Veterinary Epidemiology: Principles and Methods

Part 4: Applied Epidemiology
Chapter 10: Rationale, Strategies, and Concepts of Animal Disease Control

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CHAPTER 10

Rationale, Strategies, and Concepts of Animal Disease Control

The primary objective of epidemiologic studies is to provide data on which rational decisions for the prevention and control of disease in animal populations can be based. To this end, a number of concepts and specific methods have been presented for the investigation and understanding of disease in animal populations. In this chapter, examples of the application of these concepts and methods of disease control planning and evaluation will be described.

In pursuing these applications, the reader should be aware that only recently have quantitative epidemiologic methods been used, in a formal, explicit sense, by veterinarians outside government or research agencies. Nonetheless, with the increasing emphasis on preventive population medicine, particularly in the areas of veterinary public health and domestic animal practice, all veterinarians will require increased training in epidemiology. Certainly the authors of this text agree with the editor of the *American Journal of Public Health* and believe that, "Without epidemiology, there can be no scientific basis for public health practice, and without public health practice, the science of epidemiology becomes a meaningless academic practice" (Rosen 1972). It is hoped the readers can excerpt, from the applications presented, those ideas and methods necessary to enhance and elevate their abilities as preventive health care specialists.

10.1 Influence of Disease on Animal and Human Populations

In general terms, veterinarians are interested in the control of animal disease because they have a concern for the welfare of both animal and human populations. In fact, as Schwabe (1984) indicates, the major unifying feature of many diverse veterinary activities is their central and ultimate concern for human health. A complete assessment of the value of disease control measures necessitates an understanding of the ways that disease influences animal welfare, animal productivity, and its direct and indirect impact on humans. Without such information, the benefits of a control program cannot be readily determined. Therefore, before proceeding with a discussion of disease control strategies, a brief overview of the effects of disease is warranted.

10.1.1 Mortality

Premature death of animals is an obvious result of disease and has a pronounced effect on the productivity of animal populations. In intensive agriculture, the costs of mortality are greatest when animals of high genetic potential die during their peak reproductive years. Less concern has been evidenced about the cost of death in older animals; this is particularly true in domestic animals since the majority of these animals are culled to make room for more productive younger animals long before the human equivalent of old age occurs. In many third world countries where animals are depended on for transportation and agricultural power as well as food, mortality can have devastating effects both for individual families and for entire countries (Schwabe 1984, pp 17–22). In North America, considerable losses in young animals have been tolerated by animal owners for a number of years (witness the 20% death loss in female dairy calves in California), although it is hoped neonatal death losses can be reduced as more effective (biologically and economically) prophylaxis becomes available (Martin et al. 1975). Indicating the magnitude of the economic losses caused by mortality may provide sufficient incentive for the producer to more rigorously institute effective procedures to reduce mortality (Martin and Wiggins 1973).

10.1.2 Reduction in Yield and Quality of Product

The negative effects of ill health on the welfare of animals should be obvious to all. In addition, a number of studies have been conducted to quantify the influence of various diseases on the efficiency of production and the yield and quality of products derived from various animal species. Where intensive agriculture is practiced, decreases in one or more of these three aspects of animal "output" are now regularly used as indicators that one or more diseases or production problems may be present (Kaneene and Mather 1982). In fact, except in companion animals, these negative effects of disease on productivity are often the primary motivation for preventing and/or treating disease. Beyond these impacts of disease, it must be appreciated that the health of animals, particularly if they are pets, can have significant impact on the mental and physical health of man. Unfortunately, in many developing countries, losses from disease are often accepted as fixed costs of production, and neither individuals nor governments may be motivated to initiate adequate control measures.

For many diseases, the effects on quality are reflected in a lower market price for the animal or its product(s). In other cases the effect is not detected by the marketing process, although the consumer suffers a real loss. For example, bovine mastitis reduces both the amount of milk produced per animal and its quality (i.e., composition of the final product) (Philpot 1967). This results in less efficient production, a shortened productive life for the cow, and a reduced income for the producer. As a further example, the impact of trematode infection in sheep has been studied in some detail in recent years (Hawkins and Morris 1978) and a substantial depression in weight gain and wool growth, as well as in the quality of wool, has been demonstrated.

