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AGR Technical Note No. 7

ANIMAL DISEASES IN DEVELOPING COUNTRIES:
TECHNICAL AND ECONOMIC ASPECTS OF THEIR IMPACT AND CONTROL

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January, 1983
ABBREVIATIONS

ASF = African Swine fever
ND = Newcastle disease
CBPP = Contagious Bovine Pleuro-pneumonia
FMD = Foot-and-Mouth disease
HS = Haemorrhagic Septicaemia
PPR = Peste des Petits Ruminants
ILRAD = International Laboratory for Research of Animal Diseases, Kenya
IICA = Inter-American Institute for Cooperation in Agriculture, Costa Rica
FAO = Food and Agriculture Organization of the United Nations, Rome
ECF = East Coast Fever
WHO = World Health Organization
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ANNEX I: Brief Descriptions of Major Infectious Diseases of Livestock in Developing Countries

**Viral:**
- African Horse Sickness, African Swine Fever, Foot-and-Mouth Disease
- Hog cholera, Newcastle Disease
- Peste des Petits Ruminants
- Rift Valley Fever, Rinderpest

**Bacterial:**
- Anthrax, Black Quarter, Contagious Bovine Pleuro-pneumonia, Hemorrhagic Septicaemia

**Rickettsial:**
- Heartwater

**Protozoal:**
- Anaplasmosis, Babesiosis, East Coast Fever, African Trypanosomiasis

**Helminth Diseases:**
- Flukes, Worms

**External Parasites:**

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ANNEX II: Brief Descriptions of Major Zoonotic Diseases in Developing Countries

**Brucellosis:**

**Cysticercosis:**

**Hydatidosis:**

**Rabies:**

**Schistosomiasis:**

**Tuberculosis:**

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ANNEX III: The Eradication or Control Decision

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ANNEX IV: Example of Estimated Costs of a Regional Animal Disease Control Program: Rinderpest and CBPP in Sudan

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References
SUMMARY

1. Animal disease continues as a major constraint on the efficiency of smallholder and commercial livestock production in developing countries. Apart from the rinderpest control program in Africa, little progress has been made in reducing the incidence of the major infectious diseases such as: foot-and-mouth disease, African swine fever, contagious bovine-pleuro pneumonia and Newcastle disease. Very little headway has been achieved against vector borne diseases and internal and external parasites.

2. In striking contrast, major progress has been made in the control and eradication of the above mentioned diseases in the developed countries over the last 25 years. North America, Australia, New Zealand, Japan and large parts of Western Europe are now free of the major epizootic diseases or limit their spread, if they occur, by strict control measures. These intensive programs have involved techniques such as: external and internal quarantine and restriction of movement, slaughter and sanitary disposal of infected and exposed livestock, disinfection of premises, continuing surveillance to identify re-occurrence of infection foci and vaccination to reduce the spread and incidence of disease to manageable proportions. These are indeed costly operations and are justified in the developed countries because of the potentially intolerable inefficiencies in livestock production.

3. Although disease is a serious constraint to livestock production in developing countries, such tactics are generally not feasible or even possible. A wide range of diseases, several of which also infect humans continuously plague smallholder and commercial livestock producers. Basic infrastructure deficiencies and competing demands on scarce financial and people resources are certainly the roots of this relative inability to effectively deal with livestock diseases. This is compounded by land tenure differences, central government attitudes towards smallholders and migratory husbandry patterns.

4. The control of a few particular diseases poses exceptions to these comments about disease control problems in developing countries. By example, consider:

   a) The control of rinderpest is clearly desirable because of its frequently fatal outcome and because there is an effective, long-term immunization technique.

   b) In certain cases the eradication of African swine fever is clearly the best decision because of its generally fatal outcome and because there is no immunization technique whatsoever—so living with a frequently fatal pig disease has to be compared with the costs of eradication by depopulation, and
c) The eradication of foot-and-mouth disease may become feasible on an area or country basis if there is an established, secure market for livestock products in "FMD-free" countries.

5. These are a few exceptional situations that apply to developing countries that warrant costs of intensive disease control efforts. In general, though, the challenge is to create a cost-effective environment of animal disease control which in the long run enhances the profitability of livestock production. Many diseases are complex in nature, involving arthropod vectors and diverse seasonal and geographic variations. Some threaten human health as well and demand attention from medical as well as veterinary resources. The decisions and assessments are complex.

6. This paper presents the major technical and economic aspects of animal disease in developing countries which have practical bearing on the identification of those animal health programs offering significant promise of a net beneficial return. Data gathered over the last 10 years from the problems, results and economic consequences of several different disease control projects in developing countries are summarized to provide basis for decisions on programs and the support of animal health infrastructure. The principal implications for successful investments in animal health emerging from this information and opinions of experienced professionals are:

a) With increasing demand for livestock products, there is a continuing trend towards intensification of livestock production in developing countries often involving the use of exotic breeds or their crosses under more intensive systems of management and feeding. Effective control of infectious and parasitic diseases is a necessary condition under these more intensive production systems. Special problems exist when exotic livestock under these conditions come in contact with indigenous cattle under less intensive conditions.

b) The resources required to achieve eradication are, with a few exceptions, not available in developing countries. Control programs strategically aimed at diseases selected on the basis of high impact on production and relative ease of control, can be rewarding in reducing inefficiencies in smallholder livestock production. These strategies require clear understanding of the cycles of disease vectors.

c) In most areas of the developing world, there is a need for well designed epizootiologic and economic studies to provide information vital to determining the feasibility of control programs prior to their implementation, and the estimation basis for funding the general animal health infrastructure.
d) In practically all developing countries, there is a need to strengthen existing animal health services to a point where they can provide a level of disease control adequate for relatively efficient livestock production. Government support is necessary for such functions as: diagnostic laboratories, prevention of introduction of exotic diseases, disease surveillance and study, controlling outbreaks, training technicians at the local level, regulation and quality control of vaccines and drugs, and area vector control. As there are serious limitations of trained personnel and financial resources in developing countries, there is a need to limit the services provided at government expense to those which have the highest priority of national interest. The routine distribution and application of animal health products can be most efficiently handled within the private sector.

e) Research for development and application of more thermally stable, potent and easily administered vaccines could yield great returns directly applicable to the smallholder environment. Continued emphasis on techniques for developing breeds or sub-groups of livestock on the basis of disease resistance is well deserved. Research towards the better understanding of the mechanisms which explain differences between individuals or breeds in their relative ability to resist arthropod vectors and disease organisms is justified.
I. INTRODUCTION

1.1 In contrast to the situation in developed countries, progress against the constraints of animal disease has been slow or non-existent in livestock production in developing countries. This is particularly true for the smallholder producers whose livestock are grown mainly on a diet of grasses and crop residue or from scavenging a variety of feeds and waste.1/

1.2 Numerous efforts have been carried out to control animal disease in these countries. When one considers the technical, social and political obstacles, and the complexities of the diseases themselves, many have been successful. The potential for further increasing livestock production through reducing certain disease-caused inefficiencies remains attractive. There are other constraints to animal production. Although there may be opportunities in some areas to improve the efficiency of forage and residue utilization, the methods for achieving significant increases of forage production are generally not feasible — at least if the principal aim is for increasing traditional type livestock production. If forage production improvement is combined with more intensive livestock operations, like dairying with exotic or improved breeds, the production can be feasibly increased if demands for higher cost feed and management inputs can be met. These types of enterprises require a greater emphasis on effective animal disease control.

1.3 Each disease has its own peculiar, and frequently very complex, manner of causing production inefficiencies. The differences in the nature of the disease agent itself and its interaction with the animal host and their common environment leads to outcomes from infection ranging from no clinical signs whatsoever to serious illness or death. Through better understanding of these factors, resources can be more wisely allocated in the control of animal disease. Certainly not all animal diseases can be controlled with the technology now available and eradication in developing countries is almost impossible except in a few cases. Yet, in many cases there are reasonable indications that progress can be made. Unfortunately, most diseases do not offer the same opportunity for control as realized in the spectacular reduction of rinderpest in Africa. The challenge is to identify the control efforts against those diseases in those locations that can be expected to yield an acceptable return to investment.

1/ In this discussion livestock means all types of ruminants, pigs and poultry. A smallholder is a member of the disadvantaged portion of the population who supports his family from animal products and traction, and crops harvested from a few acres of land or from traditional grazing privileges on the vast arid and semi-arid lands. The diseases discussed are those which have major impact on livestock production. Control of animal disease is meant to include any tactic employed by the private and public sectors, or individuals, aimed at reducing the effect of disease on production. It may include the goal of eradication in an area or region. However, the eradication of a disease is generally not a competitive option in developing countries.
1.4 This paper treats animal disease mainly from the standpoints of the practicalities of production impact, and the technical and financial realities of disease control in developing countries. The objectives of this paper are:

a) To describe the nature of diseases which determines their production impact, and the factors of control which determine its cost and effectiveness.

b) To provide background useful in evaluating the economic dimensions of the benefit-cost relationships of control measures of different diseases in specific situations.

c) To examine and review aspects of certain control programs which have been executed or which have been proposed.

d) To draw implications about investments in livestock health and research that seem to offer the most rewarding potential for reducing the constraints of animal disease.

e) To describe the practical characteristics of several diseases which are common problems in developing countries.
II. CHARACTERISTICS OF THE INTERACTION OF DISEASE ORGANISMS AND HOSTS

2.1 The simple presence of a disease organism does not in itself lead to decreased output. It is the combination of a variety of factors such as: the susceptibility status of the host, the proper environment for the organism and its vectors or intermediate hosts,1/ and the penetration of a sufficient quantity of the disease organism through the hosts' barriers to cause clinical illness.

2.2 Many diseases are widespread throughout the world and would be universal except for the intervention of man. In cases like African Swine fever, foot-and-mouth disease, rinderpest and Newcastle disease, control by eradication and restricting imports has been the main reason such diseases are not prevalent in most developed countries. Another major factor in determining the geographic distribution of a disease is the prevalence of the proper vector which is absolutely necessary either for the transmission or biological development of some disease organisms. Infections like trypanosomiasis and East Coast fever which depend on tsetse flies and ticks, and fluke infections like schistosomiasis which depend on snails are limited in their prevalence by the distribution of their vector intermediaries. Some disease organisms seem to be dependent on climatic factors or soil conditions to enable them to cause damage to the host, and others are limited in their spread by factors as yet unknown.

2.3 Disease control techniques are based on either interrupting the transmission cycle of the disease organism, improving the immunity of the host against the organism, or attacking the organism itself. Achieving area-wide control is difficult because for many diseases, the hosts themselves are the reservoirs of infection which is transmitted either by direct contact or through a vector. The reservoir of infection of many bacterial diseases, such as anthrax and black quarter, is in the inanimate environment.

2.4 Since wild animals are also hosts of some diseases, this reservoir can provide a serious obstacle in the control of livestock disease. An example of this was the discovery of foot-and-mouth virus in deer during the 1924–25 outbreak in the United States. It was so threatening that 22,000 deer were killed in the ultimately successful effort to eradicate this disease. When a vector is involved, the situation quickly becomes more complex. These vectors have their own life cycles that are essential to understand if any progress is to be made in controlling disease by reducing the vector population. Consider the ticks which are vectors for such diseases as anaplasmosis, basesiosis, heartwater and thieleriosis (East Coast fever). Tick species may use one or three hosts as they go through their stages of development and some disease

1/ In this paper "vector" is used to mean the living, transmitting agent of the disease organism in which the disease organism may or may not go through biologic development.
organisms are transferred from one tick stage to another as the organisms
themselves are in cyclic development. The tick which transmits babesiosis
is a "one-host" tick completing its parasitic life cycle from immature
larva to mature adult on one animal (usually cattle). By contrast the tick
which transmits East Coast fever attaches to different animals in the
larval, nymphal and adult stages. Since the tick life cycle can take as
long as four years, they also become reservoirs in a sense. Ticks and
biting flies also serve as mechanical transmitters carrying organisms such
as African Swine fever virus and anaplasmosis from one animal to another.

Host Susceptibility

2.5 For many diseases there are methods of decreasing the suscepti-
bility of the host through artificial stimulation of the production of
antibodies production which are specific against the organism. The
antibodies act to neutralize the infection or enable phagocytosis wherein
cells engulf the organism to which the antibody is attached. The
immunizing agent may be the pathogenic organism itself or some altered or
attenuated version of it or its toxin. In some areas immunity against
certain diseases, like babesiosis, anaplasmosis and foot-and-mouth disease,
is achieved by deliberately allowing animals to be exposed to the disease
itself with the expected outcome of infection leading to immunity.
Livestock owners practice a variety of techniques to assure the desired
results—immunity without serious clinical outcome.

2.6 Immunity is not a perfect or absolute state. It can be
overwhelmed by large doses of the disease organism or changes in the
nutritional or stress status of the host. For some diseases it is
transient—lasting much less than a year. While for African swine fever
there is no known immunizing method. If the immunity reduces shedding of
the organism to the environment. This, of course, reduces the spread of
the disease. However, another situation exists for many diseases. The
immune animals harbor the organism and are carriers of the disease. The
disease organisms also have their way of survival in that strains exist or
develop which are different enough to be outside the specificity of the
immune response to other strains. East Coast fever, trypanosomiasis, and
foot-and-mouth disease organisms, among several, are notable in this
behavior. Another aspect of immunity that is being studied is an immune or
allergic mechanism which seems to provide resistance to vectors of
disease. This is observed in the lower tick burden carried by Bos indicus
(Zebu) breeds of cattle as compared to that of Bos taurus (European) breeds
under the same environmental circumstances and is hypothesized to be due to
an allergic response in the skin against the tick.

Outcome of Infection

2.7 Infection of the host by a pathogenic organism does not neces-
sarily mean clinical sickness nor does clinical sickness necessarily mean a
production loss. The hosts' complex defense mechanisms are miraculous in
their frequently successful ability to prevent illness from the invasion of
numerous pathogens. However, the mechanisms are overwhelmed in many
instances resulting in various production losses. The high mortality from
such diseases as: rinderpest, East Coast fever, Newcastle disease, hog cholera, African swine fever, anthrax, rabies and black quarter is, of course, an outstanding and absolute production loss. In other diseases mortality is low or an unlikely outcome of the clinical illness. The sickness may be transitory with complete recovery such as occurs in many common gastrointestinal or respiratory infections or it may cause a long course of weakness and substandard performance such as is seen with trypanosomiasis, and other parasitic infections and with contagious bovine pleuro-pneumonia.

