1924, membership of the OIE has grown to 114 countries each of which is represented through its official Veterinary Services.

Another early concern of some veterinary authorities was that GATT could be intending to establish its own veterinary standards for international trade regulation. This has been alleviated by the recognition of the singular authority of OIE in this area.

The International Animal Health Code of the OIE sets out recommended veterinary control procedures for the safe importation of animals and animal products in respect of a large number of specific animal diseases. (Anon. 1985) These procedures are generally regarded as minimum requirements. It is doubtful that they can serve as the standards on which GATT could resolve trade disputes unless they are modified by greater technical specification and more precision.

It is not difficult to foresee some real problems for OIE if it is to attempt to convert its "minimum requirement" approach into one involving detailed and more compulsory standards. For a start the agreement of many OIE-member exporting countries will be withheld if tighter standards would mean their inability to supply animals or products meeting those specifications. On the other hand, without tighter OIE standards many importing countries with high animal health status will not be prepared to support future OIE "minimum requirement" recommendations if by so doing they become liable to challenge under GATT for refusal to accept imports which meet those international standards.

HARMONISATION

A major objective of harmonisation of veterinary import requirements is the removal of unnecessary or excessive restrictions in international trade. This should result in no greater animal disease or public health risks to the importing country from imported products than it encounters in internal domestic trade in like products. In situations where the animal health statuses of two trading countries are substantially similar it should be possible to permit unrestricted trade for certain commodities. For example if an importing country has endemic scrapie and exercises no official control programmes for this disease it is difficult to justify import restrictions for scrapie for routine importation of sheep and goats.

For progress on harmonisation to occur there has to be an agreed basis for determination of which diseases are important in bilateral and international trade. It will always be possible to find some differences in animal health statuses between countries. However the essential question to be considered is how significant are the diseases concerned and do they justify the maintenance of specific import restrictions. The OIE has the potential to greatly assist in this problem. It has identified categories of diseases based *inter alia* on their economic importance. List A diseases are so characterised because of their highly infectious nature and their ability to cause severe economic losses nationally or regionally. List B contains a large number of diseases of lesser global impact. Yet it is usually the List B diseases which present the most difficulties in bilateral agreements on veterinary import requirements. In some ways List B is a catch-all for the majority of animal diseases. Both lists are revised regularly.

In 1986, the OIE adopted this "two lists" approach after previously having had three lists. In the light of the growing application of the lists to the question of importance of diseases in international trade, there appears to be a good case for further partitioning of diseases into new OIE lists.

It will also be necessary for countries to more readily recognise equivalent health status in others if the concept of "like freely trading with like" is to be made workable. Both GATT and OIE will have roles to play in fostering this approach.

One optimistic projection is that the pressures on Veterinary Services which will result from the GATT's move towards harmonised international standards can be transformed into political incentives for improvement in animal health standards worldwide. This situation is two-edged however. One potential drawback of higher international standards is a serious demise of export trade from the developing countries as they become increasingly locked out of lucrative import markets because of the inability of their products to comply.

It may be useful to look to a European model to help anticipate the effect of global harmonisation. The EEC Single

Market, due to come into full effect in 1993, heralds many possible improvements in animal health standards within Member States associated with the move to harmonised intra-Community veterinary standards. In spite of the harnessed political will (which would not be paralleled on the world scene) to make the Single Market succeed, it is apparent that some considerable problems still have to be solved and that time will be needed to assess the outcome. Examples are the difficulties relating to establishment or implementation of harmonised animal health controls for scrapie and rabies.

In the absence of GATT discipline on veterinary trade restrictions, there is a potential threat of deeper intrusion of trade politics into the application of these controls in future. Should a new GATT international trade agreement not be reached, it is possible that the trading world will become increasingly polarised into several free trade blocks of countries. In this process these insular groups would develop harmonised veterinary import standards. It is likely that standards will differ from OIE recommendations and that this could result in significant disparity between those of different trading groups.

There are grounds for many concerns about the potential threat that higher import standards resulting from GATT imposed trading rules governing the application of veterinary import restrictions will pose to developing countries. Apart from economic and social damage in these countries, there is a likelihood that disruption to agricultural production geared to export will cause consequential breakdowns in the domestic animal health control programmes and in the capabilities of Veterinary Services.

Two elements must be addressed to help offset this possibility. Firstly, there has to be a phased or gradual move to any new international standards which strengthen veterinary restrictions. Secondly, governments must respond to the need to improve animal health in the developing world in order to reduce the differentials in animal health status between them and developed importing countries for serious diseases of trade importance. Through the activities of the OIE and Food and Agriculture Organisation of the United Nations, infrastructures of Veterinary Services have to be improved in those countries. This highlights a prerequisite that there be greater international political will to increase funding for these organisations.

SCIENTIFIC JUSTIFICATION

Irrespective of the final outcome of the Uruguay Round, new trade attitudes will germinate as a result of the GATT's interest in veterinary and phytosanitary import restrictions.

It appears inevitable that the question of justification of veterinary requirements will be given increasing focus in trade politics. This will entail scrutiny of both the scientific basis of requirements as well as the justification on grounds of overall importance of the need to protect the importing country against the introduction of a given disease. Economic considerations centring on estimated impact costs of exotic disease introductions will be reweighed and debated.

Negotiations between trading countries on justification will lack potency if no formal GATT agreement on sanitary and phytosanitary restrictions transpires because there will be little legal obligation for countries to conform to international standards. Even in such case however the question of whether or not veterinary restrictions are justified will attract the interest of greater numbers of lawyers, administrators and industry bodies than before the Uruguay Round.

RISK ASSESSMENT

One important objective of the early 1990s for veterinary science is the development of practical methods of risk assessment and risk management in animal health. For there to be continued acceptance of veterinary import restrictions by others with trade interests, better methods to formulate and justify them have to be available. Quantitative methods to estimate risk appear to offer the best potential basis for this.

The OIE recognises the need to address this topic and has recently undertaken some preliminary work on the development of risk assessment guidelines.

Already some governments are refining prototypes of quarantine risk analysis models. The quadrilateral group consisting of veterinary officials from Australia, Canada, New Zealand and United States of America has embarked on development of a risk assessment model which uses quantitative scientific data to support risk estimates. Once developed this model will be applied to health requirements governing bilateral trade within the group. The group also recognizes a role for OIE to use an automated risk analysis system to harmonise international animal health measures. (Anon. 1990b)

Veterinary epidemiologists have a key role to play in developing techniques which will enable practical application of risk assessment to the field of veterinary trade regulation.

VETERINARY EDUCATION

In most cases veterinarians working in the import/export policy areas have developed their special applied knowledge and skills solely from their own experiences gained in those roles or from the experiences of their predecessors handed on in a variety of structured and informal ways. In the main, the scientific base of their policy decision making stems from the formal veterinary undergraduate training they have acquired. Many have augmented this by post graduate education in a variety of disciplines - some more relevant to their regulatory role than others. Very few of these structured academic programmes include segments which are specifically targeted to prepare these specialists for the complex interweave of science, decision analysis, economics and politics which they will encounter in their official roles. The scientific and technical aspects of veterinary regulatory activity in the international trade area could be given better emphasis in undergraduate preventative medicine teaching programmes.

In the late 1980s there has been a growing recognition of an inadequacy in contemporary veterinary education to equip graduates for senior level executive positions in veterinary policy roles in government service and industry. Multiskilled capabilities with particular emphasis on management are frequent prerequisites for appointment to such posts This has seen the veterinary official's role evolve in several countries into that of the scientific or technical advisor to specialist administrators - very often with non-biological professional backgrounds - who then develop and manage animal health and veterinary public health policies and programmes. This trend is set to continue throughout the 1990s as pressures continue to mount for higher efficiencies in government services and industry, especially in the countries with so-called developed economies.

It may be argued that such education and training is beyond the scope of the undergraduate veterinary science course and that other elements of the spectrum of veterinary activities are equally undernourished. However there is a strong case for some increase in coverage of training for veterinarians as business administrators and managers should be included in the undergraduate curricula. This would not only focus attention on the necessity of these skills in many fields of later veterinary endeavour but would also spark a realisation in more students of potential career pathways as veterinarians in government or industry.

FUTURE

Scientific inputs to policy determination must continue to be objective and be based on valid information and data. This remains the essential principle which must guide the veterinary role in international trade.

There is a need for improved information on animal disease transmission and for more research relating to survivability of exotic disease agents in traded commodities in order to establish a more solid basis for assessment of risks in importation. There are good recent examples of this type of specific research. The international trade in bovine embryos has been facilitated by helpful studies of this type which enabled OIE to establish sound recommendations on disease security. (Hare, 1985)

Veterinary administrations in some countries acknowledge the beneficial role of national animal disease monitoring programmes in disease control. (Martin *et al.*,1990) These programmes also serve to win the confidence of Veterinary Services in import trading partner nations. Electronic information systems are key tools for maximising their effectiveness. Importantly these systems must be supplied with high quality data from field programme components in exporting countries so as to inject greater precision into risk assessment and risk analysis.

Scrutiny of veterinary decision making and policies by high level government officials and politicians will become more penetrating. This is a cumulative effect of increased understanding of scientific concepts within the community, greater economic and budgetary pressures on governments and the growing political influence of the industry and community sectors affected by animal and veterinary public health decisions and policies.

Industry sectoral interests are becoming more sophisticated and effective political lobbies. They will be the driving force throughout the 1990s of greater demands on official veterinary decision makers to defend many animal health and veterinary public health maxims, to redefine the fundamental value systems which have sustained disease controls in the past and to publicly justify more individual policies and decisions taken. Sectoral groups comprise more than agricultural producer organisations and include processor and consumer bodies to an increasing degree. The interests of these non-farming groups often differ markedly from those producer interests which have traditionally determined the value basis for animal health controls. (King, 1989)

The past ten years showed that there has been an increasing growth in interest in veterinary epidemiology . This branch of the science is now more recognized as an essential discipline to support new policy directions and decisions in veterinary regulation of international trade. In the next five years it is likely to show further development as new attitudes emerge in the trading world as a result of the Uruguay Round of GATT. There is likely to be an increase in demand in government service for veterinarians with enhanced qualifications and skills in epidemiology. This should result in greater effectiveness in the veterinary regulatory role.

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EPIDEMIOLOGICAL AND METEOROLOGICAL ASPECTS OF AUJESZKY'S DISEASE IN DENMARK AND NORTHERN GERMANY.

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Aujeszky's disease has been subject to a national test-and-slaughter eradication programme in Denmark since 1980, and at the end of 1986 the disease was successfully eradicated (Andersen et al., 1989). However, in winter periods since 1985, Denmark has experienced recurrent outbreaks of Aujeszky's disease in the southernmost parts of the country. Due to several independent observations, it was the inevitable conclusion that these new primary outbreaks originated as airborne infections from across the German-Danish border. These observations included:

- The seasonal pattern of the Danish disease outbreak occurrence.
- A high prevalence of serologically positive German herds in areas adjacent to the German-Danish border.
- A marked association between the number of outbreaks in Denmark and the predominant wind during January and February.
- A high risk of outbreaks in large herds (relative to small herds).
- Disappearance of the classical, unique Danish Aujeszky's disease virus genome type, but appearance of European (German) genome types, in the Danish outbreaks from 1985/86 and onwards.

This paper adresses the above mentioned factors and the resulting strategy for Aujeszky's disease surveillance and control in the northwestern part of Germany and in Denmark.

MATERIALS AND METHODS

In a pilot study preceding a vaccination programme blood samples were obtained from (non-randomly selected) herds in the Nordfriesland and Schleswig-Flensburg regions of Germany. Only fatteners (in fattening herds and in mixed herds) were tested in 1989, while both sows and fatteners (in sow herds, mixed herds and fattening herds) were examined in 1990 (with approximately 20 samples per herd if obtainable). Serum was analyzed with a competitive ELISA technique for detection of gI antibodies (Van Oirschot et al., 1988).

Data on wind velocity and direction were obtained from the Danish Meteorological Institute, Kegnaes station. A cumulative index to describe the net airflow from south to north was defined as:

$$f(G_i,W_i) = T/1000km \sum_{i=1}^{n} -\cos(G_i)W_i$$

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[2] Free University of Berlin, Veterinary Ambulance Schwarzenbek, Röntgenstrasse 12, 2053 Schwarzenbek, Germany.
[3] State Veterinary Institute for Virus Research, Lindholm, DK-4771 Kalvehave, Denmark

G_i is the wind direction (degrees), W_i the wind velocity (km/h) and T is the time interval between two meteorological readings (3 hours), ranging from i=1 to n (the number of observations, Mortensen et al., 1990). Positive values indicates wind from south to north, negative the opposite direction, and values equal to zero, wind directions from east or west.

From Danish outbreaks in the winter of 1987/88 and 1989/90, data on herd size were obtained from all of the diseased herds in which no obvious route of infection (such as purchase of infected pigs or other known contacts) could be established. All non-infected herds in the outbreak areas for the two winters were assigned as control herds. This total list of 4,744 case or control herds was restricted to 11 postal districts in which data (at the present point of our ongoing investigations) has been ascertained for both winter periods. In the reduced list of herds (now originating from identical districts), a random sample of control herds was drawn, with a sampling probability equal to 5 x the number of cases divided by the total number of control herds (1,025 in 1987/88 and 1,035 in 1989/90). In the randomized sample of control herds, data on herd size were extracted from a database comprising all Danish swine producing herds. For case and control herds alike, a sow herd was defined as a herd in which the number of fatteners was less than or equal to 25 times the number of sows. Herd size was measured as the (natural) logarithm to the number of heat producing units (HPU) in the herd; sows, boars and gilts contributed 0.30 HPU/pig and fatteners 0.17 HPU/pig. Statistical methods included Student's t-test and unconditional maximum likelihood logistic regression (SAS/STAT™ User's Guide, 1988).

Restriction fragment analyses were performed on Danish isolates of Aujeszky's disease virus from 1964 to 1990 and on isolates from Schleswig-Holstein from 1965 to 1985 (Heppner, 1983; Christensen et al., 1990). Isolates were categorized according to a systematization suggested by Herrman et al. (1984) and elaborated by Christensen, 1988. Furthermore, based on the finding that a field strain generally consists of a heterogenous population being fairly stable during transmission (Christensen and Soerensen, 1991), strains belonging to the same type was discriminated by analyzing 5-10 isolates from each outbreak since 1986.

RESULTS

Danish Aujeszky's disease outbreaks (including clinical outbreaks, but excluding serologically positive herds and contact slaughterings) from 1982 to 1990 are shown in fig. 1. Prior to 1985, Aujeszky's disease was incident in most parts of Denmark. After 1985, the disease was only found in the southernmost regions. Finally it should be noted, that only 8 outbreaks were encountered in the southern regions of Denmark in the winter of 1984/85.

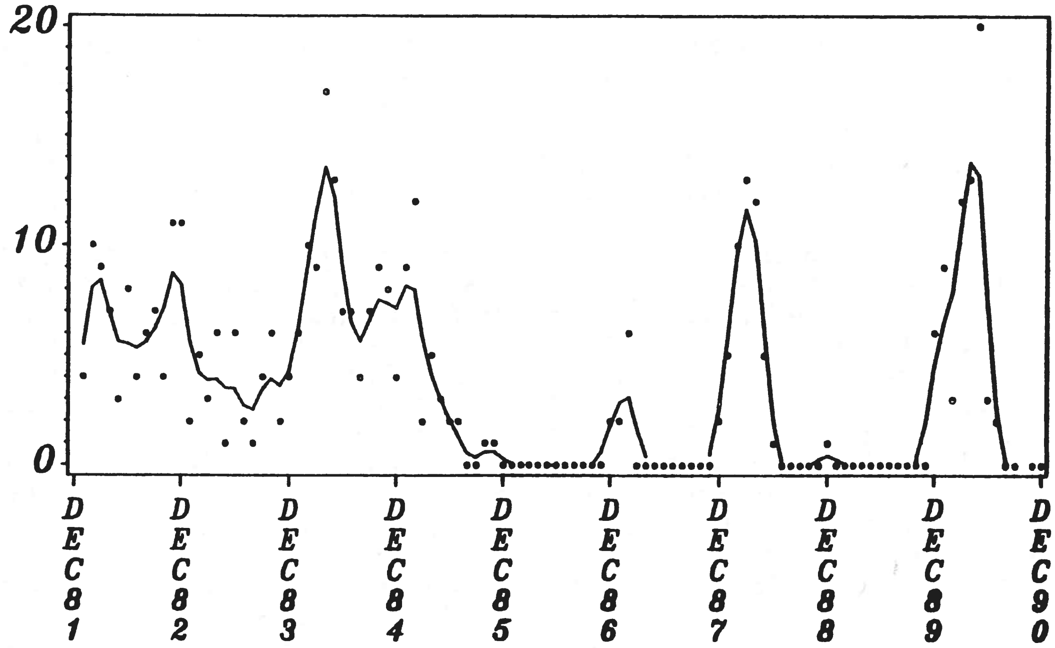

Fig. 1. Aujeszkys disease in Denmark
Clinical outbreaks 1982–1990

Table 1 displays some important findings of the serological screening of north German herds in 1989 and 1990.

Table 1. Serological screening of herds in Nordfriesland and Schleswig-Flensburg

Herd type	1989[1] Herds	gI positive	1990 Herds	gI positive
Fattening herds	125	10.4%	63	15.9%
Sow herds[2]	90	14.4%	83[3]	72.3%

[1] Only fattening pigs were tested (in fattening herds and in mixed herds).
[2] Including breeding, multiplying and mixed herds
[3] A large proportion of positive results apparently due to vaccination with old vaccine types that did not permit the distinction between vaccinated and naturally infected herds.

The cumulated wind index was calculated separately for the months of November, December, January and February in the period from 1984 to 1990. The data for each month was subsequently grouped according to (a) winters with no or few outbreaks in the southern parts of Denmark (1984/85, 1985/86, 1986/87, 1988/89) or many outbreaks (1987/88 and 1989/90) and (b) period of November-December or January-February. The results of this analysis are shown in Table 2. Due to the few number of observations, simple t-tests (and not analysis of variance) were performed.

Table 2. Cumulated wind index for the months of November, December, January and February

Mean index for:	Nov.-Dec.	Jan.-Feb.	t-test for difference between the two periods
Winters with no or few outbreaks	4.77	-0.14	1.71ns[1]
Winters with many outbreaks	1.60	10.37	3.85**
t-test for difference between the winters with few or many outbreaks.	1.31ns	3.82**	

1 Level of statistical significance for difference in mean wind index: ns: 0.05<P, *: 0.05>=P>0.01, **: 0.01>=P>0.001, ***: 0.001>=P

Figure 2A-B illustrates the wind index for the winters of 1987/88 (fig. 2A) and 1989/90 (fig. 2B). In contrast to Table 2, the wind index was cumulated over all months from November to June.

The result of the herd-level case/control logistic regression analysis is presented in the model below. The modelling was based on data from the winters of 1987/88 (58 case and 282 control herds) and 1989/90 (65 case and 347 control herds) covering 11 identical districts. As a basic model, the case probability was estimated as a function of herd size (ln(HPU)), outbreak winter (1987/88 relative to 1989/90) and herd type (sow herd relative to fattening unit). Only ln(HPU) was statistically significant (P<0.0001):

$$\text{logit}\{P(\text{case}\mid\ln(\text{HPU}))\} = 4.72 + 0.86*\ln(\text{HPU})$$

Sow herds could be shown to possess a marginally increased risk of infection with a relative risk relative to slaughter swine herds at 1.5 (estimated by odds ratio, P=0.09).

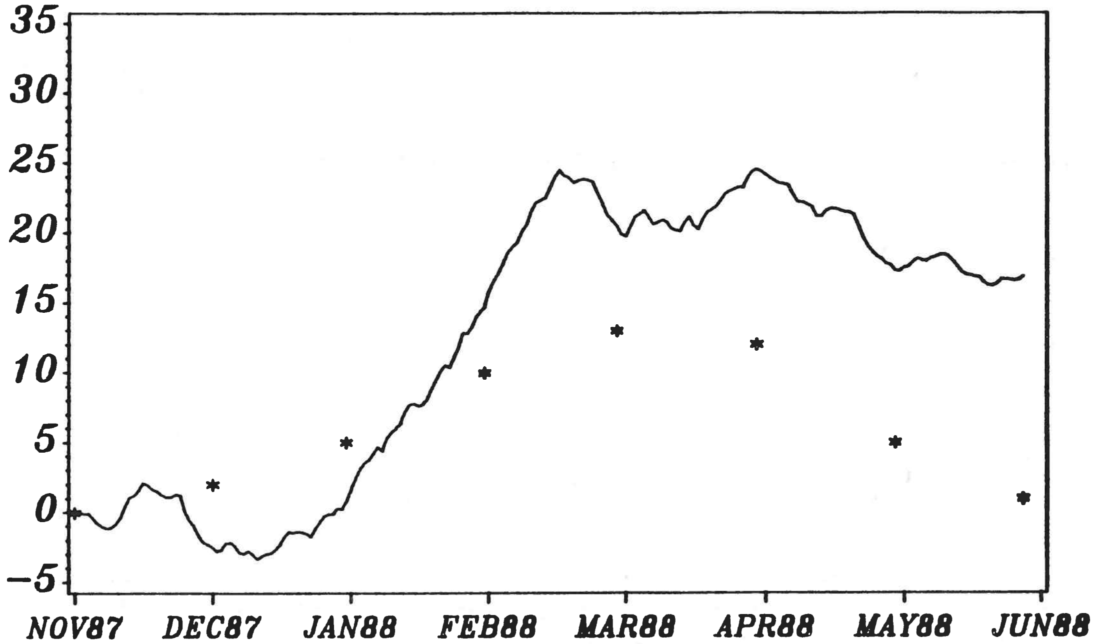

Fig. 2A. Wind index 1987/88
*With number of outbreaks indicated by **

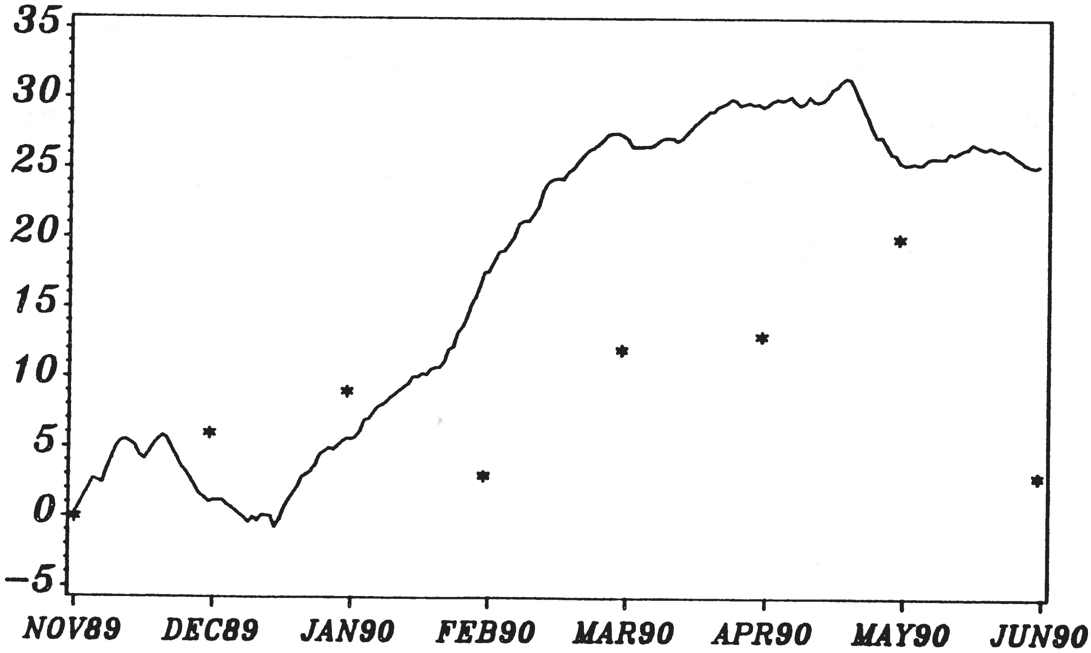

Fig. 2B. Wind index 1989/90
*With number of outbreaks indicated by **

The results of the restriction fragment analysis are summarized in Table 4. The isolates are grouped according to their genome type. For the winter outbreaks of 1986/87, 1987/88 and 1989/90 several strains were identified in Denmark. The number of isolates examined as well as the differences in band migration, determining the fragment variation distinctive for each strain, are discussed in detail by Christensen et al. (1990).

Table 4. Restriction fragment analysis of Danish and Schleswig-Holstein isolates

Country	Isolates from outbreaks in year	Genome types demonstrated	Strain
Denmark	1964-1984	Type III	
	1985	Type IIa[1]	
		Type III[2]	
	1986/87 outbreak	Type IIa	Fyn/86
		-	Als/87
		-	Bro/87
	1987/88 outbreak	Type IIa	S-2/88
		Type IIp	S-1/88
		-	S-1A/88
		-	S-3/88
		-	S-4/88
	1989/90 outbreak	Type IIa	S-1/89
		-	S-2/89
		-	S-2/90
		-	S-3/90
		-	S-4/90
		Type IIp	S-1/90
		-	S-5/90
Germany	1965-1987	Type IIa	
		Type IIp	
		Type Ii	
		Type Ip	

[1] Type IIa isolated only from outbreaks in south Jutland.
[2] Type III occurring anywhere else in Denmark.

DISCUSSION

As seen in fig. 1, Denmark has experienced massive outbreaks of Aujeszky's disease in the winters of 1987/88 and 1989/90. All outbreaks have occurred in the southernmost part of Denmark: The peninsula of Broager, the island of Als and the southern part of the island of Funen.

Wind conditions facilitating airborne disease transmission from Germany to Denmark were prominent in both of these periods, with an unusually high level of air movement from south to north during the months of January and February (Table 2, fig. 2A-B).

Epidemiological analysis of the outbreak herds revealed a marked positive correlation between herd size and risk of disease. An increase from, say, 10 to 100 HPU corresponded to a relative risk of 7.2 (estimated by odds ratio). This feature is typical for airborne transmitted diseases, as previously demonstrated for another airborne viral pig infection (Porcine Respiratory Corona Virus (PRCV), Henningsen et al., 1988).

The present preliminary case/control analysis will be followed by a more detailed study covering all outbreak districts and including herd-level data on disease control measures for both outbreak winters. The present results, however, point out that there seems to be no difference in the effect of herd size for the two winter periods. This in our view validates previous analyses of 1987/88 outbreak data (Mortensen et al., 1990).

Until 1984, all Danish outbreaks of Aujeszky's disease have been caused by genome type III, which have never been reported from any neighboring country (Christensen et al., 1990). From 1986 type III has completely disappeared, now being replaced by types, which in the past decade have become dominating south of the Danish/German border (Heppner, 1983; Christensen et al., 1990).

With the appearance of several strains within each genome type, it is further suggested that several primary introductions of virus occurred during the outbreak winters (at least 5 in 1987/88 and 7 in 1989/90).

Owing to the combined meteorological, epidemiological and virological results, Danish and German veterinary authorities and farm organizations have now adopted new and innovative disease control and surveillance measures for Aujeszky's disease in this region.

In a buffer-zone 20-50 km wide south of the German-Danish border, a vaccination programme has been initiated, based on gI-deleted vaccine types. The programme covers all herds in Nordfriesland and Schleswig-Flensburg and was officially initiated on 1. January 1990. The vaccination programme is projected to run for a period of 5 years, funded in part by the Federation of Danish Pig Producers and Slaughterhouses.

The risk of airborne disease transmission is now being continuously monitored, utilizing data from a new meterological station specially designed for this purpose. In case of meteorological conditions favoring airborne transmission (southerly wind, low turbulence, presence of cloud cover, high relative humidity) warnings will be issued in local newspapers and radio stations. If outbreaks occur south or north of the border, the most probable spread of virus particles from infected herds will be projected using contemporary meteorological models (the Risoe mesoscale puff diffusion model, RIMPUFF, Thykier-Nielsen et al., 1988).

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AFRICAN HORSE SICKNESS IN EUROPE

P S MELLOR*

African horse sickness virus (AHSV) is a double stranded RNA virus which causes a non-contagious, infectious, arthropod-borne disease of horses, mules, donkeys and wild equidae. Nine distinct serotypes of the virus have been identified so far and others may be as yet unrecognised.

The virus is transmitted biologically between its vertebrate hosts by biting midges of the genus Culicoides. There are over 1000 species of Culicoides in the world but only one, C.imicola has been proven to be a field vector of the disease (Erasmus 1987 pers. comm.)

THE DISEASE

Zebra and African donkeys are usually only affected sub-clinically by African horse sickness (AHS) but horses can be regarded as being an indicator species and in susceptible populations the effects of the disease can be devastating. Basically there are 4 forms of disease; the peracute (pulmonary) form, the acute cardio-pulmonary (mixed) form, the sub acute (cardiac) form and horse sickness fever. All types of disease can occur during an outbreak but in susceptible populations of horses the peracute and acute forms are most common. In the peracute form death can occur within a few hours of onset of disease, from asphyxia or congestive heart failure, as the entire bronchial tree fills with a surfactant, stabilised foam. Mortality rates frequently exceed 90%.

EPIDEMIOLOGY

1966

As its name implies, AHS is basically an African disease being enzootic in tropical and to a lesser extent sub-tropical African south of the Sahara. However, periodically and throughout history it has made excursions beyond Africa but until recently it has never been able to maintain itself outside that Continent for more than 2 consecutive years at most. It was during the course of such an excursion that the virus was first recorded in Europe, in Southern Spain in 1966. However, the virus failed to persist at that time and was eliminated within 3 weeks (Diaz Montilla & Panos Marti; 1967 and 1968). Subsequently, AHS remained absent from Europe for over 20 years.

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1987

However, in July 1987 the disease reappeared, in Central Spain in the Madrid/Toledo area and this time the outbreak persisted for over 3 months, until at least the end of October (Lubroth 1988). During the course of the epizootic over 300 horses died.

The likely source of the virus was a consignment of 5 zebra which had been imported into a Madrid Safari Park (El Rincon) just prior to the appearance of the disease. The first 17 Spanish horses that died from AHS in 1987 had been living in the Safari Park until the time of their death and 2 of the 5 zebra were subsequently found to be seropositive to type 4 AHSV, this being the outbreak serotype. This was the first occasion that AHSV type 4 had been recorded outside Southern Africa where it is enzootic and from where the zebra had been imported.

1988

The following year, in October 1988, a recrudescence of AHSV type 4 occurred in Spain, this time further south at Sotogrande in Cadiz. Later the same month the disease spread into the neighbouring Province of Malaga. The last officially reported death was on 8th December 1988, by which time over 150 horses had died (Mellor et al 1990).

1989

In July 1989, AHSV type 4 was again reported in Spain in the Province of Cadiz and the outbreak rapidly spread also into Seville, Huelva, Cordoba and Badajoz and then further extended its range into Portugal in September (Baixo Alentejo, Algarve) and into Morocco in October (Tetouan, Tanger, Larache) (Mellor et al 1990). Altogether approximately 2000 horses died in 1989.

1990

Unfortunately 1989 was not the end of the matter and despite a comprehensive vaccination and vector control regime which had been in operation in some areas for over two years, during August - September 1990 AHS was yet again confirmed in Spain for the 4th year running (Malaga) and in Morocco for the 2nd successive year (Larache, Kenitra, Sidi Kacem, Tetouan, Taounate, Chechaouen) (OIE 1990).