Increased knowledge has been gained regarding the underlying mechanisms by which disease reduces the productivity of the host (Roseby 1973). Disease may result in decreased feed intake, either as a direct result of decreased appetite or indirectly because of a reluctance of animals to forage (e.g., because of discomfort associated with movement, including prehension) and/or reduced feeding time (e.g., because of time spent rubbing to relieve itching). Other reductions in productive efficiency may be the result of a lowered efficiency of feed conversion due to depressed nutrient absorption or altered physiological processes resulting in lowered nutrient utilization.

A number of diseases also result in a reduced value of animals or their products at market (e.g., abscessed livers in swine and feedlot cattle, condemned carcasses because of septicemias, or decreased value of hides due to *Hypoderma bovis* infection). Other diseases influence the reproductive performance of animals; some dramatically (e.g., abortion resulting from *Brucella abortus*), whereas others have more subtle effects (e.g., delayed conception and increased health care costs due to postparturient reproductive diseases).

10.1.3 Herd Structure and Productivity

In addition to the cumulative effects of lowered individual animal productivity, there are a number of ramifications of disease that can be assessed only at the herd level. These effects generally relate to the demography (particularly the age structure) of the population. If, as the result of disease, there is a high rate of premature death or involuntary culling, the herd will often have a lower than average age. In the case of a dairy herd this may have a negative effect on productivity, because the diseased animals will not remain in the herd long enough to achieve their full genetic production potential (this occurs at approximately the fifth lactation). Another effect of the high rate of culling is the increased demand for, and hence cost of, replacement animals. The latter cost includes not only the purchase price but the increased risk of introducing disease with replacement stock. Coupled to these effects is the lowered ability to recognize and select animals of superior genetic merit (i.e., animals in the herd may not be able to express their full potential). Others could argue this is a form of natural selection in that although these animals may not be able to express their full productive potential, they may be expressing their lack of resistance to disease. Unfortunately this may be a very inefficient way of increasing the resistance of animal populations, and it also tends to reduce rather than increase productivity. In any event, production and disease should not be studied in isolation. It is encouraging to see studies being initiated by animal geneticists and veterinarians to evaluate genetic resistance to disease in concert with production potential.

10.1.4 Human and Animal Welfare

Zoonotic disease can and does directly affect human health (Schwabe 1984). Such diseases lead to human hunger, pain, and suffering, particularly in areas where medical care is not well developed. As well, animal disease can lead to decreased availability of animal products, decreased availability of animals for transportation, farm power, clothing and shelter, and even dung for fuel. In addition, using various chemicals to combat animal disease can result in residues in animal products or the environment that may directly affect human health (e.g., anaphylactic reaction to antimicrobial residues) or indirectly influence it via changed (usually increased) antibiotic resistance patterns. For further discussion of this, refer to Schwabe and Ruppanner (1972), Derbyshire (1982), and Schwabe (1984).

10.2 Methods of Disease Transmission

An examination of the methods by which disease transmission may most frequently occur is basic to an understanding of disease control. In this context, the terms "carrier" and "reservoir" require clarification.

A carrier is an infected animal that sheds pathogenic or potentially pathogenic organisms, yet remains clinically normal. Carriers have obvious epidemiologic significance as sources of infection, and they are more difficult to detect than the clinically diseased individual.

Reservoir is usually restricted to an animal species or inanimate substance upon which the organism depends for its survival. For example, the fox is a major reservoir of rabies in Canada and continental Europe; whereas the reservoir of *Histoplasma capsulatum* appears to be bird feces or soils enriched by bird feces. Many infectious agents have more than one reservoir. Other reservoir hosts of rabies in Canada include the skunk and certain species of bats. *Taenia saginata*, a cyclozoonosis, requires two reservoirs—man and cattle—to complete its life cycle.

The three common methods of transmission of infectious agents are contact, vehicle, and vector spread. Contact transmission includes direct and indirect means. Direct contact transmission denotes physical contact between the infected and susceptible individuals (e.g., venereal disease and rabies). Indirect contact transmission denotes contact between the infected and susceptible individual by means of fresh secretions (e.g., leptospiral organisms in urine), recently contaminated objects (e.g., water bowls), or by means of aerosol droplets resulting from coughing or sneezing. As mentioned earlier, contact with recently infected objects in the home, school, or workplace may be a more important means of transmitting human rhinovirus infection than aerosol transmission (Gwaltney and Hendley 1982). Knowledge that smallpox was spread primarily by direct contact was of great value in eradicating the disease. By complete traceback of a case's activities, it was possible to identify the initial source and to isolate and/or vaccinate potential cases.