2.8 Enough disease organisms must overwhelm the host's defenses, migrate to the target tissue, and then start multiplying before tissue damage and impairment of production occurs. Each pathogen seeks its tissue environment where conditions are right for survival and multiplication. For instance: rabies virus only thrives in central nervous tissue, African swine fever virus multiples rapidly in endothelial cells lining the vasculature, the Fasciola fluke lives and reproduces in the liver, and so on for each disease organism. The pathogenesis leads to the sources of production impact from uncompensated growth delay, abortion, low milk production, weakness, fatality, and less ability to get to water and feed and to care for young.

2.9 Diseases are sometimes classified either as being acute or chronic. Most diseases have an acute form in which the host either dies or goes through a period of illness in a matter of a few days. The illness may be followed by recovery with full compensation of efficiency of growth. In several diseases—notably contagious bovine pleuro-pneumonia, trypanosomiasis and liver flukes—the acute form is often followed by chronic impairment where tissue changes are permanent or the organism simply lives on usually at the expense of the host's well being. All the livestock of the world live and function with pathogenic organisms present in their body. This leads to another clinical status—the subacute form—in which the organism is present in the host's tissues but the balance is such that a harmony is achieved with both host and organism functioning well, or apparently so.

2.10 It is hard to demonstrate a production loss from a subacute infection and in a sense, this status may be beneficial by providing immunogenic stimulus. However, the balance is delicate and a change in condition can cause exacerbation resulting in illness and even death. The organism may develop antigenic characteristics against which the host has inadequate immunity -- a problem in trypanosomiasis. Several studies have shown that the host's immune response capability can be adversely affected by stresses such as: other infections, overcrowding, movement, inclement weather or weaning.

2.11 Undernourishment of livestock and, sometimes, severe malnutrition are common situations in developing countries. Malnutrition does not always aggravate the outcome of infection. In the case of some infections, malnourished hosts seem to fare better as has been observed with foot-and-mouth disease in India (Murray, et al, 1977) and anaplasmosis in Australia (Wilson and Trueman, 1978). The mechanism behind this observation is not clear and it may be related to degree of exposure to the
organism. However, evidence is mounting that malnutrition compromises certain components of the immune response system. In general, the conclusions are that malnutrition limits the competence of immune function (Sheffy and Williams, 1982). Another insult to immune response comes from the disease itself. Certain viral and many parasitic infections have been shown to depress effective function of the immune system (Solomons and Keusch, 1981). There are other factors involved in the disease and nutrition relationship. But it appears that all other factors being equal; malnutrition most commonly renders the host more susceptible to infection and more severe clinical illness. Unraveling this interaction is difficult to research because of the circular question: "Does infection aggravate malnutrition or does malnutrition decrease the beneficial immune response against infection?"

2.12 The accuracy of diagnosis of these diseases is an important practical matter. Most diagnoses are based on owners' observations of clinical signs and of organs of animals that are consumed after death or slaughter in extremis. Recently two studies in the Sudan have shown that cattle owners and traditional healers can properly and reliably recognize several animal diseases (Schwabe and Kuojok, 1981; McCauley, et al, 1982). Refined laboratory techniques are frequently not available and local control efforts may be initiated on the basis of several reports of a clinically diagnosed disease problem. If the prevention or treatment is aimed at the wrong disease the resulting failure may serve to further alienate owner cooperation. Costly errors can result from misdiagnosis. By example, consider the practical outcome of confusion of the central nervous signs sometimes seen in East Coast fever with those of rabies; the respiratory signs from mild Newcastle disease with bronchities; the severe weakness of fascioliasis with that from trypanosomiasis; the mouth erosions of bovine virus diarrhea with those from rinderpest and the high fever, skin lesions and acute deaths of hog cholera with those from African swine fever. If these confusions are not resolved, either the wrong approach may be used or nothing is done at all.

2.13 If the disease is zoonotic—affecting humans as well as animals—the impetus for control takes on added dimensions. Considerable progress against zoonoses has been made in developing countries through public health measures, abattoir hygiene and programs of animal disease control and eradication. Zoonoses such as hydatidosis and cysticercosis are common infections in man, particularly the rural poor. Animal hosts also serve as reservoirs for human infections of brucellosis, tuberculosis and "sleeping sickness." Another example is schistosomiasis or "bilharzia" which is zoonotic in the Far East where Schistosoma japonicum is prevalent. In one sense, all the animal diseases discussed in this paper adversely affect human health in that the production losses they cause contribute to human malnutrition.
III. CHARACTERISTICS OF ANIMAL DISEASE CONTROL

3.1 Understanding the disease itself is one side of the control strategy. The other is to understand the various techniques of control and their technical feasibilities. "Control programs" come in various forms. Individual livestock owners control disease in their own livestock for diseases they recognize as causing losses - if an efficacious control method is readily available at a reasonable price. Vaccination against anthrax, hemorrhagic septicaemia, foot-and-mouth disease, black quarter and hog cholera; and treatment against fascioliasis are common practices done by livestock owners as a matter of routine husbandry. However, in developing countries these products are frequently not available to the smallholder.

3.2 When the control methods are more complex (such as use of a thermally-unstable vaccine) or when area control is the only feasible approach, (such as widespread application of insecticides) government sponsored programs are required. Another indication for government involvement is for the establishment of "disease-free" zones in which considerable regulation of animal movement is a prerequisite.

3.3 There are several examples of successful eradication programs in developed countries: contagious bovine pleuro-pneumonia in Australia, brucellosis and rabies in the U.K., foot-and-mouth disease and hog cholera in the U.S. and the U.K., African swine fever in France--to mention a few. Eradication is a considerably different proposition than control. To ensure success, eradication requires drastic and costly measures, a high level of social responsibility and on-going surveillance after the disease has ceased to occur. The rationale is that it is more cost-effective to deal with the disease severely at the onset rather than by continuing the control of outbreaks over a long time. The requirements for long-term government financial commitment and owner cooperation are paramount issues. If these qualities are questionable, then eradication will not be successful. Also the existence of wildlife carriers may be an insurmountable problem.

3.4 Except on a regional or zone basis, eradication does not appear as an attractive proposition in developing countries. Control aimed at the reduction of disease incidence is another matter. It is frequently worthwhile to carry out to appropriate limits; i.e., before reaching the point of decreasing returns to additional program costs. These appropriate limits are difficult to determine even under the best conditions and in developing countries with basic infrastructure deficiencies, errors can be expected.1/

1/ See Annex III for criteria for the "eradication versus control" decision based on lessons learned from human disease eradication programs.
The Use of Vaccines

3.5 If possible, improving the resistance of the host through immunization is presently the most practical method of disease control. In comparison to reducing vector population or restricting animal movement, immunization allows animals to be produced with fewest constraints. However, as discussed earlier, there are difficulties and sometimes it simply doesn't work. Either the immunity is so faulty or costly to achieve, or the immunization procedure itself causes unacceptable disease losses that the effort is futile.

3.6 The entire question of constraints due to animal disease could be reduced to much less significance if highly potent, broad spectrum, non-pathogenic, thermally and temporally stable, easily administered, inexpensive and uncontaminated immunizing products were available for all diseases. For some diseases the "deliberate exposure" practice comes close to satisfying these criteria. Products in common use against clostridial diseases (black quarter, tetanus, botulism and others) are highly satisfactory because they produce good immunity for several years, have a long shelf life and are non-toxic and inexpensive. These are non-viable products, mainly "toxoids," which stimulate antibody production against the destructive toxins produced by clostridial organisms—not against the organisms themselves.

3.7 The most effective available vaccines are modified forms of the live disease organism. The fact that they are "live" means that the requirements of thermal stability, non-pathogeneity and ease of administration are difficult to satisfy. The attenuated, live rinderpest vaccine is probably the most successful of these. One vaccination produces a long and solid immunity (essentially for life) against a widespread disease that is frequently fatal and which has not shown antigenic variation. The obviously attractive benefit-cost ratio was the stimulus for the successful campaigns against rinderpest in Africa. Live vaccines against other viral diseases, like hog cholera and Newcastle disease, are also very effective but are less attractive from the standpoints of ease of administration and length of immunity. Also, regulation of potency can be a problem for these vaccines as it has been for foot-and-mouth vaccine and outbreaks are sometimes associated with vaccination itself.1/

1/ In contrast to control programs, the use of vaccines as part of a strict eradication program is only a temporary maneuver. The idea is that vaccination slows down the spread and that later vaccines would be prohibited because they are a form of the disease organism itself. Then, if infected animals appeared, they would be slaughtered and the premises quarantined. There are several examples of this. Most recently in the U.S., hog cholera vaccination was prohibited and the eradication of that disease after a few outbreaks (one due to illegal use of the vaccine) has been successful. The eradication of contagious bovine pleuro-pneumonia from Australia included vaccination to reduce the incidence to a very low level which was followed by quarantine and slaughter of infected herds. In 1948, foot-and-mouth disease was finally eradicated in Mexico by vaccination of animals in the area around the last outbreaks, followed by restriction of animal movement from this area and then slaughter of herds which had outbreaks.
3.8 In recent years, a few effective vaccines against multicellular pathogens (parasites) have been discovered. So far bovine schistosomiasis (S. bovis), canine hookworm and cattle lungworm are the only ones against which vaccines have been developed. For many parasitic diseases it appears that immunity or resistance is stimulated by infection, which indicates that research in this area holds promise. There are exceptions such as the Ostertagia sp. worm (Herlich, 1982).

3.9 A major breakthrough has been made in the experimental production of a vaccine against one serotype (Type A) of foot-and-mouth disease (FMD) through "genetic engineering". After the protein which elicits immunity against FMD was identified, the gene material which produces this protein was "spliced" into the genetic makeup of bacteria. The bacteria then produced the viral protein. The product was experimentally shown to protect cattle and swine against FMD type A-13 (Klied, et al, 1981). Another recent advance in this area is the chemically synthesis of peptides corresponding to several regions of the viral protein and the inducement of neutralizing and protective antibodies against foot-and-mouth disease virus by these peptides. (Bittle, et al, 1982; Beale, 1982). Field tests have not yet started as there are still several questions to be researched in the laboratory, but one can theorize on practical, multivalent biologically or chemically synthesized vaccines as being possible in the future. Upon further development, the principal advantage appears to be thermostability and that the vaccine would not contain live virus. Another possible outcome is the ability to rapidly produce a uniform quality vaccine at a lower cost. Presently there is no evidence that this cloned, viral protein vaccine will produce a longer immunity than previous vaccines and the research to evaluate this will require several years to carry out. This discovery has excited numerous researchers to apply similar technology to other diseases. A major initial task is to identify and isolate the immunogenic fractions (mostly proteins) of the disease organism. Also there is great variability in the stability and production characteristics between viruses and strains of viruses. Although not a feat of "genetic engineering", work on a vaccine against babesiosis has produced promising results from a non-viable immunizing antigen separated from the organism (Kuttler, etal, 1982). The aim of all this work is to produce a safer, more stable and more potent method of immunization.

3.10 Gene cloning techniques are also being used by molecular biologists to produce human and animal interferon, a non-specific inhibitor of viral replication, but the effects are so short-term and variable that this product is unlikely to be very useful in, reducing the impact of livestock diseases.

The Role of Drugs

3.11 In general, drugs have a limited role in the control of diseases affecting smallholder livestock production. This is related to several disadvantages: 1) expense, 2) short-term effectiveness, 3) drug-induced toxicities, 4) the critical timing of treatment or need for continuous
treatment and 5) the development of resistant strains of the organism.
There are special situations for treatment of animals to withstand the
effects of trypanosomiasis as they pass through heavily infested tsetse
fly areas or to treat valuable animals that are acutely ill with diseases
such as East Coast fever, anaplasmosis and babesiosis. With some of these
protozoan diseases, drugs are used to "save" animals which become ill after
being deliberately exposed to the disease organism to achieve immunity
without loss. A trial in Colombia to reduce losses due to anaplasmosis and
babesiosis in calves showed this technique, plus tick and helminth control
to be financially superior to: 1) treating only sick animals, and 2) tick
and helminth control alone (Thompson, et al, 1978). This "expose and
treat" technique is most commonly done when susceptible animals are brought
to anaplasmosis and babesiosis endemic areas.

3.12 This approach has also been used in the control of East Coast
fever but with less success than for anaplasmosis and babesiosis. One
reason is the existence of a variety of strains of Theileria parva which do
not always provide cross immunization. However, recently in Kenya, Zebu
cattle infected with a preparation of field strains from three Theileria
sp. and then treated when they showed high temperature (or at 12 days
post-infection) were protected against infection under unusually high tick
exposure and schizont challenge under field conditions. A new drug (993 C
or Parvaquone) was used for the treatment by these workers at the
Veterinary Research Organization at Muguga, Kenya. The death rate in the
"immunized" cattle was 2% as compared to 50% in control animals. (Young,
et al. 1982). Similar trials have also been carried out at ILRAD. It is
hoped this technique might resolve the common problem of animals immune
against only one or two strains of the organism becoming ill with East
Coast fever when they encounter a different strain.

Controlling the Vectors

3.13 Although fraught with difficulties, efforts to destroy tick and
fly vectors continue to be a principal technique in the control of some
animal diseases. In Africa these efforts have been mainly in the form of
dipping cattle to kill the tick vectors of East Coast fever and applying
insecticides to the environment of tsetse fly vectors of trypano-
somiasis.1/ One of the major problems is that once the vector control
technique is started it must be maintained properly over time or the
benefits will not accrue to the initial investment.