Previous to this series of outbreaks in Southern Europe and Morocco, AHSV serotype 4 had not been recorded outside Southern Africa and at no time during the course of these epizootics has there been any other evidence to suggest that AHS-4 has been spreading out of its enzootic areas. It therefore seems fairly clear that there was only one introduction of AHSV into Spain, via imported zebra in 1987. Since that time the virus has persisted in Spain, expanding into Portugal and Morocco and overwintering 3 times in the process.

This is unprecedented nowhere else and at no other time has any serotype of AHSV been recorded for more than 2 consecutive years outside Africa. So the question is how has the virus now managed to establish itself in Southern Europe?

Transmission

AHSV does not appear to have a long term vertebrate reservoir but persists (in tropical Africa) through continuous and endless cycles of transmission between vertebrate and invertebrate hosts. Since the maximum viraemia in horses is only 18 days (27 days in zebra) for the virus to persist in Spain and Morocco this means that there must be areas in those countries where there are both large numbers of susceptible equines and where the climate is suitable for vector Culicoides to be 'on the wing' the whole year round, with no vector-free period greater than 18 days at most.

Culicoides imicola; AHSV vector

The only confirmed field vector of AHSV is C.imicola (Erasmus 1987 - pers. comm.), a midge which is basically an African-Asiatic species and that seems to require tropical or sub-tropical climates (Mellor 1990). It was only recently that the presence of permanent populations of C.imicola in Southern Spain & Portugal were reported (Mellor et al 1983, Mellor et al 1985). Why the presence of this midge in Southern Europe had not been recorded earlier is difficult to understand since it is a relatively easy species to identify and since over 30 other species of Culicoides had already been identified in Spain and/or Portugal.

It is conceivable that C.imicola is a recent immigrant into Europe or perhaps it was previously present only as a very rare species. If that was the case it is no longer the situation. In many parts of Spain it is now the commonest biting midge comprising, in some areas, almost 90% of the Culicoides population (Table 1) and its range extends at least as far north as Madrid (Mellor & Boned - unpublished data).

Table 1. Culicoides imicola in Spain 1988

Date of Collection	Province	Number of C.imicola	Number of C.other species[a]	C.imicola % of total
March-May	Toledo	74	874	7.8
March-May	Madrid	230	1282	15.2
Oct.-Nov.	Malaga	342	1168	22.6
Oct.-Nov.	Cadiz	2127	276	88.5

[a] C.other species - one or more of: C.obsoletus, C.pulicaris, C.nubeculosus, C.circumscriptus, C.puncticollis, C.newsteadi, C.cataneii, C.cubitalis, C.fascipennis, C.punctatus.

However, C.imicola disappears 'off the wing' around the end of November in Central Spain and does not reappear until the following April (Mellor & Boned - unpublished data). In these areas, therefore, C.imicola is either not present or else is only present as larvae, for 3 - 4 months of the year. Further south in Andalucia, particularly in those areas of Malaga, Seville, Huelva & Cadiz, which remain frost-free C.imicola is present 'on the wing' throughout the year without break (Mellor et al 1990; Mellor & Boned - unpublished data).

The presence of adult C.imicola during the Summer & Autumn in Central Spain is the main reason why AHSV was able to be transmitted in this area in 1987. However, the absence of adult vectors for 3 - 4 months of the year means that overwintering of AHS in this region is probably not possible under the present climatic conditions prevailing over that country. Further south it is a different matter. The continuous presence of adult C.imicola means that overwintering of AHS is possible and this is what has been happening since 1987.

We don't yet know whether the present high populations of C.imicola in Spain are the result of a general climatic change of the sort being predicted in various global warming scenarios or whether the recent series of exceptionally mild years experienced by Spain is providing a preview of what such a change could bring about. However, as a result S. W. Europe is now an enzootic zone for AHS. All areas where the climate is suitable for the continuous presence of adult C.imicola are potential overwintering foci for AHS.

Other vector species of Culicoides

Although C.imicola has previously been considered to be the only field vector of AHSV, isolations of this virus have now been made in Spain from mixed pools of non-engorged Culicoides consisting almost entirely of C.obsoletus and C.pulicaris but excluding C.imicola (Mellor et al 1990).

This is a significant finding which has not been reported elsewhere (Erasmus 1987 pers. comm.). While C.imicola prefers tropical & sub-tropical climates the ranges of both C.obsoletus and C.pulicaris extend much further north and these species are probably among the commonest Culicoides in Northern Europe and the U.K. Intuitively one feels that if either or both of these species are involved in AHSV transmission in Spain, then they are likely to be of less importance than C.imicola. However, this assessment is based mainly upon the absence of any previous records linking C.obsoletus and C.pulicaris with AHS. Since AHS only rarely penetrates as far north as Spain, it may be that the paucity of evidence linking these 2 species with this virus have more to do with a lack of opportunity than with vector incompetence. Furthermore, it is well documented that different populations of a vector species of Culicoides can vary widely in their ability to transmit a particular virus (Jones & Foster 1978, Jennings & Mellor 1989), therefore some European populations of C.pulicaris and C.obsoletus may prove to be more efficient AHSV vectors than populations of the same species of midge further south. It is also the case that species of Culicoides which are competent to transmit AHSV (Mellor et al 1975, Du Toit 1944, Wetzel et al 1970, Boorman et al 1975) are also able to transmit the closely related bluetongue viruses (BTV) (Du Toit 1944, Foster et al 1968, Mellor 1990). If it is the case that these two groups of viruses usually share common vectors then it may be of importance to note that both C.pulicaris and C.obsoletus have been implicated as potential vectors of BTV (Mellor & Pitzolis 1979, Jennings & Mellor 1987).

It is quite possible that the northerly extension in the range of AHSV to include S.W. Europe may have brought the virus into contact with new, previously unsuspected vectors which could precipitate even further northwards spread of the disease. It is clearly of major importance that the distribution, prevalence and seasonal incidence of all potential vector species of Culicoides in Europe should be elucidated as soon as possible so that risk from AHS can be assessed and, if necessary, effective control measures devised and implemented.

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FOOD HEALTH AND SAFETY

MEAT AND MILKBORNE INFECTIONS

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A marked increase has been observed in the reported incidence of foodborne infections in Britain since the middle 1960s, a phenomenon also seen in most other countries of Western Europe and North America. Meatborne spread of infection, in particular poultry-meat, has taken an increasingly prominent role during this time in the epidemiology of salmonellosis, campylobacter enteritis and haemorrhagic colitis due to verotoxin-producing strains of *Escherichia coli* 0157 *(VTEC)*, amongst other foodborne infections. Changing patterns in national and international distribution of foods have also resulted in outbreaks of foodborne infection in recent years becoming more diffuse in their geographical and temporal presentation, and in consequence less frequently confined to discrete localised incidents focused on a social function or a retail outlet.

In 1980 the World Health Organisation implemented a Surveillance Programme for the Control of Foodborne Infections and Intoxications in Europe, collating national and international data on foodborne disease. During the first 10 years of participation in the Programme (1980-89), 2213 household and general community outbreaks affecting a total of 15,727 persons were recorded in Scotland. The responsible food vehicle could not be ascertained in over half of the outbreaks, but where such had been reported poultry-meat was incriminated most frequently (44% of outbreaks), followed by other meats (32%) and dairy produce (7%). In contrast to the continued prominence of poultry and other meats, the role of milk was significantly reduced following the implementation of legislation in 1983 requiring the compulsory heat-treatment of cows' milk sold to the public in Scotland.

POULTRY AND OTHER MEATS

Salmonellosis

The role of poultry as a vehicle of human salmonellosis in the UK has frequently been demonstrated (Reilly et al, 1988)(Humphrey et al, 1988). While poultry-meat has not always featured as the primary food vehicle, in several incidents the epidemiological and microbiological evidence indicated that the food (cooked meats, etc) eaten by those

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affected, had been contaminated from raw poultry concurrently being prepared within the kitchen premises, as happened in the large Stanley Royd Hospital outbreak in 1984.

A survey of retail frozen poultry in London undertaken in 1979 by the Public Health Laboratory Service (PHLS) demonstrated a contamination rate of 79% and a wide range of salmonella serotypes among carcases examined, with up to four serotypes isolated from individual birds (Gilbert, 1983). Subsequent surveys in 1987 and 1990 showed levels varying between 42% and 54% for fresh chilled and between 54% and 64% for frozen birds respectively (Anonymous, 1989)(RJ Gilbert - personal communication). A 12 month study in the kitchen of a long-stay hospital in Scotland revealed an overall contamination rate of 45% of individual carcases (range 27% - 66%) with a 100% recovery rate from the 38 batches examined (Reilly et al, 1991). Surveys in other countries such as Canada have demonstrated recovery rates of 69% from turkey and 61% from chicken carcases (Lammerding et al, 1988).

Salmonella hadar from infected turkey flocks became the second most common serotype causing human salmonellosis in England and Wales during the later 1970s (Rowe et al, 1980). Infection by *S.hadar* was relatively uncommon in Scotland however, a possible result of the restrictions on poultry movements at that time.

The observed rise in the incidence of *S.enteritidis* phage type 4 (pt 4) infection during the 1980s in the UK was facilitated by co-ordinated national surveillance programmes based on routine sero- and phage-typing undertaken by the Scottish Salmonella Reference Laboratory, Glasgow and the PHLS Division of Enteric Pathogens, Colindale, London. Whereas at the beginning of the decade less than 10% of all human infections were due to *S.enteritidis*, by 1989 this had increased to over 60%, amongst which phage type 4 predominated.

Up until the mid-1980's, infection due to *S.enteritidis* pt 4 in Britain was almost invariably associated with travel to Southern Europe. Thereafter an increasing proportion of those affected had no history of overseas travel. Since 1978 infection by *S.enteritidis* in Spain for example has increasingly been associated with various egg and egg-based products such as mayonnaise or lightly-cooked omelette (Perales & Audicana, 1988). Other countries worldwide have also experienced similar increases in infection by *S.enteritidis* (Rodrigue et al, 1990).

In the UK since 1985, reports made under the Zoonoses Orders and other surveillance mechanisms have increasingly featured *S.enteritidis* pt 4 in both layer and broiler flocks concurrent with the upsurge observed in human infection. Whereas *S.enteritidis* pt 4 was notable only by its absence amongst serotypes identified in the 1979 poultry carcase survey, it predominated in the 1987 and 1990 surveys.

Compared with poultry meat, red meats have less frequently been incriminated as vehicles of salmonellosis in the UK. Surveys of sausage and sausage meat have revealed a wide range of serotypes (Roberts et al, 1975) and levels of contamination (Banks et al, 1983). Various cold meats (and serotypes) such as baked ham (*S.panama*), imported pork liver pate (*S.gold-coast*) and salami-sticks (*S.typhimurium* pt 124) have featured in community outbreaks reported in recent years. In the summer of 1990, an outbreak of *S.bovis-morbificans* affected several rural communities in South West Scotland, highlighting the hazards of a diseased animal contaminating meat in a slaughterhouse (Breen et al, 1990).

Campylobacter enteritis

Campylobacters (*Campylobacter jejuni/C.coli*) have now become the most commonly recognised cause of gastro-enteritis in man in many countries. Increasingly identified throughout the 1980s, campylobacters have now overtaken salmonellas in their reported incidence in the UK. The epidemiological evidence is however much less clear than with the salmonellas. This is in part due to the lack of readily available typing facilities but also to the shorter survival time on foods, in consequence of which the vehicles of infection are less frequently identifiable. While community outbreaks involving specific foods (undercooked chicken, raw milk, water, etc) have been reported from the UK, USA, the Netherlands and elsewhere, most infections present as single cases or as household outbreaks.

The four-fold rise in the reported incidence of human campylobacter infections in the UK from 10,000 cases in 1980 to nearly 40,000 by 1990, can only in part be explained by greater interest and/or improved reporting. There is some evidence to suggest much of the continuing rise in the number of cases is due to the increasing consumption of poultry-meat during this time (Skirrow, 1989). In one survey in England, *C.jejuni* was isolated from 22 (48%) of 46 fresh birds, 12/12 uneviscerated ("New York" dressed) birds and 1 (4%) of 24 frozen birds sampled (Hood et al, 1988). The handling of raw chickens during food preparation has been shown to be a risk factor in developing infection (Hopkins & Scott, 1983)(Pearson et al, 1985), while spread within kitchens has been demonstrated (Dawkins et al, 1984). Case-control studies in the USA have also demonstrated a link between infection and the consumption of chicken and other meats (Harris et al, 1986).

Cattle, sheep and pigs also frequently harbour campylobacters with carcases being contaminated during slaughter and at retail sale (Bolton et al, 1985). *Campylobacter* sp. have been isolated from pork, beef and veal carcases surveyed in Canada (Lammerding et al, 1988) and from samples of beef, pork, lamb and various edible offals in England (Fricker & Park, 1989).

Listeriosis

A relatively rare infection in man, listeriosis has been subjected to surveillance in the UK over the past 20 years. Throughout the 1970s little of note was observed other than that infection by *Listeria monocytogenes* was a cause of serious disease presenting as meningitis or septicaemia, being particularly severe in the elderly, the immuno-compromised, pregnant women and new-born infants. While the increased incidence in salmonellosis and campylobacter enteritis is relatively clear, it is less easy to ascertain whether that observed in reported cases of listeriosis during the latter years of the 1980s was due to greater awareness, better surveillance and/or more intensive investigation.

Outbreaks attributed to contaminated foods including pasteurised milk and various cheeses, were reported from the USA and Switzerland during the mid-1980's. Sporadic cases have also been associated in the USA with eating uncooked hot-dogs and undercooked chicken (Schwartz et al, 1988). Surveys in England and Wales have demonstrated contamination by *L.monocytogenes* of a wide range of foods such as soft cheeses (14%) and raw chicken (60%) (Pini & Gilbert, 1988), ready-to-eat poultry (12%), chilled meals (18%) and main course items from cook-chill units (2%) (Gilbert et al, 1989), pate (Morris & Ribeiro, 1989), cured meats (7%), salami and continental sausages (16%) (Gilbert et al, 1989).

Concern about cook-chill meals in particular is understandable in view of the rapid expansion in the use of "cook-chill" and other precooked foods and in their consumption by vulnerable groups of the population. Unlike most other food pathogens, *L.monocytogenes* have the capability to grow after a few days at temperatures around 8^{o}-$10^{o}C$ in refrigerators that are improperly maintained, compounded by failure to observe "sell-by" or "best-before" dates.

Despite the evidence of food contamination, a causal relationship with human illness in Britain has however only occasionally been established. Since 1989 more intensive surveillance programmes, including case-control studies, were initiated in the UK in an attempt to obtain better epidemiological information about relevant "risk" food factors, the results of which are awaited.

Since the latter months of 1989 and throughout 1990, the incidence of listeriosis in the UK has however shown a marked decrease. To what extent this has been due to a change in dietary habits following government warnings issued in the summer of 1989 or to changes in the production and packaging of "high risk" foods such as pate, is not yet fully clear.

<u>Haemorrhagic colitis (*Escherichia coli 0157:H7*)</u>

Increasing attention has been given in recent years to haemorrhagic colitis and the associated haemolytic uraemic syndrome (*HUS*) caused by verocytotoxin-producing strains of *E.coli* (*VTEC*) amongst which serotype 0157:H7 has a predominant, although by no means exclusive role. The role of *VTEC* organisms as a cause of haemorrhagic colitis and *HUS* was first recognised in Canada during the early 1980s, co-incidental with outbreaks in the USA associated with a fast-food restaurant chain (Riley et al, 1983), although both disease conditions had been récognised for many years without the causative agent having been identified.

The majority of cases occur sporadically without any source of infection being ascertained. Nevertheless there is increasing evidence of the foodborne transmission of *VTEC* organisms, particularly from North America where subsequent outbreaks were associated with the consumption of hamburgers and other ground beef products (Lamothe et al, 1983)(Hockin et al, 1987)(Ostroff et al, 1990). Surveys in Canada have demonstrated *VTEC* contamination levels of 10% of beef and 4% of pork at meat-processing plants in Ontario (Read et al, 1990) and in over 5% of ground beef samples from restaurant and retail outlets in the Winnipeg area (Sekla et al, 1990). In an earlier survey of fresh retail meats in Wisconsin, USA, *E.coli* 0157:H7 was recovered from 2% of lamb and from 1.5% of pork and poultry (Doyle & Schoeni, 1987).

Surveys in the UK have to date failed to substantiate the North American findings. Although *E.coli* 0157 was isolated from cattle and pigs in studies undertaken by the Central Veterinary Laboratory, Weybridge, VT strains were not detected (Wray, 1990). The only non-human isolates of VT-producing *E.coli* 0157 reported in the UK to date, were from 2/207 bovine faeces examined at an abattoir in Sheffield over a 2 year period (Chapman et al, 1989).

An increasing number of *E.coli* 0157 human infections have been reported in the UK within the past few years as more laboratories look for the organism, with several community and point-source outbreaks being identified. An epidemiological study in Scotland in 1989, implicated various undercooked meats such as hamburgers and poultry in several affected households (Dev & Sharp, 1990). In an outbreak in Birmingham in 1987, the epidemiological evidence implicated contaminated turkey-roll sandwiches as the source of infection (Salmon et al, 1989). In 1989, in order to help co-ordinate research and other activities relating to *E.coli* 0157 infection, the PHLS set up a Working Group comprising clinicians, microbiologists, epidemiologists and veterinarians as well as representatives from Ireland, Wales and Scotland.

Clostridium perfringens "food poisoning"

Outbreaks of "food poisoning" due to heat-resistant strains of *Clostridium perfringens* continue to be reported from time-to-time. Many outbreaks are associated with institutional forms of catering in hospitals, residential homes, schools etc., where food cooked in bulk may of necessity be prepared far in advance of serving. Various red meat products, in particular made-up meats, minces, stews, pies etc, have been most commonly incriminated, with poultry-meat also featuring on occasion. The frequency of outbreaks has decreased in recent years in the UK following an improvement in the appreciation of the importance of rapid chilling and refrigeration of pre-cooked foods in prevention.

MILK

Milkborne outbreaks of salmonellosis and campylobacter were a major public health problem in Scotland throughout the 1970's and the early 1980's, and to a lesser extent also in England & Wales.

In August 1983 legislation was introduced in Scotland requiring the heat-treatment of cows' milk for retail sale, following which the large community outbreaks previously experienced were effectively controlled (Sharp et al, 1985)(Table). The success of this measure however, highlighted the prevalence of milkborne infection in dairy farming communities where farm-workers continued to receive untreated milk as a wage-benefit, a practice not prohibited by the 1983 legislation as no *retail* sale was involved. Farm outbreaks continued to be reported and in consequence further legislative control measures were introduced in September 1986, following which only heat-treated milk could be supplied as a wage-benefit. Not unexpectedly, minor episodes of milkborne infection continue to be reported from time-to-time affecting farming families drinking raw milk obtained from their own herds.

In England and Wales untreated cows' milk is still available in many rural areas as farmgate sales (including farm milkbars) or via local retail deliveries, with outbreaks of infection being reported from time-to-time (Sockett, 1991). One of the most serious of these, an outbreak due to *Streptococcus zooepidemicus* in West Yorkshire in 1984, affected 11 persons, seven of whom died (Edwards et al, 1988).

Table. Outbreaks (nos. affected) of milkborne infection in Scotland, 1980-90

Type of supply		1980-82	1983-85[a]	1986-88[b]	1989-90
Raw	*Salmonella*	21(1146)	15(101)	5(21)	-
	Campylobacter	6(278)	3(25)	4(24)	-
"Heated"	*Salmonella*	-	-	-	1(55)

a The Milk (Special Designations)(Scotland) Order 1980 - introduced 1/8/83

b The Agricultural Wages Order no. 34 - introduced 1/9/86

Untreated milk can still be obtained in rural districts of most European countries. While relatively few milkborne outbreaks are reported, surveillance programmes in Europe until recent years have generally been less well developed. Raw milk can also be sold under certain licensing conditions in many states of the USA and in most Canadian provinces and territories, although untreated dairy produce is generally not widely available. In Alberta, the only province in Canada without relevant provincial heat-treatment legislation, one-third of all campylobacter cases reported during 1985-6 were attributed to drinking unpasteurised milk. Episodes of *E.coli* 0157:H7 infection have also been reported in Canada (Duncan et al, 1987)(JR Waters - personal communication) and the USA (Martin et al, 1986) associated with the drinking of untreated milk.

Heat-treatment is however no excuse for producing "dirty" milk and requires to be complemented by good hygiene and correct operating practices throughout from producer to consumer. Potential problems exist such as the failure to achieve effective temperatures or times during pasteurisation, or may arise from post-treatment contamination as a consequence of faulty equipment or human error or both.

Outbreaks of milkborne infection (salmonellosis, campylobacteriosis, yersiniosis, listeriosis, staphylococcal "food poisoning") associated with contaminated "heat-treated" milk have been reported from North America and several European countries (Sharp, 1987). The most extensive of these in Illinois and adjacent states of the USA in 1985 affected *ca.* 200,000 persons (Ryan et al, 1987). Infection by *S.ealing* was identified in different areas of the UK over a period of several months in 1985-6, affecting infants and other persons who had been fed with a particular brand of contaminated powdered milk (Rowe et al, 1987). Outbreaks of yersiniosis (Barrett, 1986), salmonellosis (Rampling et al, 1987) and campylobacteriosis (Sockett, 1991) in England have also been associated with "heat-treated" milk supplies.

That there can be no room for any complacency in Scotland was demonstrated in 1986 when milk supplies to several Glasgow hospitals were found to be heavily contaminated with coliform and other organisms. Investigation at the processing dairy revealed several malpractices requiring immediate attention (GM Paterson - personal communciation). More recently in the autumn of 1990, an outbreak of milkborne salmonellosis affected over 50 persons in Lanarkshire as a consequence of inadequate heat-treatment (Table).

The legislative control measures introduced in Scotland did not prohibit the sale of untreated goats' and sheep milk as dairy legislation throughout the UK applies to cows' milk only. The goat and sheep milk industries in Britain have expanded in recent years and a considerable market for untreated produce has developed. Outbreaks of brucellosis, campylobacteriosis, salmonellosis, listeriosis, toxoplasmosis, staphylococcal "food poisoning" and *Corynebacterium ulcerans* "sore throat" associated with untreated goats' and sheep milk products have been recorded periodically in Canada, the USA and in the UK.

CONTROL MEASURES

It is anticipated that the range of legislative control measures *viz.* the respective Processed Animal Protein Orders, the Poultry Breeding Flocks and Hatcheries and Laying Flocks Testing and Registration Orders, the Zoonoses Order and various codes of practice, introduced by the Ministry of Agriculture, Fisheries & Food in 1989, in conjunction with the requirements of the new Food Safety Act 1990, will go a considerable way towards minimising the occurrence of poultry-borne and other foodborne infections in Britain. It has now become permissible for example to sell irradiated food in Britain, the cost-effectiveness of which in the prevention of poultry-borne salmonellosis has been demonstrated (Yule et al,. 1988).

Despite the evidence of the success of the introduction of compulsory heat-treatment of cows' milk in Scotland in 1983, regrettably the government rescinded its stated intention to introduce similar legislation in England & Wales.

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CRYPTOSPORIDIOSIS - A ZOONOTIC PROBLEM?

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Cryptosporidosis is a coccidian protozoan parasite recognised by veterinarians for many years as an important case of scouring in calves. It was first identified by Tyzzer in 1907 and occurs throughout the animal kingdom. However, it was not until 1976 that the first human case was reported (Nime et al, 1976). A thorough review of the scientific literature in 1981 could produce only 7 documented cases (Navin & Juranek, 1984). The key event leading to the recognition that cryptosporidium as an important human pathogen was the AIDS epidemic. In immunocompromised patients cryptosporidium has been found to cause severe intractable diarrhoea. Subsequent surveys in selected groups of people who were not immunocompromised demonstrated it to be one of the commonest causes of acute infectious diarrhoea.

The reason that cryptosporidium was not recognised as a human pathogen before the early 1980's, was that it was not sought in cases of acute diarrhoea! Diagnosis requires wet staining of faecal smears, a procedure which was not routinely carried out. Furthermore new or modified staining methods had to be developed to enable diagnostic laboratories to routinely look for cryptosporidium (Casemore et al, 1984).

The predominant symptoms in humans are watery diarrhoea, and abdominal cramps. About half the cases report vomiting and anorexia and a third report fever. In one study the severity of diarrhoea as measured by the maximum frequency of bowel motions in a 24 hour period increased from 6 in children to 9 in 25-34 year olds. The average duration of diarrhoea was 9 days with a range of 1-90 days (PHLS, 1990).

In immunocompetent people infection is self limiting. In immunosuppressed people, particularly AIDS patients, infection is often intractable and terminal.

PREVALENCE OF HUMAN CRYPTOSPORIDIOSIS

Almost all countries in the world now recognise cryptosporidium as a common parasitic infection. It is a major cause of travellers diarrhoea in people returning from developing countries.

To establish the importance of cryptosporidium as a human pathogen in Britain, the Public Health Laboratory Service set up a two year surveillance study beginning in July 1985 in which 16 laboratories in England and Wales participated (PHLS, 1990). Standard protocols were used both for screening and for confirmation of infection.

Laboratories choose between one of the following three screening methods for staining faecal smears which were considered to be of comparable sensitivity (a) modified Ziehl-Neelsen (b) auramine/carbol fuchsin (c) carbol (phenol) auramine. All faeces positive by methods (b) or (c) on screening were to be confirmed by the modified Ziehl-Neelson method.

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Over the 2 years of the study 62,421 patients with presumed acute infectious diarrhoea were investigated through their general practitioners; 1295 (2%) were excreting cryptosporidia, 4775 (8%) campylobacters, 2050 (3%) salmonellas and 437 (0.7%) shigellas. Twenty five patients with cryptosporidiosis were also excreting campylobacter, 4 salmonella, 10 giardia, 1 shigella and 2 enteropathogenic Escherichia coli. The positivity rate for cryptosporidium by laboratory varied from 0.5% to 3.9% and was not correlated with screening method used. Higher rates tended to be reported by laboratories serving a more rural population.

The positivity rate for cryptosporidium was highest in children 1-4 years of age (5%), whereas campylobacter rates were highest in 15-24 year olds (11%), salmonella rates in 15-44 year olds (4%) and shigella rates in 5-14 year olds (2%). In children cryptosporidium was the second commonest pathogen to campylobacter, being almost twice as common as salmonella and four times as common as shigella.

The study showed that cryptosporidium infection is almost as common as salmonella infection and almost three times more common than shigella infection. About 2% of all patients and 4% of children investigated were shown to be excreting cryptosporidium oocysts.

MODES OF TRANSMISSION AND SOURCES OF INFECTION

The earliest recognised cases of infection in immunocompetent people occurred in outbreaks amongst people exposed to infected animals. Current et al (1983) described an outbreak in 12 of 18 people exposed to calves. All had direct physical contact with faeces from infected calves. In another incident a 35 year old researcher in attempting to set up an animal model system was exposed when using a stomach tube to infect a rabbit with oocysts from an AIDS patient. The rabbit coughed droplets of the innoculum into the face of the researcher, and 5 days later he became ill with confirmed cryptosporidiosis. (The incubation period for infection in humans is now generally accepted as 1-10 days).

Subsequently outbreaks have been recognised in groups without direct contact with animals. Outbreaks in day care centres and nurseries suggest person to person faecal oral spread is important (Hunt et al, 1984). Cryptosporidium can be acquired sexually as part of the "gay bowel syndrome".

The interconnection betwen zoonotic and human to human spread is well illustrated by a family outbreak in Cardiff in 1985 (Ribeiro & Palmer, 1986). A family of 3 children, two parents and 2 grandparents visited a dairy farm in Devon. They witnessed the birth of twin calves at close quarters and then drank raw milk. 3 days later one child and the grandmother developed diarrhoea. 5 days on another child who shared the grandmother's bedroom became ill. After another 11 days the third child was ill. Finally the mother became ill 11 days after onset of illness in the 3 child. The sequence of transmission appeared to be zoonotic infection from the farm to the first two cases, either by direct contact or via contaminated milk. This was followed by faecal-oral person to person spread within the family. Of the 5 cases, 2 were probably zoonotic and 3 due to person to person spread. Oocyst excretion persists throughout the illness and for several days after. This fact, together with the small infecting dose, facilitates person to person spread.

ZOONOTIC TRANSMISSION

The relative importance of zoonotic transmission in cases in England and Wales was explored in the PHLS study. One hundred and fifty five (12%) out of 1041 patients had been overseas in the month before onset and probably acquired infection overseas. Of the remaining 1087 UK acquired cases, 9% (102) reported drinking raw milk in the month before onset. Of these, 68 (6% of UK acquired cases), and an additional 185 (17%) of the UK acquired cases, reported close contact with farm animals in the month before onset. Of the UK acquired cases 31% of children 1-4 years old and 37% of 5-14 years old reported exposure to farm animals or raw milk. There was no difference in the severity of symptoms in cases with farm animal or raw milk exposure compared with other patients.

The PHLS study found that overall, 23% of UK acquired cases reported farm animal contact. It is important to not that these were uncontrolled data, but zoonotic sources could possibly explain these infections. Spring and autumn peaks have been reported by some laboratories and this could possibly be related to excretion patterns in animals such as cattle and sheep, and possibly to farming practices such as sludge spreading. For example, (Casemore, 1989) found a significant association between spring cases of cryptosporidiosis and direct contact with newborn lambs. However, in the PHLS study a clear seasonal pattern was not seen either in cases with farm animals contact or other cases (Fig. 1).

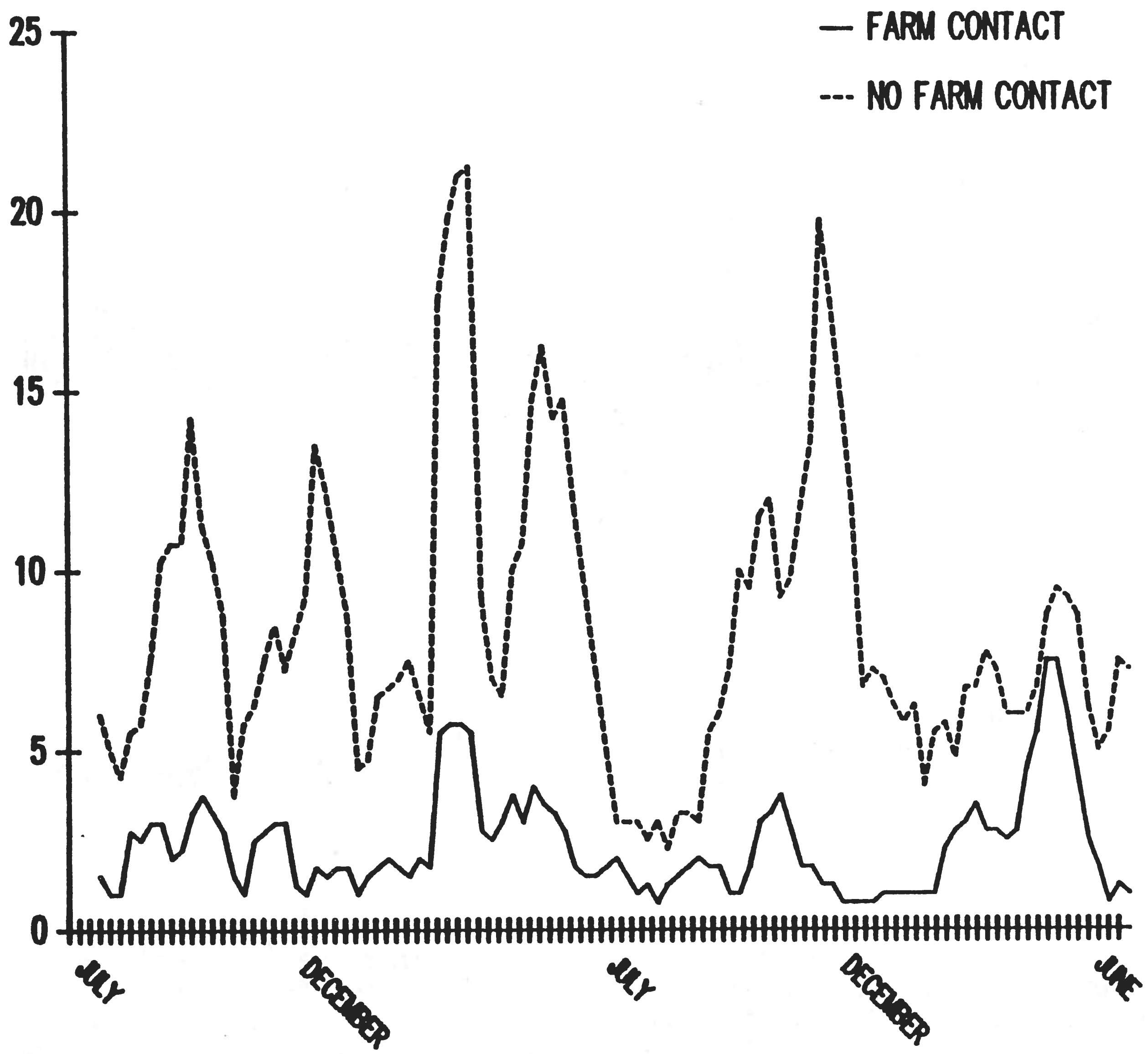
WATERBORNE INFECTION

The most important recent development in the understanding of the epidemiology of human cryptosporidium is the recognition of outbreaks of waterborne infection. This has included both drinking water and recreational exposure. In Doncaster in 1987 a large community outbreak with at least 77 cases was attributed to sewage contamination of a public swimming pool.