Vehicle transmission of infectious agents involves inanimate substances (e.g., food, water, dust, and fomites). Vehicular transfer can be mechanical, the vehicle simply acting as a physical transfer mechanism (e.g., truck tires contaminated with foot-and-mouth disease virus and poultry feathers contaminated with Newcastle disease virus), or biological (multiplication or development of the agent takes place in the vehicle). An example of biological transfer would be the transmission of bacteria in milk. Vehicle transmission plays a significant role in the transmission of both endemic and exotic infectious agents, such as in *Mycoplasma gallisepticum* epidemics in poultry (Johnson et al. 1983).

Vector transmission denotes invertebrates that carry infectious agents between vertebrates. Again, such transmission can be purely mechanical (e.g., a "flying needle," such as mosquito transmission of equine encephalitis virus) or biological (e.g., the development of the larval stages of the dog heartworm, *Dirofilaria immitis*, usually in members of the Culex species of mosquitos; such development must occur for the larvae to become infectious to animals or man).

Two other terms applied to the transmission of disease are horizontal and vertical transmission. Horizontal transmission refers to the passage of infectious agents between animals of a similar generation and can occur by any of the methods previously discussed. Vertical transmission, on the other hand, means transmission from one generation to the next; this can be accomplished transovarially, in utero (e.g., *Toxocara canis* infection from the bitch to her pups), or via colostrum (e.g., bovine leukemia virus transfer from the cow to the calf). Often the distinction between methods of spread is arbitrary; nonetheless it is useful for descriptive purposes. For example, cows shedding salmonella in their feces or milk, or cows shedding parainfluenza viruses from their respiratory tract can vertically transmit these organisms to their offspring at or soon after birth. Such transmission could also be classified as contact transmission, if direct, or vehicular, if indirect.

10.3 Disease Control Strategies

Three terms are generally used in association with disease control activities: prevention, control, and eradication.

Prevention was discussed in a holistic sense in 1.2. In its restricted usage, it is generally applied to those measures designed to exclude disease from an unaffected population. This applies both to measures to exclude infectious agents from defined geographic areas (e.g., by quarantine), or to protect a given population in an infected area (e.g., by vaccination). Prevention can be applied at either the individual or the population level.

Control describes efforts directed toward reducing the frequency of existing disease to levels biologically and/or economically justifiable or otherwise of little consequence. Control implies activities conducted at the population level. With a number of endemic diseases (such as mastitis and enteritis), and assuming there are no welfare considerations, there may be a level of disease in the population below which the cost of further expenditure on control would be greater than the benefits derived.

Eradication describes efforts to eliminate selected organisms from a defined area. These efforts usually are directed toward interfering with the natural history of an infectious organism so as to make its perpetuation unlikely if not impossible. The scale of eradication can be local (e.g., farm level), national, or global. The general features of a disease that make it susceptible to eradication are discussed elsewhere (Yekutiel 1980). These features include: the disease must be of sufficient detriment that eradication is economically justifiable; the disease should have features that enhance case detection and surveillance; and there should be at least one tool that is effective in halting disease transmission.

Specific activities used in preventing, controlling, or eradicating disease may be used either singly or in combination.

10.3.1 Slaughter

This is the deliberate killing of infected, potentially infected, or contact animals in an attempt to "stamp out" disease and prevent it from spreading to a healthy population. This can be done selectively (on an individual animal basis) or by complete depopulation (on a herd/flock or area basis). Directed activity known as selective slaughter has been used in a number of campaigns against animal disease. This involves a method of case finding, usually by means of an immunologic screening test, and then the killing of test-positive animals; hence the name "test and slaughter." The characteristics of the screening test (3.7) play a major role in the effectiveness of this method, and there may be a need to reassess the efficacy (i.e., sensitivity and specificity) of the test as the prevalence of disease changes.

Selective slaughter may be used in early control efforts, particularly if the agent spreads very slowly. Selective slaughter was used extensively in the initial phases of many bovine brucellosis eradication programs. It is less disruptive than nonselective depopulation particularly if the disease is reasonably common. Depopulation is a more extreme situation, in which the whole population, including noninfected as well as infected individuals, is sacrificed. This may be applied to wild reservoir populations as well as domestic species. All swine were slaughtered during eradication efforts against African swine fever in the Dominican Republic (Chain and Rodriquez 1983). Depopulation tends to be favored over selective slaughter if the disease agent is exotic to the area or spreads rapidly, as well as in the terminal stages of eradication schemes. In North America, depopulation is often used when a herd is found to be infected with bovine tuberculosis. In this situation, it is most important that the surveillance program identify infected herds, the actual level of disease in the herd being of lesser importance.