3.14 In the case of the tick vector of East Coast fever, if animals
not immune from previous exposure are not protected continuously, even an
occasional exposure to the disease organism results in serious losses
because of the host's high degree of susceptibility. This is the trade-off
in controlling disease by reducing exposures, mainly it reduces the

1/ This topic has recently been reviewed. See "The African
Trypanosomiasis: Methods and Concepts in Relation to Development"
stimulation of immunity. The tick vector of East Coast fever uses three hosts as it goes through its life cycle. The larva is not infective but subsequent stages, the nymph or adult, are infective. But only if the previous stage has fed on a susceptible animal, and if the tick stays on for at least three days. Therefore, immunity not only protects the animal but also breaks the transmission cycle. Insecticide application must be done at least weekly, and in some situations twice weekly if it is to protect susceptible animals from exposure to *Theileria parva*. By contrast, the vector of babesiosis is a one-host tick with the larval stage being infective. Since the larva stays on the host for several weeks until maturity, effective control by insecticides can be achieved through much less frequent (every three weeks) and seasonally strategic application.

3.15 Control of ticks by dipping or spraying is rewarding in intensive livestock production (like dairying) particularly with exotic breeds which have low resistance to tick infestation and the blood protozoa. Indigenous Zebu breeds are much better adapted to the vector and disease environment and dipping may actually be counter productive. Traditional cattle owners in East Coast fever areas have become discouraged because the dip insecticide concentrations have not been regularly maintained. Their cattle may be more susceptible because of previous prevention of exposure. The same type of problems and indications are encountered to a lesser extent in the control of tick vectors of anaplasmosis and babesiosis.

3.16 A new compound, ivermectin, has shown remarkable efficacy as an anthelmintic and against ticks and mites. It can be administered either orally or by injection (Drummond, et al, 1981; Egerton, et al, 1981). Recently this compound has shown residual efficacy against reinfection of the scabies mite 25 days after treatment. It is being suggested as a more cost-effective replacement for dipping against this mite as it has shown advantage over externally applied insecticides (Meleney, et al, 1982). The degree of residual effect against ticks is being investigated.

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1/ A dramatic example of the importance of maintaining disease control programs has recently been reported from Zimbabwe. The efficient control and, essentially, eradication of East Coast fever was disrupted in 1973 by the war with the result that this disease and other tick-borne diseases appeared again and, due to the susceptibility of the animal population, caused the death of an estimated 1 million cattle between 1974 and 1979. This disruption of animal health service also resulted in sizeable increases in incidence of trypanosomiasis, foot-and-mouth disease, anthrax and rabies (Lawrence, et al, 1980).

In Latin America animals which have not been exposed to ticks are worth less at market than those which have. Producers in tick areas are well aware of the "immunity by exposure" phenomenon and are willing to pay more for cattle they know have come from ranches in high tick infested areas where no dipping is practiced. This is also true of cattle from East Coast fever enzootic areas which bring a higher price because of their resistance.
and preliminary indications are promising, particularly as it affects fertility and rate of blood engorgement in one-host ticks. (Lancaster, et al, 1982).

3.17 Tse-tse fly control measures also depend on a continuous effort. Discouragement on the part of relocated farmers has come from the inability to maintain an area "free" of tsetse resulting in a resurgence of trypanosomiasis in their livestock and, more importantly, in the farmers themselves if sleeping sickness trypanosomes are present. So far, the vector control technology available has specific uses in areas of high land and livestock productivity, endemic sleeping sickness and in other selected smaller areas. (Jahnke, 1974, Putt, et al, 1980). Newer approaches such as sterile male fly release, insect growth regulation and attractant fly traps have not been developed to the point of economic feasibility for widespread use against these vectors.1/ (WHO, 1982).

Controlling the Animal Population

3.18 In the developed countries, "disease-free" environments are established and maintained by restricting animal movement and depopulating livestock on premises or in areas where eradication of a disease is the goal. In developing countries, the "disease-free zone" approach has been most commonly employed in the control of foot-and-mouth disease. It is used to establish a buffer zone between FMD-enzootic areas and FMD-free areas such as at the Colombia-Panama border and in certain areas of Botswana. It is sometimes proposed as a pilot project with the idea that if it is successful over several years it could be expanded. This approach has been tried in Kenya and Botswana in an attempt to produce meat which meets the requirements of potential buyers with regard to disease. It has been most successful in Botswana. But, numerous difficulties have been encountered stemming from maintaining the discipline necessary to restrict animal movement, lack of funds and keeping wild animal carriers out.

3.19 Another caveat to such an investment is the degree of security of the purchase commitments of prospective buyers with respect to meat import restrictions based on disease status. An example of this occurred in trade relations between Botswana and UK. When UK joined the EEC, the restrictions on cysticercosis were made more stringent. This forced Botswana to sell to less lucrative markets. (Grindle, 1978).

3.20 Following recent outbreaks in France and Cuba, African swine fever (ASF) has been rapidly eradicated by depopulation of pigs in contained areas. In the Dominican Republic and Malta, eradication was achieved by depopulation of all the pigs. Presently the eradication of ASF in Haiti is progressing through a total depopulation program. The impetus for eradication is greater for this disease than others because of the high mortality and the lack of a method of immunization. Following the introduction of this disease into Spain, decisions to eradicate were

1/ The sterile male fly technique has been used successfully in screwworm eradication in the United States. The principal reasons for its success were the ability to inexpensively produce sufficient quantities of flies to outcompete the fertile males and the once-in-a-lifetime breeding behavior of the females. This approach is presently being used successfully against screwworm in Mexico.
delayed and the disease became widespread. They live with the situation using a combination of quarantine and depopulation methods in outbreak areas to reduce the spread.

**Innate Disease Resistance or Tolerance**

3.21 In general the indigenous breeds are greatly more disease resistant than are exotic breeds. European breeds are much more susceptible than indigenous breeds to East Coast fever as well as babesiosis because of their lower ability to resist the tick vector and the organism itself. The further observation that certain breeds of indigenous cattle seem to be more disease resistant or tolerant stimulates interest in selecting for this quality. "Trypano-tolerance" demonstrated by certain West African cattle breeds (mainly N'Dama) has lead to the widely accepted emphasis that the development of this control approach deserves continued research. It would be the most practical way of reducing the impact of bovine trypanosomiasis. The tolerance is not absolute and can be overwhelmed. But experimentally, it appears that ten times the infection dose is required to produce the same degree of anemia in "trypanotolerant" cattle as seen in "non-trypanotolerant" cattle.1/

3.22 Not only has trypanosomiasis resistance been observed in different breeds, but certain individuals within breeds appear to be less susceptible to trypanosomiasis than other individuals (Cunningham, 1966). This is also true for tick infestation and tick borne diseases. The ability to identify individuals in some manner other than observing how they behave under field conditions would enable more rapid development of disease resistant livestock through genetic selection.

3.23 Technology developed in the field of organ transplantation leads to the indication that innate resistance to disease may involve the interaction of several "immune response" genes which are related to the genes controlling histo (tissue) compatibility. (Benacerraf, 1972; Stone, 1981).

3.24 If the major histocompatibility complexes and their recognition markers were identified in cattle followed by the establishment of statistical associations between these histocompatibility types and resistance to various diseases, the background can evolve for genetic selection of individuals on the basis of their disease resistance. The use of artificial insemination and the recent advances in bovine embryo transplant techniques and embryo splitting would increase the production potential of commercial quantities of such "genetically resistant" cattle regardless of the breed and the process would be hastened more by use of "genetic manipulation" techniques that are rapidly developing. This would overcome some of the problems of new breeds not being acceptable to producers because of real or perceived deficiencies in production characteristics as compared to the cattle they presently grow. This possibility is not limited to cattle and, in fact, may be more quickly achieved other livestock. Recently the resistance to avian leucosis has been associated with "immune response" genes. Also some breeds of sheep have shown marked by better immune response to inactivated Blue Tongue virus. (Berry et al. 1982).

1/ This topic has recently been reviewed by Murray, Morrison and Whitelaw, 1982.
IV. EVALUATING THE RETURN TO INVESTMENT IN ANIMAL DISEASE CONTROL:
The Decision Makers' Dilemma

4.1 Decisions on the allocation of funds for control of animal disease are difficult because the impact of the disease on production and the efficacy of the control methods are, at best, rough estimates. If data or, in many cases, even defensible estimates on the important aspects of the production impact and control effectiveness were available, the decision process would be simplified. Some of these aspects have been discussed in qualitative terms previously in this paper.

The Major Questions

a) How many animals actually get sick from this disease per year and what is the risk if infection?

b) Of those that get sick, how many show true production losses and what are the dimensions of these losses?

c) What is the financial value of these losses over time?

d) If the control method were employed, what decrease in losses would be realized and who benefits from these "avoided losses?"

e) What is the cost over time of the control method?

f) What are the technical and economic factors external to the actual disease and control problems?

4.2 Even in developed countries data on the production loss question are scarce. The data are hard to discover because the answers are not in the laboratory; but in the field where one must accept and deal with such illusive issues as: the degree of exposure risk, accuracy of clinical diagnosis, owner memories of history and observations, seasonal variation, livestock migratory patterns, the interplay of nutrition and clinical outcome, unknown numbers of animals-at-risk; and over or under exaggeration on all counts. It is untidy research. In contrast to data on incidence of clinical cases, there are considerable reliable data on the prevalence of infection.1/ However, the connection of prevalence of infection to incidence of clinical cases and then to production loss is hard to make. All that can be deduced from a known prevalence of infection in a given area is that the disease organism had infected some portion of the livestock population and the potential for losses exists or existed. Translation of this to production losses is frequently based on isolated

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1/ Incidence is a rate of a new event or observation occurring during a period of time. Prevalence is a rate of an event or observation occurring at one point in time, such as: number of animals having parasite eggs in their feces, antibodies in their blood or lesions in their livers, based on examinations of numerous samples collected at some point.
reports or antecedental information particularly in developing countries.\(^1\)
There are comparatively few field surveys of disease incidence and production loss experiences even in developed countries.

4.3 Once the estimates are collected and annual, disease-caused production deficiencies are calculated: the economic analysis can be made. The avoidance of these losses is the benefit yielded by the control strategy. The best approach is to estimate the benefits as accruing to consumers in the form of lower prices they have to pay for livestock products or to the economy in aggregate in the form of a more favorable balance of trade. These approaches assume that the increased productivity can be marketed - not always true. Another issue to take into account is the human consumption of meat from moribund animals, which happens frequently in developing countries to the extent that 25 to 50% of moribund animals may be eaten. A dimension of the problems can be expressed by simply multiplying the product quantity by the current market price. But this does not account for the price effect from increased supply.\(^2\) If the producers are the reputed beneficiaries, such measurement refers only to benefits enjoyed by producers who suffer frequent losses where as other producers with little or no disease problem may find lower prices for their products at the market place. This also has direct bearing on the degree of voluntary adoption of the control practice.

4.4 Then comes the question of the effect a control strategy has on reducing the production losses. By considering the efficacy of the technique--vaccination or vector control--and the probabilities of distribution and proper application to a reasonable proportion of the population, hypotheses can be made on a "worst-case/best-case" reduction of the production loss, say a 25% or a 75% reduction.\(^3\)

\(^1\) See Putt, et al, 1980, for their treatment of this question for trypanosomiasis in Nigeria and McCauley, et al, 1979, for approaches used to estimate the potential foot-and-mouth disease impact in the US; and Grindle, 1981, for his analysis of East Coast fever losses under various conditions of disease exposure risk and cattle management in Malawi and Tanzania.

\(^2\) Estimating the consumer price effect of more plentiful supply of food products is difficult in developing countries because of the scarcity of data for price elasticity calculations. If the commodity has no close substitute, the price elasticity could be broadly estimated as the negative of the income elasticity. By example: if income elasticity is 1.3, then the price consumers would have to pay for a given livestock product would be decreased about 3%, if, say, a 4% increase in supply were yielded from disease control. \([\text{(-)} 1.3 = 4\% / \text{price change} \%]\). If there are close substitutes, the absolute value of the price elasticity for the product will be higher than its income elasticity. The price effect would be felt by producers in low per-unit market prices, but those who had achieved higher yields would have more units to sell.

\(^3\) It should be kept in mind that such percentages are applied to the production loss estimates, which may be based on data of poor quality.
4.5 The direct control program costs are basically "financial engineering" calculations of capital and operating costs for such items as: personnel, vehicles, training, diagnostic services, insecticides, vaccines, equipment and supplies.\(^1\) In the case of eradication programs, additional costs for slaughter, quarantine, unrecovered indemnization and animal movement surveillance have to be calculated. There are generally other indirect costs that have to be considered and their estimation is more difficult. These costs stem from such potential sources as disruption of production practices and marketing procedures.

4.6 Likewise on the benefit side, there are external features which may be greater considerations than the production losses themselves. Most notable of these is the securing of new markets for "disease-free" livestock products as in the case of foot-and-mouth "disease-free" zones or in the eradication of African swine fever. Another external benefit is the building of animal health infrastructures capable of preventing losses from other diseases besides the particular one aimed at by a specific control program. If human infections (zoonoses) are involved; this, of course, increases the scope of the benefits.

4.7 Even though a very favorable benefit/cost relationship may be estimated for a given disease control strategy, other "common-sense" questions about the technical feasibility prevail in the final analysis. There are issues such as: "Can the terrain be covered?"; "Does the program seriously disrupt traditional management and land use practices?"; "Are adverse reactions or inadequate immunity serious risks?"; "Is the government committed to the idea?"; and, finally, "Do the livestock producers perceive the problem and trust in the control method?" This last point of owner responsiveness is critical. They cannot take risks of adverse reactions to a vaccine or treatment, or of inadequate immunity.\(^2\) They are frequently suspicious of government intervention anyway, so that if there are problems in the early stages of a program, their cooperation can be diminished or be reversed—becoming antithetic.

\(^1\) See Annex IV for an example of estimated control program costs in the Sudan.