The first recognised drinking water outbreak occurred in 1984 in USA (D'Antonio et al, 1985). The cause was thought to be sewage contamination of well water. In 1987 there were an estimated 13,000 cases in a town of 65,000 people in Georgia, USA (Hayes et al, 1989). The water treatment plant, though meeting accepted standards, was shown to be inadequate to filter out all cryptosporidia oocysts in raw water. A possible source of water contamination was considered to be cattle in the watershed area. In March 1989 an outbreak in Oxfordshire and Swindon was attributed to contamination of a reservoir supply. Since cryptosporidia are resistent to chlorine; attention is now being given to improvements in flocculation and filtration systems to exclude cryptosporidia from drinking water.

Fig. 1 PHLS CRYPTOSPORIDIUM STUDY: JULY 1985 - JUNE 1987

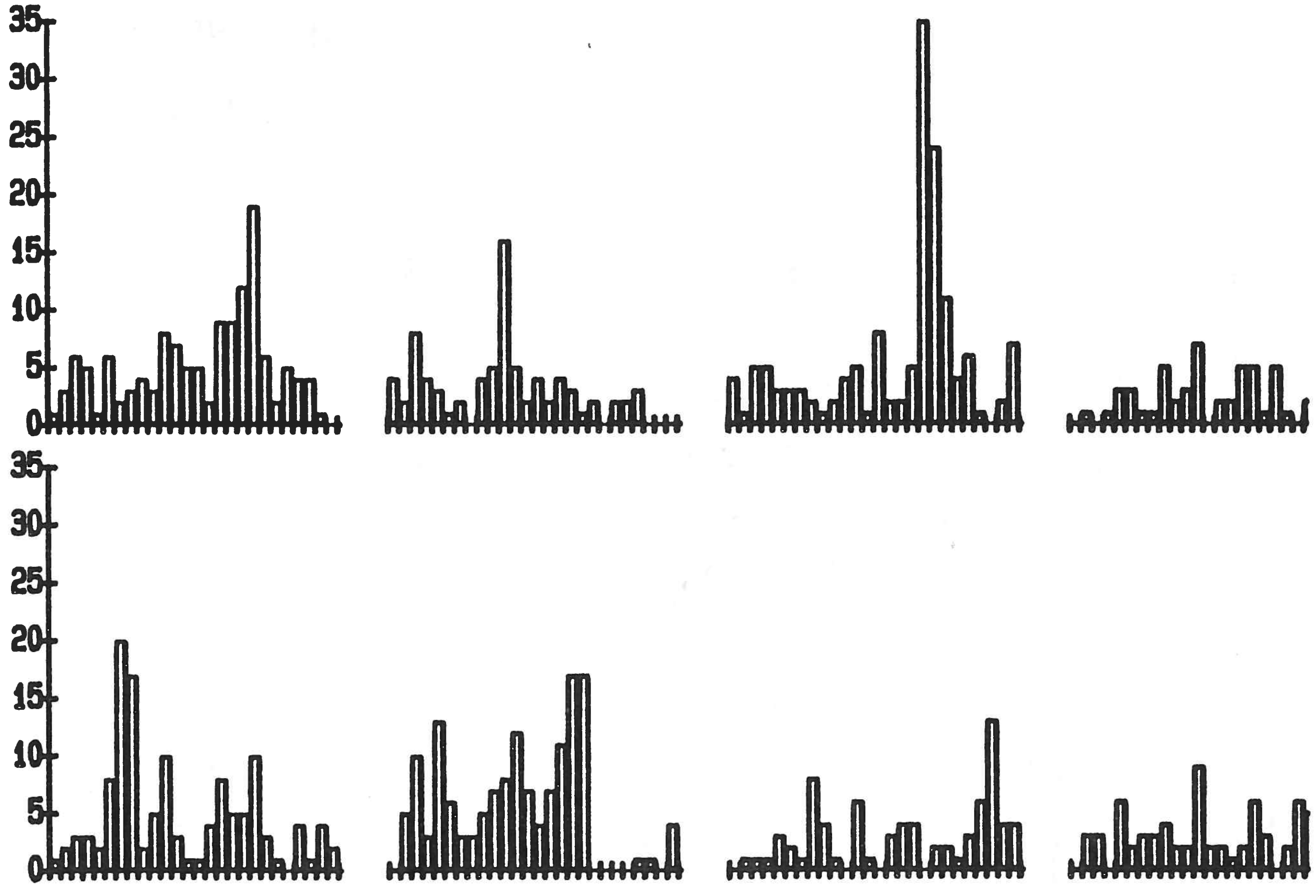
Four Weekly Moving Averages of percent of cases reported each week



Household pets have occasionally been implicated as sources of human infection (Lewis et al, 1985).

The contribution of waterborne infection to the prevalence of the infection in the United Kingdom is not yet known. The PHLS survey suggests, however, that waterborne outbreaks may be relatively common. When monthly incidence patterns were examined for each laboratory four laboratories had relatively constant monthly isolation rates with <10 cases in any month. In the 10 other laboratories there were one or two sharp peaks over the two years of the study, but in only one laboratory did a peak coincide with a defined outbreak (in a nursery). The other peaks represent community-wide increases (Fig. 2).

Fig. 2 Numbers of reports of cryptosporidium from eight laboratories by four week periods. July, 1985 - June, 1987. (9th July WO CESA)



During October 1987 Cardiff PHL noted an increase in isolations of Cryptosporidium. Eighty four cases were identified from August 1st to December 1st, 1987. Fourty nine were male and 35 female. Ages ranged from <1 year to over 85 years. Cases were scattered over Barry (population 42,000), Cardiff (population 280,000) and Penarth (population 25,000). Cases were reported from 48 (77%) of the 62 electoral divisions in South Glamorgan. Date of onset of symptoms showed an outbreak beginning in mid September and affection all age groups simultaneously. Interviews failed to identify possible common sources of infection from milk, food, animals or pets. Only 4 cases drank raw milk and 15 cases had been on holiday outside of Cardiff in the month before onset. When these 15 cases and the 10 probable secondary household cases were excluded the occurrence of cases could be seen to have slowed down in the week beginning 12 October.

Discussions with the water company revealed that during August there had been a shortage of water in the Brecon Beacons reservoirs so that increased demand was placed upon the Usk-Llandegfedd reservoir supply. In September, flocculation was discontinued at the water treatment works which supplied the Cardiff area. Between 9th and 16th September a small proportion (about 5-10% as reported by the water company) of water supplying Cardiff was not gravity sand filtered.

Fifteen of the cases had been on holiday in the previous 4 weeks and therefore may have acquired infection outside of Cardiff. When these cases and the secondary household cases were excluded the rate of occurrence of cases was seen to slow down in the week beginning 12th October 1989. This phase of the outbreak began the week after Cardiff residents had received partly unfiltered but chlorinated water. The incubation period for Cryptosporidium is usually cited as 1-10 days although it may possible be longer. Assuming unfiltered water remained in the distribution system for some days the main part of the outbreak could be explained by the unfiltered domestic water. Later cases could be explained by other modes of transmission eg. faecal oral spread following "seeding" of the population via water supplies.

The origin of cryptosporidium in water is likely to be animal faeces. Data from the MAFF indicated that 18 incidents of cryptosporidium in cattle in Powys had been reported between January and September 1989, and 17 incidents in sheep. Possibly occysts from sheep and cattle in Powys could find their way into the River Usk and from there to the Llandegfedd reservoir. Normal chlorination of water will not reliably inactiviate cryptosporidium and bypassing filtration procedures could result in infective oocysts entering the domestic water supply.

CONCLUSION

Human cryptosporidiosis can be acquired from direct contact with animals or indirectly via milk. The PHLS survey in England and Wales suggests that only up to 25% of infections can be explained by zoonotic transmision. Person to person faecal oral spread appears to be at least as important. However, the contribution of waterborne infection to the incidence in humans has yet to be determined. It is possible that water is an important means of "seeding" the population, followed by person-to-person spread. The source of water contamination may be human sewage or animals. Prevention and control will focus on improving filtration systems to remove occysts from raw water.

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BIRDS, BEASTS AND BOTULISM

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Botulism, a paralytic and often fatal form of food poisoning of vertebrates, is important in relation to agriculture, wildlife, public health, food and the environment. The causative organism, Clostridium botulinum, a spore-forming anaerobe inhabiting soil and mud, occurs as seven types (A-G), distinguishable by the production of immunologically distinct though pharmacologically similar neurotoxins. In recent years subtypes (e.g. Af, Ba, Bf), producing a major and minor toxin, have occasionally been isolated; and strains of Clostridium butyricum and C. barati producing E and F botulinal toxins respectively have also been described (see Smith, 1990). Type C and D toxicity depends on the presence of bacteriophage, and various degrees of antigenic overlap occur between the toxins of type C and D strains. Such strains are notorious for producing botulism in animals but, for reasons that are obscure, seldom if ever do so in man. Types A, B and E are the main causes of human botulism.

Most cases of botulism are essentially intoxications resulting from the ingestion of food in which toxigenesis has taken place, but because both toxin and C. botulinum organisms are inevitably present in such food, it is often difficult to exclude completely the possibility that in-vivo toxigenesis played some part in the disease. Human infant botulism clearly demonstrates that this can occur when the composition of the gut microflora permits; and cases of a disease succinctly described as "infant botulism in adults" have also been recognized (see Smith, 1990). Evidence of infection in botulism is less easily come by in animals, but high counts of C. botulinum in deep litter have been demonstrated in outbreaks on poultry farms (Smart & Roberts, 1977) and, experimentally, caecal toxigenesis occurred in young chicks given small numbers of spores by mouth (Miyazaki & Sakaguchi, 1978).

GEOGRAPHICAL DISTRIBUTION OF C. BOTULINUM

The distribution of the various types is, for reasons unknown, strikingly regional. For example type A preponderates in the western part of the USA and type B in the eastern; and type D occurs much more commonly in the southern than in the northern hemisphere.

As part of a study of botulism in waterfowl, surveys of C. botulinum in the mud of lakes and other aquatic environments in the UK were made by the Institute of Zoology in the 1970s and 1980s. The results (see Smith, 1987) are summarized in Table 1.

London's lakes and waterways

Of 69 mud samples collected from various sites, mainly lakes in public parks within a radius of 11 miles from Charing Cross, 50 (72%) contained C. botulinum of one type or another. Type C, which was present in 17% of samples, occurred about as frequently as type E, but type B was much more common (45% of samples). Type D was found in only one sample.

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The Norfolk Broads

Towards the end of a summer outbreak of botulism in which several thousand birds died, 45 mud samples from 22 well-distributed sites representing the majority of the Broads were collected and examined. Waterfowl mortality was observed in about half these sites. The results suggested that a handful of mud taken anywhere in the Broads was almost certain to contain C. botulinum, usually of more than one type. Here, in contrast to London, types C (in 51% of samples) and E (60%) were almost as common as type B (62%).

Britain (excluding London and the Norfolk Broads) and Ireland

Mud samples (a total of 554) were collected from lakes, ponds, reservoirs, marshes, mudflats, streams, rivers and canals in areas which, in general, were selected for their interest in relation to waterfowl.

C. botulinum type B, present in almost one-third of the samples, was well-distributed throughout all the areas examined. Type C, like type E, was found in only 3% of samples, and type D in only 1%. Although encountered relatively infrequently, type C was widespread, occurring in the south and east of England, in Wales, and in the north of Scotland, in both fresh and saline waters.

The Camargue (France)

This region consists of the island that lies between the Grand and Petit Rhones and the Mediterranean. Its area is about 757 km² of which 142 are covered by lakes and rather more by marshes. Salt, the dominant ecological influence, is absent only in the northernmost part of the delta, where the height above sea level is 2-3 m.

Mud samples were collected, mainly from lakes and marshes. Both branches of the Rhone were shown to contain C. botulinum (types B and E), but of 44 samples from the Camargue proper 42 were negative; type E was found but in only two samples (Table 1).

Table 1. Prevalence of Clostridium botulinum in different aquatic environments

Area	Number of mud samples	Percentage of mud samples containing C. botulinum of: any type	type B	type C	type D	type E	more than one type
London	69	72*	45	17	1	14	6
Norfolk Broads	45	98	62	51	0	60	58
UK and Eire (excluding London and Norfolk Broads)	554	35	30	3	1	3	2
Camargue (France)	44	5	0	0	0	5	0

*Resampling of apparently negative London sites increased the positive results from 55 to 72%.

Resident and migratory birds abound in the Camargue. In mid-winter the number of Anatidae and coots (Fulica atra) may be between 150 000 and 180 000, i.e. approximately 50% of the wintering population in France. C. botulinum spores can be transferred from one aquatic area to another in the alimentary tract of birds or on their external surface, and it seems certain that the mud of the Camargue must regularly be seeded in this way. The failure of C. botulinum of any type to become established suggests, therefore, that inhibitory factors are present. Such factors, which may be microbiological (Graham, 1978), warrant further study in relation to the possible biological control of botulism in waterfowl.

The salinity that prevails in much of the Camargue seems unlikely to exert any direct influence on the prevalence of C. botulinum, as marine muds have frequently been shown to contain different types of the organism, including type C. Botulism in waterfowl does not occur in waters of high salinity (7% or greater) but may do so in adjacent marshes where the salinity is lower and concentration of organic matter higher. Indeed, some of the largest outbreaks on record occurred on the shores of the Great Salt Lake.

Comparison of mud and soil

Samples of soil from various parts of Britain were examined. Of 174 samples tested, only 10 (5.7%) could be shown to contain C. botulinum (type B). It seemed clear therefore that, in Britain, mud provided a more favourable environment than soil for C. botulinum. Indeed, heavily contaminated soil was found in only one location, namely, the site of the former Metropolitan Cattle Market, London, which existed from 1855 to 1939. Of 60 samples from the site, 15 (25%) contained C. botulinum, and as many as four types (B,C,D,E) were identified (Smith & Milligan, 1979).

BOTULISM IN WATERFOWL AND GULLS

Waterfowl

From about the year 1910, reports appeared annually of summer mortality, often on a huge scale, in waterfowl on lakes and mudflats in the western USA. The 1910 outbreak on the Great Salt Lake was exceptionally severe. In 1932, fully 250 000 birds died at the northern end of the lake, where "The dead lay at the rate of 8000 to 10 000 to the mile of shore line" (Kalmbach, 1935). Whether outbreaks of such magnitude occurred in the nineteenth century is in doubt. Kalmbach (1968) comments on the lack of evidence in reports written by the observant naturalists who accompanied the various early expeditions into the western regions. The disease, which became known as "western duck sickness", was initially thought to be due to an alkali poisoning, but this explanation lost credibility as outbreaks began to be reported in aquatic environments less highly saline than the Great Salt Lake. Some 20 years after it was first reported, western duck sickness was shown to be type C botulism. In 1952 severe flooding was associated with no less than 4-5 million fatal cases in the western USA and "This severe mortality undoubtedly exerted a profound influence on the population dynamics governing waterfowl" (Rosen, 1971).

Type C botulism in waterfowl is by no means confined to the USA, and millions of deaths occur annually in lakes, marshes and waterways throughout the temperate zones of the world. In the absence of a laboratory diagnosis the disease is easily confused with poisoning by agricultural or industrial chemicals. In 1969 botulism in waterfowl was confirmed for the first time in Britain, deaths being reported in the Midlands (Blandford et al., 1969) and in St James's Park, London (Keymer et al., 1972). Since then, numerous outbreaks have been recognized. These outbreaks included one in 1975 that caused the death of several thousand birds on the Norfolk Broads (Borland et al., 1977) and was followed by a similar episode in 1976. Haagsma et al. (1972) reported mass mortality in the Netherlands. Mountfort (1973) described a disastrous outbreak, initially thought to be due to pesticide poisoning, in the Coto Donana Reserve at the mouth of the Rio Guadalquivir. About 50 000 birds of various species, including 80% of the spoonbill colony, died in the marshes of this famous reserve, jointly created by the World Wildlife Fund and the Spanish Government. There has been further mortality since 1973.

The factors that favour precipitation of an outbreak in an area already contaminated with type C spores are: a prolonged period of warm weather; increasing areas of shallow stagnant water; alkalinity; an abundance of dead aquatic invertebrates; and oxygen depletion associated with rotting vegetation and other organic matter (see Smith, 1976). A favourable combination of precipitating factors leads to germination, explosive multiplication and toxigenesis. Bacterial multiplication may occur in sludge or rotting vegetation, or inside particles of organic matter such as decaying aquatic invertebrates (Bell et al., 1955). Such particles may protect the organism from an unfavourable macroenvironment. Waterfowl carcasses also provide hospitable surroundings and may become contaminated with massive concentrations of toxin. Dipterous fly larvae that crawl through and ingest the contaminated flesh may become dangerous sources of toxin for other birds.

Toxin can persist in the environment for considerable periods. In an unusual episode on the Norfolk Broads, several waterfowl died from botulism in March and April 1977 (Graham et al., 1978); the evidence suggested that the toxin had been formed the previous summer.

The almost total absence of reports of botulism in waterfowl in the tropics, other than in zoos, is a matter that requires study. Possibly the disease occurs but remains undiagnosed. On the other hand outbreaks in temperate climates are precipitated by conditions that are lacking in the tropics, where the temperature of the mud remains comparatively high and fluctuates little.

Gulls

Since about 1975 there has been a steadily growing awareness that in Britain type C botulism plays a role of some importance in gull mortality. In that year Macdonald & Standring (1978) investigated the first recorded outbreak in gulls in this country. It occurred between June and October around the Firth of Forth, causing the deaths of at least 2080 birds belonging to several species of the genus *Larus*. Numerous further outbreaks have since been recorded in coastal Britain and Eire.

At Walney Island (Cumbria) considerable annual mortality was observed from 1975 onwards between the months of April and September, and laboratory confirmation of botulism was obtained in 1978, 1980, and 1981; between 26 April and 30 June 1978 approximately 1600 deaths occurred in the breeding colony of 60 000 *L. argentatus* and *L. fuscus* (R. McCleery & A. Hart, pers. comm.). In this laboratory type C toxin was found in deep frozen serum taken in 1981 from three moribund gulls on Walney Island as early as 20 May - at least a month before deaths from summer botulism begin to occur in mallard (*Anas platyrhynchos*) in Britain. This observation is of possible interest in relation to the source of toxin for gulls, at present unknown.

Deaths of *L. argentatus* and *L. ridibundus* from botulism were reported in Motherwell, Scotland, in December 1976, a month in which the local mean maximal air temperature was only 3.5°C (Graham et al., 1978). This temperature was well below the minimum necessary for growth and toxin production. A search for the source of toxin proved fruitless, but the scavenging habits of gulls were suspected to be in some way responsible for the disease. It seems possible that gulls ingest toxin from refuse dumps, but an invertigation is needed to provide firm evidence.

CARRION AND ANIMAL BOTULISM

Because animals are less fastidious than man in their dietary preferences, and because their food is seldom cooked, animal botulism is much more common than the human disease. Carrion is one of the major sources of toxin for animals.

C. botulinum is not a normal member of the gut microflora but is inevitably present in the alimentary tract of an animal that has died from botulism; it may also be present in an animal that has died from another cause if the immediate environment is heavily contaminated with spores. When the carcasses of such animals putrefy, C. botulinum leaves the gut, multiplies, and produces large amounts of toxin in the organs and muscle. The ingestion of this toxic carrion will lead to death from botulism and, unless the new carcasses are safely disposed of, to a repetition of the cycle just described.

Examples of the role of carrion in botulism are seen in (1) the sometimes huge outbreaks that occur on fish farms, (2) countries such as South Africa and Australia, where cattle on phosphorus deficient pastures are driven by depraved appetite to chew the bones of cadavers, and (3) the UK and elsewhere, where poultry litter containing chicken carrion is sometimes spread on cattle pasture as fertilizer, or ensiled as a foodstuff for cattle (see Smith, 1990). The feeding of ensiled poultry litter caused the death of some 5000 Queensland feedlot cattle in January 1990 (P.M. Summers, pers.comm.).

Factors influencing toxigenesis in carrion

Experiments with C. botulinum types C and E, the respective causes of botulism in (1) waterfowl throughout the world, and (2) gulls and loons on the shores of Lake Michigan (Brand et al., 1983), showed that toxin production in rotting carcasses sometimes differed strikingly from that in pure broth cultures, no doubt due in part to the mixed microflora of carrion (Smith & Turner, 1987, 1989; Smith et al., 1988).

Animals, usually mice, were killed after being inoculated orally with spores and the carcasses were incubated for different periods and at different temperatures. Cooked meat broth cultures, also inoculated with spores, were incubated in parallel. After incubation, titrations were made of the toxin present in (1) sterile membrane filtrates of individual carcass homogenates, and (2) broth culture filtrates.

A temperature of 37°C produced less type C toxicity in carcasses than in cultures. At 30°C, however, toxicity (often 2×10^5 to 2×10^6 mouse intraperitoneal LD/g or ml) was roughly similar in both systems, and some carcasses and cultures were still toxic (2×10^4 to 2×10^5 LD/g or ml) after 349 days. Surprisingly, at 23°C, though greatly reduced in the cultures, toxicity was high in many carcasses for at least 28 days. Little or no toxin was produced in either system at 16°C. Unfiltered homogenates (17.8-22.5%, w/v; dose 0.25 ml per os) of toxic carcasses incubated at 30°C for 7 days invariably produced death from botulism, often within as little as 4 h, but a 1 in 10 dilution produced less than 100% mortality.

Type E toxicity produced at 37°C was poor in both carcasses and cultures (2×10^2 to 2×10^4 LD/g or ml). It was good in both systems at 30 and 23°C, usually reaching 2×10^4 to 2×10^5 LD/g or ml, and in carcasses occasionally more; at 30°C maximal toxicity was reached more quickly in carcasses than in cultures. Prolonged incubation (40 days) at 30°C resulted in complete loss of toxicity in virtually all carcasses but not in cultures. At 16°C the development of toxicity in carcasses was strikingly greater than in cultures. At 9°C neither system produced more than slight toxicity after prolonged incubation. Trypsinization increased the toxicity of cultures but not usually of carcasses. Unfiltered carcass homogenate (10%, w/v) with maximal intraperitoneal toxicity was harmless for mice by mouth in doses of 0.25 ml.

In further experiments, mammalian, avian and piscine carrion were compared for their toxigenic potential, usually at an incubation temperature of 23°C.

Table 2. C. botulinum types C and E in carrion

Observation	Results with type	
	C	E
Maximum toxicity of MC	High	Moderate
Maximum toxicity of FC	Low	Moderate
Toxigenesis in MC, 16°C	Nil	Moderate
Duration of toxicity of MC	> 1 year	< 40 days
Oral toxicity of MC for mice	High	Nil

MC, mouse carrion; FC, fish carrion.
For details see text.

In mouse carcasses a type C strain of C. botulinum usually produced $>2 \times 10^5$ LD/g; in fish carcasses it usually produced less - often much less - than 2×10^4 LD/g. Avian carcasses appeared to be intermediate between those of mice and fish in their ability to support toxigenesis. A type E strain of C. botulinum, unlike type C, produced toxin equally well in fish and mouse carrion, usually at a concentration of between 2×10^4 and 2×10^5 LD/g.

Some of the main differences found between type C and E toxicity in carrion are briefly indicated in Table 2.

CONCLUSIONS

The causative organism of botulism was isolated almost 100 years ago, but knowledge of the disease and of Clostridium botulinum continues to grow. In type C and D strains, which are frequent causes of animal botulism, bacteriophage plays a decisive role in toxigenesis. Surprisingly, botulinal toxin is occasionally produced by clostridia other than C. botulinum. Evidence, particularly from human medicine, shows that botulism can on occasion arise from the multiplication of C. botulinum in the gut, although it is probably more often a pure intoxication. The use of ensiled poultry litter as cattle feed has recently caused huge losses and even its use as a pasture fertilizer is not without risk. Type C botulism in waterfowl, easily confused with poisoning by agricultural or industrial chemicals, continues to cause millions of deaths annually in temperate zones, but the apparent lack of outbreaks in the tropics requires investigation. C. botulinum is much more prevalent in mud from aquatic environments than in soil, as has been shown in surveys in the UK. Some muds, however, are inhibitory for C. botulinum and this invites further study in relation to the possible biological control of botulism in waterfowl. Also needed is a study of refuse dumps as a probable source of toxin for gulls, in which botulism is a cause of considerable mortality. Carrion is a major source of toxin for animals and studies based on the growth of C. botulinum in rotting carcasses instead of in pure laboratory cultures give surprising insights into toxigenicity.

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FELINE EPIDEMIOLOGY AND PREVENTIVE MEDICINE

DETERMINANTS OF THE NATURAL OCCURRENCE OF FELINE LEUKAEMIA VIRUSES

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Feline leukaemia virus (FeLV) causes several very serious diseases of domestic cats including lymphosarcoma, the most common type of feline tumour. In addition the virus is responsible for other haemopoietic tumours including myeloid and erythroid leukaemias, and for anaemia and immunodeficiency. FeLV has also been implicated as the most common infectious cause of reproductive failure in the cat.

TRANSMISSION OF FeLV

The source of FeLV is the persistently infected cat which excretes virus in the saliva, urine and faeces (Hardy et al 1973). Following the establishment of a persistent infection cats may remain asymptomatic for many months or years during which time they can transmit virus to other cats. Persistent infection is diagnosed by the demonstration of either infectious virus or viral antigen in the plasma. The virus is generally transmitted either by contact through the saliva, in the milk or across the placenta to the developing foetus.

DETERMINANTS OF THE OUTCOME OF FeLV INFECTION

Direct transmission involves very close contact in which the virus is transferred from the saliva during licking and grooming. Not all exposures to the virus result in persistent infection. In fact the majority of cats which are exposed recover and become immune. The factors which determine the outcome of the infection are first, the age at which the cat is exposed, and secondly, the dose of virus which is transmitted. Cats show a remarkable age-related susceptibility to FeLV. Kittens up to the age of about 12 weeks are highly susceptible and easily infectable but kittens over the age of 16 weeks are very difficult to infect, either experimentally or naturally (Hoover et al 1976). It is likely that the maturing immune response of the cat is responsible for increasing resistance to the development of persistence. The importance of the dose of virus is seen in the contrast between the outcome of infection in multiple cat households where the dose is high and in free-ranging cats from single cat households where the dose is low. As discussed below the chance of transmission in the former situation is high because of a high dose of virus whereas the chance of infection in the latter situation is low.

Congenital infection occurs by transmission of virus across the placenta rather than through the egg. The consequence of all prenatal infections which have been studied is that kittens are born with a persistent infection. Infection can also occur in the perinatal period through the milk.

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PREVALENCE OF FeLV IN DOMESTIC CATS

Early epidemiological studies based on the occurrence of leukaemia in cats failed to find evidence that feline leukaemia was an infectious disease. However with the development of specific virological and serological tests it became obvious that the virus was common in cat populations and was transmitted readily under appropriate circumstances. A recent survey of cats in the United Kingdom has shown that the prevalence of active infection is 18% in sick cats and 6% in healthy cats (Hosie et al 1989). The peak prevalence of the infection occurs in the age groups 3-4 years old. Therefore, as would be expected from experimental infections, there appears to be an age-related susceptibility to the virus. In addition the major diseases which are associated with the virus also occur in this age group suggesting that the incubation period from infection to the development of disease is relatively short, in the order of 2-3 years. This is a much shorter incubation period that has been suggested for the other feline retrovirus, feline immunodeficency virus.

EPIDEMIOLOGICAL PATTERNS OF FeLV

Different patterns of infection are seen in multi-cat households and in free-ranging cats. If the virus is introduced into the former environment it spreads rapidly between cats so that approximately 30-40% of the cats will develop a persistent infection (Hardy et al 1976). The remainder of the animals will have virus neutralising antibody and will be immune. By contrast, in free-ranging cats and single cat households, the prevalence of active infection is much lower. However, based on serological surveys some studies have suggested that transmission of the virus within the community is relatively high and that antibodies to a virus-associated antigen can be found in about 50% of urban and suburban cats (Rogerson et al 1976). These results suggest that while the virus may be commonly transmitted in this community the frequent but intermittent nature of the transmission is such that animals tend to be immunised rather than overwhelmed by the infection. In the past the prevalence of infection in any epidemiological situation was related to the incidence of FeLV-associated diseases, most diseases being seen in pedigree cats and multiple cat households. This picture has changed over the years with the control of FeLV infections in pedigree households, until the present time when most diseases are seen in domestic short-haired cats kept as individual pets.

THE OCCURRENCE OF SUBGROUPS OF FeLV

A complication of the epidemiology of FeLV is that there are three different subgroups, A, B or C. An interesting feature of the occurrence of these subgroups is that FeLV-A is present in all isolates, FeLV-B is present in addition in 50% of isolates, while FeLV-C is rarely found occurring in only about 2% of isolates (Jarrett et al 1978). FeLV-A is readily transmissible between cats both experimentally and in nature. However FeLV-B is transmitted very inefficiently. On experimental inoculation of newborn kittens, which would all be susceptible to FeLV-A, only about 20% of kittens become persistently viraemic with FeLV-B. The transmissibility of

FeLV-C falls part way between FeLV-A and B. Thus newborn kittens are fully susceptible to FeLV-C but within 2 weeks of birth they become fully resistant. There is no evidence that FeLV-B or C can be transmitted to susceptible cats under natural conditions. The question then arises how FeLV-B and C survive in nature. The answer is that they are dependent on FeLV-A, either for generation or transmission within cat communities. If either of these viruses is transmitted experimentally as a mixture with FeLV-A then the efficiency of transmission is dramatically increased. The reason for this difference is probably that phenotypic mixtures are generated between FeLV-A and the other subgroup so that FeLV-B or C viruses are produced with FeLV-A envelopes. Since the nature of the envelope determines the type of cell which the virus can infect the provision of an FeLV-A envelope ensures that B or C viruses can infect a much wider range of cells in the cat and therefore have a greater chance of survival.