10.3.2 Quarantine

Quarantine implies the enforced physical separation from the healthy population of infected or potentially infected individuals, their products, or items they may have contaminated. Such measures may be applied at the national, regional, or herd level, and they may be voluntary or required by legislation. For example, imported cattle are usually placed in quarantine stations for a defined period (usually the maximum incubation period) prior to being transferred to the property of the purchaser, to ensure (by clinical and/or serologic monitoring) that they are not infected with undesirable agents such as the virus of foot-and-mouth disease. Similarly, dogs are usually quarantined for a period to ensure they are free of rabies, before admitting them to rabies-free countries.

10.3.3 Reduction of Contact

As with quarantine measures, the objective here is to reduce or prevent contact (either physical or aerosol) between infected and noninfected animals. This can be done by separating animals in time (e.g., "all in–all out" husbandry methods for poultry, swine, veal calves, and beef feedlot cattle), by separating animals physically using barriers such as solid partitions between pens, or by building separate facilities (e.g., a separate calf barn so that adult and young animals are physically separated; hence the calves have a reduced risk of acquiring enzootic pneumonia). The installation of adequate ventilation systems is necessary to reduce aerosol transmission in intensively housed poultry, swine, and cattle (e.g., veal calf) systems.

10.3.4 Chemical Use

Chemicals may be used to reduce disease transmission in a number of ways. Disinfectants may be used to reduce the risk of transmission of infectious agents (e.g., the use of formaldehyde between batches of eggs in hatcheries, or the use of lime as a disinfectant subsequent to removal of brucella infected cattle from a premise). Pesticides may be used to reduce or eliminate vector populations (e.g., subsequent to a build up of mosquito populations or the occurrence of equine encephalitis in horses) and hence aid in the control of disease. An early example of the successful use of chemicals was the use of arsenic dips in the southern United States during the 1800s to free cattle from the tick vector of bovine piroplasmosis. As was mentioned previously, this allowed control of the disease even before the agent (*Babesia bigemina*) was identified. Today, antimicrobials often are used for mass prophylaxis or treatment (e.g., sulfonamides in drinking water for the control of coccidiosis in birds). Other applications of mass treatment are the use of teat dips and dry cow therapy for the control of bovine mastitis. Chemicals (such as in dry cow therapy) can also be used on a selective basis, after culturing each cow, or on a herd-wide basis. In general, because of resistance on the part of the vector and/or the agent, and because of problems related to drug residues and other direct health dangers to people handling these chemicals, it is important to focus on the safe application of chemicals and, it is hoped, to reduce industry dependence on them. Decision analysis (9.4) and other econometric tools can be extremely helpful in selecting the optimal time and place to use chemicals. For example, applying mass antimicrobial therapy only in groups of cattle experiencing disease outbreaks (such as thromboembolic meningoencephalitis) rather than unselective application of therapy to all groups of cattle. Formal studies of the total antimicrobial usage and the resultant productivity of animals in mass prophylactic programs versus selective therapeutic programs would provide useful data on this subject.

10.3.5 Modification of Host Resistance

A host's resistance to infection and/or disease may be modified by increasing genetic resistance (e.g., by selecting strains of poultry resistant to Marek's disease), by stimulating acquired resistance (e.g., mass immunization), or by means of ensuring the transfer of passive immunity (e.g., assisting calves to nurse their dam and/or force feeding pooled colostrum).

Mass immunization programs have been successfully used in controlling many diseases of farm animals such as bovine brucellosis, and in diseases of companion animals such as canine distemper. In farm animals, vaccination is often used in an attempt to reduce the prevalence of endemic disease to levels such that selective slaughter and/or depopulation can be used. For example, vaccination against foot-and-mouth disease is practiced in many countries where the infection is meso- or hyperendemic. Identifying the appropriate time to eliminate vaccination as an element of an eradication program is difficult and has both scientific and social ramifications. If mass immunization is used, difficulties may arise with the ability of screening tests to distinguish between the natural and the vaccine induced immunological responses. This can cause particular difficulty for disease control programs and also for routine serological surveillance; if the vaccinal agent is capable of spreading, these difficulties are compounded. Mass vaccination is a frequent component of control programs directed against many exotic diseases, although the value of this practice is difficult to establish. Also, there is some concern about the spread of infection by vaccine crews in the early stages of eradication programs (Burridge et al. 1975).