\(^2\) Failure to produce immunity by vaccination results from faulty preparation, improper refrigeration or inadequate administration of the vaccine. Another cause of failure is the vaccination of calves still carrying interfering maternal antibodies. Adverse reactions were problems with early rinderpest vaccines which caused about a 2% death rate following vaccination. Use of the Plowright tissue culture vaccine solved this problem. Also, the vaccine against CBPP caused such severe local skin reactions that inoculations were given in the tip of the tail. These reactions diminished owner cooperation in some areas.
V. SELECTED INFORMATION FROM LIVESTOCK DISEASE CONTROL PROGRAMS

5.1 The information in this section is selected to demonstrate some of the more important technical and economic features of some control programs that have been carried out. It is not exhaustive and is taken from data available on certain defined disease control programs. Whereas these are clearly defined efforts, throughout the developing world there are various on-going animal health programs or services. This animal health infrastructure serves to reduce the impact of animal disease by: regulating the quality of vaccines and drugs, and providing basic diagnostic services and investigation, and assistance in response to disease outbreaks. These services are usually conducted under the Ministries of Agriculture, although a few are run by the producer cooperatives.1/

The Control of Rinderpest in Africa

5.2 The JP15, mass vaccination campaign against rinderpest moved from West Africa to East Africa, then to Ethiopia and Sudan from 1962 through 1976 in six phases. Though the campaign did not achieve eradication, rinderpest outbreaks dropped substantially, even in areas like Ethiopia and southern Sudan where the vaccination coverage was low (10-20% of the cattle per year) due to lack of an infrastructure to carry out an effective program compounded by civil disturbance. Throughout the JP15 campaign, some 70 million cattle were vaccinated, mostly with the tissue culture vaccine developed at the East African Veterinary Research Organization in Kenya. The funding was from a mixture of international development agencies and the countries themselves. The idea was to break the chain of infection by having a high (70%) proportion of the population immune to the virus over a three-year period and, then, to follow-up with the annual vaccination of yearlings. Even with the immense problems of transport, refrigeration and political obstacles; the results were spectacularly good. Presently, there are efforts to start another campaign including the concurrent vaccination against CBPP. However now the outbreaks are fewer and much more localised compared to the pre-JP15 era so that the stimulus

1/ The activities and costs of these animal health services are usually sequestered in the reports of veterinary service officers. Information on veterinary services provided by the Anand Milk Cooperatives of Gujarat, India has been described (McCauley and Stoops, 1973).
for widespread regional control is somewhat diminished.1/

5.3 Another indication of the success of vaccination is that the losses during recent outbreaks are much lower now than in the pre-JP15 years in areas where vaccinations were done. This was reported in Nigeria where mortality of livestock in the area during outbreaks has been in the 3-to-5% range since the JP15 campaign compared to a threefold greater mortality during outbreaks prior to the campaign (Felton and Ellis, 1978). 2/

5.4 One account of the campaign in Cameroon, Niger, Nigeria and Chad for years 1962-65 reports that some 33 million vaccinations were given (many cattle were vaccinated three times to assure establishment of immunity) at an average total cost of $0.32 per vaccination (Lepissier, 1969). In Nigeria, the economic consequences of the rinderpest vaccination campaign carried out both by Nigerian and JP15 programs from 1962-63 were analyzed. Using mortality losses avoided by vaccination as the benefit, the discounted benefit/cost ratio was 2.48. Additional benefits occurred from avoided losses due to reproductive inefficiency (Felton and Ellis, 1978). The success of the campaign in Africa was noteworthy because of the dimensions and the number of countries involved. In the Far East and India campaigns have also been successfully carried out on much smaller scales, usually in areas which have experienced outbreaks. In these countries, the water buffaloes constitute a large portion of the susceptible population.

1/ In recent years rinderpest has reappeared in outbreak form in several African countries due principally to the relaxation of local vaccination coverage. Several outbreaks have occurred in a number of countries in West Africa since 1978. It appears that Southern Mauritania and an area along the Mali border with Mauritania are an enzootic focus of rinderpest. An emergency vaccination campaign was carried out in 1980-81 in West Africa in which some 2 million vaccinations were given—it appears to have been successful. (Anon., 1981. Eradication Campaign Against Rinderpest and Contagious Bovine Pluero-pneumonia Funding Report). There has also been a resurgence of rinderpest reported from Sokoto, Nigeria during 1980-81. In 2 of the 14 outbreaks, about 1,000 cattle were affected with mortality rates (exposure fatality) of 10.6% and 30.4%. In some of the smaller outbreaks the mortality rate was zero. The overall mortality was 14.5% (Oluokin and David-West, 1981). Also in several areas of Nigeria, a case-fatality rate during 1980-82 of 51% was reported from 46 outbreaks in which 2,269 cattle were sick with rinderpest (Nawathe and Lamorde, 1982). Serious outbreaks have also been recently reported in Sudan and Tanzania.

2/ There are several ways to express mortality. The highest rate is the percent which die having shown clinical signs (case-fatality rate); the next is the percent which die of those susceptible and exposed. The lowest is the percent which die of the total number in the area and are, therefore, presumptively exposed without knowledge of their susceptibility. These figures probably represent the latter case.
5.5 In the southern regions of Mauritania, an animal health program funded by the World Bank was carried out during 1973-1977 after the drought had reduced livestock numbers by 70%. In spite of less than ideal coverage (55-70%) and thoroughness, the project maintained a sound health environment which allowed the rapid herd increase in the project area to an estimated 450,000 in 1979 from 250,000 after the drought. The principal aim was to reduce losses due to rinderpest and CBPP but vaccinations against black quarter, anthrax, hemorrhagic septicemia and botulism were also done. Treatments done against trypanosomiasis and parasitic diseases were judged to not have been very effective. Some of the data from the completion report is summarized below:

Mauritania Animal Health Project 1973-1977

(Livestock Development Project, Credit 273-MAU, Selected Data from Completion Report 1980, No. 3208)

<table>
<thead>
<tr>
<th>Vaccination/Injection</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rinderpest Vaccinations</td>
<td>880,710</td>
</tr>
<tr>
<td>CBPP Vaccinations</td>
<td>660,607</td>
</tr>
<tr>
<td>Anti-Botulism Serum Injections*</td>
<td>464,529</td>
</tr>
<tr>
<td>Animal Health Project Investment Cost</td>
<td>$303,300</td>
</tr>
<tr>
<td>Animal Health Project Operating Cost**</td>
<td>$667,300</td>
</tr>
</tbody>
</table>

* These injections were given because of strong demands from cattle owners; not for reasons of recognized technical advantage. This demand may have resulted from losses due to presumptive botulism during the drought when phosphorus-deficient cattle consumed parts of carrion which may have carried the Cl. botulinum spores.

** Some vaccine and salary expenses were financed by government and are not included.

5.6 As in all animal disease preventive efforts, it is difficult to determine how many losses were avoided because the exposure risk and previous susceptibility can only be estimated. In Mauritania, rinderpest outbreaks had been reported more frequently in years prior to the project because of deterioration of the animal health infrastructure left over from the JP15 campaign. One of the benefits of the project was the rebuilding of this infrastructure. Also, direct benefits were observed in that several severe outbreaks of rinderpest occurred in 1975 and 1978 in areas not covered by the project. None occurred in the vaccination areas even though cattle from outbreak areas were known to have had significant direct contact with cattle in the project area resulting in the death due to rinderpest of some young, unvaccinated cattle.

The Control of Foot-and-Mouth Disease in Latin America

5.7 Almost every developing country lives with some degree of problem from foot-and-mouth disease (FMD). Except for dairy cattle and draft
animals, the production losses are low in comparison to other diseases such that control programs are rarely initiated on that basis alone, or only sporadically so. The main interest in FMD control is on the part of the meat and livestock industries in infected countries which wish to export products to "FMD-free" areas of the world. In Latin America, vaccination is used widely, but with varying degrees of success. The necessity of vaccination at least twice a year, antigenic variations of the FMD virus and substandard vaccine production causing poor protection or clinical illness; have led to cattle owners becoming disenchanted with vaccination against FMD. However, in Chile, using a uniform quality vaccine on a regular basis, they reduced the outbreak incidence to essentially none, and then, gradually discontinued vaccination in one area after another until they reached a status of "disease-free without vaccination" in 1977. It is considered unlikely that other Latin American countries will achieve this goal, at least not until a better vaccine can be developed (Sutmoller and Casas, 1981).

5.8 At the Panama-Colombia border, an "FMD-free" area has been established since 1974. It is maintained by strict control of movement and continual veterinary surveillance for indications of FMD. In an area just south of this, strict control and surveillance are maintained and vaccination is routinely done three times per year by government vaccination teams. Just beyond this, a control area is maintained where outbreaks are investigated and intensive publicity campaigns about the value of vaccination and surveillance are directed at livestock owners. The main idea is to establish a large buffer zone to prevent the introduction of FMD to Central and North America via the Pan American Highway. During 1974 through 1982, the total costs of this program have amounted to about $17 million, with 65% being supplied by the U.S. The cattle population in all areas under control is about 1,800,000 head, with 50,000 being in the "FMD-free" area. (Wyss, 1981). In Panama, animal agriculture is being "discouraged" near the Colombian border to further reduce the threat of disease spread. Obviously, the main concern for the success of this effort is from Central America, Mexico and the U.S. It is estimated that endemic FMD in the U.S. would cost some $12 billion in increased prices consumers would have to pay over 15 years for livestock products. (McCuenley, et al, 1979). Such U.S. concern also was the stimulus for the eradication of FMD in Mexico after outbreaks in 1946.

5.9 An important study to determine the production and productivity losses associated with FMD has been carried out in three states in Brazil over the recent years. The study was aimed at measuring production changes which actually occurred in herds following natural FMD outbreaks as compared to production data from the same herd prior to the outbreaks and/or to herds under similar feed and management conditions. Briefly this study

1/ Milk production in clinically infected dairy cattle is diminished greatly, usually for the remainder of the lactation and abortions sometimes occur. The disabling foot lesions and, particularly in the Far East and India, there is considerable smallholder interest in protection against FMD.
indicated that FMD caused: 1) 7% increase in calf mortality, 2) 10% decrease in milk produced by affected but recovered cows in that lactation, and 3) 10% uncompensated decrease in growth (weight) in infected young cattle.1/

African Swine Fever in the Dominican Republic

5.10 Because of the high mortality from African swine fever (ASF) infection and the lack of an immunizing method against it, outbreaks of ASF require immediate and drastic attention. The slaughter and quarantine technique followed by area or country-wide depopulation of pigs is the only way to eradicate the disease. And eradication is by far the most desirable status because living with it is so costly—as Spain has discovered. This disease is particularly devastating to the smallholder because his scavenging pigs are frequently the only method he has to utilize plant residue and household waste feed resources.

5.11 The 1978 outbreak in the Dominican Republic started when a pig grower, noting his pigs were sick and dying, sold out his herd thereby spreading the disease to several locations in the country. His pigs were fed airline garbage which, undoubtedly, was the source of the virus. After a few outbreaks occurred, the differentiation of ASF from hog cholera was made and slaughter and quarantine procedures were started. Later, it was decided to eradicate the disease by depopulating the pigs and then rebuild the industry. Some 1 million hogs were consumed from 1979 to 1981 in the depopulation. The U.S. and the Dominican Republic spent about $10 million in program costs. Costs from higher import quantities of pork products also occurred. The eradication was determined successful after "sentinel" pigs placed on several previously infected areas did not show signs of ASF 2/. Hog cholera, which had been enzootic, was also eradicated. Now, the pig industry is being rebuilt. Since the disease is also in Haiti and threatens the Western Hemisphere, depopulation was recently started there under a scheme in which the government buys the pigs and allows the previous owners to have the carcass after slaughter. This program is conducted through Interamerican Institute for Cooperation in Agriculture. The funding by the U.S., Mexico and Canada reflects the threat this disease poses for these countries.

1/ This study was a joint project between the Brazilian Ministry of Agriculture, Inter-American Development Bank and Pan American FMD Center in Rio de Janeiro. The final reports and manuscripts are in preparation.

2/ Outbreaks in Cuba in 1971 and 1981 were dealt with in a similar fashion, except that depopulation was done in certain areas rather than the entire country. In Malta, the pigs were depopulated country-wide after an outbreak in 1979. In 1978, ASF was diagnosed in Brazil, but it apparently "disappeared" following eradication as there have been no reports of new infections since then. FAO assisted in these programs as well as in the Dominican Republic.
Trypanosomiasis Control Programs in Nigeria and Cameroon

5.12 Throughout the major portion of tropical Africa, numerous projects have been aimed at the reduction of trypanosomiasis through control of the tsetse fly vector. The control of this disease is much more complex than others, but the potential benefits from reduced livestock production losses, increased availability of arable land and reduced human sleeping sickness provide a constant stimulus to keep on with the efforts. These are expensive endeavors requiring recurrent costs to claim new tsetse-free areas and then to maintain their tsetse-free status through ground or aerial insecticide spraying and barrier upkeep. The preferable strategy is eradication in an area which is protected against reinestation by natural barriers, which greatly reduces recurrent costs. South Africa has been successful in maintaining the eradication of the tsetse fly.

5.13 Nigeria has been the scene of the largest tsetse control program in Africa. The technical and economic aspects of the control of this disease in Nigeria have been analyzed recently by a team from the University of Reading (Putt, et al., 1980).

5.14 Data on the costs of insecticide application to various areas and for various purposes were gathered for the period 1973-74 to 1977-78. Selected data are shown in Table 5.1 to indicate the great variation in costs for different purposes, areas and methods of spraying (Currency converted at the 1977 rate of 1 Miara = $1.54).

<table>
<thead>
<tr>
<th>Description of work</th>
<th>Ground Spray</th>
<th>Helicopter Spray</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (km²)</td>
<td>Variable Costs ($/km²)</td>
</tr>
<tr>
<td>Work on newly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>reclaimed areas</td>
<td>29,333</td>
<td>134</td>
</tr>
<tr>
<td>Work on respraying</td>
<td></td>
<td></td>
</tr>
<tr>
<td>certain reinvaded</td>
<td>4,242</td>
<td>266</td>
</tr>
<tr>
<td>or residual foci</td>
<td></td>
<td></td>
</tr>
<tr>
<td>areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sudan vegetation</td>
<td>9,641</td>
<td>51</td>
</tr>
<tr>
<td>Northern Guinea</td>
<td>21,209</td>
<td>209</td>
</tr>
</tbody>
</table>

* Selected from Tables 8.23 and 8.24 of Putt, et al., 1980.
5.15 When the fixed costs of staff and headquarters are added to the variable costs, ground spraying total average costs per km² ($549/km²) appear much closer to helicopter spraying ($616/km²) than is indicated by comparing only the variable costs (From Table 8.26 Putt, et al, 1980). However, since the helicopter spraying is almost entirely paid by foreign exchange, the current scarcities of foreign exchange must be taken into account resulting in an equivalent of $594/km² for ground spraying compared to $947/km² for helicopter spraying. The authors point out that further advantages in ground spraying come from providing local employment, road construction and personnel training.