GENERATION OF FeLV-B AND FeLV-C STRAINS

FeLV-B strains are generated by recombination between FeLV-A and endogenous FeLV-B proviral DNA which is present in every cat cell (Stewart et al 1986). Recombination occurs within the envelope gene to generate new viruses which have a novel surface glycoprotein. The point at which recombination occurs within the envelope gene differs between isolates of FeLV-B and this variety is reflected in different antigenic types of the virus. This is in contrast to FeLV-A strains which are monotypic.

Strains of FeLV-C appear to result not as recombinants but as mutants of FeLV-A. The region within the envelope gene which appears to distinguish FeLV-A and C viruses has been defined to a few nucleotides within the first variable region of the gene. The resulting change in amino acid structure of the surface glycoprotein completely alters the cell range of the virus.

In nature it is unlikely that FeLV-C strains are transmitted from cat to cat. It is likely that when these viruses do appear their lethal effect is very rapid therefore there is little opportunity for the virus to be transmitted to other cats. However FeLV-B viruses are certainly transmitted, although not as efficiently as FeLV-A. Only a proportion, approximately half, of cats which are exposed naturally or experimentally to cats which are viraemic with both FeLV-A and FeLV-B, will become persistently infected with FeLV-B (of course also in association with FeLV-A). This finding would suggest that FeLV-B viruses might be expected to eventually die out and their continued existence presumably means that new strains are continually generated by recombination in cats viraemic with FeLV-A.

CONSEQUENCES OF THE GENERATION OF NEW FeLV SUBGROUPS

The impact of the generation of these new viruses can be quite dramatic (Jarrett et al 1990). FeLV-C is intimately associated with non-regenerative anaemia in cats. This condition is analogous to pure red cell aplasia in man in which there is a block in the differentiation of erythroid cells. FeLV-C strains have been isolated from over 30% of cases of anaemia in the cat and 5 individual isolates of FeLV-C have produced the same disease when inoculated into kittens. The impact of FeLV-B on cat disease is not quite so clear. It is known from experimental inoculations of the virus that in the small proportion of cats which develops a persistent infection with FeLV-B a high proportion will develop thymic lymphosarcoma. There is also some epidemiological evidence of an association between FeLV-B and the development of lymphoid leukaemias.

MOLECULAR DETERMINANTS OF LEUKAEMOGENESIS

In the study of the molecular mechanisms involved in FeLV-related diseases, we have found that most involve genetic changes in the FeLV-A viruses with which the cats were originally infected. Mutation to FeLV-C and the production of anaemia has already been discussed. The production of leukaemia appears also to be related to changes in FeLV-A. Thus in many cases of thymic lymphosarcoma a recombinant between FeLV-A and the <u>myc</u> oncogene has been found in the tumour cells which is capable of inducing rapid leukaemia in experimental kittens. These results suggest that the generation of this recombinant, acute leukaemia virus is a proximal cause of the disease. Another mechanism demonstrated recently is that FeLV-A strains which produced leukaemia by inserting the proviruses into or adjacent to the <u>myc</u> gene have duplications of enhancer elements in their Long terminal repeats which presumably has a stimulatory effect on the transcription of the oncogene products in cells.

CONCLUSION

The picture which emerges from all of these studies is that in cats there is efficient transmission of FeLV-A strains which are highly conserved, show no apparent antigenic diversity, and are minimally pathogenic. These cats are immunologically tolerant of FeLV-A and therefore exert no evolutionary pressure for the virus to change. However the unrestricted growth of the virus in these cats provides the opportunity for further genetic events to occur which have drastic consequences. Mutation or recombination with cellular FeLV genes results in the production of new subgroups of FeLV which can cause lethal diseases. Alternatively recombination with cellular oncogenes can produce viruses causing leukaemia.

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THE EPIDEMIOLOGY OF FELINE IMMUNODEFICIENCY VIRUS INFECTION IN CATS IN THE UNITED KINGDOM

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Feline immunodeficiency virus (FIV) was discovered in 1986 (Pedersen *et al*, 1987) and was classified as a member of the Retrovirus family, subfamily Lentivirinae. The first isolation of FIV in the UK was made in 1987 (Harbour *et al*, 1988). Infection with FIV has been shown to be associated with a variety of clinical problems, many of which are chronic or recurrent (Pedersen *et al*, 1987; Ishida *et al*, 1989; Hopper *et al*, 1989).

Diagnosis of FIV can be performed by the detection of antibody to the virus, as the humoral immune response does not eliminate infection and cats appear to remain persistently infected with FIV. Several large sero-epidemiological surveys have been carried out (Yamamoto *et al*, 1989; Ishida *et al* , 1989; Friend *et al*, 1990) including one in the UK (Hosie *et al*, 1989). This paper describes the findings of a second major UK survey.

MATERIALS AND METHODS

Collection of serum samples

A total of 1,975 serum samples were obtained for testing for antibody to FIV.

Samples from sick cats: Samples were submitted to the Langford Feline Diagnostic Service (LFDS) by veterinary surgeons from practices throughout the UK. Many of the cats had clinical signs suggestive of FIV infection.

Samples from healthy cats: One hundred and eighteen of the samples submitted to the LFDS came from healthy cats which were undergoing routine screening. A further 106 were obtained from healthy cats from households in and around Bristol; all the latter cats underwent a clinical examination carried out by the principal author prior to blood sampling.

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Samples from in-contact cats: Veterinary surgeons were requested to submit samples from cats which were in contact with known FIV-infected cats: 211 such samples were obtained. Of these, 12 came from cats described as sick, 83 from healthy cats and 116 were from cats of unspecified health status.

Serological tests

Most tests were performed on serum or plasma separated from blood samples taken no more than three days prior to testing. A small number of samples was separated and stored at -20°C before being tested.

FIV antibody detection: A commercial kit (Petchek FTLV: Idexx) was used to test all serum samples. All tests were performed prior to the introduction of the updated kit (Petchek FIV: Idexx).

FeLV antigen detection: A total of 896 serum samples were also tested for FeLV antigen using a commercial ELISA kit (Leukassay: C-Vet). All positive samples were confirmed using a second ELISA (CITE FeLV: Idexx).

Isolation of FIV

Concurrent virus isolation and antibody detection were performed on 202 samples. Virus isolation was carried out using previously established methods (Harbour *et al*, 1988).

Data Collection

Information relating to the serum samples submitted to the LFDS was obtained from the laboratory submission forms. Details for the remainder of cats tested were obtained directly from the owners.

A data base was established to record the following information from each cat tested: reference number, breed, age, sex, health status i.e. whether healthy or showing clinical signs (sick), whether in contact with any known FIV-infected cat, result of FIV antibody testing and, where relevant, results of FIV isolation and FeLV antigen testing. In addition, the presence or absence of a number of clinical signs thought to be associated with FIV infection was recorded. These signs included pyrexia, weight loss, anorexia, malaise, lymphadenopathy, anaemia, gingivitis/stomatitis, respiratory problems, vomiting and/or diarrhoea, conjunctivitis, uveitis, neurological signs and neoplasia.

Data analysis

Simple descriptive statistical analysis was performed on all variables. Associations between age, breed, sex and health status were examined prior to assessing the variation of prevalence of FIV antibody with each factor. The significance of the latter findings was determined by chi square analysis and forward stepwise logistic regression using maximum likelihood estimation. For these calculations cats were grouped either as pedigree or domestic (domestic short hair [DSH] and domestic long hair [DLH]). The ages were divided into four categories: <1 year, 1-5 years, 6-10 years and >10 years. Four categories of sex were used: male entire, male neuter, female entire and female neuter.

Chi square analysis was also used to determine the significance of the associations between individual clinical signs and positve FIV antibody status.

RESULTS

The age distribution of pedigree cats was biased towards young cats when compared with the age distribution of domestic breeds, Table 1. These findings were shown to be significant by the Kruskal-Wallis test ($p<0.001$).

Table 1. Variation of age distribution with breed

Breed	N	Mean yrs	Median yrs	SD yrs
DSH/DLH	1304	5.5	5	4.14
Pedigree	518	4.2	3	3.7

The prevalence of FIV antibody was significantly affected by breed, age, sex and health status, Table 2. Pedigree cats were less likely to have FIV antibody than domestic short or long haired cats; the prevalence of FIV antibody was least amongst cats less than one year of age and increased with age, peaking in the six to 10 year old age group, Fig.1; male cats had a much higher prevalence of FIV antibody than females, with neutered males having the highest prevalence and entire females the lowest; the prevalence of FIV antibody was also significantly higher in sick cats than healthy cats. The difference in prevalence became more marked when healthy in-contact cats were excluded from the assessment. From these findings, the likelihood of having FIV antibody appeared least amongst healthy, entire female pedigree cats, under one year of age and greatest amongst sick, domestic neutered male cats in the six to 10 year old age group.

As it was known that the factors of breed, age, sex and health status were not independent of one another, logistic regression was used to provide a truer estimation of the probability of cats within given categories having FIV antibody. The results are given in Table 3 and are shown in the order that the different variables were selected by the forward stepwise regression procedure.

From this analysis it is evident that the estimated minimum probability of being FIV antibody positive actually occurs in *neutered* female, pedigree healthy cats, less than one year of age. The estimated maximum probability of having FIV antibody occurs in sick, *entire* male DSH or DLH cats in the six to 10 year old category.

Table 2. The variation of prevalence of FIV antibody with age, breed, sex and health status

Group	N	No. (%) FIV Antibody +	X^2	DF	Significance Probability
<1 year	212	7 (3.3)	73.8	3	0.0001
1-5 years	894	114 (12.8)			
6-10 years	512	133 (26.0)			
>10 years	247	53 (21.5)			
DSH/DLH	1341	280 (17.3)	71.9	1	0.0001
Pedigree	517	24 (4.4)			
Male	388	83 (21.4)	48.4	3	0.0001
Male neuter	687	153 (22.3)			
Female	361	29 (8.0)			
Female neuter	464	55 (11.8)			
Sick	1450	241 (16.6)	12	1	0.0005
Healthy	307	27 (8.8)			
Healthy (minus in-contact cats)	224	14 (5.9)	-	-	-

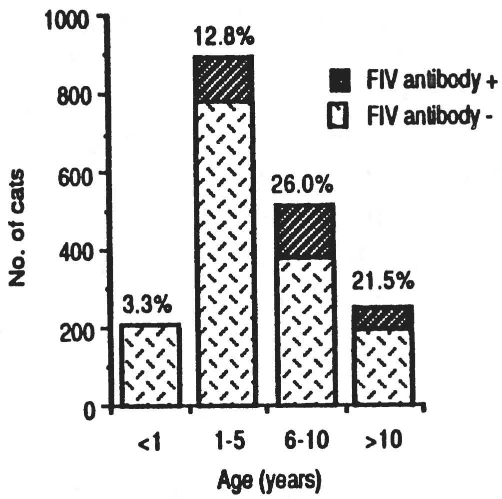

Fig. 1. Variation of prevalence of FIV antibody with age

Table 3. Results of logistic regression analysis

Risk Factor*	Effect on odds ratio	Approximate 95% CI
Constant (entire female, <1 yr, pedigree, healthy)	1.0	1.0
Breed		
DSH/DLH	4.6	2.86 - 7.53
Age		
1-5 yrs	3.8	1.65 - 8.85
6-10 yrs	9.3	3.89 - 21.30
>10 yrs	7.1	2.72 - 16.44
Sex		
Female neuter	0.77	0.43 - 1.40
Male entire	2.28	1.28 - 3.71
Male neuter	1.97	1.12 - 3.12
Health status		
Sick	1.62	1.00 - 2.62

* Addition of each of the above factors in the order shown resulted in a significant reduction in the Residual Deviance: significance probability < 0.001 for breed, age and sex and 0.025 < SP < 0.05 for health status.

Chi square analysis showed that the clinical findings of gingivitis/stomatitis, pyrexia, neoplasia and anaemia, together with FeLV infection were associated with the presence of FIV antibody, Table 4. Vomiting and/or diarrhoea was negatively associated with the presence of FIV antibody.

Table 4. Clinical findings associated with the presence of FIV antibody

Clinical Sign	No. with Sign	No. (%) FIV Antibody + with sign	No. (%) FIV Antibody - with sign	Significance probability
Gingivitis/ Stomatitis	243	62 (19.8)	181 (12.0)	0.0003
Pyrexia	195	57 (18.2)	138 (9.1)	0.0001
Anaemia	69	23 (7.3)	46 (3.0)	0.0005
Neoplasia	23	11 (3.5)	12 (0.8)	0.0003
FeLV infection	88	21 (16.9)	67 (8.7)	0.0066
Vomiting &/or Diarrhoea	201	24 (7.7)	177 (11.7)	0.0464

The results of FIV isolation and FIV antibody testing were not in complete agreement. There were no discrepancies between negative virus isolation and negative antibody results but of the 88 samples from which virus was isolated, 16 (18%) did not have detectable FIV antibody. Nine of these samples came from cats which were in-contact with known FIV-infected cats. Fifty seven (27%) of the 211 in-contact cats had FIV antibody, making an overall prevalence of 31% (66/211).

DISCUSSION

Before discussing the significance of these results, it is important to appreciate the probable limitations of serological diagnosis in the detection of FIV infection since the comparison of serology with virus isolation suggests that a considerable proportion (18%) of infected cats will be overlooked if assessed by serology alone. This finding could be relevant when interpreting data, especially in relation to factors which appear to have only a tenuous association with FIV infection.

The relatively high prevalence of antibody to FIV confirms that infection is commonplace in the UK. The prevalence of 16.6% amongst sick cats is in good agreement with the value of 18.6% which was reported in the previous UK survey (Hosie *et al*, 1989). However, the prevalence in healthy cats (8.8%) is higher than that of 5.8% found by Hosie *et al* (1989). One probable reason for this discrepancy is that a relatively high proportion of healthy cats assessed in this survey were known to be in-contact with FIV-infected cats. At least one other study (Yamamoto *et al*, 1989) ranks such cats alongside sick cats in a "high-risk" category. The relatively high prevalence (15.6%) of FIV antibody amongst the healthy in-contact cats, and the in-contact cats overall (31%) in this study suggests that this ranking is justified and that a simple division between healthy and sick cats may not give a reliable estimate of the association of FIV infection with disease. This reasoning may help to explain why there was little difference between the prevalence of FIV in sick and healthy cats in a recent Australian survey (S.E. Shaw, personal communication). As the prevalence in both populations was around 30%, many cats tested would have been in-contact with FIV-infected cats, even though their owners may have been unaware of the fact.

As in all other sero-epidemiological surveys to date, this study shows that pedigree/domestic status has a marked influence on the prevalence of FIV antibody in cats, with prevalence always being higher in domestic cats. This influence is clear from simple statistical description of the data and chi square analysis, but stepwise forward regression shows that breed has the greatest effect on the probabilty of positive FIV antibody status of all the factors analysed. The main explanation for the lower prevalence of FIV antibody amongst pedigree cats is thought to relate to management factors in that a high proportion of pedigree cats, especially those for which serological diagnosis is carried out, are kept in a confined or partially confined manner, with little or no contact with other cats besides those in the household.

Careful consideration of other factors affecting the prevalence of FIV, especially with the benefit of using regression analysis, shows the association between the maximum probability of having FIV antibody and factors which result in the maximum exposure to other cats *outside* the household. For example, in general, entire male cats, which have the greatest probability of being FIV antibody positive, have the greatest interaction with unfamiliar cats because they are more territorial, wander more widely and fight more frequently than neutered males or either group of female cats. It is interesting that in this study the estimated probability of being FIV antibody positive is not significantly different between entire females and neutered females. This contrasts with the conclusions of Hosie *et al* (1989) who showed, using log linear modelling, that the parameter estimate for likelihood of infection was significantly lower in entire females than neutered females. The difference may reflect the population studied since in this survey only 43% of the entire females were pedigree whereas the previous UK survey may have included ia greater proportion of pedigree (and therefore "low-risk") entire females. Behavioural considerations would suggest that in natural circumstances entire females, because of their sexual activities, would have, if anything, a greater interaction with other cats, and therefore a higher probability of having FIV antibody than neutered females.

The marked increase in prevalence of FIV antibody with age can also be explained by considering exposure to cats outside the household. Kittens and adolescent cats i.e. those less than one year of age, are unlikely to wander far or undertake territorial battles. However with increasing age, the opportunity for becoming infected with FIV through contact with other cats increases and there is an apparent cumulative rise in prevalence which peaks at middle age i.e. between six and 10 years. In cats older than 10 years the prevalence and probability of being FIV antibody positive decline, although the difference between the 6 to 10 and >10 age groups is not significant. It can be postulated that the prevalence declines because, assuming that most cats become infected with FIV between one and five years of age, this age grouping coincides with the time when most infected cats reach the later stages of infection, become seriously ill and die or require euthanasia.

The significant association of positive FIV antibody status with gingivitis/stomatitis, pyrexia and anaemia agrees with that reported previously (Hosie *et al*, 1989) In contrast to Hosie's findings, there was no association with respiratory problems but an association between neoplasia and the presence of FIV antibody was demonstrated together with an association between FeLV infection and FIV antibody positivity. The latter has been reported in an American survey (Cohen *et al*, 1990). It is interesting that the clinical signs shown by this survey to be significantly associated with FeLV infection also included gingivitis/stomatitis, pyrexia and anaemia (results not given).

In conclusion, the marked variations in the probability of having FIV antibody according to breed, age and sex are helpful in adding further evidence that FIV is primarily spread through the introduction of virus in saliva into bite wounds incurred whilst fighting with other cats encountered when roaming freely outdoors. Sexual activity may have an indirect effect but is unlikely to be directly significant in transmission of FIV. Similarly the epidemiological evidence does not support the hypothesis that vector transmission, e.g. through flea bites, occurs.

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ANIMAL WELFARE

ANIMAL WELFARE STUDIES: EPIDEMIOLOGICAL CONSIDERATIONS

PREBEN WILLEBERG*

There is presently a world-wide public interest in animal welfare issues, and veterinarians are often confronted with difficult questions and issues related to animal welfare. It is a delicate task to be a fair and unbiased expert and eg. to advocate the welfare of production animals and at the same time being paid by the producer to optimize his economic benefit of the operation.

Also on the political arena is animal welfare a hot issue. A current example is the debate about the possible future use of bovine somatotropin (BST) to increase milk production in the European Community. A part of this debate concerns the welfare problems which may occur if and when BST becomes available for general use. Here there is a demand for data to document the presence or absence of welfare problems, as in other situations eg. in connection with EEC legislation under way on how to house and manage poultry, pigs and calves. Needless to say, that other viewpoints have to enter into an overall assessment of the suitability of draft legislation, eg. ethical, economical and political angles will also have to be considered.

The initial problem of defining animal welfare is not an easy one, but for the present presentation it suffices to observe, that one important component is objective information on the health status of the animals under consideration. The two other main biological fields which provide data for welfare evaluations are ethology (behaviour) and physiology.

That animal health is an important parameter has been said before, eg. by Duncan & Dawkins (1983), Webster (cit. Phipps 1989) and Hurnik & Lehmann (985), but there is so far little information available to document that actual measurements of the animal health status have been applied using the proper epidemiological principles and methods.

This presentation will therefore attempt to outline some important issues for bringing epidemiological thinking in line with important welfare questions.

HEALTH AS PART OF WELFARE MONITORING

National animal disease data banks may yield important information on trends in animal welfare developments. Data on calf mortality, slaughter condemnations, clinical cases and drug

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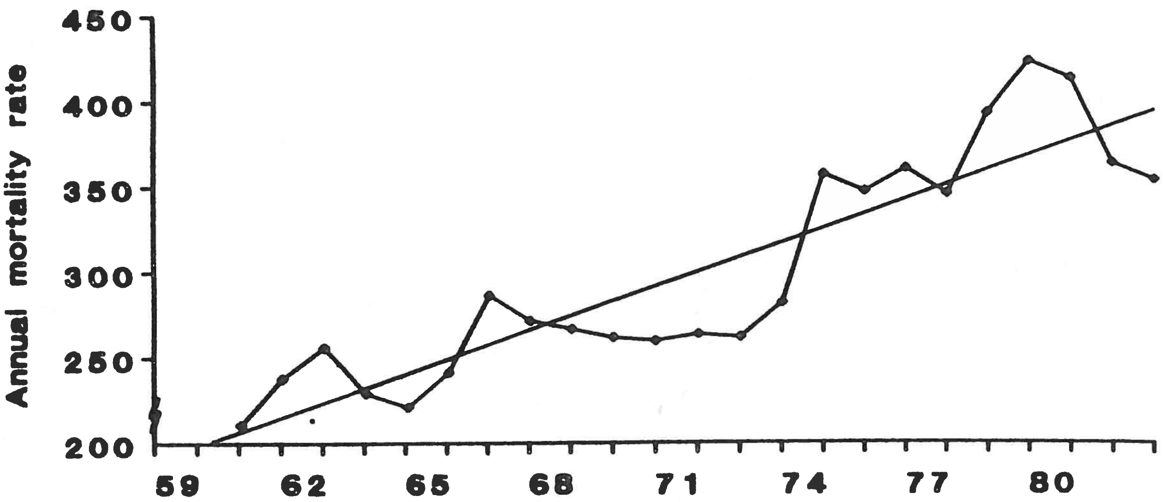
usage are available in some countries, and may with caution (see later) be used to illustrate certain aspects of the general welfare.

A good example of this type of approach is the time series analysis by Agger (1983) of the mortality in the adult Danish cattle population during 1960 - 1982, based on carcasses received at the rendering plants. An apparent two-fold increase in crude mortality rate from 2 per 100 cow-years to 4 per 100 cow-years can be seen in Fig.1:



Other results from this study show seasonal variations in mortality following the calving season distribution with a delay of 1 - 2 months (the peak of lactation), and a remarkable correlation between the cyclical component of the mortality and an index of investments in farm buildings approximately one year earlier. The latter findings have of course general interest as possible causal factor in adult cattle mortality. The design and methodology in this example, however, do not allow for strict causal interpretation.

Application of disease data at the farm level as a tool in monitoring the farm animal welfare situation has not been formally described, but a somewhat similar approach as shown above may be possible. The pronounced variation among farms in disease occurrence, which are apparent from ad-hoc investigations of various diseases, indicates that it may be fruitful to monitor the time trends in the highest ranking herds, eg. as part of any future national or community farm animal welfare monitoring system.

WELFARE ASPECTS OF DIFFERENT DISEASES

Although all disease incidents contribute to impaired farm animal welfare there must be some diseases which are more serious than others in terms of their welfare consequences.

A formal representation of a "welfare" parameter (G) for a population in terms of the negative contribution from a particular disease to the overall welfare of the population may be as follows:

$$G = I * D * S \quad (1)$$

where I is the incidence (rate/proportion) of the disease in the population, D is the average duration of the disease in affected individuals, and S is the average intensity of pain or discomfort associated with the disease.

Although the latter may rarely be estimated in absolute terms, the relative importance of various common diseases may be considered. Furthermore, when it comes to comparative studies the size of S may be considered to be equal and therefore Eq. (1) may be simplified for use in analytical studies as will be seen later.

Equation (1) may theoretically be summed up across diseases, subpopulations etc. to give more complete population estimates of the contributions of disease to impaired welfare.

The above example using mortality data can be considered a special case of the principles illustrated in Eq. (1), since D is not relevant when dealing with mortality, and since S may be considered to be of no particular need, since death always indicates that a serious health and thereby welfare problem has presented itself.

As an example of the use of incidence data in welfare Table 1 contains data from Tind & Ambrosen (1988) on the mortality from cannibalism in caged hens.

Table 1. Mortality from cannibalism in caged hens

Factor	No. of cages	w. cannibalism	RR	AF(%)
Breed				
Skalborg	442	65 (14.7%)	3.3	69
Shaver	442	20 (4.5%)	1	-
No. of hens per cage*				
6	180	37 (20.6%)	6.6	85
5	212	27 (12.7%)	4.1	76
4	140	10 (7.1%)	2.3	57
3	352	11 (3.1%)	1	-

* All hens had 600 cm^2 floor area

CHOICE OF COMPARISON GROUP IN ANALYTICAL STUDIES

The apparent welfare effect of a factor (eg. a new housing system) will depend on the selection of which of the existing systems or population segments to use for comparison. Two main approaches may be taken:

- compare to the best of the available systems, which will tend to give a conservative estimate of the welfare consequences of the new principle. This is in accordance with the desire to only introduce new systems or procedures if they represent true improvements over the existing ones;

- compare to the system or procedure which is most likely to be given up or changed if the new principle is introduced. This will tend to give realistic estimates of the expected change in the population's health situation.

For example, it has been suggested that the possible mastitis promoting effect of BST injections to dairy cows should be compared using mastitis levels in equally high producing cows, which of course would underestimate the mastitis increase one might see in cows in general when given BST. As in clinical trials in general, exposed and non-exposed individuals should be randomized or made similar with respect to other important factors, which may otherwise act as confounders. Thereby it is also possible to observe simultaneously the change in yield and any difference in mastitis incidence between the two groups.

Another way of validating this point is to say, that as the "risk factor" high yield becomes more prevalent through BST usage, then the overall disease occurrence as well as the etiologic fraction (population attributable fraction) will increase.

Another point to consider is to use a comparison group where the parameters D and S in Eq. (1) are similar in the two systems, which may well be a valid assumption with many diseases. Thereby the welfare aspects of the systems can be compared through an estimate of the relative risk (RR) or the attributable fraction (AF):

$$G1/G2 = I1/I2 = RR \qquad (2)$$

and

$$(G1 - G2)/G1 = (I1 - I2)/I1 = AF \qquad (3)$$

PREVALENCE-BASED STUDIES

Since prevalence (P) under certain standard conditions may be considered to have the following composition:

$$P = I * D \qquad (4)$$

When prevalence data are used it is no longer necessary to explicitly consider the duration of the disease, since eg. differences in time of recovery between two systems will be absorbed in the prevalence data. This could be important in studies of eg. lameness and hoof problems based on market or slaughterhouse surveys.

Using Eq. (4) in Eq. (1) we get:

$$G = P * S \tag{5}$$

It is therefore possible to compare welfare properties of two systems on the basis of prevalence estimates, if the intensity of pain and discomfort caused by the disease is the same in both systems. This may not always be a safe assumption, eg. when it comes to pain associated with lameness and hoof problems, where it is likely that a floor surface which gives rise to an increased number of conditions most likely also will cause more discomfort to the sick cow than if that cow was placed on a floor with less damaging surface.

A further limitation with prevalence data is due to the "rare disease effect", ie. that only diseases of long duration (chronic conditions) may be as prevalent as to actually find cases in a cross-sectional survey.

An example using prevalence data (Sanker & Gerbola 1989) is given in Table 2.

Table 2. Prevalence of lung lesions at slaughter by type of pig herd

Type of herd	No. of carcasses examined	Prevalence of lesions	RR	AF(%)
Conventional	7953	11.0%	2.8	64
MS'	1121	4.1%	1.0	0
SPF	1210	4.0%	1	-

' SPF-herds reinfected with Mycoplasma (enzootic pneumonia)

EFFECT OF PREVALENCE OF EXPOSURE

As mentioned earlier, the extent to which a system will be used will determine the overall changes in welfare of the population, eg. using estimates of the population attributable fraction. One may therefore get the same net effect from introducing a system with only small welfare consequences to a large number of herds as one will get from using a very poor system in a few herds. Whether it is an ethically sound way of looking at welfare problems is not easy to resolve - but it appears to be a valid epidemiological approach.

SAMPLE SIZE CONSIDERATIONS

When new systems or procedures are evaluated prior to marketing it will initially be on the basis of their abilities to increase production or to lower the costs of production. Disease problems which have welfare consequences are passively recorded as side effects. Such effects are relatively rare, and production trials therefore have low statistical power when it comes to demonstrating such welfare consequences. This means, that the conclusion will invariably be, that there are no significant side effects - due to an improper design of the studies.

To get large enough samples for testing if side effects occur with a realistic difference between two systems is therefore a problem, especially in the pre-marketing phase. The study will most often have to be performed as a post-marketing epidemiological study of the effects of production systems.

The BST situation may possibly be an exception to this general situation. Because of the wide-ranging implications and the intervention by the EEC, the pharmaceutical industry has had to master a series of trials, which may be looked upon as a multicenter study, and the results may be combined using an appropriate technique.

From the available literature (Craven 1990) it appears that in a European series of trials, the incidence of clinical mastitis increased among BST injected cows by 17% from 14.5 cases per 100 cows to 17.0 cases per 100 cows (Table 3). This difference was not statistically significant in this sample of 6 - 700 cows in each group.

Table 3. Occurrence of clinical mastitis in European and North American BST trials

Group	Period*	No. of cow-years	Cases	RR
European series				
BST treated	Pretr.	523	78 (14.9%)	1.01
Non-treated	Pretr.	446	66 (14.8%)	1
BST treated	Treat.	730	124 (17.0%)	1.17
Non-treated	Treat.	580	84 (14.5%)	1
North American series				
BST treated	Pretr.	202	40 (19.8%)	1.58
Non-treated	Pretr.	192	24 (12.5%)	1
BST treated	Treat.	202	78 (38.6%)	1.32
Non-treated	Treat.	192	56 (29.2%)	1

*: Pretreatment period: 0 - 60 days of lactation
Treatment period: After 60 days of lactation

The point is, however, that an increase in the incidence of clinical mastitis by 17% may well be of considerable importance in terms of welfare considerations. If this is so, then a total of 3,500 cows should be tested in each group in order to be sufficiently confident to detect a difference of this magnitude. The whole discussion about BST and documentation of its welfare implications must be seen in this light.

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ECONOMIC ASPECTS OF THE ANIMAL WELFARE ISSUE

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Human interest in the welfare of other living creatures is nothing new. Ever since man domesticated animals so as to use them for his own purposes it has been simply a matter of self-interest to ensure they were kept in a way that enabled them to best serve him. This is true in relation both to 'productive' livestock like farm animals, and those with which emotional connections develop, such as pets. Generally speaking, however, it is only with domesticated animals that such welfare interest becomes of any significance. There is little effective concern over the unsavoury manner in which hyenas terrorise a weakling Thompson's gazelle or the rather excruciating way in which rodent pests are debilitated by anticoagulant compounds. Recognition of this fact that welfare concerns are selective rather than generalised underlies the basic proposition of this paper - namely, that animal welfare is simply part of man's perception of his *own* welfare, and only indirectly to do with any objective aspects of how the animals themselves are affected by their environment. It follows that, because economics is the discipline concerned with studying how people pursue their own wellbeing, it should therefore have a central role in the debates about animal welfare.

This assertion of the social scientist's role may appear strange to those who find much of the formal study (as opposed to popular advocacy) about welfare lies in the literature of animal science. Certainly it is those who study animal health and behaviour who feel able to make the most specific statements about what constitutes 'good' or 'bad' welfare conditions. However, this does not make the definition of appropriate welfare standards a scientific issue, as though it were akin to specifying the appropriate dosage of a drug to correct a disease condition. Notwithstanding the different standpoints from which the issue can be viewed, in practical terms the appropriate way to treat animals remains strictly a matter of human preference. That preference may be informed by science-based information, but no more than it is also influenced by Walt Disney-based information, or by culture, education, experience, income, collective or personal beliefs, and a range of other factors that determine what people think and do. The failing of social scientists so far is that they have not given animal welfare issues the attention they deserve, and so there is a lack of the useful economic information that should also inform attempts to define appropriate welfare codes.