Vaccination programs have usually been applied directly to protect the species of interest. However, recently there have been investigations in Europe and North America into vaccinating wildlife reservoirs against rabies by the use of oral vaccines (World Health Organization 1981). The intent of such programs is to control the disease in the reservoir population, and hence to reduce the risk of transmission to companion and farm animals and humans.

If there has been a drawback to mass immunization, perhaps it has been in the narrowing of our thinking and approach to the control of disease, as considerable emphasis has been placed on this single measure. Although many vaccines currently sold for the prevention of endemic diseases (such as respiratory and/or gastrointestinal disease) have never been shown to be effective, huge sums of money are spent advertising their potential benefit to professionals and lay people alike. The unfortunate aspect of this dependence on immunization is the potential for some of these vaccines to actually do more harm than good (Martin 1983).

10.3.6 Environment and/or Management Control

As discussed in Chapter 4, most disease results from an ecological imbalance between the host and its environment. If the environment can be altered to reduce the severity or likelihood of such imbalances, the result will be a reduced level of disease. Examples of such measures include improving the physical environment in barns by means of ventilation and lighting, the regular maintenance of milking equipment, and the use of single service paper towels as measures to aid in the control of bovine mastitis. This remains an area not fully investigated or utilized, although many practitioners are now stressing this aspect of disease control and placing less emphasis on the use of biologics. There is, however, a great need to formally evaluate the efficacy of any such disease control program.

Environmental hygiene also includes the physical cleaning of animals and their environment as well as management schemes such as pasture rotation and the use of portable calf pens. Environmental hygiene is essential during the slaughtering process both to prevent spread of infection to susceptible animals (e.g., preventing dogs and other animals from having access to offal) and to ensure a safe, wholesome product for the consumer. Despite the high level of slaughtering plant hygiene in developed countries, the consumer needs to be aware of hygienic food preparation methods at home, because agents such as salmonella are likely to remain on the final product.

10.3.7 Education

Programs to educate the public should be an integral part of disease control and eradication efforts. Unfortunately this often appears to be overlooked or becomes reduced to secondary importance relative to other more direct or dramatic measures such as mass vaccination. In veterinary medicine there are several classic examples where educational programs have been integral parts of a control program, such as the campaign to control hydatid disease in New Zealand (Schwabe 1984, pp 474–79) and Cyprus (Polydorou 1983), and recent efforts against African swine fever in the Carribean (Chain and Rodriquez 1983).

The requirement for veterinarians to educate themselves in a number of social areas where their activities have an impact is also related to this subject. This includes the human-animal bond (Schwabe 1984), how dairy farmers view veterinary services (Goodger and Ruppanner 1983), and how dairy farmers view themselves (Bigras-Poulin et al. 1983). Such understanding should greatly enhance the effectiveness of veterinary service.

10.3.8 Biological Control

This control method utilizes living things that humankind considers to be reasonably nondetrimental to its purposes to control other living things that have been judged to be harmful. Such measures may be aimed directly at agents of disease, or indirectly via control of vectors or reservoir populations. An example of the use of this method to control rabbits in Australia using myxomatosis virus was presented in 4.8.1. Another example involves the use of sterile male flies to control screwworm disease in cattle in the southern United States. Male flies are grown in large numbers in captivity, sterilized by radiation, and then released. The objective is to interfere with the reproductive cycle of the fly. Since the females mate only once, mating with an irradiated male leads to no offspring and hence a subsequent reduction in numbers of adult flies (Knipling 1960). Similar programs are now being mounted against the vector(s) of trypanosomiasis in Africa (Stephen 1975).

10.4 Integrated Disease Control Planning (A Conceptual Framework)

Disease control programs need to be well designed from both a biologic and economic point of view. They also need to be dynamic so they can evolve with the changing situation (i.e., the disease frequency and/or the biologic, economic, political, and/or social climate may change necessitating changes in the program) (Hanson and Hanson 1983).