5.16 Bringing new land into crop production is a potential benefit of tsetse area eradication. This benefit is highly variable in its occurrence and depends on land pressure in the immediate area and the willingness of farmers to move and homestead new areas recently cleared of tsetse. The farmers must be sure of the removal of the risk of disease to their animals and themselves and be convinced that the opportunity for reward (larger farms, better land) is substantially greater than staying on their present holdings. Because of the variability and complexities of estimating the potential benefits from this source, the authors did not include land use in the overall, nationwide benefit/cost evaluation. However, they did analyze the cropland benefit issue for two districts. In one of these Sokwa District, where tsetse clearing was done in 1961-62 and good records were available, farmers emigrated to riverine areas and cultivated high income yielding vegetable and rice land. This land yield is estimated to be some three times that of ordinary land in that area, and figures as a major item (38.4%) in their high-level, benefit assumptions which resulted in a B/C ration after discounting of 7.97 for this district.

5.17 Benefit-cost ratios were figured at a national level considering the elimination of the Glossina morsitans tsetse fly in five years and in ten years. If one-third of the carrying capacity resulting from this elimination were used for cattle production; the benefits of the meat production, reduced trypanosomiasis treatments and reduced trypanosomiasis morbidity were calculated to be 3.34 times greater than the costs as discounted over ten years at 12%. This does not include benefits from the reduction in sleeping sickness incidence, sheep and goat production losses, nor increased land availability.1/

5.18 In Cameroon a tsetse fly eradication program was carried out in an area of 800,000 hectares during 1976-80. Although the costs were higher than expected, the effort appears to have been successful as some 60,000 head of cattle had been moved in by 1981. As yet, not enough time has elapsed to assess the durability of the eradication in terms of occurrence of tsetse reinestation. In the project completion report, several experiences are described which hold important lessons bearing on the implementation of such programs (IBRD Loan 983-CM; Project Completion Report, 1981).

1/ The question of the economic consequences of the control of tsetse flies and cattle trypanosomiasis has also been evaluated for Uganda (Jahnke, H.E., 1974). The conclusions of Putt, et al. are essentially in agreement with those of Jahnke.
a) Effective tsetse survey capability is critical to the success. Prior to the eradication, extensive surveys are required to estimate the size of the effort needed to achieve the goal—if achievable. During the insecticide application campaigns, surveys must be maintained to assess the efficacy and to identify areas where respraying is required. Following the eradication, funding is required for recurrent costs to maintain the survey capability in order to protect the investment.

b) Reinfestation apparently occurred despite barriers of a mountain range (up to 1,800 m high) and deforested strips of land 2.5 km wide. Such barriers had previously been thought to be a sufficient detriment to reinfestation. The implication is that annual maintenance costs will be higher than expected.

c) Because of unforeseen technical difficulties, costs were 103% above appraisal estimates. (Table 5.2). A more thorough survey prior to implementation could have revealed this discrepancy. The costs shown in the following table are higher than those reported in Nigeria, possibly because of different terrain and more dense tsetse infestation. Also, in making such comparisons one has to take into account the criteria being used for designating the area reclaimed.

Table 5.2: Costs and Other Data
From Tsetse Eradication Program in Cameroon
1976-1980*

<table>
<thead>
<tr>
<th>Description</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helicopter Flying Time</td>
<td>3,147 h</td>
</tr>
<tr>
<td>Area Sprayed per Hour Flying time</td>
<td>54 ha</td>
</tr>
<tr>
<td>Area Actually Sprayed</td>
<td>170,187 ha</td>
</tr>
<tr>
<td>Total Area Reclaimed</td>
<td>794,500 ha</td>
</tr>
<tr>
<td>Portion of Reclaimed Area Actually Sprayed</td>
<td>21 %</td>
</tr>
<tr>
<td>Area Resprayed Including 3,499 ha Barrier Spray</td>
<td>102,800 ha</td>
</tr>
<tr>
<td>Insecticide Applied to Reclaimed Area</td>
<td>2 l/ha</td>
</tr>
<tr>
<td>Actual Total Cost per km² Reclaimed (excluding technical assistance, consultants and surveys)</td>
<td>733 $/km²</td>
</tr>
<tr>
<td>Actual Total Cost per km² Reclaimed</td>
<td>958 $/km²</td>
</tr>
</tbody>
</table>

VI. OTHER ISSUES
Reducing Animal Disease and Overstocking the Land in Pastoralist Systems

6.1 Particularly in relation to the Sahel, the point has been raised that reducing animal disease threatens to seriously degrade grazing lands because of overstocking. However, even without disease control overstocking occurs because owners facing a constant threat of disease and drought will attempt to hold as large a herd as possible — including cows of doubtful production potential.1/ This is their way of surviving against these threats. It would be irrational for such pastoralists to behave any other way. When they become confident that disease losses can be reduced on a continual basis, they may start to sell some cows as they sense the security that they can support their family through the disasters with a smaller, more efficient herd. The uncertainty of "When will disease strike and how many animals will I loose?" is diminished. As an indication of this: in Nigeria after the success of JP15 in 1968, cattle owners sold a higher proportion of females than in previous years.

Who Should Pay?

6.2 The argument is that if the livestock owner, regardless of the size or intensity of his enterprise, understands the benefit of vaccination; he will seek it out and pay a price which seems fair when weighed against his perception of the risk avoided.2/ This is true and happens fairly

1/ A worthwhile discussion of potential overstocking and the pastoralist system equilibrium is made with regard to the implementation difficulties encountered in the development of public water wells in Mauritania. The sensitive balance between pastoralists and their traditional land use rights is cited as being "primitive at first glance" but "efficient" when environmental realities are taken into account. The increase in cattle numbers aided by the animal health component did not compromise this equilibrium in the post-drought era. The difficulty of economically increasing forage availability is pointed out. (Mauritania Livestock Development Project Performance Audit Report. No. 3208, 1980. Section II). (In contrast, production improvement through disease control does not tamper as directly with sensitive land use rights as does water well development).

In another study evaluating the impact of USAID's Livestock Projects on the sociologic aspects of the West African pastoralist system, the author attributes "the poor success of livestock sector interventions to fundamental discrepancies between assumptions commonly made about pastoral behavior and the social and ecological realities of African pastoral life". He also presents valuable discussion on the question of "Why do they seek to keep larger herds?" (Horowitz, 1979).

2/ This perception of risk is more accurate than many expatriate technicians might expect as shown by a study of the knowledge of Dinka cattle healers and cattle owners in southern Sudan (Schwabe and Kuojok, 1981). Similar information is described for Somaliland (Mares, 1954) and for the White Nile area of Sudan (McCauley, et al, 1982).
routinely in developing countries for diseases like black quarter, anthrax, hog cholera, hemorrhagic septicaemia and Newcastle disease if the owners have confidence in the vaccine. However, such behavior can not be uniformly counted on and vaccine failures may have undermined the confidence.

6.3 One important role of government animal health services is to assure the availability of properly preserved and immunogenically potent vaccines. This leads to more widespread use of appropriate vaccines and fewer disease outbreaks. However, when outbreaks do occur in developing countries, the public good is best served by government sponsored disease control programs - particularly when human infection or rapid spreading is possible. The private sector is very limited in its abilities to mount such control programs.

6.4 Additional activities of: regulation of animal movement, laboratory diagnostic services, technician training, animal health extension, disease surveillance and control strategy planning are most appropriately operated by the public sector. The benefits are external to the enterprises of individual livestock producers or private veterinarians. The distribution and marketing of most vaccines, drugs and insecticides can be most efficiently handled within the private sector.\(^1\) Undoubtedly the efficacy of application of these products would be enhanced by extension and training activities by government.

\(^1\) Further discussion on this question is offered for West Africa (Nissen, 1982).
VII. IMPLICATIONS FOR INVESTMENTS IN LIVESTOCK DISEASE CONTROL

7.1 Several implications emerge from this review about the potential reward to investments in livestock disease control programs or animal health infrastructure. They are discussed briefly under three headings of: basic research, field investigations, and livestock health services.

Basic Research

7.2 Vaccine Discovery and Development. The closer vaccines approach conditions of being thermostable and potent immunizers coupled with ease of administration; the greater will be their usefulness for livestock producers of all types, particularly for the smallholder. Although progress has been made in the case of foot-and-mouth disease, for many diseases these goals seem a long way off, or even completely baffling. But the potential return to success is high and the requirements to keep up the search justify prudent funding. A key to these achievements is the identification of the organism's specific antigens which stimulate immunity in the host. The mechanisms for reproducing such protein antigens are becoming better understood and more practical.

7.3 Techniques of Vector Control. The use of insecticides is a temporary and costly maneuver with some serious trade-offs in terms of immunity and, possibly, of environmental quality and insecticide resistance. Success from vector control relies entirely on the full understanding of the vector's life cycle, disease epidemiology and livestock management procedures. The economic returns are attractive only in instances of intensive, high yield production systems and where it is possible to maintain thorough control continuously. Breakthroughs in the area of biologic controls and long-acting, systemic drugs against vectors could resolve some of these problems—at least under specific circumstances.

7.4 Genetic Selection of Disease Resistant Livestock. In the short term, continued emphasis should be placed on identifying indigenous breeds or sub-groups which seem to show disease resistance. The evaluation and confirmation of this resistance is difficult but worthy of further investigation. An important practical consideration is the transfer of this resistance, once established, to offspring from crossbreedings with other livestock.

7.5 In the long term, the possibility of developing livestock breeds on the basis of disease resistance as associated with the genetic makeup of the major histocompatibility complexes would provide a more accurate basis for individual selection and monitoring disease-resistant breed development.

Field Investigation

7.6 Determination of Clinical Case Incidence and Production Losses. The funding of research and animal health delivery should be related to the potential of increased production. To measure or estimate this, better
field information of losses due to clinical illness and on efficacy of control procedures is needed prior to implementation of animal health control programs or the funding of research. The value of this information depends on diagnostic accuracy so that funding emphasis is deserved for this as well as properly executed field studies.1/ These activities are commonly considered as part of the task of the livestock health infrastructure. But unfortunately, their importance frequently is assigned a low priority in comparison to the day-to-day exigencies of such activities as regulating animal movement, vaccine distribution and disease outbreak management.

Livestock Health Services

7.7 Training Personnel. In most developing countries there is a need for more investment in training of local technicians rather than training more veterinarians. Such training would best be conducted in various outlying areas, through low-cost, short sessions with periodic reviews. The trainees should be expected to develop abilities in such topics as: proper handling of different vaccines, basic differential histories and signs (including gross necropsy examination) of common diseases, simple field diagnostic techniques (hemoparasitic and fecal egg identification), preparation of samples for laboratory examination and routine treatment of certain diseases. Further, if such technicians could be "encouraged" to periodically describe their observations on disease occurrence, this would provide a basis for continual incidence estimates. The selection of prospective trainees could probably best be made on the basis of nomination by their community.2/ Their transportation would be by the common, local means. In most cases, they should not be responsible for any regulatory action as this could interfere with the local trust network. Because of the public-good basis and police-type aspects of regulatory action and movement restriction, government officials are best fit for this role.

7.8 Building and Maintaining a Livestock Health Infrastructures. A stable, effective livestock health program requires continuous funding in order to deliver various animal health services (diagnostic facilities, control of outbreaks, vaccine regulation and quality control, animal movement restriction, vector control and disease surveillance).3/ Numerous

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1/ The importance of such studies is emphasized in a supervision report on the Ituri Zaire, Livestock Development Project. The consultants describe numerous deficiencies in insecticide dip management resulting in low insecticide concentrations. They emphasize the need for a study on the production impact of East Coast fever before further funding of tick control is considered (Supervision Report, Ituri Livestock Development Project, Credit 697-ZR, 1982).


3/ The capability of the livestock disease diagnostic laboratories in Latin America was recently surveyed and categorized by IICA. Their report provides useful guidelines for assessing the diagnostic capacity of laboratories. In general their conclusion was that the majority of the laboratories did not have adequate diagnostic capability necessary for efficient animal production (Arellano, et al, 1982).
problems plague such services in developing countries and the organizations sometimes become inordinately political. Funding for the sake of maintaining the bureaucracy without evidence of its effectiveness in performance of its mission of animal disease control would be unacceptable. However, the potential for achieving cost-effective reduction of appropriately selected diseases exists in developing countries. The assessment is difficult, but the most rewarding investments will come from the most realistic estimates of their link to production impact.
Brief Descriptions of Major Infectious Diseases of Livestock in Developing Countries

Viral

African Horse Sickness

1. Horses, donkeys and mules are infected by the virus transmitted by biting insects with the results of high mortality, particularly in horses. It is enzootic with annual outbreaks occurring in Southern, Equatorial and East Africa south of the Sahara, and it has extended to the Arabian Peninsula, the Mid-East, North Africa and Spain. Excessive fluid in the lungs and hemorrhage of vessels of the heart and gut are the common causes of death. A long-lasting immunity is produced by infection or by vaccination using modified live vaccine. There are nine serotypes which have little cross-immunity, so a broad spectrum vaccine is required.