In fact, welfare codes are not 'defined' in any objective sense but rather *chosen* - and that choice is likely to change over time (as with the recent decision to ban the tethering of sows, a practice that until now has been widespread and quite accepted). Consequently we need to study the determinants and the mechanisms of welfare choices in society if we are to better identify the standards appropriate to that society. It is not easy to put those choices into a framework of scientific assessment, or to base them on scientific principles. Indeed, there appear to be so many contradictions and arbitrary assertions in the framework of welfare regulation as to make it totally inconsistent with the rigorous conceptualisation, specification and measurement that is the hallmark of science. As a result, notwithstanding the apparent definitiveness of standard welfare statements they are all disturbingly wishy-

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washy underneath. If 400 square centimetres is insufficient space for a battery hen what is so good about 550? Why is it unacceptable to prevent a sow turning round by tethering it, but good practice to do the same thing using a farrowing crate? If the use of BST threatens animal welfare, what is so different about other drugs and feeding regimes that allow more of a cow's productive capacity to be captured? What makes it cruel to dock the tails of pigs but not in the case of spaniels? Why does being eaten by a Jew or a Moslem make it unnecessary to stun an animal before slaughter? The list of such awkward questions is endless, but they all share a common characteristic - the answer lies in boundaries set by social choice, not by scientific assessment.

CONCEPTS OF ANIMAL WELFARE

The concern humans show over animal welfare is based on their own perceptions of how animals are affected by the conditions under which they are kept. Despite studies to measure the stress that animals feel (Stott, 1981), or experiments to determine their preferences for alternative husbandry conditions, we can never actually know what they would choose for themselves. Indeed, it is not clear to what extent animals do have preferences in the considered way that we do, as opposed to largely instinctive reactions to their environment. (And anyway, even if we do recognise animal preference we then largely ignore it, because by definition the management of livestock is the imposition of our preference over theirs.) Therefore, discussions of welfare unavoidably involve a subjective human judgement on what *we* believe are appropriate conditions for animals to enjoy or suffer. In this sense it is more correct to talk in terms of 'perceived welfare' to avoid any suggestion that we are dealing with something that has been or can be objectively assessed. This distinction becomes important when we face questions of whether animal welfare should be improved, and how this might be achieved. Because the issue involves a subjective judgement there will, by definition, be no uniform basis on which that judgement can be made. Different people will have their own views as to what constitutes a welfare improvement and what the target level of attainment should be. This, then, is the real source of the problem, because if welfare standards are a matter of social choice it is not clear where those standards are appropriately set - or whether logically there can be any uniform standards.

Anyone seeking to make these arbitrary specifications of welfare standards would seem to have four different reference points, each of which represents some concept of animal welfare and hence could serve as a guide for actions.

A. The first, and philosophically perhaps the most defensible of these concepts would define welfare by placing maximum emphasis on what the animal itself would choose, taking this to represent what is 'most right' for its welfare. This would offer animals the freedom to act as naturally as their innate instincts determine in terms of dietary choice, mating behaviour, rearing young, establishing and maintaining territory, aggression and imposing social dominance, etc. While the most extreme advocates of animal rights might support such a concept of **natural** welfare it is obviously quite inconsistent with any notion of domesticated animals, and so is hardly relevant in the context of livestock farming.

B. A rather less libertarian but nevertheless still animal-centred concept would grant to livestock the best conditions attainable in the (unnatural) environment of domestication. While some of their natural behaviour patterns have inevitably to be controlled, the emphasis would lie in making the greatest possible provision for all their other perceived needs in terms of food, shelter, space, physical comfort, health, safety, social interaction, and so forth. This concept of **maximal** welfare is the most anthropomorphic in its style, and would result in all domesticated animals being treated as we treat our pets (or our children) based on what we think is 'good for them'. The simple fact that animals are kept for specific human purposes, however, means that this also is an unrealistic benchmark for any action on welfare.

C. In practical terms we inevitably move on towards situations where the animal's interests have to become more subservient to human interests, and so livestock are subject to conditions that create human benefit at some perceived cost to the animal. This is clear not only because we confine them, castrate them, conjugate them and do other things they would not choose, we then in many cases kill them off when it suits us best. However, because man in general has some sensitivity towards other living creatures, particularly those he has close contact with, there exists some overall balance between human and animal interest that would define the **desired** welfare standards in any society. These would reflect the conditions of husbandry and treatment that leave us feeling broadly comfortable with what we impose on the animals we exploit, without losing sight of why we keep them in the first place.

D. At the furthest extreme from the natural concept of welfare is a boundary beyond which the exploitation of animals would be regarded virtually universally in society as being unacceptable. In a practical sense this concept of minimal welfare is the one most amenable to definition and specification, because it represents a lower limit rather than necessarily a norm. As a result a large proportion of the formal legislation and statutory requirements for animal welfare is recognisable in this context.

The popular concern over animal welfare has ingredients of all four of the above concepts - which is why it is worth separating them out. They are clearly mutually inconsistent, and any attempt to pursue welfare objectives which are a blend of them all will fail to yield any functional guidelines. It is worth noting that the first two welfare concepts are essentially animal-centred, being based on considerations solely concerned with what the animal wants; however, for this reason they are also irrelevant as practical targets. The last two concepts are effectively people-centred, in that they are defined in relation to what people want or will accept. They are therefore also not fixed positions, but are subject to adjustment over time or in response to changing social or economic conditions. This is yet another demonstration of the fact that animal welfare is simply a subset of human welfare.

Much of the formal discussion in this field centres on the idea of 'positive' welfare, implying a concern not simply with the avoidance of cruelty but more with the specification of whatever standards are now appropriate for livestock farming in the UK and Europe in the 1990s. In other words the focus is on what we have called 'desired' welfare. Although there is plenty of attention directed at minimal acceptable standards, these have the more negative or defensive objectives of ensuring that production practices are not cruel or inhumane. The celebrated 'five freedoms' (Webster, 1984) are not in themselves a particularly helpful guide because, although they seem to imply a specific style of animal husbandry, in reality they are so imprecise that they embrace anything between the maximal and the minimal definitions. If we are to identify what constitutes an appropriate standard of animal welfare we must explore what conditions people want associated with the food they eat, so it is a problem in socio-economic research.

ANIMAL WELFARE AND ECONOMIC BENEFIT

From a strictly economic standpoint farm animals are no more than resources that are employed in economic processes which generate benefits for people (McInerney, 1988). In this sense they are no different from the other resources, whether land, labour or capital, that are 'exploited' in economic activity. Welfare considerations arise only because a possible side-effect of gaining economically valuable output from animals can be that their well-being is to a greater or lesser extent 'used up'. There is, in effect, an additional element of cost that should be included in the accounting framework along with the other more conventional costs chargeable to livestock production. Because this cost does not appear in a monetary form and is borne by animals rather than people, however, it is excluded from all the commercial calculations and so is not reflected in the money price of the livestock product. The welfare of the animal appears in this sense as a free good; and like all other apparent free goods in the economy (air, the environment, domestic tap water) there is a tendency to use as much of it as suits the user.

However, further examination reveals that animal welfare is not at all outside the economic calculus. Quite the contrary, like many other similar phenomena that provide a basis for policy intervention it has real and complex economic connections. First, reductions in animal welfare at some stage start to represent a real economic cost to society. By definition, a cost is simply a loss of benefit experienced by people. So if we feel unease at the way our domestic animals are treated, if the thought that they are not content causes us discontent, then we gain less value (benefit) than we otherwise might from the products of those animals - we suffer an economic cost. This cost is just as real as that experienced when our holiday is spoiled by bad weather, when the filet mignon is not as tender as we would like, or any of the myriad of ways in which external factors detract from the value we enjoy from the resources we utilise. The fact that it may not be a monetary cost nor appear in any commercial computations may confuse the accountant, but is irrelevant to economic analysis (McInerney, 1991). Second, the reason we are drawn into husbandry practices that have negative effects on the welfare of animals is the pursuit of our own economic benefit - principally in the form of cheaper, better quality or more predictable food supplies. Any move to improve the welfare of animals, therefore, may involve giving up some of this benefit - i.e. impose an economic cost.

We are thus confronted by the apparently paradoxical proposition that a reduction in animal welfare, and an equivalent improvement, both result in an economic cost. (Small wonder that economics is called the dismal science.) The distinction is that, though both are real economic costs, they are different forms (in the same way as are the costs of disease and the costs of the treatment). The loss of human benefit experienced when animals are subject to suffering is not identical to the loss of human benefit experienced when food prices rise. But it is this duality that places animal welfare four square in the realm of economics. The search for appropriate welfare standards involves economic choices about whether the benefits of cheaper food compensate for the costs in terms of unease over the animals' welfare. Alternatively they are choices between the benefits we gain from feeling more comfortable about 'kinder' livestock husbandry methods and the cost this implies in terms of more expensive food. This is the standard stuff of consumer choice, of course, on which the every day workings of the economy are built. It is entirely analogous to the assessments we make about whether the benefit we will get from changing the TV for a better one will be worth the money we have to pay to do it.

A SIMPLE ECONOMIC MODEL

The current concerns over the welfare of farm animals stem from the way in which developments in livestock farming over the years have introduced production methods which many now view as involving unacceptable conditions for the animals. The prospect that further new developments on or over the horizon (e.g. BST) might be adopted exacerbate these concerns. The incentive for such developments to occur is the potential they bring for extending animal productivity, allowing higher output levels, greater conversion efficiencies, faster production rates, and so conferring economic benefits in terms of cheaper and better food supplies. The more this production potential is exploited, however, the greater the possible stress on the animal. All this implies a general relationship between the technical productivity of farm animals and their perceived welfare. That relationship reflects the inherent conflict between the interests of animals and humans, and lies at the heart of the choices society has to make in this area. The basic form of such a relationship is portrayed in Figure 1. The vertical axis indicates the level of animal welfare as we perceive it, while along the horizontal axis is measured the animals' technical productivity (eggs per bird, pigs weaned per litter, rate of liveweight gain, etc) which is a direct reflection of our own economic benefit. Increasing animal productivity through greater control and intensity of input use is broadly synonymous with higher output and lower unit costs of production, changes we regard as the benefits of increased efficiency.

The postulated relationship between these two variables is derived from simple logical reasoning, but is thought to be typical of any livestock production process. Point A is an initial reference point representing the situation where there is virtually no management or control of the animals' production processes, and approximates the concept of 'natural' welfare referred to earlier. By providing shelter, security, regular and balanced feeding, treating and preventing disease, and undertaking all the activities we associate with good husbandry we not only raise the productivity of animals to our own benefit but also believe that we raise their welfare at the same time. Such a complementary relationship may extend over quite a range of increasingly intensive management practices, ultimately reaching point B where the welfare of the animals is perceived to be as high as possible. This situation is equivalent to what we have called the 'maximal' welfare concept, and possibly represents the situation many farmers would have us believe when they assert that the welfare of their animals is obviously their primary consideration because otherwise they would not produce profitably. The fallacy in this view is evident by the fact that inevitably livestock production techniques will develop beyond this point as the commercial incentives encourage the search for greater productivity. The history of technological change in livestock farming has been to continually extend this relationship, but the gains in terms of economic productivity have come at increasing cost to animal welfare as the curve turns progressively downwards. As long as new production techniques yield sufficient extra output to pay for the additional and increasingly expensive new inputs, however, there is an unavoidable commercial logic in favour of their adoption; the welfare of the animals, not being a market commodity has no market price and so has not contributed any component to this cost calculation.

What society is now looking for is the equivalent of point C, the appropriate balance between livestock productivity and economic efficiency on the one hand, and our perception of the animals' interests on the other. This we have identified earlier as the 'desired' welfare concept. The primary questions to be resolved are whether such a balance exists as

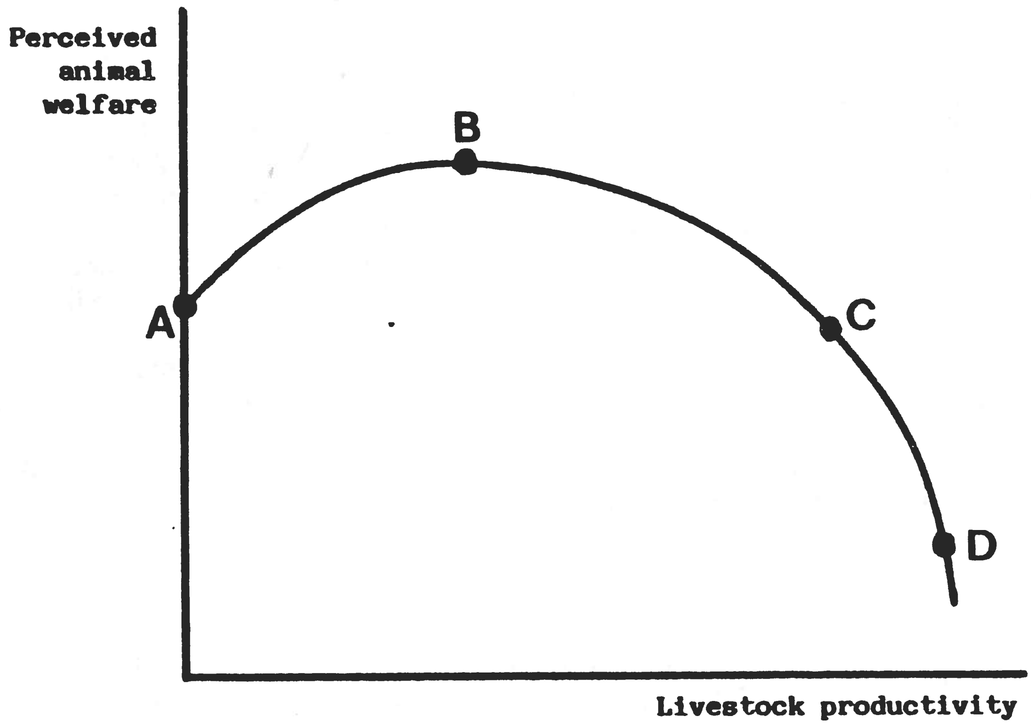

Fig. 1 The relationship between animal welfare and livestock productivity

a single attainable target - and if so, where it lies and how it becomes embodied in our livestock husbandry systems. Much of the current precise specification of welfare standards which are imposed by statutory codes and regulations are equivalent to the position shown in Figure 1 as point D. This reflects the 'minimal' concept of welfare, the threshold of defined standards below which society would consider the conditions experienced by animals to be unacceptable, regardless of the fact that they may exploit more of the animal's production potential and so offer reductions in the cost of livestock production. The setting of these standards, too, is therefore an economic choice, but is of a slightly different nature because it defines boundary conditions rather than a norm.

THE COSTS OF IMPROVED ANIMAL WELFARE

The relationship in Figure 1 makes clear the conflict between animal welfare and human welfare inherent in modern livestock farming. The stresses imposed on animals have not come from man's nastiness but as an incidental side effect of the quest for higher productivity. Any improvement in welfare conditions, therefore, implies a movement back up the curve and an inevitable sacrifice of economic benefit. There is an unavoidable cost to better welfare.* That cost, however, although mathematically positive may be relatively insignificant in very many circumstances. This will tend to be the case, for example, with any moderate upward adjustments in the minimum welfare standards that are enforced by regulation and statutory codes. These lie by definition at the 'lower' end of the relationship (the position indicated at point D) where it would seem that quite noticeable increases in perceived welfare could be achieved with very little effect on economic productivity. Some examples of this situation immediately spring to mind. The use of veal crates or sow tethers does offer some cost economies or they would not have been adopted in the first place, but prohibiting their use would have only marginal effects on the end price of veal or pigmeat. The cost consequences of raising the unit space requirements for livestock in transit, limiting the maximum journey times or increasing the required period in lairage can add only very little to the overall costs of production.

The importance of such cost increases - and hence the likelihood of their being accepted as reasonable or justified - depends on three separate factors. The first is their magnitude relative to all the other costs incurred in the livestock process. The examples quoted relate to adjustments in relatively minor components of the whole configuration of production activities, and so they have little significance on overall productivity or the final economic cost of the consumed food product. A second factor is the level of income of consumers, the impact of somewhat higher food prices being obviously less the higher the disposable income. Finally, the preferences and personal values in the society will greatly influence how prepared people are to accept extra costs to protect the welfare of farm animals. All these factors reflect the complexity of social choice that underlies welfare reform. They lead us to expect that far higher minimum standards are relevant to the UK, where a comparatively small component of final food price is value originating in the farm sector, and where a relatively affluent population is generally literate and increasingly aware of issues outside the environment of narrow self-interest, compared to a low-income Third World country with food products that are more basic and closer to the farm production sector, and where human living conditions inevitably engender a less liberal image of what constitutes minimal animal welfare.

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*There is one escape from this apparent harsh truth. If animal science research can devise new production techniques which effectively shift 'outwards' the curve in Figure 1, rather than simply searching for advances in achievable technical productivity, it opens the prospect of production systems which offer both higher productivity *and* higher animal welfare.

When we move to consider more dramatic welfare reforms, however, the potential economic costs become more noticeable. Interpreting the appropriate animal welfare standards for a society as meaning the 'desired' welfare level, rather than simply the threshold of minimal acceptable practice, puts us higher up the curve in Figure 1 in the region of the point labelled as C. Here the relationship between perceived welfare gains and productivity losses implies much higher costs and therefore potentially more significant impacts on final food prices. It is a matter for detailed economic research to estimate the nature and magnitude of these possible production cost effects, and of course it depends on the extent of the welfare reforms under consideration. Unfortunately very little relevant empirical work has been done, despite the obvious importance of the issue. Such estimates as are available (e.g. Sandiford, 1985) suggest that in some instances the effects could be considerable, and superficial evidence of this is seen in the approximately 40 per cent price difference between 'welfare friendly' free range eggs and those produced in intensive battery systems.

While inevitably the move towards higher standards of minimal welfare will result in some additions to production costs there is nothing to say that this is 'wrong' or unacceptable. As already discussed, if higher welfare standards in livestock production is something that society genuinely wants, then it will gain a benefit if those conditions are satisfied. All of our economic activity is concerned with incurring costs in order to gain benefits, so there is no basis for characterising the outcome of our actions solely in terms of their costs. (It is unnecessary costs, or costs which are not outweighed by realised benefits, that are to be regretted.) Consequently there is no reason for livestock producers to fight against the demands for higher welfare standards on the grounds that it will raise production costs (as did the National Pig Breeders Association in January 1991 when the UK government introduced proposals to ban sow stalls and tethers). Of course it will raise costs - but if that's what consumers are demanding then economic logic asserts that it is the role of the producer to supply it. It is the *economy* that incurs higher production costs, not simply the producers, and if society does not think that cost is worth paying it will cease to demand the higher welfare product. We would be very surprised if our friendly neighbourhood electrical goods storekeeper protested when we asked for a colour TV because it was more expensive to supply than a black and white one!

MECHANISMS FOR EFFECTING WELFARE IMPROVEMENTS

The discussion developed here suggests there is no single concept of the welfare standards appropriate to any society. From a functional point of view there are at least two, the minimal level and the desired level - and the second of these is itself not a uniformly definable standard. This diversity is evident even if we consider only a single livestock production process, such as pig production, so it is magnified when the full range of animal farming systems are covered. The reason for this non-specificity is the fact that livestock production is a composite of numerous actions and activities, each of which has its own implications for the animal's welfare, and also because there is inevitably a diversity of view within a society as to what welfare standards are 'right'. This raises the prospect that any attempt to specify desirable welfare targets will result in a vast compendium of statements about what should, or should not, be done. It is for this reason that the primary thrust of formal animal welfare policy ends up with the rather negative orientation of setting just the lower boundaries, specifying the minimum requirements but giving little impetus to positive welfare measures. It is, however, feasible for welfare considerations to be determined by economic signals and not solely institutional regulation.

Returning to the proposition that animal welfare standards are a matter of social choice, there are two main mechanisms whereby those choices are made - by collective, or by individual decision. *Collective* choices are made in situations in which the interest of society as a whole is defined, widely accepted*, and then imposed upon everybody. In an economic context resources are used to produce all manner of 'public goods' - things which none of us as individuals may choose to acquire or produce but which are considered to be desirable for the benefit of all - and then everyone is forced to pay the costs of provision whether they agree or not. The textbook examples are defence, law and order, health and education services, street lighting, environmental protection, libraries, etc. Many aspects of animal welfare have the characteristics of a public good because they are considered to be standards of 'service' which everyone in a civilised and humane society should be forced to purchase as part of their food supply. Hence there is a strong economic logic for the regulation and statutory enforcement of welfare codes, not only to establish the general style of livestock production but also to constrain those careless or uncaring individual livestock keepers whose personal inclinations may not be consistent with those of everyone else. However, this method of establishing animal welfare levels can never be more than a 'bottom line' approach, and involves difficult political decisions about how high to set the standards (and therefore costs) that everyone is forced to accept. As a result, despite the vast array of legislation from the Protection of Animals Acts of 1911 onwards, the enforceable requirements are far from restrictive and tend to deal only with specific aspects of welfare. At one extreme there is a fairly horrific list of prohibited operations and practices that tend to make the eyes water just by reading them, while at the other are the legally convenient but descriptively non-specific requirements to avoid 'unnecessary' pain, suffering or distress (Baker 1986, MAFF 1990). While some welfare orders prevent livestock production from transgressing accepted notions of cruelty many others (such as requirements to inspect animals daily or provide adequate food, water and shelter) set out what to the intelligent and rational producer is merely sensible commercial practice.

Government regulation can cater for only a subset of society's preferences with respect to animal welfare. Those aspects that relate to clearly unacceptable activities and practices or insufficient provision for the animals wellbeing are obvious candidates for handling within a public good framework, and in this sense are the easy bit of the problem because they are fairly definitive. The other major characteristic of society's preferences with respect to desired animal welfare levels is that, as with everything else, they vary widely between different individuals and groups. Some people have very precise views about how they want the animals kept that provide the eggs, meat and milk they consume, views which lay great emphasis on the perceived interests of the animal and accept the consequent implications in terms of production cost. Others, while in no way being indifferent or cruel, see animals in a different context, are satisfied with lower welfare standards, and feel more concern over the food prices they have to pay. Yet others will have given no consideration to what goes on in livestock farming, either because they have no relevant information or no particular concern anyway. If the society's attitude towards the welfare of animals is characterised by this diversity, how can there be any specific set of conditions (such as represented by point C in Figure 1) which reflect the 'desired' welfare standards for that society? The answer is, of course, that there cannot be any such specification of socially appropriate animal welfare levels. Nor can one assert that any one sub-group within this spectrum, whether in favour of kinder treatment of animals or more extreme exploitation of them, should determine the choices of everyone else.

Realisation of this fact leads one towards an approach to animal welfare provision based on *individual* choice. Given the safeguards of minimal standards by statutory means, there seems no reason why the array of different attitudes towards animal welfare beyond this level which characterise the overall social preference should not then be expressed through the market for livestock products, as is done elsewhere in the economy. This then makes animal welfare a 'private good', something which each individual can decide to buy more or less of according to preference. Those who wish to manifest their personal concern for the wellbeing of animals create a demand for livestock products with a 'high

*Never universally accepted - there are always individuals who object to even the most reasonable of propositions!

welfare' image. Those whose priorities are dominated more by the cost of the food product will seek the cheaper article produced from more intensive and apparently less welfare friendly systems. Provided that sufficient consumer information is available to help people identify their relevant choices, and suitable provisions for labelling and monitoring of standards is enforced, there is every prospect that the differential pattern of demands for animal welfare can be catered for in the same way as it is for newspapers, clothes, financial services, holidays abroad and all other commodity groups with recognisably different quality characteristics. Livestock producers will have the incentive to identify specific markets and cater for them, with the expectation that if there is a genuine demand for a higher cost product with higher welfare characteristics it will sell for an appropriately higher price; if not, then that demand does not exist. That this is so is already evident (Paxman, 1986) with distinct higher priced markets emerging for 'free range' eggs and poultry, 'natural' meats, and Sainsbury's recent introduction of 'traditional' beef and 'tenderlean' lamb. The potential for greater growth and diversity has only just started to be developed.

There are a number of apparent advantages in this approach. It is probably the only way for welfare decisions which relate to different overall *systems* of production (as opposed to individual practices) to be handled. Like all market processes, it responds to the differential pattern of demands that constitute the overall social preference in a way that minimises the need for centralised decision or administrative involvements. And it avoids the undesirability of any one group - whether 'experts', civil servants, special interest advocates, or merely effective lobbyists - imposing their preferences on everyone else without reference to the implications for everyone else. In effect it transforms animal welfare into a consumer commodity like taste, shape, quality, erotic appeal, time from 0-60mph, pop music and fine art, and then treats it along with the other economic decisions in our society. People who want it will buy it if it is available and they can afford it; if they don't or can't, they won't.

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OPEN SESSION

CONSTRUCTION OF QUESTIONNAIRES AND THEIR USE IN VETERINARY MEDICINE

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The determination of risk factors associated with health status has lead to an increasing use of quantitative methods in epidemiologic research (Martin et al, 1987). The resulting challenge is to assure the quality of the "raw data" which are generated for analysis. "For no scientific discipline can be any better than the quality of its raw data. Improvements in study design or in analytic techniques cannot compensate for data of questionable quality" (Gordis, 1979).

Questionnaires are now commonly used to gather veterinary epidemiologic data. Unfortunately, surveys are often conducted poorly (Edwards, 1990). Research papers are frequently submitted to peer review journals without the survey instrument (Gordis, 1979). Its description, when included in the paper, is often sketchy. As a result, it is very difficult for the reviewers to appreciate the quality of the information presented. If the article is published, the reader is also unable to assess the validity and reliability of the instrument or of the data derived from it (Gordis, 1979).

The objective of this paper was first to briefly describe the various phases in the design and evaluation of questionnaires, with emphasis on mail surveys. Secondly, and concurrently, we tried to determine whether Gordis's criticism applied to veterinary medicine. To do so, we report on the evaluation of 120 articles published in peer review journals between 1984 and 1988, in which the authors were referring to questionnaires as source of data for their study.

EVALUATION OF SELECTED ARTICLES

Articles published between 1984 and 1988, inclusively, in six peer-reviewed veterinary

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journals were investigated. The six journals considered for this study were: the Australian Veterinary Journal (17 articles, 14.2%), the Journal of the American Veterinary Medical Association (30 articles, 25%), the Canadian Veterinary Journal (14 articles, 11.7%), the Journal of Preventive Veterinary Medicine (19 articles, 15.8%), the Veterinary Record (31 articles, 25.8%), and the New Zealand Veterinary Journal (9 articles, 7.5%). The articles were selected if the authors reported using a questionnaire to gather all or part of the data for their study. The articles considered were not limited to original studies. "Special reports", "economic notes" and a few letters to the editors were also included. Articles in which the authors reported contacting the animal owners simply to query about the health status of their animals following surgery or medical treatment were not considered. When a series of articles were published based on one research project, the series was considered as one single publication. When a study was repeated every year and results reported yearly, the series counted for one article. For these particular cases, information such as response rates and sample sizes were averaged. Thus, articles representing 120 different studies were examined. They were classified according to their design, as defined in Table 1. A list of the articles reviewed in this study is available upon request to the senior author.

Table 1: Classification of epidemiologic study designs.

Study design	Description
Case-Report	Fewer than 10 subjects or epidemics examined.
Cross-sectional	Ten or more subjects or epidemics examined. Observations are made at essentially one point in time. Cases and non-cases are present.
Case series	Like cross-sectional. However, the comparison group (non-cases) is absent.
Case Control	Observation are either made at one point in time or over a period of time (longitudinal). Cases and non-cases are selected, but not necessarily from members of the same population. Groups may be formed in past (from records) or in present (> 10 subjects).
Cohort	Group of subjects identified at one point in time and followed, without any intervention, for a given period for detection of cases (>10 subjects). Group formed in past (from records) or in present.
Clinical trial	Like prospective cohort study. However, an intervention is present.
Survey design	Project focusing on the construction of a questionnaire.

(adapted from Smith, 1988)

QUESTIONNAIRES AND STUDY DESIGN

Questionnaires can be used in a wide variety of study designs. In our investigation, all questionnaires were part of observational studies. Case-series and cross-sectional investigations were the most frequent study designs associated with questionnaires (Table 2). Mailed surveys were most often used, followed by personal interviews and telephone questionnaires. Only about 4% of the articles reported on the use of more than one type of questionnaire (Table 2).

The target population

The target population is the group of individuals from which the study sample is drawn. In veterinary research, animal owners or farm employees are the most frequently targeted population (Table 3). However, the percentage of studies involving veterinarians is indicative of the key role practitioners are and will be playing in veterinary epidemiologic research (Table 3). Besides studies on veterinarians per se, veterinarians were asked to collaborate in filling out questionnaires on conditions encountered in their practices. They were also asked to act as interviewers or to be part of the survey validation process (Studdert, 1985; Edney and Smith, 1986)

The sampling method(s) used influences ability to generalize the study findings to the target population. The majority of the 120 studies investigated were performed using non-random procedures. Convenience sampling or entire datasets or all hospital cases were frequently used. A fair percentage of papers (18.3%) failed to even mention the sampling procedure (Table 4). Proper sampling protocols are well described in several publications (Cochran, 1977; Levy and Lemeshow, 1980).

Questionnaire design

The design and follow-up of a questionnaire varies depending on the objectives, the targeted population (e.i. veterinarians, animal owners, etc.) and, of course, the type of survey (mail, telephone, personal interview). In this section, we will briefly describe the main considerations involved in the construction of a questionnaire. The emphasis will be put on mail surveys, but many of the principles are applicable to telephone and personal interview surveys.

A questionnaire should be easy to read (by respondents or interviewers), have clear instructions and be relevant (Edwards, 1990). Considerable planning and care should go into the design of a questionnaire because question formation and presentation can affect validity.

The title of the survey: The title of the survey introduces the study to the selected individuals. The title has to be concise and clear without revealing the project's hypothesis, in order to minimize response bias. For example, "*study of environmental factors associated with temporal patterns in preweaning mortality in pigs*" is to long and gives away the main

Table 2: Cross-tabulation of the type of survey with the study design

Type of survey	Study designs							
	Case report	Case series	Cross sectional	Case control	Cohort	Clinical trial	Quest. design	total
Mail	100[a] (1)[b]	38.5 (10)	58.7 (37)	18.2 (2)	26.7 (4)	33.3 (1)	-	45.8 (55)
Telephone	-	23.1 (6)	6.3 (4)	-	-	-	-	8.3 (10)
Personal interview	-	19.2 (5)	22.2 (14)	36.4 (4)	60 (9)	66.7 (2)	100 (1)	29.2 (35)
More than one type	-	3.8 (1)	4.8 (3)	9.1 (1)	-	-	-	4.2 (5)
Not specified	-	15.4 (4)	7.9 (5)	36.4 (4)	13.3 (2)	-	-	12.5 (15)
Total	100 (1)	100 (26)	100 (63)	100 (11)	100 (15)	100 (3)	100 (1)	100 (120)
% of total	0.8	21.7	52.5	9.2	12.5	2.5	0.8	100

[a] column percentage
[b] number of articles

Table 3: Distribution of articles according to the targeted population.

Targeted population	No. articles	% of total
General population[a]	1	0.8
Animal owners/managers & Farm employees	85	70.9
Veterinarians & Animal specialists	25	20.8
Animal owners & Veterinarians	9	7.5
Total	120	100.0

[a]General population refers to a group of individuals selected at random within a community without any specific selection criterion

Table 4: Distribution of the selection procedure reported in 120 articles.

Selection of sample	No. articles	% of total
Not reported	22	18.3
All people from a database or region, all hospital or diagnostic laboratory cases	54	45
Sample of targeted population:		
a) non random	23	19.2
b) random		
♦ described	12	10
♦ not described	9	7.5
Total	120	100.0

hypothesis. "*Study on preweaning mortality in pigs*" would be preferable.