When combating specific diseases, particularly if the objective is eradication, there are four general phases to the control program (Yekutiel 1980). In the first phase, personnel are trained, the population of concern is enumerated, the supply of local health services is assessed, and the required program administration is put into place. In the second phase, the area-wide directed activity against the disease commences. The nature of these activities will depend on the disease, the main method of attack (e.g., mass testing and slaughter versus vector control), and the social, political, geographic, and economic constraints of the area. This phase continues until the prevalence of disease is reduced to a level where continued transmission of the agent is unlikely to occur. The third phase is really a "mopping-up period" combined with intensive surveillance for remaining cases, and a traceback of all cases to ensure that the original source and all contacts of the case are detected and controlled. It is here the quality of disease detection activities is of paramount importance. The procedures used in the second phase may need to be reassessed for their accuracy since the relative importance of false negatives and false positives may change with disease prevalence. It is not unusual to find that the characteristics of the residual disease differ dramatically from the main features of disease when it was more prevalent; this feature was apparent in the terminal stages of the hog cholera eradication campaign in the United States (Hanson and Hanson 1983). The final phase of disease eradication programs involves vigilance in preventing the reintroduction of the disease and developing an early warning system for such introductions. This is of utmost importance if the time, effort, and money spent in the earlier phases is not to be wasted by allowing reentry of the disease. Most regional and national programs require an efficient local veterinary health-care delivery system, as well as good communication to those formally charged with the task of ongoing surveillance. Without an ongoing and appropriate veterinary infrastructure in the area, the early successes may be short lived.

As indicated, the process of disease control requires data that can be used to generate information on which to base and/or modify the control program. Much of the current gathering and processing of data on endemic disease is done to achieve an immediate perceived need (e.g., a particular research project or one particular disease), but does not have an ongoing or broad thrust. It would be extremely useful and informative to have a system to rationalize the current data collection systems so the overall effort can be more directed and effective.

For example, one could envisage a hierarchical data collection (monitoring/surveillance) system for endemic disease in which farms form the basic building blocks or foundation. Much data generated on a farm are of interest only to the individual manager; however, a portion is of direct value to the veterinarian. At the farm level, information of value to the manager would include action lists (e.g., cows due to calve in the next week, cows due in heat in the next week, etc.), and monitoring of production (e.g., the period from calving to first observed heat, milk production per day, etc.) so that problems can be identified early. Summaries of health problems and productivity are needed on a regular basis on each farm so that objectives can be compared to targets and health maintenance activities modified accordingly. The latter summary data could be put to good advantage at the veterinary practice level by integrating it with data from other clients (Stephens et al. 1982). This would allow a veterinarian to compare levels of disease and measures of reproductive and productive efficiency on an individual property with those of other clients, and also to continually monitor and quantify the health status of the population of animals in the area. Data on individual animals would also be of value to the veterinarian as a means of monitoring the response to therapy and/or the efficacy of prophylactic procedures directed at the individual. The veterinarian could prepare lists of problem cows and discuss alternative control measures with colleagues prior to visiting the farm.

In a similar manner, data from a number of veterinary practices could be combined with data from other sources (e.g., milk quality control laboratories, abattoirs, and diagnostic laboratories) at a Regional Epidemiology Center. These centers would use the integrated data for ongoing research dedicated to assist the veterinarians in that area solve problems related to disease control (the number of sampling units required and the complexity of the data sets would prohibit this at the individual veterinary practice level). In addition, such data could be used as a rational basis for establishing research priorities, monitoring disease, and for the signaling of problems requiring immediate follow up. Knowledge derived from such activities could then be fed back through the system by way of formal meetings, extension workers, research papers, shared information data bases, etc. Overall, such a system should result in a more efficient, directed, and harmonized thrust of the efforts of those involved with animal health maintenance.

If there was a desire to use the data from such a system for disease monitoring (see Chapter 11), then to ensure representativeness of these data, it would necessitate formal sampling of source farms. However, this should not be a major objective of the system, at least initially; rather, interested and capable farmers and veterinarians should serve as collaborators. Because almost all animal disease monitoring systems impact on or require the input of the individual animal owner, it seems logical that high levels of collaboration (hence representativeness) would be ensured if the system served the direct needs of animal owners and not just the needs of a governmental or other outside agency. Although no such overall system currently exists, there are a number of systems, for example, health management data systems for individual herds such as DAISY (Stephens et al. 1982), and others (Etherington et al. 1984). With appropriate nudging, modifications, and assistance, the current systems could form the basis of an overall hierarchical system.

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