African Swine Fever

2. This disease only affects pigs. Wild pigs act as reservoirs in Africa. In most outbreaks mortality is nearly 100%, although recent experiences in Angola, Spain and Portugal show that a subacute form can exist or develop with decreasing virulence of the virus where the disease is enzootic in domestic pigs. This virus is unusual in that it is the only member of its family which infects mammals. The other family members infect reptiles and insects. There is no vaccine and infection itself does not produce uniform immunity in recovered pigs. Eradication can only be achieved through slaughter of pigs and quarantine of infected premises or areas. Outbreaks of ASF have occurred outside Africa in Spain, Portugal, France, Malta, Brazil, Cuba and the Dominican Republic. The virus is spread by contact, through mechanical transfer by certain soft-tick species and through garbage pork. The recent outbreaks in Brazil, Cuba and the Dominican Republic were due to airline or ship garbage being fed to pigs. The virus destroys endothelial cells causing uniform loss of vasculature integrity and subsequent hemorrhage in all tissues. It is important to differentiate ASF from hog cholera since the clinical signs are very similar in the acute stages.

Foot-and-Mouth Disease (Fiebre Aftosa)

3. Cloven-hoofed animals in the developing world are frequently infected by this virus, while most of the developed world is either completely free or lives with very low incidence of infection under organized vaccination and eradication programs. The production losses result from mortality in the young, inability to move about to graze, teat lesions and delayed growth. These losses result from the blisters and erosions of the epithelium on the tongue, mouth, nose, teats and feet caused by the virus. Confusion in diagnosis comes from similar lesions seen in other vesicular diseases. The most notable of these is vesicular stomatitis disease which causes lesions identical to FMD in cloven hoofed
animals and in horses - the principle differentiating factor under field conditions. Recently a serious outbreak of vesicular stomatitis occurred in the U.S. following presumed introduction from Mexico. Outbreaks occur in Latin America sporadically and damage, particularly from teat and foot lesions, have caused significant losses. Immunity is short, even from natural infection, and is further complicated by the existence of seven major serotypes and over 60 subtypes -- some of which show only weak cross immunity. Although production losses are usually low, FMD poses problems for countries wishing to export live animals or meat to "FMD-free" countries of Europe, Central and North America; and Australia, New Zealand, South Africa and Japan.

**Hog Cholera**

4. This disease causes problems in pig production worldwide. In most developed countries, either a killed-vaccine is used or the disease has been eradicated (U.S., England, Australia, Canada, South Africa, New Zealand). Hog cholera causes clinical illness and death in nearly 100% of susceptible pigs. However, recently a milder form has been more frequently seen which raises concern because of the "inapparent carrier" status of such pigs. The virus damages vessels in the blood cell forming tissues. Small hemorrhages are seen on the surface of internal organs and the skin. Severely depressed white blood cells contribute to the sudden onset of weakness and acute deaths. Various vaccines are produced. Hog cholera is one disease in which the live, virulent organism has been extensively used to immunize, but it is a dangerous approach since it perpetuates the virus in the environment. Modified-live, tissue culture vaccines are safer while the killed vaccine is the safest and most stable, but produces a shorter duration of immunity.

**Newcastle Disease**

5. Throughout the world, chicken raisers are aware of the damage caused by ND. The second worldwide panzootic occurred during 1962-72 and virulent strains of ND virus causing over 90% mortality in susceptible chickens were isolated from all continents except Australia. since the vaccines are frequently not available to smallholders, they probably suffer greater losses than do the more sophisticated enterprises. An important aspect of effective ND control or reduction of incidence is government ability to curtail the spread from outbreaks and to monitor the potency and safety of vaccines being offered to farmers.

6. The various clinical outcomes and results of immunization depend on the strain of ND virus involved. This disease is similar to foot-and-mouth disease in that it is important to determine which strain or type is causing the illness. The following table shows the differences in the major types of ND.
### Types of Newcastle Disease in Adult Chickens

<table>
<thead>
<tr>
<th>Disease</th>
<th>Virus Strains Associated</th>
<th>Signs</th>
<th>Gross Lesions</th>
<th>Survival Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asiatic; Viscerotropic</td>
<td>Facial edema, Hemorrhage of lower eyelid, nasal discharge, diarrhea</td>
<td>Hemorrhages in trachea and larynx and gut (particularly proven- tricusulus and cecal tonsil)</td>
<td>4-8 days</td>
<td></td>
</tr>
<tr>
<td>Facial Edema Fever</td>
<td></td>
<td></td>
<td></td>
<td>0-19%</td>
</tr>
<tr>
<td>Neurologic</td>
<td>Labored breathing and nasal discharge, tremor, paralysis and torticollis</td>
<td>Air sac thickening, hemorrhages rare</td>
<td>8-12 days</td>
<td></td>
</tr>
<tr>
<td>Respiratory-Virulent</td>
<td></td>
<td></td>
<td></td>
<td>10-80%</td>
</tr>
<tr>
<td>Respiratory-Mesogenic</td>
<td>Mild respiratory signs, decreased appetite, decreased egg production</td>
<td>Unremarkable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory-Avirulent</td>
<td>None **</td>
<td>None</td>
<td></td>
<td>100% *</td>
</tr>
<tr>
<td>Respiratory-B-1; B-4; F; Lasota</td>
<td>None **</td>
<td>None</td>
<td></td>
<td>100% **</td>
</tr>
</tbody>
</table>

Mortality in young chicks ranges from 5 to 20%
May increase signs of concurrent infection.

(Prepared by R. P. Hanson, University of Wisconsin.)
7. The body of knowledge on Newcastle disease is probably more sophisticated than for most mammalian livestock diseases. Effective techniques of vaccination through drinking water and aerosol have been developed which, under good management, can keep free of clinical disease even in high risk areas. As simple as water and aerosol vaccination may sound; several conditions have to be satisfied in order to achieve immunity in a large proportion of the chickens. Some of these are:

a) Water cannot be too hot or too alkaline and must be accessible to all chickens over a few hours.

b) Aerosol spray must be of a certain droplet size and houses must be enclosed.

c) Proper vaccination schedule (such as every six weeks) must be carried out to overcome the problem of partial coverage.

8. These conditions are frequently unattainable under smallholder management, even if the product is readily available and properly stored. Presently work is underway at the University of Wisconsin to develop a stable, potent vaccine that can be easily administered (probably orally in a pill form) for use in developing countries.

9. The problem of ND in younger chickens is more difficult to deal with than in adult birds principally because of the poor immune response under six weeks of age. The only course is to isolate them from older birds and vaccinate frequently.

10. The disease is transmitted by chickens, which carry the virus in a transitory state, and by certain wild birds in which the virus is carried in a long, persisting state which show no signs of clinical disease. In the U.S., ND was recently introduced by parrots imported either legally or clandestinely as pets. Eradication was achieved after considerable difficulty and expense. In the 1972-73 campaign in Southern California, 12 million exposed or infected poultry were destroyed at an indemnification cost of $27.5 million. The program costs were $28.5 million. Subsequent to that campaign, further expenses were incurred for surveillance and to deal with infected pet birds found in areas along the Mexican border and in New York City.

**Peste des Petits Ruminants**

11. This virus is so closely related to rinderpest that it is considered as "a unique" member of the rinderpest virus family. The signs are almost identical to rinderpest in cattle. Kata (pseudo-rinderpest), a disease of West African goats is clinically and immunologically indistinguishable from PPR. Goats are more susceptible than sheep and mortality ranges from 10% to 90%. Rinderpest vaccine effectively protects animals against PPR infection.
Rift Valley Fever

12. This disease occurs in epidemic form about every 10 to 20 years resulting in extremely high death losses of very young cattle, sheep, goats, dogs and cats, and frequently an influenza-like illness in humans. In older animals, mortality is low but abortion is a very common sequela to infection. In man, infection causes high fever, headache, muscle pain, weakness and eye problems. Fatalities and blindness occur, generally, in a low portion of clinically ill persons. It can be transmitted between animals by biting insects, most commonly mosquitoes, which may explain cycles of disease outbreaks coinciding with heavy rainfall in low terrain. The disease is not thought to be transmitted to man by mosquito but through contact with the virus in animal tissue. Conditions may be right for epidemics in areas other than the Rift Valley to which outbreaks appeared to have been restricted in previous years (except for an outbreak in South Africa in 1951). Only recently a virus found in West Africa, commonly called "Zinga" virus, has been identified as being the Rift Valley fever virus, which extends the range of this disease through Central and Western Africa. (Meegan, unpublished data, 1982).

13. A serious epidemic occurred for the first reported time along the Nile in Egypt in 1977-78. New irrigation areas may have created new mosquito habitats and therefore been indirectly connected with this Egyptian outbreak in which deaths of thousands of young livestock and high numbers of abortions in adult livestock were described and 18,000 human cases with 568 fatalities were officially reported.

14. There are two types of vaccine - (one attenuated and one inactivated) that are used to effectively protect livestock. However, there are still some dangers of the vaccine being a threat to human health and the risk of human infection is a serious concern in the vaccine production process. Because of the epizootic aspects, insect transmission and multiple hosts, eradication would be unrealistic and control would be extremely difficult. (Lupton, et al, 1982).

Rinderpest

15. Serious rinderpest outbreaks in cattle and buffalo frequently occur throughout the developing world, except in Latin America. It is particularly a problem in Africa due to the widespread migration patterns of cattle and, possibly, the free-ranging wild life which may be carriers. Fatality occurs in a high percentage of susceptible animals but milder forms are seen more frequently in recent years which may be due to partial immunity or a less virulent strain of the virus. The principal lesions are necrotic erosions in the mouth and widespread hemorrhage in the large intestine leading to profuse hemorrhagic diarrhea. The disease is spread through animal contact since the virus is shed in all body excretions. Vaccination is very effective. One injection produces essentially a life-long immunity to all virus strains. Rinderpest virus is closely related to the measles and dog distemper viruses which also have this desirable immunogenic trait.
16. Sheep and goats can show clinical signs (very similar to Peste des Petits (Ruminants) after infection but serious problems are uncommon. Pigs can be infected but rarely show serious disease.

**Bacterial**

**Anthrax**

17. This organism is picked up from the soil, particularly in dry periods, when animals graze close and either eat or inhale the spores. Certain areas of the tropical and subtropical world have enzootic anthrax with outbreaks occurring in all species. The spores are very resistant—living for years in the soil. The organism produces a lethal toxin which prevents blood clotting and causes sudden death in cattle and sheep and a 2-to-4 day illness in pigs before death. The enlarged, black spleen is one of the most outstanding signs recognized by traditional cattle growers when they salvage recently dead or in extremis animals for consumption. Even though they may recognize the threat anthrax to human health, pastoralists in some areas will eat the meat. In humans, anthrax causes skin pustules (most common) and lung and intestinal damage which may lead to acute death depending on the location and degree of infection. The skin form is called "wool sorters" disease because of contaminated wool (also leather) being the most common source. Anthrax vaccine is one of the more frequently used vaccines in the developing countries. This reflects the seriousness of the disease and the stability, efficacy and reasonable price of the vaccine. However, the immunity for periods longer than one year is questionable.

**Black Quarter (Black Leg)**

18. Black quarter occurs sporadically in cattle worldwide and would probably be a significant economic problem except for the relatively long, solid immunity produced by vaccination against it. Infection almost invariably results in death. The vaccine is a killed and altered form of the bacteria which neutralizes the effects of the muscle-tissue damaging toxin and is very stable and inexpensive. It is commonly used by smallholders. Susceptible cattle usually die with 24 hours after onset of signs. The spores of the organism persist in the soil for years and are found in intestines and liver tissue of healthy animals at slaughter. The reasons that the spores suddenly start to proliferate in tissue are unknown. It appears related to trauma or the nutritional status and age of the host—it occurs most often in young, well nourished cattle. Tetanus and botulism diseases are caused by organisms of this genus (Clostridium).

**Contagious Bovine Pleuro-pneumonia**

19. CBPP occurs most frequently in cattle gathered together for trekking or shipping. Recovered animals are the most common source of infection—shedding the organism (a mycoplasma) for up to three years in droplets which may be inhaled by other cattle. Totally susceptible animals suffer a long course (1 to 6 months) of gradual respiratory embarrassment causing them to lag behind others when trekked. Sufficient portions of the lungs are damaged in about 50% of the clinically infected cattle to cause...
death in the early stages. The remainder of the infected cattle go through life as poor-doing, chronic "lungers" or as recovered carriers. The "marbled" appearance of the lungs and fibrinous pleuritis are the classic lesions. CBPP is present throughout Africa (except South Africa), Asia and the Far East. Vaccination is sometimes done in conjunction with rinderpest vaccination which is probably the only time it is feasible to carry out area-wide vaccination against CBPP. Otherwise vaccination is appropriate in moving cattle or in areas where outbreaks are common. There are numerous practical problems with the various vaccines such as: instability when exposed to light and heat, shedding of the organism causing sickness in susceptible cattle, and occasional severe tissue reactions at the vaccination site. Sometimes to achieve a good immunity, a virulent strain is used followed by antibiotics to prevent serious illness.

Hemorrhagic Septicaemia (Pastuerella multocida-Carter Type B)

20. Losses due to HS are most common during the wet season of the year in cattle and buffalo predominantly in the Far East, India, Pakistan, Bangladesh and Sri Lanka. However, outbreaks also occur at other times of the year. The organism seems to require environmental stress to proliferate and cause widespread hemorrhage with fluid accumulating in the tissue spaces. A common sign after the first signs of illness is diffuse swelling of the brisket and lung damage causing difficulties in breathing. Death usually follows these signs in 24 to 72 hours. However, as in many bacterial diseases, treatment at the first signs of illness with antibiotics is justified. The buffalo is particularly susceptible and HS seems more common where buffalo and cattle commingle. The vaccine produces only short immunity (6-8 months) so vaccination is normally done at the start of the monsoon season. The impact on buffalo draught power during the rainy season is a constraint to rice production in the Far East. Recent HS has emerged as a major problem in parts of West Africa. In the past outbreaks have occurred occasionally in Europe and the U.S. Since other P. multocida infections are common in the U.S., it is not known why "type B" infections are essentially non-existent.

Rickettsial

21. The disease organisms of this family are transmitted by fleas, ticks, lice or mites and many infect humans. Epidemic typhus and spotted fevers are the most common diseases. The basic lesions that occur in rickettsial disease are in the blood vessel walls because the organism proliferates in the endothelial cells. The diseases responds to antibiotic therapy if given early in the course of infection.