Questions: Questions should be short, clear and unambiguous. For interview and telephone questionnaires, interviewers should use the exact questions as written in the questionnaire (Edwards, 1990). Word selection is critical. Payne (1951) offers a detailed review of commonly used words, indicating those which may cause problems. Each word should be carefully selected and used in a clear context. For example, when ask about litter size, should a swine producer assume that stillborn pigs are included?...and how about mummified fetuses? For a comprehensive discussion on question construction, the reader is referred to Gardner (1976) and Payne (1951).

There are three main types of questions: open-ended (allows the subject to answer freely in his or her words), closed-ended (subject has to select from among the answers already chosen by the researchers) and semi-open-ended (offers the subject a limited number of choices and the freedom to include additional information). Preference in type of questions is usually dictated by factors such as sample size, prior knowledge of possible responses, the hypothesis, the degree of education of respondents, etc.

Open-ended questions are valuable when a continuous variable response is expected. It allows unanticipated responses and relieves the tedium of too many closed-ended questions. However, coding is often difficult and could be a source of error. Under-reporting of an event is more likely since people often forget unless prompted. Finally, this type of question is not recommended when the degree of education of respondents is considered low.

Closed-ended questions are more popular than open-ended questions because choices are forced, they are easy to code and, consequently, they are easier to analyze. It is important for all choices to be mutually exclusive (DelGreco and Walop, 1987). Unfortunately, valuable information may be missed, the order of choices may affect the respondent's answer, and there is a practical limit in the number of choices that can be offered. While up to 10 choices for a single question could be considered in mail surveys, it is difficult to offer more than 5 choices by phone or during personal interview surveys. For personal interviews, the interviewer should present the choices on a card to the respondent when more than 5 options are given. Indeed, with more than 5 options, the respondent is more likely to choose the first or the last because they are easier to remember. Closed-ended questions can be designed as rating or intensity scales. These are often used to determine the strength of attitudes or opinions (strongly disagree....strongly agree). Fifteen of the 29 articles which stated question type reported using this type of close-ended question. More elaborate scales or indexes can be designed when a single question cannot adequately represent a complex variable. They are typically ordinal measures of variables. They are constructed in such a way as to rank-order survey respondents by summarizing a respondent's several responses in a single score. Nine of 29 articles reporting question type used this kind of measurement.

When the most frequent choices are known, but several other minor options are possible, semi-open-ended questions are a suitable alternative. The most frequent options are offered with the last choice being an open category allowing the respondent to add a personal choice. It is the "other, please specify" option.

"Don't know" and "no opinion" options must also be considered, mainly when presenting a two-way question where opposite alternatives are designed to elicit a response of yes or no, or agree/disagree.

To evaluate questionnaires, one should have access to the questions asked. Unfortunately, only 19 out of 120 articles (15.8%) listed all or some of the questions used in their study. About three quarters (91/120) of the articles did not even mention the type (open-ended, close-ended, etc.) of questions used. The questionnaire was available upon request in one article.

Appearance of the questionnaire: Questions must be presented in a professional manner. This is particularly critical in mail questionnaires because it is self-administered. Several aspects of the questionnaire appearance will have an impact on the responses and on the response rate, which is the proportion of surveys completed and returned.

The standard 8.5" X 11" format is more likely to yield higher response rates than the legal one (8.5" X 14") (Childers and Ferrell, 1979). For mail questionnaires, it is recommended to bind the pages as a booklet. This makes it easier to use both sides of each page and reduces the risk of loosing part of a questionnaire. If pages are coloured to differentiate between sections of the questionnaire, pastels are highly recommended in order to maintain a good contrast with the lettering. However, except for the cover page, the use of colours has never been shown to have much impact on the response rate (Dunlap, 1950; Gullahorn and Gullahorn, 1959; Bender, 1967).

Although a lengthy questionnaire may deter more people from responding, studies on this particular aspect of questionnaire design indicate that the response rate is not necessarily proportional to the number of pages (Childers and Ferrell, 1979). Therefore, one should not try to "cramp" several questions on a single page just to reduce their number. Enough space between each question will make the questionnaire look easier to answer. We recommend to keep a mail survey under 15 pages.

The number of questions per page will vary depending on the type of questions. In our investigation, 26 articles (21.5%) reported the number of questions in their survey. On average, 34 questions were asked, ranging from 5 to 135 depending on the study. Some authors reported using multipart questions.

PRETESTING

Pretesting is a multistep procedure that should be performed if a questionnaire is to be used in a research project.

The objectives of pretesting are to evaluate the design of the questionnaire and the degree of understanding of each question. Is there enough room after each question to write down the answer? Are some questions likely to be inadvertently overlooked? How many minutes does it take to complete the questionnaire? Questions on a given topic are usually clustered. When a skip pattern is used the first question determines whether the respondent or interviewer should be directed to skip to the next set of questions. If skip patterns are used, are they adequate? Are all questions necessary? Are some necessary questions omitted?

The participation of 5 to 20 individuals who are comparable to the target population is needed for the first step. The questionnaire is presented to each individual in this group in a format as close as possible to what should be the final version of the survey. Written comments from each participant should be obtained. The ideal scenario is to schedule a meeting of all participants in order to gather their comments and foster a discussion among them about the questionnaire. This could be done as part of a dinner organized to thank the participants. For telephone or personal interview questionnaires, comments from participants are usually collected immediately after the interview is completed. Again, it would be preferable to get a few interviewees to meet and discuss the questionnaire. Following this procedure, the survey is then modified according to the participants' recommendations, and the previous step is repeated. If need may be, this should be done a third time. If possible, participants in the pretest procedure should not be included in the study. It is recommended, as a gesture of appreciation, to provide the participants with a summary of the study results.

Although this is an essential procedure in questionnaire construction, it was reported in only 10 articles (8.3%) out of the 120 reviewed.

QUESTIONNAIRE FOLLOW-UP

Certainly one of the most important factors affecting the response rate is the follow-up given to the survey by the investigators.

The Minnesota Center for Survey Research proposes a three step approach to achieve a 70% or better response rate by mail (Anon., 1987).

1. An initial copy of the survey is sent with cover letter(s) and a stamped returned envelope.

2. A reminder postcard is sent to the entire sample one week after the initial mailing.

3. A follow-up copy of the survey with cover letter(s) and stamped return envelope is sent to all who have not returned the initial survey. This second copy is sent two weeks after the postcard mailing.

Other devices that have been shown to increase the response rate:

-Hand stamped mailing survey form with commemorative stamps (Gullahorn and Gullahorn, 1963).
-Hand sign cover letters (Maheux et al, 1989).
-Hand addressed each envelope (Anon., 1987).

-Offering incentives to participate such as a summary of the results. A small amount of money (less than $1) has been successful in increasing the response rate (Kanuk and Berenson, 1975; Linsky, 1975). Although incentives have proved effective in increasing participation, only 2 articles out of 120 reported using this approach. This may be due to the fact that such information was not considered worthy of being mentioned in a scientific publication.

-Pre-contacts (contacting study subjects in advance) identifying the researchers and the study's purpose accompanied with a request to participate appear to increase the response rate, mainly when this is done by phone (Linsky, 1975).

-Involving veterinary practitioners in research projects may also help increase the response rate. In a comparison between the response rate to a mail questionnaire sent by a research unit and the response rate to the same questionnaire sent by the respondents' local physicians, a significant difference was noted in favour of the local physicians; presumably because the respondents knew them personally (Smith et al, 1985).

It is well known that medical doctors are not avid responders to surveys (Maheux et al, 1989). This may be because they are so often asked to participate in surveys. In veterinary medicine, however, no significant difference was found between veterinarians and other people when comparing response rates reported in 45 articles (Table 5).

High response rates can be achieved even when several hundred people are surveyed. This is reflected in the large standard deviation of response rates (Table 5). The wide range in response rates obtained from the reviewed articles could depend on the type of questionnaire used, the degree of interest within the target population, and the quality of the follow-up given to the surveys.

QUALITY CONTROL

Reliability and validity

When producing a questionnaire, it is important to determine the quality of the questionnaire. Reliability, the ability of a question to give consistent results on repeated trials, and validity, the degree to which the answers reflect the true state of nature, are critical qualities of a questionnaire. These qualities should be evaluated because of the multiple sources of error associated with questionnaires (Cannell et al, 1977). Unfortunately, this is rarely done or, at least, reported. Indeed, total or partial validation of the survey was stated in only 11 (9.2%) articles.

Reliability may be best measured as the repeatability of response after a brief time period (Samet, 1978). The consistency within the questionnaire, the degree to which a subject answers similar questions in a similar manner, is another way to determine reliability (DelGreco et al, 1987). For interviews, inter-observer reliability, the same subject being evaluated by two interviewers using the same questionnaire, should also be assessed. This is expensive and time-consuming, and may explain why such evaluations are almost never performed. Testing validity is more often considered when an independent criterion or

Table 5: Descriptive statistics of the response rate for studies where veterinarians were surveyed versus other people, depending on the sample size (number of individuals included in the study)

Sample size	Response rate								
	Veterinarians			Others[a]			Overall		
	No.	Mean	SD	No.	Mean	SD	No.	Mean	SD
1-99	3	69.9	27.5	7	78.9	14.3	10	76.2	18
100-300	4	74.6	17.8	6	49	12.7	10	59.2	19.2
301-500	5	59.5	24.3	4	60.3	19.2	9	59.9	20.8
> 500	6	43.8	22.5	10	60.2	11.7	16	54.1	17.8
Overall[b]	18	59.4	24.3	27	62.6	16.9	45	61.3	20

[a] Others: non-veterinarian respondents (general population, animal owners, etc.)
[b] Response rates were reported in 45 articles out of the 120 investigated.
No difference between the overall means (veterinarians vs others, $P>0.1$.

measure of the same variable is available. In practical terms, this is often limited to comparing existing datasets (computerized record systems like PigCHAMP, DAISY, PigTale, government records, etc.) or information gathered during a farm visit (facilities, some management procedures, etc.) to the respondent's answers.

Non-respondents

A major component in the evaluation of data quality is the determination of non-respondents' characteristics. The lower a response rate is, the more likely a response bias is possible. Indeed, unless one can establish the similarities or differences between respondents and non-respondents, any association between two variables could be the result of a particular characteristic common to many respondents but not shared by the non-respondents. This is so basic and crucial that one would expect to see this issue addressed in every publications where non-respondents are reported. Are non-respondents from larger farms than the study participants? Are they more likely to have experienced less complications from the disease under investigation? Every efforts should be made to answer such questions. Unfortunately, of all articles in which non-respondents were reported (105 articles), only 6 (5.7%) attempted to assess their characteristics.

THE ANALYSIS

Fifty percent of the articles reviewed were strictly descriptive in nature. No statistical comparison was made between any of the questionnaire variables or between questionnaire data and data obtained through other means. The proportion of such articles varied with the study design and with the type of survey. Descriptive analyses were more frequent in case series (22/26 articles, 84.6%) than in case-control (4/11 articles, 36.4) or cohort (4/15 articles, 26.7%) studies. About 43% (27/63 articles) of the cross-sectional studies were purely descriptive. The majority of mail (57.4%) and telephone (72.7%) questionnaires were associated with descriptive analyses only. Only 8 out of 35 articles dealing with personal interviews limited their investigation to descriptive information. However, the apparent association between personal interviews and a more analytic use of the data could be confounded by the type of study design. Indeed, personal interviews were more frequently used for cohort and case-control studies than the other two types of survey (Table 2).

CONCLUSION

The results of this investigation reveal that questionnaire surveys are often poorly described or performed. The lack of basic details dealing with response rates, validation, and description of questions, make it very difficult to assess the quality of the information presented in the reviewed articles.

In order to better assess the quality of publications referring to questionnaires as sources of data, we make the following recommendations:

1. Broad statements such as "the appropriate questions were asked" should be avoided.

2. The target population should be well defined.

3. Sample sizes, selection procedures and response rates must be clearly stated.

4. The presence or absence of pretesting and validation (even partial) should be indicated and briefly described.

5. If possible, the questionnaire should be reproduced in the "Materials and Methods" section or put in an appendix. If too long, key questions from which the main findings originated should be presented. In all cases, unless the entire survey is included in the article, the questionnaire should be made available upon request and included with reprints. The journal publishing the article should also have a copy of the questionnaire available upon request.

6. If interviews are conducted, the type of training which the interviewers received, the efforts made to "standardize" the interviewers, and the extend to which the interviewers were instructed to probe in order to elicit a response to a specific question should be described.

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PREVALENCE OF LAMENESS AND RISK INDICATORS FOR DERMATITIS DIGITALIS (MORTELLARO DISEASE) DURING PASTURING AND HOUSING OF DAIRY CATTLE

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From an economic point of view, lameness in dairy cattle is the third health disorder, after mastitis and reproductive failures, in the Netherlands. For Dutch conditions a loss of 38 Dutch guilders per lame cow and 2280 Dutch guilders per 60 cows has been calculated at an incidence rate of 25% per year (Dijkhuizen, 1987). Whitaker *et al.* (1983) estimated the economic losses due to lameness in the U.K. to be £ 30 per lame cow and £ 1175 per 100 cows at a 25% incidence.

Lameness as a term represents the collection of primary clinical and subclinical lameness diagnoses and of symptoms, which have been categorized by Espinasse (1984). In this paper, prevalences, as found at the end of the pasture and the housing period, of dermatitis digitalis (DD), dermatitis interdigitalis (DI), laminitis (LA) and of the symptoms: sole ulcer (SUL), specific traumatic solear contusion (SOC), white line process (WLP), white line separation (WLS), interdigital hyperplasia (HYP), respectively, will be presented. Subsequently, a risk factor analysis for dermatitis digitalis will be discussed.

Dermatitis digitalis, or Mortellaro disease, was described for the first time by Cheli and Mortellaro in 1976. The disease has been reported in the Netherlands five years later (Cornelisse, 1981). It is a superficial ulceration of the skin along the coronary margin, varying in diameter from one to three centimetres, and mostly causing a severe clinical lameness. The most prone locations are at the plantar and volar side of the underfoot, and between the digits (Cornelisse, 1981). The etiology still has to be elucidated. Various bacteria species such as *F. necrophorum*, *B. nodosus*, *B. melaninogenicus*, and *Campylobacter* have been detected in lesion material, but none of these were specific. Most researchers in this field consider Mortellaro disease to be contagious although no specific agent with the potential of reinducing the disease has been detected (e.g. Bassett *et al.*, 1990). Therefore, a multifactorial causal pathway should be considered, for which a modern epidemiological analysis could be appropriate. According to Thrusfield (1986), epidemiology is an approach to identify possible risk factors related to disease occurrence and to quantify their impact.

The objectives of this observational analytic field study with regard to dermatitis digitalis are:

(1) to identify possible risk factors at the cow and the farm/environment level, and

(2) to quantify their effect

In this way, specific high-risk indicators, which might be a support to the clarification of the disease etiology, might be detected.

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MATERIALS AND METHODS.

Study population

At the end of the pasture period, 59 commercial dairy farms in the province of Utrecht, The Netherlands were visited. Data for this pasture study (referred to as the P-study) were collected during a routine herd trimming visit between the 26th of September and the 1st of December 1989. Usually only hind claws were trimmed. Another 59 farms, not necessarily the same as in the P-study, were visited at the end of the housing period, between the 6th of March and the 11th of May (referred to as the H-study).

The farmers belong to the clientele of 2 professional claw trimmers who trimmed the cows on a routine basis at least once per year. All farms were of the loose housing type.

Diagnosis

The clinical and/or subclinical findings on hind claws were recorded during trimming according to a diagnosis list based on the description by Espinasse (1984). The following diseases were registered: dermatitis digitalis (DD), dermatitis interdigitalis (DI) and laminitis (LA). The following symptoms were recorded as well: sole ulcer (SUL), specific traumatic solear contusion (SOC), white line process (WLP), white line separation (WLS), interdigital hyperplasia (HYP).

Potential risk factors

Risk factors concerned both cow and farm factors. Cow factors (breed, parity, stage of lactation) were obtained by on-farm registration systems. Factors concerning the environment (including management) were obtained by means of a questionnaire.

Data analysis

Data were entered using DBASEIV (Ashton-Tate, 1988), validated using SAS (SAS, 1989) and analyzed using multivariate logistic regression. The output of the latter consisted of 3 parameters: the estimate of the regression coefficient (ß), its standard error (s.e.) and the residual deviance. From the ß's, odds ratio can be calculated by exponentiating it according to e^{β}. A ß larger than 0 (OR>1) indicates a risk factor, a ß less than 0, a preventive factor (OR<1). A factor is statistically related to the disease ($p<0.05$) when 0 is excluded from the interval given by $\beta \pm 1.96 \times s.e.$ The difference in deviance is a likelihood-ratio statistic and was used to compare nested models (McCullagh and Nelder, 1989).

The logistic binomial multivariate model we used, accounted for cow factors and also for the fact that observations within farms are not independent (random effect model with herd as main plot). The number of quadrature nodes was set to 5 (Jansen, 1990).

The first step in the statistical analysis concerned cow factors. Subsequently, herd milk production level, herd size and clusters of environment variables were added to this model. Each cluster represented a set of variables which are more or less related. The clusters that were evaluated contained characteristics of: pasture in the P-study and stable, cubicle, floor and hygienic measures in the H-study. Outcomes of some variables were split into 2 or more categories. The borderline between categories was determined arbitrarily (either in such a way that each category showed about an equal number of observations or that each category had a very distinctive meaning, e.g. present *vs.* absent).

Significant variables out of each cluster were offered to a 'total' model.

From this model a final model was constructed by deletion of non-significant variables ($p<0.10$).

RESULTS

Descriptive results

In the P-study, a total of 3048 cows was trimmed, in the H-study 3208. After validation, 2494 and 2795 cows, respectively, were used for further analysis. The main reasons for deleting an observation were 'parity 0' or 'missing calving date'. The latter resulted in a missing value for the stage of lactation.

About 90% of the cows consisted of both pure breed and crossbreed Holstein Friesian and Dutch Friesian cattle. Distributions of breed, parity and stage of lactation at the time of trimming are shown in table 1. The classes of these variables are the same as used in the statistical analysis. The stage of lactation was split into 4 categories: dry, 1 to 50 days in milk (pre-top), 51 to 70 days in milk (top) and more than 70 days in milk (past-top).

Table 1. The distribution of parity, breed and stage of lactation at the time of claw trimming in the study populations.

Parameter and classes	Study P	H
Parity		
1	28.6	27.0
2	23.3	21.5
≥3	48.1	51.5
Breed[a]		
> 50% HF	33.7	38.2
> 50% DF	24.8	17.4
50/50 HF/DF	33.5	34.2
> 50% MRY	4.1	4.5
> 50% Other	3.9	5.7
Stage of lactation[b]		
Dry	8.0	17.8
Pre top	12.0	3.9
Top	6.0	4.8
Past top	74.0	73.5

[a] HF = Holstein Friesian; DF = Dutch Frisian; MRY = Meuse Rhine IJssel
[b] Pre top: ≤ 30 days in milk; Top: between 30 and 70 days in milk; Past top: over 70 days in milk

Clinical signs of lameness were seldom found: 1% and 2% in the P- and H-study, respectively. At the contrary, subclinical signs were found in the majority of cows (table 2). In the P-study, 93.1% of the study population showed at least one symptom. In the H-study only 4 cows (0.1%) without any signs were found. Most cows showed 1 (P-study) or 2 (H-study) subclinical findings.

Table 2. Distribution of the number of different subclinical diagnoses or symptoms per cow.

	Number per cow						
	0	1	2	3	4	5	6
P-study	6.9	59.6	21.8	8.2	2.7	0.7	0.0
H-study	0.1	15.5	48.3	26.1	8.1	1.6	0.3

The prevalences of the subclinical findings per cow and per claw are presented in table 3. As could be expected, no large differences were found between left and right feet. However, for a number of diagnoses and symptoms (laminitis, white line process and separation, sole ulcer, solear contusion) the outer claws were more often and more severely affected. Comparing the P- and H-study it appears that dermatitis digitalis and laminitis are much more prevalent during housing, while dermatitis interdigitalis is more severe during housing.

Table 3. Prevalences of subclinical claw disorders and distribution over inner and outer claws and over feet

Diagnosis[a]	% of cows affected[b]		% of outer claws[c]		% left feet[c]	
	P	H	P	H	P	H
DI grade 1	76.1	46.9	49.0	51.2	49.3	49.1
grade 2	10.7	47.3	56.6	46.8	53.6	51.3
grade 3	4.1	5.4	81.8	71.9	52.9	55.3
total	**90.9**	**99.6**	**50.0**	**48.0**	**49.7**	**52.0**
DD grade 1	7.7	10.2	----	----	50.6	51.8
grade 2	0.4	3.6	----	----	80.0	53.3
total	**8.1**	**13.8**	----	----	51.9	52.1
LA grade 1	11.2	55.7	84.1	76.9	48.7	53.2
grade 2	2.8	19.2	83.1	85.5	52.2	50.4
grade 3	0.6	1.9	85.7	85.1	52.4	47.8
total	**14.6**	**76.8**	**84.3**	**78.6**	**49.4**	**52.6**
WLP	2.8	2.2	95.8	88.9	56.2	57.1
WLS	0.4	7.5	100.0	91.8	60.0	58.2
SOC grade 1	10.4	11.7	94.0	92.6	48.3	53.3
grade 2	3.2	6.2	93.3	92.9	48.9	51.0
total	13.6	18.0	93.9	92.7	48.6	52.6
SUL	4.4	5.5	95.6	87.4	42.1	44.5
HYP	6.7	7.1	----	----	50.7	52.5
PI (# of cases)	7	6				

[a] DI = dermatitis interdigitalis; DD = dermatitis digitalis; LA = laminitis; WLP = white line process; WLS = white line separation; SOC = solear contusion; SUL = sole ulcer; HYP = interdigital hyperplasia; PI = phlegmona interdigitalis

[b] regardless of the number of affected claws

[c] as % of affected claws (100-%outer = %inner; 100-%left = %right)

Analysis of dermatitis digitalis

The prevalence of dermatitis digitalis in hind feet was 8.1% (201 cows) and 13.8% (387 cows) in for the P- and H-study, respectively. The distribution of the disease over herds is given in fig. 1. In the H-study only 4 herds were free from DD. In the majority of herds, less than 15% of the cows were affected, the maximum being 58.3%. Farmers of affected herds were often not aware of the presence of this disease on their farms. Twelve farmers (21.8%) of affected herds in the H-study answered that no DD was present, although in some cases up to 10% of the animals were diagnosed positively.

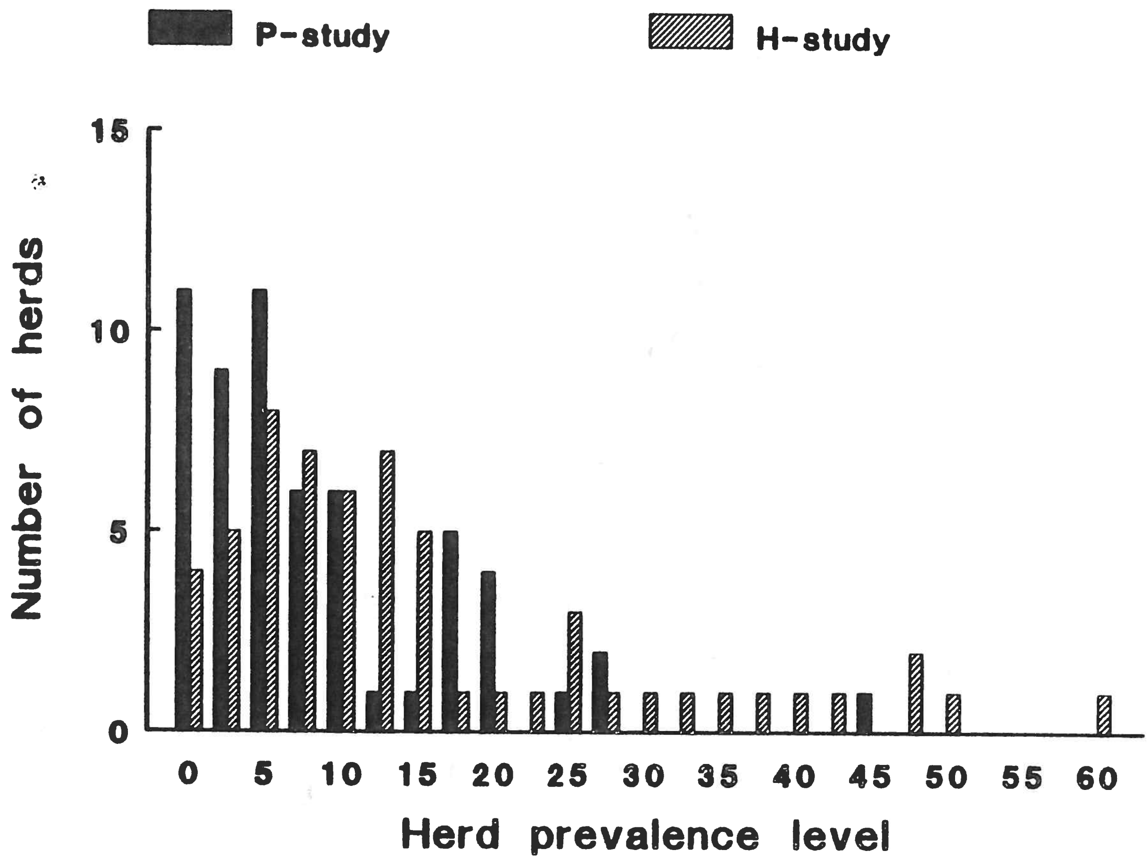

Figure 1. Distribution of herd prevalences for dermatitis digitalis at the end of the pasture period and the housing period respectively.

Regression coefficients of cow factors are presented in table 4. Table 4 shows that younger cows (parity 1 and 2) are a high risk group for dermatitis digitalis. It is also obvious that Friesian cattle is more susceptible than MRY or 'other' breeds (most beef type breeds). In the P-study the stage of lactation is related to DD, the dry status being preventive and the top of production period being a risk factor. However, this was not the case in the H-study. The amount of overdispersion was 36.3% and 30.8% in the P- and H-study, respectively (see note below table 4).

Table 4. Regression coefficients and s.e. of cow factors.

Parameter		P-study		H-study	
		ß	s.e.	ß	s.e.
Parity	1	0.52*	0.16	0.43*	0.16
	2	0.18	0.18	0.38*	0.15
	≥3	ref.		ref.	
Breed	> 50% HF	0.12	0.18	0.02	0.15
	> 50% DF	0.18	0.18	-0.25	0.18
	> 50% MRY	-1.02*	0.42	-0.43	0.29
	OTHER	-1.12*	0.55	-0.84*	0.31
	HF/DF 50%	ref.		ref.	
Stage of lactation	Dry	-1.15*	0.43	-0.07	0.16
	Pretop	-0.25	0.23	0.15	0.31
	Top	0.58*	0.22	-0.21	0.29
	Pasttop	ref.		ref.	
Sigma[a] (σ)		1.37*	0.09	1.21*	0.10

* $p < 0.05$

[a] if $S=3x\sigma^2/\pi^2$ then $S/(1+S)$ equals the percentage of the total variance that is due to between herd variance

Regression coefficients for cow factors and environmental factors that are related to pasturing are listed in table 5. Breed and stage of lactation still influence the presence of DD significantly. Medium herd size and medium production level are positively related to DD. Limited access to pasture, a long walking distance from stable to pasture and a metalled walking path all turn out to be risk factors. Pastures at low or high level show a negative relationship with DD. Grassland soil type was not significantly related to DD.

Table 5. Regression coefficients and s.e. of cow factors and pasture factors using data of the P-study.

Parameter		ß	s.e.
Parity	1	0.28	0.18
	2	0.05	0.20
	≥3	ref.	
Breed	> 50% HF	0.18	0.19
	> 50% DF	0.02	0.19
	> 50% MRY	-2.10*	0.67
	OTHER	-1.09*	0.41
	HF/DF 50%	ref.	
Stage of lactation	Dry	-1.08*	0.50
	Pre top	-0.21	0.25
	Top	0.53*	0.24
	Past top	ref.	
Herd size	< 50 cows	-0.50⁰	0.26
	≥ 50 and <65	ref.	
	≥ 65	-0.30	0.23
Herd production level (kg milk)	< 7000	-0.75*	0.25
	≥ 7000 and <8000	ref.	
	≥ 8000	-0.94*	0.28
Access to pasture	limited	0.41*	0.18
	free	ref.	
Walking distance	< 200 meter	ref.	
	> 200 meter	1.68*	0.33
Walking path condition	grass	-0.94*	0.30
	metalled	ref.	
Pasture level	low	-0.64*	0.23
	medium	ref.	
	high	-0.52*	0.22
Sigma		1.45*	0.15

⁰: $p<0.10$ *: $p<0.05$

Table 6 presents the significant regression coefficients of cow factors and environmental factors related to housing. During housing, lower parities, medium herd size and low herd milk production are indicated as risk factors. Housing factors like shoulder rail heigth and the distance between the wall and the shoulder rail are related to DD. A rough floor condition is predisposing for DD. Mixing chalk with cubicle bedding and disinfection measures are related to DD as well, although in opposite directions.

Variables with regard to cubicle measures (width, length), cubicle cleaning, cubicle floor (concrete or other), slatter condition (irregular, damaged), slatter cleaning, slatter width, feed bunk level were not significant.

Table 6. Regression coefficients and s.e. of cow factors and housing factors using data of the H-study.

Parameter		ß	s.e.
Parity	1	0.39*	0.15
	2	0.39*	0.16
	≥3	ref.	
Breed	> 50% HF	0.13	0.16
	> 50% DF	-0.27	0.19
	> 50% MRY	-0.59⁰	0.35
	OTHER	-0.49	0.32
	HF/DF 50%	ref.	
Stage of lactation	Dry	-0.04	0.16
	Pre top	0.31	0.31
	Top	-0.21	0.31
	Past top	ref.	
Herd size	< 50 cows	-0.47⁰	0.26
	≥ 50 and <65	ref.	
	≥ 65	-0.54*	0.21
Herd production level (kg milk)	< 7000	1.00*	0.28
	≥ 7000 and < 8000	ref.	
	≥ 8000	-0.56*	0.24
Shoulder rail height (cm)	< 103	0.25	0.17
	≥ 103 and < 109	ref.	
	≥ 109	-0.53⁰	0.33
Distance shoulder rail and wall (cm)	< 70	-0.23	0.25
	≥ 70 and < 77	ref.	
	≥ 77	0.57*	0.22
Floor surface	rough	0.46*	0.20
	smooth	ref.	
Use of chalk	yes	0.69*	0.21
	no	ref.	
Disinfection with walk-through bath	present	-0.82*	0.21
	absent	ref.	
Disinfection with standing bath	present	-1.18*	0.39
	absent	ref.	
Number of troughs	< 71	0.38	0.23
	≥ 72 and < 91	ref.	
	≥ 91	0.73*	0.22
Sigma		0.92*	0.13

⁰: $p<0.10$ *: $p<0.05$

DISCUSSION

Overall prevalence rates

Cross-sectional studies were carried out to investigate the prevalence and potential risk factors of lameness. Cross sectional designs are highly valuable for diseases of long duration or with frequent incidents. For rare diseases or diseases of short duration, such as phlegmona interdigitalis, case-control and longitudinal designs are more appropriate (Martin *et al.*, 1987).

The relative small area around Utrecht reduces the representativeness of the results for the Dutch dairy cattle population. The average milk production per cow (P-study: 7470 kg; H-study: 7350 kg) is higher than the average of the Dutch milk recording population (6978 kg; NRS, 1989). The parity distributions are comparable to that of the milk recording population (NRS, 1989).

Clinical lameness was seldom encountered. However, over 90% of the animals showed at least one disease or symptom subclinically. Dermatitis interdigitalis (DI) was the main cause of this high level. Peterse (1980) found comparable percentages for DI during pasturing and housing and also that the severity of the disease increases during housing. Also laminitis and dermatitis digitalis were more prevalent and more severe during housing.

The differences between the P- and H-study with regard to prevalence and severity of the diagnoses might have several causes. Firstly, the quality of the diagnoses might have been different between studies. However, as the diagnoses were carried out by 4 observers (2 in each study) who were specifically trained for diagnosing lameness categories, the effect of misclassification is considered to be small. Also the fact that data is collected with the help of professional claw trimmers resulted in an uniform claw trimming procedure.

Secondly, differences between both study populations with regard to breed, age or stage of lactation might exist. As can be seen from table 2 only the latter differs considerably between both populations and is a reflection of the calving pattern in The Netherlands. This pattern is closely related to the higher price of milk during winter. If this factor does affect prevalence and severity, then the difference between both studies is even underestimated because during the housing period (high risk period) less animals are at the top of production, which is a risk factor according to table 4.

Thirdly, differences might be due to a higher level of exposure to risk factors during housing and/or to the non-exposure to preventive factors that are active during the pasture period. Higher incidences or prevalences of foot lesions during housing were found in many other investigations as well (Rowlands *et al.* , 1983; Faye and Lescourret, 1989; Enevoldsen *et al.*, 1991). The length of housing also appeared to be a risk factor (Faye and Lescourret, 1989).

<u>Risk indicators for dermatitis digitalis</u>

It appears that cow characteristics affect the occurrence of DD (table 4), although the results were not totally consistent in both studies, especially with regard to the stage of lactation. The fact that lower parities are more susceptible to develop signs of DD might points to the involvement of immunity.

Grazing animals at the top of production are more likely to develop DD at the subclinical level, which might be related to a greater susceptibility. Medium herd size was indicated as a risk factor in both studies. In larger herds, the management and care might be at higher levels, while at smaller farms the exposure level to pathogens (if involved in DD) might be lower. Medium herd production level is positively related to DD during pasturing, while at housing the low productive herds are at highest risk. This shift is difficult to explain.

Giving limited access to pasture affects DD increasingly when compared to free access. This can be interpreted in 2 ways: either access to pasture acts preventive (e.g. pH of soil or body exercise) or staying indoors for longer periods leads to a higher exposure to pathogen(s) or to risk factors. This finding was not surprising because the prevalence of DD is higher during housing. On zero-grazing farms the prevalence of DD at the end of the housing period was 17.6% (based on 34 farms, 2127 cows, - unpublished results) and is even higher when compared to the H-study (13.8%).

Long walking distances to the pasture and a metalled walking path are both risk factors, possibly acting by affecting the claw quality negatively. Grass land soil type (clay, sandy clay, sand or peat) did not affect the prevalence of DD, although high and low pasture levels act preventive.

Housing factors like height of the shoulder rail and the distance between this rail and the wall appear to be related to DD. A relatively high rail and acts preventive, which might be explained by the fact that cattle might get up more easily and that the claws are less exposed to high pressure. A large space between wall and shoulder rail acts like a risk factor, possibly by torsion of claw tissue. A rough floor might cause micro-lesions and hence act as a predisposing factor for DD. Use of disinfection measures (baths) are preventive which indicates that infectious agents might be involved in the etiology of DD. It also appears that a standing bath is more effective than a walk-through bath. Mixing chalk with cubicle bedding is generally done to raise the pH and by that acting bacteriostatic, especially for pathogens causing mastitis. However, it might also affect the pH of the skin and in that way act predisposing for pathogens related to DD. The number of troughs is positively related to DD, which is difficult to explain as it is expected to be closely related to herd size. However, a subsequent analysis showed that the number of troughs per cow varied from 0.64 to 2.23 between herds. This possibly is a better parameter than the total number of troughs as Hannan and Murphy (1983) found that the available trough space per head was related to lameness.

Analysis

Risk factor analysis using multiple logistic regression is very complicated due to the possible lack of independence between cows within herds. Dependency could be expected as Smit *et al.* (1986) found that herd, season and sire influence claw disorders. When dependency exists but is being ignored, the standard errors of the regression coefficients will be too small. Subsequently, the parameter of interest might be erroneously indicated as significantly related to the disease. Using random effect models is the best way to account for the herd effect (Curtis *et al.*, 1988). We accounted for the factor herd by using a random effect model, the factor season was regarded as not being present within the P- and H-study, while we did not correct for possible sire effects.

The large amount of environmental parameters needs a structured model building strategy. We have chosen for a basic model containing cow factors, herd milk production level and herd size because it is known from literature that these are related to lameness (Rowlands *et al.*, 1983; Rowlands *et al.*, 1985; Smit *et al.*, 1986; Enevoldsen *et al.*, 1991a; Enevoldsen *et al.*, 1991b). Subsequently, clusters of variables were added to the basic model. Next, significant variables out of each cluster were offered to a final model. This method might be criticized from a statistical point of view (e.g. the constitution of clusters is subjective and relations between variables might get lost because they are assigned to different clusters). Another possibility is to use stepwise procedures but due to the large amount of parameters and the considerable stress that random effect models put on computer systems, this is not feasible. In fact, we followed the method described by Hosmer and Lemeshow (1989), but replacing the first step, univariate analysis, by analysis of all variables of one cluster. Also the analysis of interaction was not carried out into depth. Another point to be mentioned is that the number of quadrature nodes (5) is rather low. Increasing this number (e.g. up to 9) would result in more accurate standard errors of the ß's (Jansen, 1990). However, computational effort would increase rapidly.

CONCLUDING REMARKS

From this study no definite conclusions can be made with regard to the etiology of DD, although strong indications are found that pathogens are involved. A large number of factors that are related to DD have been quantified and might be of help by the prevention of this disease. The statistical analysis has not been carried out into depth yet. Interactions between parameters should be inspected more closely. A severe draw back on a complete analysis is the huge amount of computer time that is needed for random effect models, even on main frame computers.

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CANINE NEOPLASIA - AN EPIDEMIOLOGICAL REVIEW

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Neoplasia is a common clinical problem in the dog. Knowledge of the incidence of canine neoplasia and factors which influence its development is fundamental to the study of the natural history of the disease.

It is difficult to gather accurate data on the frequency of canine neoplasia, but a few centres have undertaken population based studies. The estimated annual incidence rate for canine malignant neoplasms of all sites was reported as 381.2/100,000 in a Californian Survey in 1968 (Dorn et al 1968 (ii)) and as 687/100,000 in a study in 1971, based upon information from the American Veterinary Medical Data Programme (Priester and Mantel 1971). Malignant neoplasms accounted for 34% (Dorn et al 1968 (i)) and 40% (Priester and Mantel 1971) of the total canine neoplasms recorded. The dog is susceptible to a wider range of neoplasms by site and histological type than other domestic species; Skin neoplasms are the most frequently reported and estimated to account for 24% of all canine tumours followed by mammary gland (11.4%), digestive tract (15.1%) and haemolymphatic system (10.9%) (Theilen and Madewell 1987). The approximate proportion of neoplasms at these sites reported to be malignant is skin (20%) (Priester and Mantel 1971, Priester 1973), mammary (50%), digestive tract (50%) and haemolymphatic (90%) (Theilen and Madewell 1987). The cell types most commonly affected by neoplastic development in the dog are epithelial (48.3%). mesenchymal (24.6%) and haemopoeitic (10.3%) (Theilen and Madewell 1987).

A variety of factors influence the frequency of neoplasia in the dog, including age, breed, sex and environmental agents. The estimated relative risk of neoplasia increases with age, with a peak occurence at an average age of eight years (Priester and Mantel 1971, Hardy 1976, Moulton 1978). Age specific incidence rates vary according to the tumour type, for example the occurrence of epithelial neoplasms is reported to increase after five years of age and mesenchymal tumours increase in frequency after seven years old, whilst the incidence of oropharyngeal neoplasms rises later, over ten years of age (Dorn et al 1968 (ii)). Although the majority of neoplasms occur in older dogs, tumours also develop in the younger animal, the most frequent types reported being histiocytoma, papilloma, lymphoma, osteosarcoma and fibrosarcoma (Theilen and Madewell 1987).

Significant variations are noted in the occurence of neoplasia between breeds with, overall, an increased prevalence in purebred dogs (Dorn et al 1968 (ii), Priester and Mantel 1971). Certain breeds have been identified at high risk for the development of particular neoplasms:- The Boxer is known to be prone to a wide variety of neoplasms and is at significantly greater risk that other breeds for the development of multiple primary neoplasms (Theilen and Madewell 1987). In the Boxer, the sites most commonly affected by neoplastic development are skin, testicle, lymphoid tissue, oral cavity and bone, and the most common tumour types reported are mast cell, lymphosarcoma, squamous cell carcinoma and osteosarcoma (Cohen et al 1974).

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Other Brachycephalic breeds, in particular the Boston Terrier are also predisposed to a number of neoplasms including skin, mammary gland, testicular and brain (Cohen et al 1974). Cocker Spaniels are reported to be at high risk for the development of several tumours including skin, circumanal, mammary gland and oropharyngeal (Theilen and Madewell 1987). The German Shepherd breed is at increased risk of oropharyngeal, nasal, testicular and primary bone neoplasia (Dorn et al 1968 (ii), Theilen and Madewell 1987). The cause of breed susceptibility to neoplasia is unknown, though it may be related to intensive breeding programmes inadvertently selecting for oncogene expression or deficient immune surveillance systems against neoplastic development (Withrow and MacEwen 1989). Breed colour and skeletal structure also appear to be important factors influencing the development of tumours - heavily pigmented breeds such as Scottish Terriers and Cocker Spaniels suffer an increased frequency of malignant melanoma compared to lightly pigmented breeds (Mulligan 1949, Cotchin 1955). Large and giant breeds such as Great Dane, Irish Wolfhound, St Bernard, Rottweiler and German Shepherd Dog are at high risk for osteosarcoma and other primary bone malignancies, which develop most frequently in the appendicular skeleton (Brodey, Sauer and Medway 1963, Brodey and Riser 1969, Riser 1985, Theilen and Madewell 1987). Increased height, weight and growth rate in such breeds causing increased compression and stress to growing points of the bones is proposed as the probable cause of the predisposition to malignant development (Riser 1985, Theilen and Madewell 1987). Doliocephalic breeds including the Collie, Shetland Sheepdog and German Shepherd dog are considered to be at increased risk for the development of intranasal malignancy (Theilen and Madewell 1987, Withrow and MacEwen 1989). This observation may be related to increased area of nasal mucosa exposed to inhaled carcinogens.

Overall incidence of neoplasia is greater in female dogs than males and distinct differences exist between the frequency of tumour types which develop in the male and female of the species (Moulton 1978). Sex specific neoplasms obviously occur including testicular, prostatic, ovarian and vaginal. The male dog is reported to have higher incidence rates of skin, oropharyngeal and bone malignancies than the female (Dorn et al 1968 (i) and (ii)). Entire male dogs are more prone to the development of perianal gland neoplasms than castrated males and females (Nielson 1964). Dorn et al (1968 (ii)) reported that males had a relative risk of 7.3 compared to females for the development of perianal gland adenocarcinoma. These findings may be related to testicular hormone stimulation causing glandular proliferation in the male. Females have a markedley higher incidence of mammary neoplasia than males; mammary neoplasms accounting for the single most frequent tumour type in the bitch. Dorn et al (1968 (ii)), reported that males comprised only 2.7% of the total canine mammary cancer cases. It is considered that endocrine factors play an important role in the development of canine mammary neoplasia as entire females are reported to be at sevenfold greater risk of mammary tumour development than bitches spayed at less than two years old (Dorn et al 1968 (ii)). The risk apparently reduces with age at spaying, with bitches ovariectomized prior to the first oestrus having 0.5 risk, those ovariectomized after one oestrus having 8% risk and those ovariectomized after two or more oestrous cycles having 26% risk compared to intact females (Dorn et al 1968 (ii), Schneider, Dorn and Taylor 1969). Lipoma has also been reported more frequently in canine females than males (Brodey 1970, Priester 1973).

The incidence of certain canine neoplasms may be influenced by environmental factors. Industrial chemical pollutants, pesticides and herbicides are important potential carcinogens and their effects may be studied in the domestic dog which shares the human environment. A study of canine mesothelioma revealed a statistically significant association between mesothelioma occurrence and asbestos exposure - a previously established relationship in man (Glickman et al 1983).

Tonsillar and lung carcinoma has been reported more frequently in dogs from urban environments suggesting that air pollution may be an important aetiological agent. (Brodey 1961, Cohen, Brodey and Cohen 1964, Brodey and Craig 1965). It is interesting to note that, since the Clean Air Act of 1956, the incidence of canine tonsillar carcinoma recorded at the Royal Veterinary College, London, reduced significantly (Cotchin 1984).

A statistically significant correlation was demonstrated by Hayes (1976), between the incidence of bladder cancer in dogs in certain areas and the industrial activity of these areas. Industrial pollution may, therefore, have been the source of the urinary tract carcinogen.

In view of these observations, the dog may provide a useful sentinel model for the role of human environmental carcinogens, due to its relatively short life span and close association with man's environment.

Further, well designed epidemiological studies of canine spontaneous neoplasia may therefore reveal more, valuable information on the natural history of the disease of veterinary and comparative importance.

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A SHEEP HEALTH SURVEY OF BREEDING SHEEP IN GRAMPIAN & THE BORDERS OF SCOTLAND

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INTRODUCTION

The Scottish sheep industry is facing one of its greatest challenges with the withdrawal of market support through the European Community's Common Agricultural Policy Sheepmeat Regime and with intense pressure from consumers concerned about food, health, nutrition, animal welfare and production methods. Against this background a number of developments have been started with the aim of improving the health and productive performance of the Scottish flock. One area which may offer opportunities for development is that of sheep health schemes for producing and marketing high health status breeding sheep. In order to assess the potential for this development opportunity, two surveys were undertaken in Grampian and the Borders of Scotland. The first survey was aimed at potential lowground breeding sheep purchasers and the second survey was targeted at veterinary practices. This paper compares and contrasts the results of the two surveys.

AIMS AND METHODS OF THE SURVEYS

Survey A - Lowground Breeding Sheep Purchasers

The survey of lowground purchasers of breeding sheep (Survey A) had the following aims:

- To establish flockmasters' attitudes, opinions and practices when purchasing breeding sheep.

- To consider their management approach to sheep health.

- To assess trends in Enzootic Abortion of Ewes (EAE) including farmers' experience, prevention and control methods.

- To measure awareness of health schemes and interest in purchasing high health status breeding sheep.

The survey was carried out by postal questionnaire. The Economics and Statistics Unit of the Department of Agriculture and Fisheries for Scotland (DAFS) prepared a mailing list from their census records. The DAFS also undertook the despatch and receipt of the questionnaire to preserve farmer confidentiality. As an incentive, farmers who sent in completed questionnaires were promised a report on the survey.

Survey B - Veterinary Practices

The aims of the survey of veterinary practices (Survey B) were as follows:

- to determine the policy of veterinary practices on the control and prevention of EAE;

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- to utilise the veterinary practices' experience with sheep health problems to estimate trends in the incidence of EAE;

- to assess current veterinary practice involvement in and attitudes and opinions on sheep health schemes;

- to seek the views of veterinary practices on the future possibilities and requirements for controlling or eradicating EAE.

The survey was carried out by postal questionnaire. The Scottish Veterinary Investigation Service (SVIS) Headquarters provided assistance in the preparation of a mailing list. The assistance of the SVIS Laboratories in Aberdeen and St Boswells was enlisted to refine the target veterinary practices for the survey. The responses were accepted as representing the policy and views of all members of a given veterinary practice. As an incentive veterinary practices completing and returning questionnaires were promised a report on the survey.

The data for both Survey A and Survey B were analysed using the Scientific Information Retrieval Data Base Management Systems analytical package.

RESULTS

Nature of the Survey Samples

Survey A - The number of lowground sheep farmers receiving and returning usable questionnaires is shown in Table 1. The response to the survey was a total of 195 usable questionnaires (63% of the sample). A further 11 survey questionnaires (6 in Borders and 5 in Grampian) were returned without being completed and hence were not suitable for use. Of these questionnaires, 9 respondents gave no reason for non-completion, one declared that they had no breeding sheep and one reported no intention to purchase breeding sheep.

TABLE 1: NUMBER OF LOWGROUND SHEEP FARMERS RECEIVING AND RETURNING USABLE QUESTIONNAIRES BY REGION

Region	No of Farmers Receiving a Questionnaire (A)	No of Usable Questionnaires Returned (B)	Response Rate (B as Percentage of A)
Grampian	206	124	60
Borders	105	71	68
Total	311	195	63

Over three-quarters of all farmers in the survey indicated that they were regular purchasers of breeding sheep (77% in both Grampian and Borders). The majority of farmers (67%) use the auction markets when buying breeding sheep and this is followed by private purchase (only 16%) and purchase through a livestock agent or dealer (only 4%). Only 10% of farmers use more than one method of purchasing breeding sheep and none appear to buy through a livestock marketing group. The total number of breeding sheep purchased annually at auction sales was 13914 (7506 in Grampian and 6408 in Borders).

When classified by age, of all breeding sheep purchased by the farmers, 49% were ewe lambs, 28% were draft ewes, 17% were maiden gimmers and 4% were gimmers which lambed as hoggs.

Survey B - The number of veterinary practices involved in the survey is shown in Table 2 along with the regional breakdown of veterinary practices receiving and returning questionnaires. Usable questionnaires were returned by 67% of veterinary practices in the total sample. The response rate from Borders at 80% was much higher than for Grampian at 62%. The 24 veterinary practices accounted for 94 full-time and 8 part-time veterinary practitioners. All of the Borders' veterinary practices and 38% of those in Grampian indicated that some of their veterinary surgeons are members of the Sheep Veterinary Society. On average, sheep accounts for 23% of the veterinary practices' income and the range is from 10 to 55% for individual practices.

TABLE 2 NUMBER OF VETERINARY PRACTICES RECEIVING AND RETURNING QUESTIONNAIRES BY VETERINARY INVESTIGATION LABORATORY LOCATION

Veterinary Investigation Laboratory	No. of Vet. Practices Receiving a Questionnaire (A)	No. of Usable Questionnaires Returned (B)	Response Rate (B as % of A)
St Boswells	10	8	80
Aberdeen	26	16	62
Total	36	24	67

Trends in the Incidence and Diagnosis of EAE

Farmers and veterinary practices were asked if they had experienced an outbreak of EAE on their farm or if they were aware of EAE outbreaks in their area. A third (32%) of farmers (38% in Borders and 28% in Grampian) had had EAE diagnosed on their farm within the last five years. In contrast all 24 veterinary practices in the survey (100%) had experienced an EAE outbreak in their area. Less than half of the farmers (41% in both Grampian and Borders) consider that the incidence of EAE is rising. Table 3 provides data on trends in the incidence of EAE for both farmers and veterinary practices. The results indicate that a higher proportion of veterinary practices than farmers believe that the incidence of EAE is rising (67% of veterinary practices and 41% of farmers). None of the veterinary practices believe that the incidence of the disease is falling compared to 8% of the farmers. It is noteworthy that 20% of Grampian and 4% of Borders' farmers did not express an opinion on the incidence of EAE.

TABLE 3 TRENDS IN THE INCIDENCE OF EAE FOR FARMERS AND VETERINARY PRACTICES

Region	Rising		Static		Falling	
	Vets. %	Farmers %	Vets. %	Farmers %	Vets. %	Farmers %
Grampian	75	41	25	33	-	6
Borders	50	41	50	45	-	10
Total	67	41	33	37	-	8

Policy on EAE Prevention

Table 4 gives details of the farmers' responses on their policy to prevent an EAE infection. Buying stock from reliable healthy farms, breeding one's own replacements and vaccinating replacements on arrival are the most important elements of the farmers' policy to prevent an EAE infection (39, 38 and 34% of farmers, respectively).

TABLE 4 FARMERS' POLICY ON EAE PREVENTION

Policy Statement	Percentage of Farmers		
	Grampian	Borders	Total Survey
Buy stock from previously reliable healthy farm	38	41	39
Breed own replacements	35	44	38
Vaccinate replacements on arrival	32	38	34
Vaccinate replacements on arrival with repeat injection after 2 years	14	15	14
Isolate replacements until after first lambing period	13	14	13
Buy stock through a health scheme	8	3	6
Become a member of a sheep health scheme	4	3	4
Isolate replacements on arrival and blood test	2	1	2
No action taken	14	13	13

Veterinary practices were asked how they advised farmer clients to prevent an outbreak of EAE in a non-infected flock. The results are shown in Table 5 and have been expressed as indices. The most frequent advice offered to farmer clients is to "buy stock from reliable healthy farms". This advice was given an index of 100 and other forms of advice expressed as indices of 100.

TABLE 5 - VETERINARY PRACTICES' POLICY ON EAE PREVENTION

Nature of Recommendation or Advice	Relative Indices		
	Grampian	Borders	Total Survey
Buy stock from reliable healthy farms	100	100	100
Breed your own replacements	88	88	88
Vaccination	94	76	88
Buy stock through a sheep health scheme	65	71	67
Become a member of a sheep health scheme	65	65	65

Farmers and veterinary practices are agreed that EAE prevention is best achieved by buying from reliable healthy farms, breeding one's own replacements and vaccination. Farmers give a very low priority to buying stock through a health scheme and to joining one. They also give a low priority to the husbandry practices of isolating replacements on arrival at the farm and to blood testing them. On average 13% of farmers take no action to prevent the disease.

As part of their sheep health policy as many as 65% of all farmers carry out health checks prior to purchasing female breeding sheep (70% in Borders and 62% in Grampian). Table 6 provides details of the types of health checks made by farmers. Buying stock from a regular or recommended source is the most frequent health check made and this does correspond to the principal advice being given by veterinary practices. Checks on the previous health history of the breeding stock receives a low score, with "previous vaccination against Clostridial Diseases" at 24% "health status of farm of origin" at 21%, "previous vaccination against Pasteurella" at 17%, and only 10% of farmers act to "determine previous breeding history".

TABLE 6: HEALTH CHECKS CARRIED OUT BY FARMERS ON PURCHASED FEMALE BREEDING SHEEP

Type of Action Taken	Percentage of Farmers		
	Grampian	Borders	Total Survey
Buy stock from a regular or recommended source	39	45	42
Previous vaccination treatment against Clostridial Diseases	19	32	24
Check health status of farm of origin	19	25	21
Previous vaccination treatment against Pasteurella	18	17	17
Determine previous breeding history	10	10	10

Gaps in the Understanding of and Methods for the Control of EAE

Forty-five per cent of veterinary practices believe that there are gaps in current methods available for veterinary surgeons to control EAE. The following is a summarised list of the replies to this open question in Survey B under the headings of Vaccination Gaps and Diagnostic Testing Gaps:

Vaccination Gaps

- the lack of a cost effective vaccine
- difficulties in the interpretation of low titres
- the impossibility of differentiating vaccinated and unvaccinated stock
- the poor efficiency of vaccination
- inadequate methods of serology
- problems with the typing of Chlamydia to improve the efficiency of vaccination

Diagnostic Testing Gaps

- poor understanding of the relative importance of enteric and ophthalmic Chlamydia
- difficulties in the identification of carriers
- problems in the identification of latently infected ewes
- problems in the identification of recently infected stock before lambing
- the inability to diagnose virgin carriers
- gaps in the understanding of methods of transmission
- difficulties in the identification of carrier state
- lack of knowledge of the role of the ram in the spread of the disease
- inability to detect ewes infected but not yet aborted
- inability to detect ewes which subsequently become excreters

Evidently a large number of farmers do not fully understand how to control and prevent EAE. Nearly half (48%) of all farmers feel that there are gaps in their understanding with 40% replying that there are no gaps and 12% not expressing an opinion.

Sheep Health Schemes

Veterinary practices were asked to provide information on sheep health schemes. A total of 19 practices declared that farmers in their area are members of sheep health schemes, with an estimated 429 farmers in some form of sheep health scheme. Local Veterinary Practice Based Health Schemes (231 farmers) and the ADAS Sheep and Goat Health Scheme (166 farmers) account for the majority of these farmers.

Farmers were questioned on their awareness of existing sheep health schemes. A different pattern emerged from that among veterinary practices. The Highlands and Islands Sheep Health Association registers the highest level of awareness (49% of farmers in Grampian and 35% in Borders). Next in order of awareness comes the ADAS Sheep and Goat Health Scheme (14% of all farmers), the Premium Health Scheme (11%) and Veterinary Practice Based Schemes (7%).

High Health Status Sheep

Both farmers and veterinary surgeons in practice have positive attitudes towards sheep health schemes and recognise the potential of high health status sheep as a means of maintaining a healthy flock. A large percentage of veterinary practices believe that sheep health schemes can raise income to the practice (49%). In addition 42% believe that they will have a neutral effect on income. Only 9% see sheep health schemes leading to a reduced income to the practice.

Farmers were asked if they would be interested in purchasing breeding sheep from flocks participating in a health scheme. The findings are presented in Table 7. A large majority of farmers (83% in Borders and 82% in Grampian) are interested in purchasing EAE free breeding sheep. There is also interest, albeit at a lower level, for breeding sheep vaccinated against the Clostridial Diseases (62% Borders; 58% Grampian) and a similar level of interest is expressed in vaccination against Pasteurella (59% Grampian; 56% Borders).

TABLE 7 FARMERS' INTEREST IN PURCHASING HIGH HEALTH STATUS SHEEP (PERCENTAGE OF FARMERS)

Farmers Declaring an Interest	Grampian %	Borders %
Purchasing breeding sheep that are free of EAE	82	83
Purchasing breeding sheep that have been vaccinated against the Clostridial Diseases	58	62
Purchasing breeding sheep that have been vaccinated against Pasteurella	59	56

Veterinary practices believe that the principal advantages of sheep health schemes are "to maintain a healthy flock", "to produce high health sheep" and "to eradicate a disease problem". The other advantages are tightly grouped with the exception of animal welfare which achieves a low index. Table 8 provides data on the relative indices of the advantages of a sheep health scheme as perceived by veterinary practices.

TABLE 8: VETERINARY PRACTICES' PERCEIVED ADVANTAGES OF A SHEEP HEALTH SCHEME

Advantages of a Sheep Health Scheme	Relative Indices
To maintain a healthy flock	100
To produce high health sheep	98
To eradicate a disease problem	95
To improve production	87
To increase producers' awareness of health and health risks	86
To make producers more aware of sources of healthy stock	85
To enhance opportunities for promoting preventive medicine	80
To offer a better service to farmers	78
To improve animal welfare	70

Farmers were asked what proof of health status would be required when buying high health breeding sheep through a sheep health scheme. Table 9 itemises the responses and shows the importance attached to the Scottish Veterinary Investigation Service supervising a health scheme (43% of all farmers). A veterinary surgeon's certificate is next in importance (29% of all farmers), followed by post-sale insurance (21%), identification ear tags (19%) and reputation of the seller (15%).

TABLE 9: FARMERS' REQUIREMENTS OF PROOF OF HEALTH STATUS

Proof of Health Status	Percentage of Farmers		
	Grampian	Borders	Total
Health Scheme to be supervised by the Scottish Veterinary Investigation Service	38	51	43
A veterinary surgeon's certificate	30	27	29
Post-sale insurance	16	28	21
High health identification ear tags	21	17	19
Reputation of seller is sufficient	13	18	15

DISCUSSION

An encouragingly high proportion (58%) of veterinary practices have one or more of their veterinary surgeons as members of the Sheep Veterinary Society. Income from the sheep enterprise is obviously important to the veterinary practices with an average income of 23% and a range of 10 to 55%.

Veterinary practices appear to view sheep health schemes in a positive manner, not as a threat, with just under half of them believing that income can be improved. Nearly a quarter (23%) of veterinary practices are running a local sheep health scheme for their farmer clients.

The majority of lowground sheep farmers (77%) are regular purchasers of breeding sheep and therefore potential customers for high health status breeding sheep. Nearly one third of the farmers had experienced an outbreak of EAE within the last 5 years and the level of experience was higher in Borders than in Grampian. In contrast, 100% of veterinary practices had experienced an EAE outbreak in their area. A greater proportion of veterinary practices, than farmers, believe that the incidence of the disease is rising. In Grampian 75% of practices believe that the incidence is rising compared with 50% in Borders. No practices believe that the incidence is falling compared with 8% of farmers. The results on trends in EAE incidence suggest that the progression of the disease through the regional flock is at a more advanced level in Borders than in Grampian.

Farmers and veterinary practices agree on their policy to prevent an EAE infection. The policy of both groups is based on buying reliable stock from healthy farms, breeding one's own replacements and vaccination. Farmers give a very low priority to other forms of prevention. Veterinary practices on the other hand give a much higher priority to farmers buying stock through a sheep health scheme or to joining one. The fact that 13% of farmers declare that they take no action is a cause for concern and must result in a potential reservoir of infection for other farmers.

Nearly two thirds of all farmers carry out health checks on purchased female breeding sheep. The principal checks carried out are buying stock from a regular or recommended source, determining previous vaccination treatment for the Clostridial Diseases and checking the health status of the farm of origin. Higher proportions of Borders' farmers, on average, undertake health checks and this may be related to the higher level of experience of EAE when compared to Grampian farmers. Relatively few farmers (10% in both Grampian and Borders) check the previous breeding history of purchased female breeding sheep.

Nearly half of both the farmers and the veterinary practices perceive gaps in their knowledge of EAE. For the veterinary practices their main concern is with methods for controlling the disease. The efficiency of vaccination appears to be their main concern as well as a requirement for improvements in serological methods and typing of different strains of Chlamydia. On the subject of diagnostic testing, there is a general requirement for further research into techniques to improve veterinary practices' ability to treat and prevent the disease. Farmers feel that there is a requirement for training and education on EAE control and prevention.

Farmers' awareness of sheep health schemes is good with the highest awareness being registered for the Highlands and Islands Sheep Health Association. The awareness of HISHA was higher in Grampian than Borders reflecting the close proximity of the Highlands and Islands to Grampian Region. Awareness of the ADAS Sheep and Goat Health Scheme, the Premium Health Scheme and veterinary practice based schemes is much lower by comparison. A different pattern emerges among veterinary practices with the ADAS Sheep and Goat Health Scheme registering the highest level followed by veterinary practice based schemes.

Both veterinary practices and farmers view sheep health schemes positively. On the one hand, nearly half of the veterinary practices believe that they can raise income to the practice and on the other, farmers are very interested in purchasing high health status sheep through a sheep health scheme. The principal interest among farmers is for purchasing breeding sheep free of EAE (83% of farmers in Borders and 82% in Grampian). Majorities of farmers are also interested in purchasing breeding sheep vaccinated against the Clostridial Diseases and Pasteurella. Farmers responses to these questions gives strong support to the concept of sheep health schemes and of marketing high health status breeding sheep.

Farmers believe that veterinary practices are crucial to the supervision and authentication of sheep health schemes. Supervision by the Scottish Veterinary Investigation Service is the principal requirement of proof of health status. A veterinary surgeon's certificate is the next most important requirement of proof with 29% of farmers. These findings reinforce veterinary practices' positive view of the future opportunities for sheep health schemes.

CONCLUSIONS

1 Farmers and veterinary practices agree that the incidence of EAE is rising. A higher proportion of veterinary practices in Grampian than Borders believe the incidence is increasing.

2 All of the veterinary practices surveyed have experienced EAE in their area and this compares to 32% of farmers surveyed.

3 Farmers and veterinary practices follow the same prevention policy and this is based principally on buying replacement stock from reliable or regular sources, breeding one's own replacements and vaccination.

4 13% of farmers take no action to prevent EAE infection and are therefore a source of risk to other farmers.