Heartwater (Cowdria ruminantium)

22. Heartwater occurs in much of Africa south of the Sahara and in the southwest Arabian Peninsula. The occurrence is determined by the distribution of the principal vector, the "Bont" tick of the Amblyomma sp. However, other ticks also transmit the disease. Recently it has been shown that Amblyomma ticks found in the Western hemisphere can transmit
heartwater and it is suspected to be on the island of Guadalupe. In susceptible animals, the organism causes a fairly rapidly developing series of central nervous signs leading convulsion and death in less than a week. Fluid accumulates in various body cavities and tissues including the heart sack—from which comes the name of "heartwater". The disease produces such a wide variety of signs that it is easily confused clinically with other diseases or toxicities. There is no vaccine. Prevention is similar to that practiced with other hemoparasitic protozoa. Deliberate exposure combined with antibiotic treatment produces a solid community for 6 to 18 months which is reinforced by continued natural exposure. Tick control must be practiced on a frequent basis, like that for the East Coast fever tick, if it is to be effective.

Protozoal

23. These diseases are carried by tick, fly or mosquito vectors in which the protozoa disease organism may undergo cyclic development. Upon infection, the host's blood cells or blood cell production system is invaded resulting in signs associated with anemia or lymphocyte damage. The major problems occur in cattle, but sheep and goats can become seriously infected in some areas. In most cases, young animals (up to one year) are more resistant than older animals leading to the common practice of exposing young animals to the disease in order to produce immunity. Also, typically, immunity is difficult to achieve by means other than natural exposure due to the variety of antigens which protozoa have and the need for continuous natural exposure to maintain immunity.

Anaplasmosis (Anaplasma marginale) 1/

24. Losses in cattle due to anaplasmosis are most common in North and South America, South Africa and Australia due to the presence of suitable insect vectors. In susceptible cattle, destruction of red blood cells leads to signs of severe anemia and jaundice, after a month incubation period. The course of weakness and moderate fever may continue for several days followed by death or a long convalescent period before normal production is regained. In newly introduced and susceptible cattle, mortality is high while indigenous cattle show very few signs of illness and are inapparent carriers. This is probably due to immunity from continuous exposure. A wide variety of ticks (20 species) and flies (10 species) can serve as vectors. Vector control is feasible under certain conditions like maintaining an area control zone or for valuable cattle, but in most cases it is too costly to keep up. Also it interferes with the production of immunity. Tetracycline is an effective treatment and is used to prevent serious losses in animals deliberately exposed for

1/ Anaplasmosis is included under protozoal diseases here but it may belong properly with rickettsial diseases depending on certain taxonomic arguments.
immunization. Various attenuated, live *A. marginale* vaccines are produced which yield successful results provided the challenge is not too virulent. Also vaccination may be done with the live, non-pathogenic species, *A. centrale*, which reduces the severity of the reaction to *A. marginale* infection. These vaccines have not always been potent enough to protect cattle under field challenge in Central and South America, and although natural exposure provides good immunity, it sometimes causes illness and death particularly in imported cattle.

**Babesiosis (Piroplasmosis, Tick Fever)**

25. *Babesia argentina* is the principal cause of the most serious clinical disease in cattle in Africa. *B. bigemina* is the most significant species in Latin America. Most tick vectors are "one-host" ticks. Heaviest losses occur where tick populations vary and cattle may become intermittently susceptible. Concurrent infections of babesiosis and anaplasmosis are common in Latin America, where tick vectors for both are present. Weakness, high fever, and severe anemia are the common signs which sometimes continue for three weeks. In fully susceptible cattle, the death rate may be 60% and recovered animals are carriers. As with anaplasmosis, deliberate infection of young cattle provides the best immunity. Recently, a non-viable vaccine has shown promise experimentally as being an alternative to deliberate exposure. Highly effective drugs have been available for over 40 years; e.g. Acaprin. Certain new drugs (Imidocarb) have given good results in treatment without toxicities. Tetracycline is not nearly as effective in the treatment of babesiosis as it is against anaplasmosis.

**East Coast Fever (Theileriosis)**

26. Of the animal protozoal diseases, ECF causes the most serious clinical outcome with fatality in cattle and buffaloe being common. Fortunately it is restricted in its distribution by the distribution of its vector -- the "three-host", *Rhipicephalus appendiculatus* tick. Although ticks common in other areas, including the Americas, have been shown capable of transmitting the disease, ECF is still enzootic only in East Africa. Following outbreaks in South Africa in the early 1900's the disease was eradicated by dipping cattle and quarantine and slaughter of cattle involved in outbreaks. Previously unexposed young cattle are highly susceptible and mortality may be 70% to 90%. As described by survey and other studies, indigenous cattle of all ages in enzootic areas of Malawi appear to annually suffer a 3% mortality due to ECF. Most of this mortality (10%) occurs in calves with adult cattle having a much lower death rate (1%). Calf mortality due to ECF in Tanzania has been estimated to range from 11% to 19% depending on the ECF risk of the area. Cattle which survive the clinical disease are estimated to have a 25% reduction in productivity. (Grindle, 1981). The clinical signs of enlarged lymph nodes, fluid in the lungs and a severe drop in white blood cell count are related to the depletion of lymphocyte cells from the invasion and proliferation of the organism in the lymphoid tissue.
27. The immunology related to protection is complex and has thwarted attempts to develop a vaccine so far. Recovered animals have long lasting immunity to the strain(s) causing that infection. However, there is antigenic differences among the strains and the infection immunity from one strain may not hold against another. Deliberate infection with several strains followed by drug treatment is being explored to provide host immunity. Because of the grave clinical outcome of infection, this "expose and treat" technique may be more uniformly feasible than for other protozoal diseases. Insecticide dipping against the tick is effective but must be continued indefinitely as it leaves the host susceptible. This practice is most common in dairy cattle production, particularly for exotic (European) breeds and their crosses which are more susceptible than indigenous (Zebu) breeds.

African Trypanosomiasis (Nagana" in Cattle and "Sleeping Sickness" in Man)

28. Trypanosomiasis is a collective term for infections caused by various Trypanosoma spp. mostly in tropical Africa where numerous efforts have been made to control or eradicate the tsetse fly-the principal vector. Trypanosomiasis causes major problems in cattle. However, sheep, goats, pigs, horses and camels also become infected but problems in these livestock do not result in the widespread economic impact suffered in cattle production. There is a complex relationship between the host, the trypanosome and the tsetse fly. Certain tsetse fly species are more easily infected by certain trypanosome species and, in turn, certain hosts are more easily infected than other hosts by the various tsetse fly species and the particular trypanosome they may be carrying. Much of this relationship is dependent on the characteristics of agriculture and the density of human population.

29. The clinical signs in cattle are general weakness and fever, in the acute stages. Survivors of this stage gradually deteriorate, are anemic, and may die or continue in a chronically fragile state of infection which may be exacerbated by stresses of movement, concurrent disease or increased draught work. These animals are the "chronic carriers" or "reservoirs" which perpetuate the disease. Antigenic variation occurs throughout the infected period and may be the reason for periodic relapses in that the immune response is not able to cope with newly developed antigens. Obviously vaccination or even infection by exposure is not a feasible protective mechanism at present. Prophylactic trypanosomal drugs are occasionally used in anticipation of a high challenge, such as trekking through a known high-incidence area. The observation that N'Dama cattle of West Africa show a degree of resistance to infection ("trypanotolerance") suggests that selecting for breed resistance may be ultimately a much better solution than the large scale tsetse fly control programs now practiced.

Helminth Diseases

30. Control of helminth diseases is a matter of individual producer concern and does not lend itself to widespread control programs. Since the
Infective forms of these parasites are ubiquitous in the animal's environment — on the pastures and in the water— it is difficult to avoid exposure under most conditions in developing countries. When possible, producers practice a variety of husbandry techniques aimed at reducing the challenge dose. Avoiding certain grazing areas at certain times of the year, breeding at times so that the young are not heavily exposed and moving livestock frequently are some of these practices. Frequent drug treatment, although temporarily effective, is not usually feasible under conditions of smallholder livestock production. Strategic drug treatment done with the knowledge of the timing of the life cycles can be feasible. There is an indirect relationship of nutrition to the outcome of parasitic infection.

Flukes (Trematodes)

31. The principal disease problems are from *Fasciola* and *Schistosoma* spp. all of which have snails as their intermediate host. The highest prevalence of fascioliasis (*F. gigantica* and *F. hepatica*) is in the areas of sedentary cattle, sheep and goat production which are near permanent streams. The *Fasciola* fluke resides in the liver and causes a wasting condition with marked anemia which looks very much like trypanosomiasis. At the start of the wet season when susceptible animals ingest large numbers of the metacercariae, high death losses can occur but the most common syndrome is one of deteriorating condition and poor performance which later shows up markedly with concurrent undernourishment in the dry season. Drug treatment (hexachloroethane and rafoxinide) of fascioliasis is common and owners are convinced of its effectiveness. There are several new flukacides currently available which have less toxic side effects than the older drugs.

32. Schistosomiasis due to *S. bovis* in northern Africa and the Mediterranean countries, *S. mattheei* in southern Africa and *S. japonicum* in the Far east; is most common in ruminant livestock which are exposed to swamps, paddies canals, ponds and slow-moving waters in which the snails thrive. After leaving the snail, free-living forms of the organism penetrate the skin and migrate to reside in vessels of the intestine from which they excrete eggs for several years. At the stage of early invasion, these flukes cause bloody diarrhea and death in younger animals which are susceptible. There is no economically feasible drug treatment against schistosomiasis. Recently in Sudan, a vaccine has been discovered which was effective in reducing *S. bovis* infection in cattle. The importance of the disease in Sudanese livestock is being evaluated. The principal impetus for this research stems from the on-going search for ways to improve the resistance of humans to the disease.

33. Schistosomiasis (bilharzia) is a major human disease in the tropics and is caused by different species to those that infect livestock; except in the Far East, where *S. japonicum* is a zoonotic infection.
Intestinal Nematodes

34. Worms of the Haemonchus, Ostertagia, Strongylus and Trichostrongylus genera are the most common causes of production losses, particularly in sheep. They have a life cycle of: ingestion of larvae during grazing; growth to adult in the host's intestinal tract and excretion of eggs which develop to larvae to start the cycle over again. The larvae live best in warm, humid conditions. Generally, the greatest losses due to clinical parasitism occur at the start of the wet season when animals having low resistance encounter large number of larvae in their environment. Sheep and goats are more susceptible to helminth infections than cattle. There is considerable evidence that animals previously infected by some worms, are not as "hospitable" to later infection in that they carry a much lower worm burden and the egg production is reduced as compared to animals never exposed. This "immunity" or "resistance" is being studied by numerous researchers.

35. Several drugs have shown at least 90% broad-spectrum efficacy in reducing infection of adult worms, however their efficacy in killing migrating immature forms is less and more variable as to spectrum. Most of these drugs are related to thibendaole. Recently, ivermectin has been shown to be effective against migrating immature stages as well as against ectoparasites, (ticks, mites and warbles) being carried at the time of treatment. The benefits from using these anthelmintics is greatly dependent on the timing strategy, i.e., use at the time(s) of the year when the greatest number of worms are present in animals at greatest risk of suffering serious production setbacks.

External Parasites

36. The losses due to external parasite infestation are generally not as devastating as those due to some of the epizootic and helminth diseases discussed in this paper. However, in certain areas, these parasites cause significant production inefficiencies. Most notable are the cattle scabies mite which causes skin irritation and anemia from bites, and the screw worm fly larvae which invade wounds leading to weakness and death.

37. In addition to being disease vectors, ticks also cause debilitating skin irritation and sometimes an allergic type of sickness and death (tick paralysis). Treatment with insecticidal compounds and biologic techniques (sterile male) are the principle methods of external parasite control and eradication.
Brief Descriptions of Major Zoonotic Diseases
In Developing Countries

1. Zoonosis is properly defined as "diseases or infections shared by both animals and man". Although the greatest concern is about human infections transmitted from animals, the reverse occurs so that, in a sense, humans become reservoirs and carriers of certain diseases which infect livestock. Zoonoses are a constant health threat to the smallholder because of his frequent contact with animals and lack of sanitation measures. Other zoonoses - anthrax, Rift Valley fever and trypanosomiasis are discussed in Annex I.

Brucellosis

2. Because of the significance of this disease in humans, several successful eradication and control programs have been carried out in developed countries. Clinical brucellosis in man is not easily characterized. It may take a prolonged course of recurring bouts of malaise, headache, sweating and high fever. Unexplained "night sweats" are a frequent complaint. The signs in humans are similar in all Brucella infections, but sometimes more acute and severe in B. melitensis infection. The major source of infection to man and animals is from fetal and placental tissues of aborting cows, goats and pigs and from uterine discharges from infected animals and that do not abort. Milk from infected animals can also transmit the disease to man, particularly from goats infected with B. melitensis. Brucellosis from B. suis is most common in abattoir workers.

**Brucella Infections**

<table>
<thead>
<tr>
<th>Species</th>
<th>Disease in Man</th>
<th>Livestock Infected</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. abortus</td>
<td>&quot;Undulant Fever&quot;</td>
<td>Cattle (&quot;Bang's Disease&quot; or &quot;Contagious Abortion&quot;)</td>
</tr>
<tr>
<td>B. melitensis</td>
<td>&quot;Malta Fever&quot; or &quot;Mediterranean Fever&quot;</td>
<td>Goats (most susceptible) and sheep (less so)</td>
</tr>
<tr>
<td>B. suis</td>
<td>&quot;Undulant Fever&quot;</td>
<td>Pigs</td>
</tr>
</tbody>
</table>

3. The infection is persistent in cattle and it appears that, once infected, cows shed the organism intermittently in their milk and most heavily at calving. The organism localizes in lymph nodes, testicles and uterine and mammary tissue. Abortion usually occurs in late gestation. There is evidence of widespread prevalence of B. abortus in developing countries as determined by several antibody detection tests. In most Latin American countries, 3% to 25% of the cows are positive to serologic tests. In some countries increased abortion rates have been associated with high B. abortus antibody levels. Although the loss due to abortion can be high, production impact has not been adequately assessed and it may be lower than prevalence rates indicate because of naturally acquired immunity. There are very effective live, avirulent vaccines (Strain 19 is the most widely used) against infection from B. abortus. The strategic application
of these vaccines and eradication has reduced human and animal brucellosis infection to very low levels or non-existence in developed countries. Low human brucellosis incidence is also attributable to the pasteurization of milk. In these countries the vaccine is only used on young animals because adult vaccination confuses the sophisticated testing procedures used in the control and eradication programs. In developing countries adult vaccination may be indicated if the prevalence of the disease is high.

Cysticercosis (Beef Measles, Taeniasis in Man)

4. Humans are infected by eating uncooked or rare beef or pork harboring living cysticerci of _Taenia saginata_ (beef tapeworm) or _T. solium_ (pork bladderworm). The tapeworm develops in the human intestine and the gravid segments passed in the feces shed eggs which may infect cattle upon ingestion. The eggs can live for five months on grass and two months in liquid manure. The clinical signs in man generally are minor except when migrations through the liver and the brain (only _T. solium_) leave severe lesions. In contrast to the life cycle of hydatid disease, man is the definitive host for these _Taenia_ tapeworms in livestock. Restricting animal contact with human feces and killing the cysticerci by cooking or freezing meat are the methods to break the cycle. _T. solium_ is most commonly found in Latin America where pigs, a preferred enterprise, have frequent access to human waste. _T. saginata_ is fairly widespread in the developing world. Meat inspection programs and extra freezing costs and condemned carcasses are the main sources of economic disadvantages caused by this disease. These additional costs can be quite significant in developing countries which are attempting to produce beef for countries which have stringent hygiene requirements for imported meat.

5. The "average year" losses from condemnation, extra costs, and loss in carcass value have been calculated to be about $2 million in Kenya and about $1 million in Botswana. Also there is a potentially damaging effect on exports from the bad image developed countries may attach to meat from countries with a high prevalence of cysticercosis (Grindle, 1978).

Hydatidosis

6. Humans may become intermediate hosts in the life cycle of the dog tapeworm _Echinococcus granulosa_ and other tapeworm species, by handling infected dogs resulting in the ingestion of eggs shed in the feces. The eggs grow to large cysts (10 to 50 cm) in the liver, lungs and, occasionally, the brain. The disease is worldwide, but it is most common in countries with large sheep populations which are the most common intermediate hosts. Dogs, the most common definitive hosts, are infected with fertile hydatids which they consume by eating sheep or pig (occasionally other mammalian) livers, lungs and heart in which the hydatid cysts have developed. Hydatidosis is diagnosed in man by immunologic techniques and radiology. The most effective preventive methods are through public education to restrict dogs from eating fresh internal organs from slaughtered animals. Various drugs are used also to monitor infection in dogs as well as reduce their infectivity.
Rabies

7. Rabies occurs in all mammalian species worldwide (except the United Kingdom, New Zealand, Australia, Guyana and some islands). It is transmitted by animal bite and, rarely, by aerosol from infected insectivorous bats in caves. It is almost always fatal after long incubation periods (up to 6 or 7 months).

8. The most common transmission, both in rural and urban areas, is from the bites of dogs and wild animals (most frequently skunks, foxes, bats, mongooses and raccoons). In livestock, mostly cattle and horses, death is preceded by a wide variety of central nervous signs ranging from severe depression to maniacal behavior. These signs are frequently confused with other diseases or toxicities. However, paralytic vampire bat rabies (derriengue) common in Mexico, Trinidad and Brazil, presents a more consistent clinical syndrome of progressive paralysis terminating in death in a few days. Some producers have suffered high death losses in their cattle and there have been several human cases attributed to vampire bat bites (Acha, 1981). Transmission of rabies from livestock to humans has not been documented, but the risk exists principally from human's abraded skin coming in contact with saliva or fresh tissue from infected livestock.

9. The control of rabies is based on vaccination of dogs and killing wildlife which show abnormal behavior. In some areas of high occurrence of vampire bat rabies in Latin American cattle, the dog vaccine is sometimes used. But recently some successful techniques have been developed in which bats ingest an anticoagulant which causes fatal hemorrhage. The anticoagulant is either taken in by bats feeding on a sacrificial cow injected with the compound (at doses too low to affect cattle) or by licking other bats on which the compound has been applied. The bats are not persistent carriers but excrete the virus in their saliva during the incubating period before they themselves eventually succumb. The same may be true for other animals.

Schistosomiasis (Bilharzia or Snail Fever)

10. Schistosomiasis is a major zoonosis only in areas of the Far East where Schistosoma japonicum occurs. Human bilharzia in Africa is caused by S. mansoni and S. hematobium. The Schistosome species which infect African livestock (S. bovis and S. matthei) are often found concurrently in areas in which the human Schistosomes are prevalent.

11. Except for S. hematobium infection, the main lesions in man are due to interruption of blood flow in the liver caused by eggs in the blood stream to which the liver tissue responds by compensatory hypertrophy and cirrhosis. In the acute stage, diarrhea and severe weakness are seen. The overall affect in seriously affected people is a chronic debilitation with intermittent episodes of hemorrhagic diarrhea caused by egg passage through the lining of the intestine. S. hematobium causes obstruction of the urinary tract from tissue reaction to eggs.
## Common Schistosome Infections in Man and Livestock

<table>
<thead>
<tr>
<th>Species</th>
<th>Geographic Prevalence</th>
<th>Definitive Hosts</th>
<th>Tissue Damage/Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>S. japonicum</em></td>
<td>Far East, Philippines, China, Malaysia, plus other locations with less reported prevalence</td>
<td>Man, Livestock</td>
<td>Liver, intestines/debilitation, diarrhea, anemia, mortality, poor performance</td>
</tr>
<tr>
<td><em>S. mansoni</em></td>
<td>Africa, East coast of South America, West Indies and Saudi Arabia</td>
<td>Man</td>
<td>Liver, intestines/debilitation, diarrhea, anemia, mortality, poor performance</td>
</tr>
<tr>
<td><em>S. hematobium</em></td>
<td>Africa and Middle East</td>
<td>Man</td>
<td>Bladder/bloody urine, debilitation</td>
</tr>
<tr>
<td><em>S. bovis</em></td>
<td>North, East and West Africa, the Mediterranean</td>
<td>Livestock</td>
<td>Intestines and vessels, liver/debilitation, hem. diarrhea, anemia, poor performance</td>
</tr>
<tr>
<td><em>S. mattheei</em></td>
<td>Southern and Eastern Africa</td>
<td>Livestock</td>
<td>Intestines and liver/debilitation, hem. diarrhea, performance, mortality</td>
</tr>
<tr>
<td><em>S. indicum</em> and <em>S. spindale</em></td>
<td>India, Malaysia</td>
<td>Livestock</td>
<td>Intestines and vessels, liver/debilitation, hem. diarrhea, poor performance, mortality</td>
</tr>
<tr>
<td><em>S. nasalis</em></td>
<td>India, Sri Lanka</td>
<td>Livestock</td>
<td>Nasal granulomas/&quot;snoring&quot; disease</td>
</tr>
</tbody>
</table>
12. In animals, the liver lesions are not as serious but the early stages of infection in young animals causes hemorrhagic diarrhea and debilitation in many cases. Severe infections cause death or weight loss and poor reproductive performance.

13. The life cycle in both human and animal schistosomes involves a snail intermediate host in which development of cercaria takes place. The cercaria penetrate the skin of the man or animal and immature forms migrate to the liver or intestinal veins where they develop further. Eggs shed in the feces into streams and canal waters develop into forms which enter the snail. Public education about the danger of contact with snail infested waters would seem to be the most efficient preventive technique. But this is difficult for rural people of the developing countries to do even if they recognize the risk. Their daily habits and work invariably expose them to infective schistosome cercaria. The zoonotic S. japonicum organism is the cause of some 20% of the estimated 200 million people infected worldwide with schistosomiasis. Controlling this disease in domestic livestock would reduce this human exposure considerably. Recently, a drug (Praziquantel) has been developed which shows exceptional advantages in efficacy and lack of toxic side effects as compared to previous drugs. It is not at the present time feasible for treatment of livestock schistosomiasis. A vaccine against S. bovis has been experimentally shown to provide resistance to infection in Sudanese cattle (Majid et al, 1980).

14. In India, schistosomiasis occurs in cattle, buffaloe, goats and sheep caused by S. indicum, S. spindale and S. nasale (causes lesions in nasal cavity but not in internal organs). None of these cause infection in humans.

**Tuberculosis**

15. Tuberculosis caused by *Mycobacterium bovis* is spread to man principally through unpasteurized cow's milk or dairy products. Complete eradication has not really been achieved even in developed countries. In many countries it appears to be eradicated, but a few minor cases in cattle occur sporadically. Tuberculosis in humans is most commonly caused by *M. tuberculosis* which is much more likely to result in serious lung lesions than that caused by *M. bovis*. But nevertheless, *M. bovis* causes serious disease in humans, especially children drinking unpasteurized milk. Indigenous cattle (Zebu) are much more resistant than European breeds. It is disease commonly found in housed cattle as the bacilli are readily spread by the airborne route, but is also seen in cattle under pastoral conditions.

16. Generally in cattle the result of infection is a long-term (years) debilitating condition which pulmonary and lymph node lesions. A live, attenuated vaccine of *M. bovis* (B.C.G.) provides long-term protection for humans and is used widely except in countries where eradication is practiced, as the vaccinated persons will react to the commonly used skin diagnostic tests. Traditional cattle owners recognise tuberculosis by the enlarged lymph nodes. Such animals are not generally salvaged for
consumption. M. bovis is also infective to pigs, sheep, goats and horses. Tuberculosis, M. avium, in chickens can be a serious cause of losses particularly under dirty housing conditions.
1. On the question of "eradication versus control," six preconditions have been described as essential criteria in deciding whether to opt for control or eradication. The preconditions were derived from experiences in campaigns against malaria, smallpox, yellow fever and yaws in humans and are directly applicable to decisions on the eradication of animal disease.

   a. "There should be a control measure that is completely effective in breaking transmission, simple in application; and relatively inexpensive."

   b. "The disease should have epidemiological features facilitating effective case (and/or carrier) detection and surveillance in the advanced stages of the eradication program." (It should be easily recognized in all stages and forms, or the surveillance cannot be successful and the previous investment is in jeopardy. In animal diseases, the frequently common exposure of domestic animals to infected wild animals make the achievement of this condition difficult, if not impossible.)

   c. "The disease must be of recognized socio-economic importance; national or international."

   d. "There should be a specific reason(s) for eradication, rather than control, of the disease." (Eradication should enable other development or technical activities of great magnitude to take place; where control does not -- otherwise opt for control.)

   e. "There should be adequate financial, administrative, manpower and health service resources."

   f. "There should be the necessary socio-ecological conditions." (Seasonal migrations, extreme dispersal in remote areas and rejection of the practice based on cultural beliefs can significantly impede the total coverage required for eradication.)

2. The author emphasizes that in order to satisfy preconditions a, d, and 5, strict criteria must be met. His definition of eradication is: "The purposeful reduction in the prevalence of a specific disease to the point of continued absence of transmission within a specified area by means of a time-limited campaign." (Note that he is not saying that we must exterminate the species - only its significant transmission.) An implicit point in all of Mr. Yekutiel's preconditions for the eradication decision is that there is sufficient data on which to base the integral judgments. Particularly for animal diseases, data is frequently inadequate to answer

such questions as: "Is the technique adequate to reduce infection to a point of continued absence?", "Are there unknown reservoirs of infection?", and "Does this disease cause economic losses of a sufficient magnitude to justify the eradication expense?"

3. Although eradication may not be a feasible option at first, it may become so later, when control has reduced prevalence to such a point that the new situation invites eradication as a more serious consideration.
Examples of Estimated Cost of a Regional Animal Disease Control Program

These costs were estimated for a regional rinderpest and contagious bovine pleuro-pneumonia vaccination project for Sudan and Ethiopia (only the costs for Sudan are summarized here). Improvement of the overall animal health infrastructure along with the vaccination program was an important objective of this proposal and is reflected in the costs. The economic rate of return was calculated to be 21% from reduced mortality as applied to the entire cattle population over 20 years. In areas where vaccine coverage was estimated to be 80%, mortality due to these diseases would decrease from 2% to zero while in areas of 50% vaccine coverage it would drop to 0.75%. 1/

<table>
<thead>
<tr>
<th>Item</th>
<th>Capital ($1,000)</th>
<th>Operations ($1,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Services Development*</td>
<td>909</td>
<td>1,288</td>
</tr>
<tr>
<td>Vaccine Production</td>
<td>516</td>
<td>127</td>
</tr>
<tr>
<td>Vaccine Distribution</td>
<td>283</td>
<td>127</td>
</tr>
<tr>
<td>Disease Monitoring &amp; Evaluation</td>
<td>49</td>
<td>101</td>
</tr>
<tr>
<td>Field Investigation</td>
<td>530</td>
<td>586</td>
</tr>
<tr>
<td>Diagnostic Facilities</td>
<td>216</td>
<td>50</td>
</tr>
<tr>
<td>Coordination Unit</td>
<td>25</td>
<td>121</td>
</tr>
<tr>
<td>Training</td>
<td>--</td>
<td>53</td>
</tr>
<tr>
<td>Technical Cooperation</td>
<td>--</td>
<td>904</td>
</tr>
<tr>
<td><strong>Total Base Cost Without Physical or Price Contingencies</strong></td>
<td><strong>2,528</strong></td>
<td><strong>3,357</strong></td>
</tr>
</tbody>
</table>

Approximate unofficial exchange rate (1981) $1.00 = 1.00 Sudanese pound.

* These costs are for a vaccination program in three provinces with a 6.3 million cattle population.

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Some of these references were cited in the text. Others were used as general background. The list is far from exhaustive and covers a broad range of literature on animal health, production and livestock economic subjects. Recent review articles and texts have been included — if available and appropriate.


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