5 An encouraging 65% of farmers undertake health checks on purchased breeding sheep. These checks are consistent with the prevention policy of veterinary practices and farmers in the two surveys.

6 Sheep health schemes are viewed positively by both farmers and veterinary practices. There is strong interest among farmers in purchasing EAE-free breeding sheep and also, at a lower level, in sheep vaccinated against the Clostridial Diseases and Pasteurella.

7 Veterinary practices perceive shortcomings in current vaccination and diagnostic testing methods for controlling EAE and this may pose difficulties in the treatment of the disease in an infected flock.

8 The results appear to suggest that there are serious gaps in farmers' understanding of EAE and that there is an opportunity for veterinary practices to support their clients by providing appropriate training and educational services.

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OBSERVATIONS FROM AN EPIDEMIOLOGICAL STUDY OF TUBERCULOSIS IN A NATURALLY-INFECTED BADGER POPULATION

J W WILESMITH* AND R S CLIFTON-HADLEY*

A national bovine tuberculosis eradication programme was started in the United Kingdom in 1935 following the recommendations of the Gowland Hopkins Committee (1934). This was essentially a 'test and slaughter' policy relying on the intradermal tuberculin skin test to identify infected animals. In addition, there were measures to prevent the spread (eg movement restrictions) and introduction (eg import controls) of the disease. By 1960 attestation in Great Britain was complete, and total eradication from the national herd must have been thought possible. In 1961 only 20 clinical cases were identified compared with over 22,000 cases slaughtered in 1935, and the cumulative reactor incidence was reduced to 0.162%. Although the reactor rate has declined further, in 1989 it was still 0.049%.

A predominance of unexplained cases was noticed in south-west England, a situation now documented over many years (Wilesmith, 1983). The herd reactor rate in the south-west still remains about 12 times that in the rest of the country. This increased risk was correlated with the existence of local badger (*Meles meles*) populations and to some extent with the density of badger setts (Wilesmith et al, 1986; Cheeseman et al, 1989). However, it was not until 1974 that badgers in the UK were described with *Mycobacterium bovis* infection in a survey of 165 carcases from Gloucestershire (Muirhead et al, 1974). Further reports provided additional, circumstantial evidence of a causal association between tuberculosis in badgers and cattle (MAFF, 1976-1990; Little et al, 1982; Cheeseman et al, 1985).

Because of the perceived risk from infected badgers to the national cattle herd, the Ministry of Agriculture, Fisheries and Food initiated a badger control policy for England and Wales in 1975. Essentially, this involved the sampling of local badger populations associated with herd breakdowns where no other cause could be established. If tuberculosis was found, setts in the vicinity of a breakdown were cleared, by gassing using cyanide powder, in a centrifugal fashion in an attempt to establish a so-called 'clean ring' round the original focus of infection.

Considerable animosity was generated against badger control operations, especially with regard to the method of killing. This

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culminated in the Zuckerman report (1980), which suggested that shooting after trapping or snaring should replace gassing. Although these procedures were more labour-intensive, costly and time-consuming than gassing, and were themselves open to criticism on humane grounds, gassing ceased in 1982. Other criticisms detailed in the Zuckerman report (1980) were directed at the policy itself. Chief among these were that many badgers had to be destroyed while assessing whether they were the cause of a particular herd breakdown; that there was no satisfactory diagnostic test that could be applied to the live animal; that many badgers were killed relative to the number found infected. In a further review of MAFF policy (Dunnet et al, 1986), the foundations of the then current policy were reconsidered, and an 'interim' strategy proposed. This reduced the action to be taken when a herd breakdown could not be explained except by badger involvement. Badgers were only to be trapped on the area of a farm where cattle had grazed. It was hoped that this would reduce the numbers of badgers killed without substantially increasing the risk of recurrent breakdowns. It is too soon to assess the success or otherwise of this strategy.

At the inception of the original control policy, badger ecology in its broadest terms was a subject studied more by the enthusiastic amateur naturalist than the analytical scientist. Virtually nothing was known about tuberculosis in badgers and how the disease might be spread to cattle. It was decided, therefore that a major field project should be undertaken involving the study, over several years, of a badger population known to be infected with *M.bovis*. This prospective study started in 1976 and has continued to the present day. The aims of the study initially were twofold:

1) To understand the behaviour and ecology of badgers, with special reference to population dynamics,
2) To understand the epidemiology of *M.bovis* infection in a naturally infected population.

The overall objective of the study was, and still is, to provide quantitative information to assist in evaluating potential methods of bovine tuberculosis control in badgers and cattle.

This paper describes the methodology developed during the study, morbidity and mortality patterns within the badger population, and the properties of a blocking ELISA developed for diagnosing tuberculosis in the live badger.

MATERIALS AND METHODS

Experimental Study Site

The experimental study site is an area of approximately 8km^2 centred on a valley in the Cotswold escarpment region of Gloucestershire in south-west England. Although farming is mixed, beef and milk production predominate. The area has the highest recorded badger density in the country with 20 adult animals per km^2 (Cheeseman et al, 1981). Badger setts are situated mainly in

Cotteswold sand outcrops along the sides of the principal valley.

Ecological methods

Capture-Mark-Release Programme:

Information about badger movements and the spread of *M.bovis* has come from a continuing capture-mark-release programme. Initially, effort was concentrated on social groups identified as containing tuberculous badgers, following a programme of culturing faeces samples collected every two weeks from 'latrines' nearest to main sett entrances. This meant that two areas, cleared in 1978 and 1979 when subject to badger removal operations, were left virtually untrapped until 1987. However, since October 1987 five sectors, including the cleared areas, have been trapped in rotation once every three months.

At first capture, badgers are tattooed on the abdomen and have both ears tagged (Cheeseman & Harris, 1982). They have their sex and year of birth, if cub or yearling, recorded. Where it is not obvious whether a badger is a yearling or adult it is placed in the two-three year old category for the purposes of further calculations. Each badger is weighed, its general condition, degree of tooth wear and reproductive state, if female, noted and its site of capture recorded. Badgers known from the previous sampling to be infected with *M.bovis* are fitted with a radio transmitter by means of a collar (Cheeseman & Mallinson, 1980) to allow regular tracking and retrieval of carcases for post mortem examination.

Ageing badgers:

Date of birth has been taken as the 1st January of the year of birth. Badgers caught as cubs (0-1 yrs old) and yearlings (1-2 yrs old) are referred to as 'known-age' badgers. Their ages throughout the study period can be calculated accurately within the constraints of assumed date of birth within the birth year. If a badger is not caught for the first time as a cub, it is sometimes difficult to determine whether it is a large yearling or a small adult. Where there is doubt, badgers have been classed as adults (>2yrs old) and given a year of birth two years prior to that of the date of first capture and a birth date of the 1st January of that year.

Clinical sampling and post mortem examination

Serological examination:

Since 1981 blood samples have been taken from all captured badgers unless there have been contraindications, eg cubs too small at first capture. Sera from these blood samples now form a unique badger sera bank. This bank has provided raw material for the development and validation of the ELISA described in this study.

Bacteriological examination:

Faeces and urine samples, tracheal aspirates, swabs from bite wounds, abscesses and other external, suppurating injuries, and aspirates from unruptured abscesses and swollen lymph nodes are cultured using standard techniques for *M.bovis* isolation (Marks, 1976; Gallagher & Horwill, 1977).

Post mortem examination:

Any badgers found dead as well as those killed *in extremis* for humane reasons have their last location noted and are subjected to post mortem examination. A cause of death is ascribed where possible. Tissues with gross lesions typical of tuberculosis are examined histologically. Samples from all lymph nodes and from viscera form separate pools for bacteriological examination.

Monoclonal Antibody Blocking ELISA Test (BELT)

The enzyme-linked immunosorbant assay (ELISA) investigated in this study has been developed by staff at CVL in response to the perceived need for a test to detect *M.bovis* infection in the live badger (Dunnet et al, 1986). It is a blocking ELISA which relies for its specificity on a monoclonal antibody which binds to *M.bovis*. Sera are tested against standardised controls and three categories of results are defined depending on the extent of blocking that occurs: negative, inconclusive or positive. A positive result indicates the presence of anti-*M.bovis* antibodies in the test serum which have bound to the monoclonal antibody binding sites in the crude *M.bovis* extract attached to the ELISA plates.

Data Analyses

i) Woodchester Park Database:

Capture, sampling and culture data are stored on a database designed and created in-house by staff at CVL on Prime Information (Prime Computer,Inc., Framingham, Massachusetts).

ii) Prevalence:

The yearly period prevalences of *M.bovis* infection from 1981-1990 were estimated separately for cubs, yearlings and adults. The numerator included each badger with a positive culture result from the year of detection to the year of death. The denominator comprised all known-age badgers, and all badgers caught for the first time as adults, from the year of first capture until the year of last capture, including the years when not caught if there was a subsequent capture.

iii) Sensitivity and specificity of the BELT:

The BELT was applied to 2277 serum samples collected from 636 badgers between 1981 and 1989. A badger's BELT status was compared with its *M.bovis* status. BELT status was taken as positive following one positive result, regardless of previous or subsequent BELT results. Inconclusive results were treated as negative. A badger's *M.bovis* status was determined from its clinical sampling history and any post mortem findings. If any clinical sample from a badger yielded *M.bovis* on culture, that badger was considered infected, whatever its subsequent sampling history.

iv) Incidence rates:

Incidence rates for seroconversion and for *M.bovis* infection by age group were calculated. Rates are given per 1000 badger-months-at-risk (bmar). Sex of animal was considered to be a variable of interest.

a) Incidence calculated from BELT results.
Analyses used only known-age badgers with one or more BELT results. The entry date was the calculated date of birth or 1st January 1981, whichever was the later. The exit date for BELT-negative animals was the date of last negative result, and for BELT-positive animals this was either the date halfway between the first positive result and the previous negative result or, if there were no previous negative results, the date halfway between the date of birth and the positive result. If this produced a date prior to 1st January 1981 then 1st January 1981 was taken as the entry date. Again, inconclusive results were treated as negative.

b) Incidence calculated from *M.bovis* culture results.
Analysis was confined to known-age badgers where clinical samples had been taken and/or a post mortem performed, whatever the year. The date of entry was 1st January 1981 or the calculated date of birth, whichever was the later. For those badgers ever *M.bovis*-positive, the date of exit was either the date halfway between the date of birth and the first positive result or the date halfway between the positive result and the previous negative sampling. Those badgers *M.bovis*-positive prior to 1st January 1981 would not enter the study. For *M.bovis*-negative badgers, the exit date was the last negative result (whether from clinical samples or post mortem examination).

v) Comparison of mortality rates by a)BELT and b)*M.bovis* status:
Only known-age badgers were included in the analyses. Badgers were categorized as 'alive' if their last capture date was within two years of 1st January 1990, 'dead' if a post mortem examination had been performed, or 'missing' if the previous capture was two years or more before 1st January 1990.

The entry date was their calculated date of birth. The exit date was either the date of death (ie when the carcase was found) or, if classified as 'missing', the date halfway between the last sample date and the date of receiving the 'missing' classification, or, if classified as 'alive', the 1st January 1990. The status of each badger at exit from the study was either 'alive' or 'dead', with 'dead' including both those badgers with a post mortem result and those classified as 'missing'. Summary relative risk measures adjusted for age were derived using the method of Mantel and Haenszel (1959). Badgers with one or more inconclusive BELT result and no positive result were excluded from the BELT analysis.

RESULTS AND DISCUSSION

The overall prevalence of infection from 1981-1989 in badgers with BELT results is summarised in Table 1.The properties of the BELT were assessed using culture results as the gold standard (Table 2). The overall test specificity was 95.4%, and sensitivity was 43.8%. The predictive value of a positive test was 43.8%.

Table 1. Prevalence of *M.bovis* infection

	Number	Positive	Prevalence (%)
Cubs	190	9	4.7
Yearlings	142	12	8.4
Adults	304	27	8.9
Total	636	48	7.5

Table 2. Properties of the BELT

		M.bovis status		
		+ve	-ve	TOTAL
BELT status	+ve	21	27	48
	-ve	27	561	588
TOTAL		48	588	636

Changes in properties according to age group are summarised in Table 3. The low prevalence in the cub age group, despite the fact that sensitivity of the test was highest in this category, provided the lowest predictive value of a positive test, 35.7% compared to 50.0% in adults.It also increased the relative number of false positives.

Table 3. Properties of the BELT by age group

	Cubs	Yearlings	Adults
Sensitivity (%)	55.6	50.0	37.0
Specificity (%)	95.0	93.8	96.4
Predictive value of +ve test (%)	35.7	42.9	50.0

The lead time to diagnosis, using the BELT, in infected animals which were subsequently culture-positive at post mortem examination was reduced compared to that based solely on culture results. This is potentially important on two counts. Firstly, the test would prove useful in earlier identification of animals of particular interest in the study of badger tuberculosis epidemiology. These animals could be followed more closely and sooner than is possible at present. Secondly, there are important implications for the control of badger tuberculosis, since early detection of infection would decrease *M.bovis* excretion time and, hence, the amount and geographical extent of environmental contamination. The prospective study of more animals are required to confirm this finding.

Crude prevalences of seroconversion and infection are summarized in Fig.1. Temporal trends in BELT-positive rates appear to precede similar trends in *M.bovis* infection rates. If a positive test result is taken as a proxy for *M.bovis* infection, then the continued increase in the epidemic curve seen in 1990 could have been predicted.

Further examination of the BELT results suggest that two other groups of animals should be followed with particular attention. Firstly, there were 27 badgers which were test-positive but culture-negative. Only two of these animals had been examined at post mortem, both with negative results. It is important for the specificity of the test to show that animals which seroconvert are infected and remain so. Six of these 27 badgers are still alive and special efforts to retrieve their carcases will be made. The other group of particular interest were eight badgers, four being cubs, which were test-positive and subsequently became sero-negative (Table 4). It is important to follow these animal's fluctuating antibody levels to see if they are truly uninfected or if at a later date they become *M.bovis* excretors. In very young cubs, the question of passive immunity from maternal antibody transfer may have to be explored.

Table 4. Test histories subsequent to seroconversion

	Age at first BELT+ve result			
	cub	yearling	adult	TOTAL
No subsequent tests	4	4	11	19
Further tests all +ve	4	6	6	16
Next test +ve,[a]I/R or -ve, then all negative	4	2	2	8
Subsequent tests I/R	1	1	0	2
Subsequent tests -ve then +ve again	1	0	1	2
Next test I/R, then +ve	0	1	0	1
TOTAL	14	14	20	48

[a]I/R = inconclusive reactor

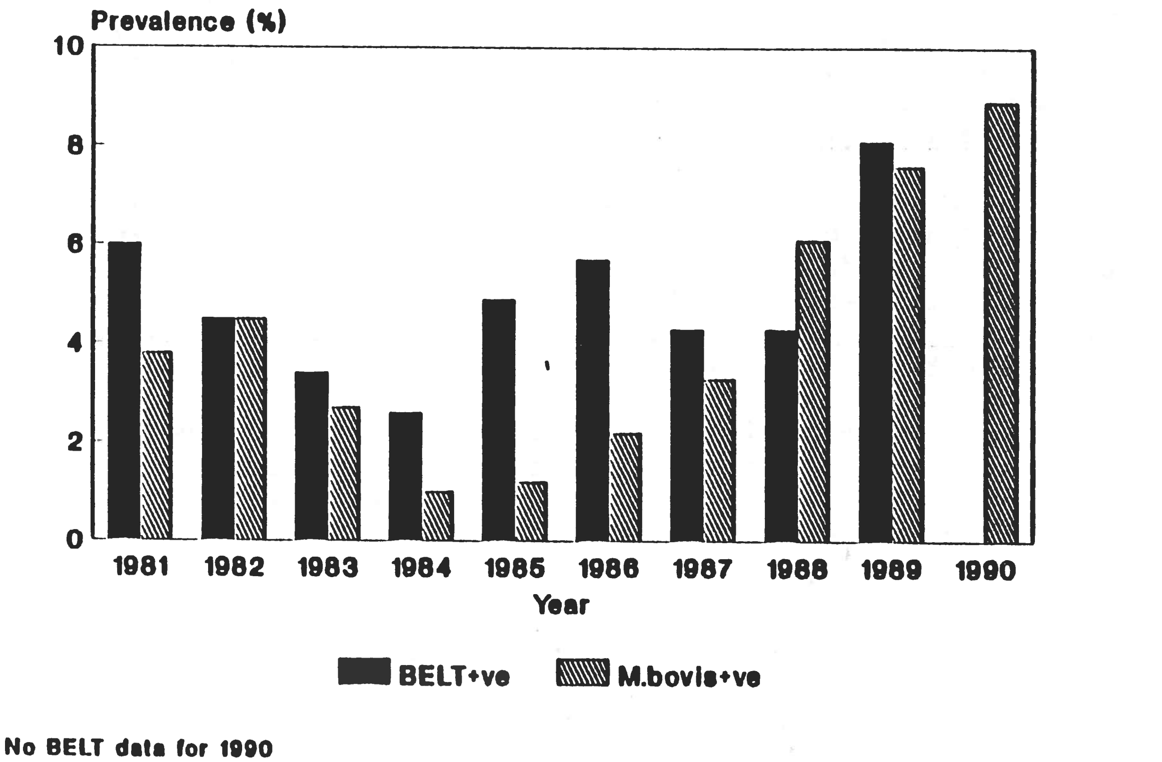

Fig.1 Yearly prevalences of seroconversion and *M.bovis* infection

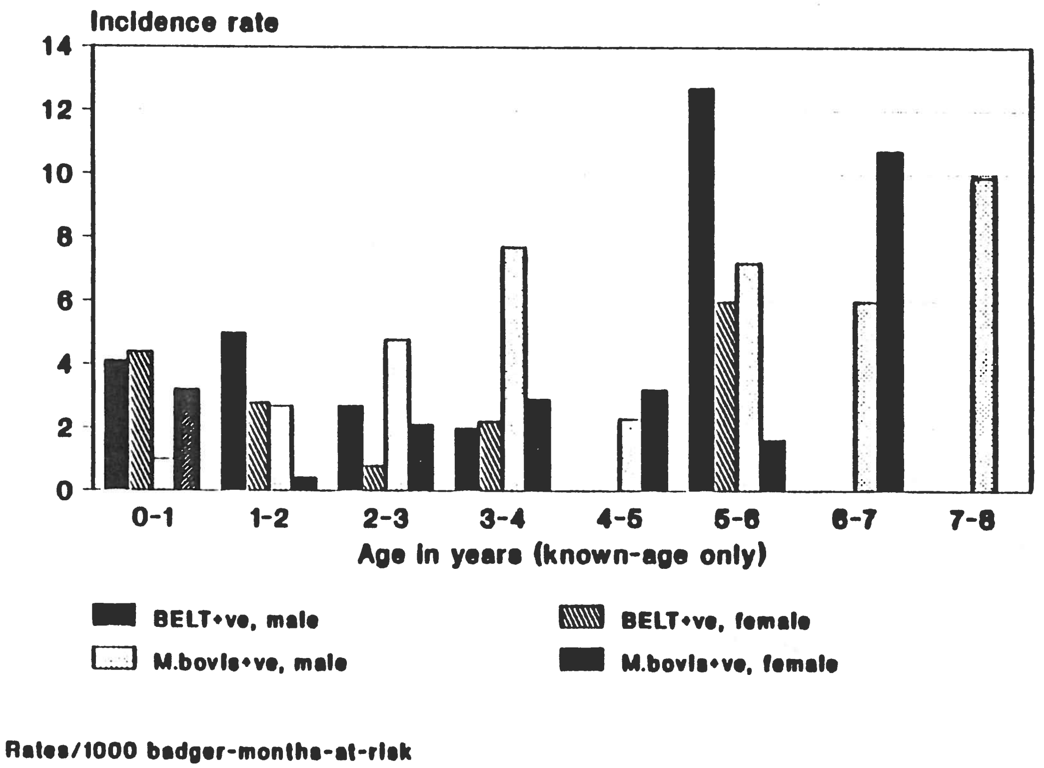

Fig.2 Incidence rates of seroconversion and *M.bovis* infection

As with infection, test-positive incidence rates were generally greater in males than females, except as might be expected in cubs, where there was no differential (Fig.2). This difference in infection rates has been commented on before (Cheeseman et al, 1988) and probably reflects behavioural differences. However, the importance of the infected female should not be overlooked when considering transmission of infection to cubs. Previous estimates of pre-capture mortality rates in cubs suggest that the rate increases as the prevalence of tuberculosis infection at the site rises. This aspect of infection dynamics will be investigated further.

Comparison of mortality rates between test-positive and -negative badgers and between *M.bovis*-positive and -negative badgers suggests no overall difference (Table 5). However, when age group is considered, the rates in cubs and yearlings perhaps point to an advantage, or at least no disadvantage, for the test-positive or *M.bovis*-positive animals, whereas the opposite may be true in 3-5 year old badgers (Fig.3). Seroconversion in the younger groups may indicate a successful response to challenge, whereas in older animals it might just reflect infection. How important *M.bovis* is in cub pre-capture mortality remains an unanswered question.

Table 5. Mortality rates by i) BELT and ii) *M.bovis* status

	BELT status		*M.bovis* status	
	+ve	-ve	+ve	-ve
Unadjusted [a]mortality rate, 1981-1989				
a) all	11.4	12.3	15.4	15.2
b) females	12.2	11.1	14.7	13.7
c) males	10.6	13.9	16.2	17.4
Unadjusted rate ratio				
a) males : females (95% CI)	0.87 (0.37-2.05)	1.25 (0.97-1.61)	1.10 (0.54-2.22)	1.27 (1.02-1.59)
b) BELT +ve : -ve	0.93		-	
c) M.bovis +ve : -ve	-		1.01	
Mantel-Haenszel age-adjusted rate ratio (95% CI)	0.88 (0.56-1.37)		0.96 (0.66-1.39)	

[a]Mortalities/1000 badger-months-at-risk

This prospective study has presented various problems for the epidemiologist, principally related to the study species and its lifestyle. Sampling is not comprehensive, since not all animals will be captured at each sampling. Capture efficiency can easily be disrupted on particular sampling dates just by the vagaries of

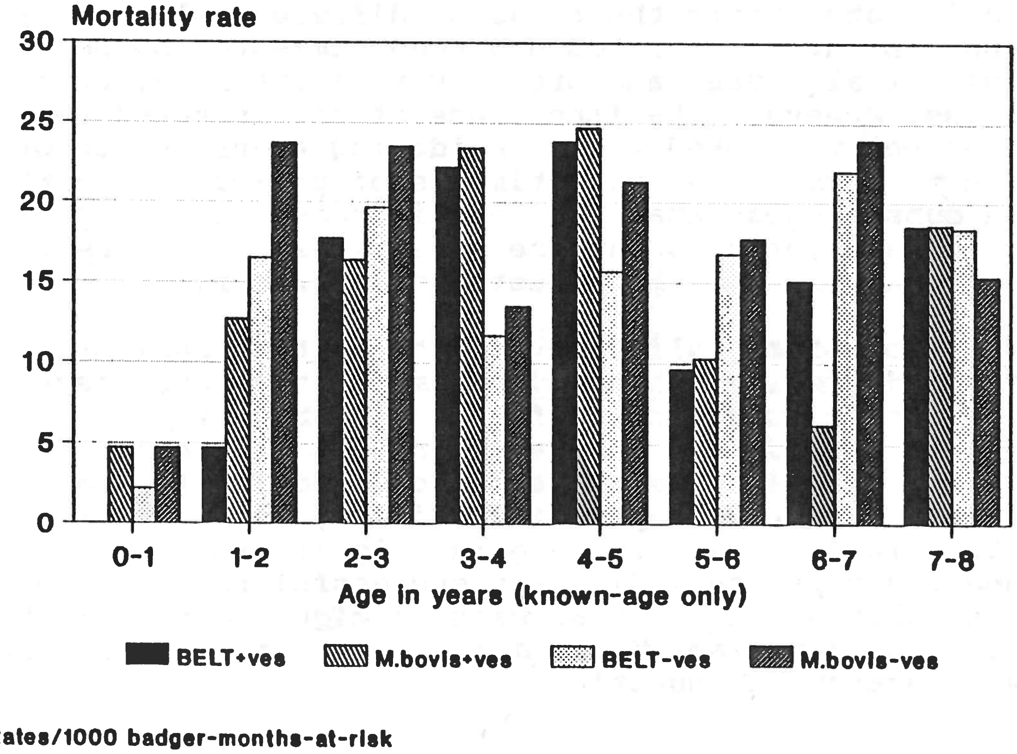

Fig.3 Mortality rates by BELT and *M.bovis* status

the weather and for individual animals by their movement within the field site and their behaviour towards trapping. Although badgers live within social groups, this does not preclude large movements across social group boundaries and in and out of the study area, amounting to migration, a classic cause of loss to follow-up in human studies.

With badger studies, various causes of death apart from those resulting from tuberculosis, eg road traffic accidents, and trap-shyness, are additional, major causes of loss to follow-up, and each is a potential source of bias. Two other categories of badger could result in sampling bias. Firstly, in animals found dead at the site without a previous capture record tuberculosis has a greater prevalence (14.8%) than in groups with capture records. Secondly, live, known-infected badgers are radio-tagged at subsequent capture so that their movements can be monitored. The heightened surveillance of these animals results both in a more precise date of death and in a greater likelihood of post mortem examination. Observation time contributing to mortality rates will be influenced with a tendency to increased rates in tagged animals.

No valid means of ageing badgers, such as from long bone epiphyseal closure, lens weight and histology of teeth, has been established. There is consequently an unresolvable source of error should yearlings be wrongly classified as adults at first capture. Also, animals first caught as adults cannot be attributed a known age. In the initial years of the study it was inevitable that most animals would be first caught as adults.

However, with the passage of time and the improvement in trapping efficiency, the number and proportion of animals first caught as adults has become negligible, but there will be a certain loss of data from earlier years in age specific analyses.

Finally, the study is concerned with a high density population. There is some evidence that the ecology of low badger density populations may be different particularly with respect to movement ranges of badgers and the rigidity of the social group territories. Such differences may have a bearing on the dynamics of infection (Wilesmith et al, 1986). However, there is some corroborative evidence on test performance from its application to samples from badgers killed in statutory removal operations.

Further analysis of existing and prospective results is required so that the effects and dynamics of tuberculosis within and between social groups can be determined. The effects of badger removals on adjacent social groups, recolonization and reintroduction of tuberculosis after badger removal operations can now be studied after the accrual of more than ten years' results. Understanding of these two points is fundamental to developing a rational strategy of tuberculosis control involving the use of a 'live' diagnostic test.

In conclusion, the epidemiological and ecological data derived from the project have to a great extent fulfilled its original aims. However, the continued evolution of badger control policy makes the overall objective of the project, namely to provide quantitative information to assist in evaluating potential methods of bovine tuberculosis control in badgers and cattle, as valid now as at the project's inception.

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SOCIETY FOR VETERINARY EPIDEMIOLOGY AND PREVENTIVE MEDICINE

APPLICATION FOR MEMBERSHIP

Name ....

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I wish to be elected to membership of the Society for Veterinary Epidemiology and Preventive Medicine.

Signed ....

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INTEREST GROUPS

Please tick the appropriate boxes to indicate your interests:

- ☐ Computing, including data-logging
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- ☐ The economic effects of disease on animal production
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Please send this form to the Society's Secretary:

J.M. Booth
Milk Marketing Board
Veterinary Laboratory
Cleeve House
Lower Wick
Worcester
WR2 4NS

The annual subscription is £10.

SOCIETY FOR VETERINARY EPIDEMIOLOGY AND PREVENTIVE MEDICINE

CONSTITUTION AND RULES

NAME

1. The society will be named the Society for Veterinary Epidemiology and Preventive Medicine.

OBJECTS

2. The objects of the Society will be to promote veterinary epidemiology and preventive medicine.

MEMBERSHIP

3. Membership will be open to persons either actively engaged or interested in veterinary epidemiology and preventive medicine.

4. Candidates for election must return a completed application form. The Secretary will then circulate the names of candidates on the agenda for the next general meeting. Election of candidates will be by a simple majority vote of members present at the general meeting.

5. Non-payment of subscription for six months will be interpreted as resignation from the Society.

OFFICERS OF THE SOCIETY

6. The Officers of the Society will be President, Senior Vice-President, Junior Vice-President, Honorary Secretary and Honorary Treasurer. Officers will be elected annually at the Annual General Meeting, with the exception of the President and Senior Vice-President who will assume office. No officer can continue in the same office for longer than six years.

COMMITTEE

7. The Executive Committee of the Society normally will comprise the officers of the Society and not more than four ordinary elected members. However, the Committee will have powers of co-option.

ELECTION

8. The election of office bearers and ordinary committee members will take place at the Annual General Meeting. Ordinary members of the Executive Committee will be elected for a period of three years. Retiring members of the Executive Committee will be eligible for re-election. Members will receive nomination forms with notification of the Annual General Meeting. Completed nomination forms, including the signatures of a proposer, seconder, and the nominee, will be returned to the Secretary at least 21 days before the date of the Annual General Meeting. Unless a nomination is unopposed, election will be by secret ballot at the Annual General Meeting. Only in the event of there being no nomination for any vacant post will the Chairman take nominations at the Annual General Meeting. Election will be by simple majority of members voting at the Annual General Meeting. Tellers will be appointed by unanimous agreement of the Annual General Meeting.

FINANCE

9. An annual subscription will be paid by each member in advance on the first day of May each year. The amount will be decided at the annual general meeting and will be decided by a simple majority vote of members present at the annual general meeting.

10. The Honorary Treasurer will receive, for the use of the Society, all monies payable to it and from such monies will pay all sums payable by the Society. He will keep account of all such receipts and payments in a manner directed by the Executive Committee. All monies received

by the Society will be paid into such a bank as may be decided by the Executive Committee of the Society and in the name of the Society. All cheques will be signed by either the Honorary Treasurer or the Honorary Secretary.

11. Two auditors will be appointed annually by members at the annual general meeting. The audited accounts and balance sheet will be circulated to members with the notice concerning the annual general meeting and will be presented to the meeting.

MEETINGS

12. Ordinary general meetings of the Society will be held at such a time as the Executive Committee may decide on the recommendation of members. The annual general meeting will be held in conjunction with an ordinary general meeting.

GUESTS

13. Members may invite non-members to ordinary general meetings.

PUBLICATION

14. The proceedings of the meetings of the Society will not be reported either in part or in whole without the written permission of the Executive Committee.

15. The Society may produce publications at the discretion of the Executive Committee.

GENERAL

16. All meetings will be convened by notice at least 21 days before the meeting.

17. The President will preside at all general and executive meetings or, in his absence, the Senior Vice-President or, in his absence, the Junior Vice-President or, in his absence, the Honorary Secretary or, in his absence, the Honorary Treasurer. Failing any of these, the members present will elect one of their number to preside as Chairman.

18. The conduct of all business transacted will be under the control of the Chairman, to whom all remarks must be addressed and whose ruling on a point of order, or on the admissibility of an explanation, will be final and will not be open to discussion at the meeting at which it is delivered. However, this rule will not preclude any member from raising any question upon the ruling of the chair by notice of motion.

19. In case of an equal division of votes, the Chairman of the meeting will have a second or casting vote.

20. All members on election will be supplied with a copy of this constitution.

21. No alteration will be made to these rules except by a two-thirds majority of those members voting at an annual general meeting of the Society, and then only if notice of intention to alter the constitution concerned will have appeared in the notice convening the meeting. A quorum will constitute twenty per cent of members.

22. Any matter not provided for in this constitution will be dealt with at the discretion of the Executive Committee.

April, 1982
Revised March, 1985; April, 1988