Investing in Animal Health Research to Alleviate Poverty

The International Livestock Research Institute (ILRI), based in Nairobi, Kenya, and working worldwide, helps reduce poverty, hunger and environmental degradation through global livestock research. ILRI is one of 16 Future Harvest Centres supported by the Consultative Group on International Agricultural Research (CGIAR). ILRI is funded by more than 50 private, public and government organisations, including the World Bank and the United Nations, and collaborates with more than 500 national, regional and international institutions, in addition to non-governmental organisations and private companies.

The Department for International Development (DFID), the sponsor of this study and publication, is the United Kingdom Government department responsible for promoting international development and the reduction of poverty. DFID works in partnership with governments of developing countries, international organisations, voluntary bodies, the private sector and the research community. DFID has a long tradition of support for long-term research for livestock development in the world's poorest countries.

ILRI and DFID have strong interests in developing a greater understanding of the factors affecting poverty in order that they can focus their investments on activities that have significant impact on poverty reduction. An important step in this process is the better definition of spatial and temporal trends in global poverty; for this reason, DFID commissioned ILRI to develop a series of analytical poverty maps of the developing world.

Another important step in this process is to take advantage of the availability of such spatial and temporal data on poverty to prioritise constraints to livelihoods of the poor. One set of constraints is the poor health of their livestock, which feature in so many different livelihoods and enterprises of the poor. With DFID support, ILRI has used the poverty maps as a basis for developing research priorities in animal health for poverty alleviation.

The results of these two DFID-supported studies, one mapping poverty and livestock and the other prioritising animal health research for poverty reduction, are presented as companion volumes.

ILRI is a
FUTURE HARVEST
Centre supported
by the CGIAR

Investing in Animal Health Research to Alleviate Poverty

B.D. Perry, T.F. Randolph, J.J. McDermott,
K.R. Sones and P.K. Thornton

International Livestock Research Institute
PO Box 30709, Nairobi, Kenya
2002

This report was commissioned by the Department for International Development (DFID) of the Government of the United Kingdom, on behalf of the Inter-Agency Group of Donors Supporting Research on Livestock Production and Health in the Developing World.

Authors' affiliations
B.D. Perry, veterinary surgeon, epidemiologist and coordinator, Epidemiology and Disease Control Project, ILRI, Nairobi.
T.F. Randolph, agricultural economist, Epidemiology and Disease Control Project, ILRI, Nairobi.
J.J. McDermott, veterinarian/epidemiologist, Epidemiology and Disease Control Project, ILRI, Nairobi.
K.R. Sones, consultant, StockWatch Ltd., Nairobi.
P.K. Thornton, systems analyst and programme coordinator, Systems Analysis and Impact Assessment Programme, ILRI, Nairobi.

ISBN 92-9146-108-3

Correct citation: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K. 2002. *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 148 pp.

This publication houses a CD-ROM version of the printed edition, plus:
extensive appendices, a PowerPoint presentation summarising the report and the content of a companion publication, *Mapping Poverty and Livestock in the Developing World.*

The publication may also be found on the Websites of DFID and ILRI: www.dfid.gov.uk and www.ilri.org

For further information or to request more copies of the printed or CD-ROM editions of this publication, please contact:
ILRI Information Services, PO Box 5689, Addis Ababa, Ethiopia.
ILRI-Ethiopia@cgiar.org

Contents

Tables

Boxes

Figures

Appendices (on CD inside back cover)

Foreword

Poverty is at the root of most of the world's problems. Diseases—in both animals and people—are a major contributor to poverty in developing countries.

Livestock offer to the poor an important pathway out of poverty. Livestock contribute in a wide variety of ways to the livelihoods of the poor, often in ways that cash, or bricks and mortar, cannot. And healthy livestock provide a rich variety of assets and commodities that enable the poor to escape the poverty trap.

The difficulty that governments, international organisations and donors face when contemplating policies and strategies for improved animal health is knowing where to start. There are so many different diseases affecting the livestock in the developing world, and these vary in importance from one region to another. In the past, decisions on priorities for control and for research, have been based primarily on the importance of a given disease to the livestock industries. However, these priorities are not necessarily appropriate if poverty alleviation is the goal. Some diseases are reasonably well controlled in the more commercially oriented livestock production enterprises, but are major problems for poor livestock keepers due to the ineffectiveness, costliness or inappropriateness of the control technology in smallholder livestock systems. In addition, some diseases, the zoonoses, affect not only livestock productivity in its many forms, but also the health of the livestock keepers themselves, as well as the consumers of their livestock products and the poor are particularly vulnerable to multiple zoonotic diseases.

Several major international donors to livestock research and development took a bold decision in late 2000 to commission this study to evaluate which diseases of livestock are most important to the poor, and where the major research and development options to address these diseases lie. The idea was to start with a clean slate and a unique focus on poverty alleviation. The Department for International Development (DFID) of the Government of the United Kingdom agreed to fund the study, and contracted a team at the International Livestock Research Institute (ILRI) to undertake it.

The results involved three major regions of the world (sub-Saharan Africa [SSA], South Asia [SA] and South-East Asia [SEA]), a broad set of authorities and representatives from the major stakeholder groups, all packed into a study completed within 5 months. The methodology developed will have wider use for future studies on individual countries, regions and production systems to further define animal health research and development priorities. A follow-up study is being planned for Latin America.

The most significant and original product of this report is the grouping of diseases into categories based on the way they constrain poverty alleviation, and the grouping of research opportunities by the pathway they offer out of poverty. These categories of securing assets, enhancing market opportunities and promoting improved production efficiencies provide an effective framework for bringing greater focus into priority setting. It will be important to further develop this framework, complementing the direct production and marketing benefits to the poor with those that can be gained from longer-term, trade-related economic development. More specific attention to the effect of animal disease as an impediment to formal market access is needed.

ILRI, together with its international partners involved in improving animal health, namely the Food and Agriculture Organization of the United Nations (FAO), the World Organization for Animal Health (Office International des Epizooties: OIE) and the World Health Organization (WHO), are proud to acknowledge their association with, and support of, this important venture.

H.A. Fitzhugh, Director General, ILRI
S. Jutzi, Director, Animal Production and Health Division, FAO
F.-X. Meslin, Coordinator for Emerging Public Health Risks, WHO
B. Vallat, Director General, OIE

December 2001

Preface

In December 2000, the Department for International Development (DFID) of the British Government sponsored a meeting of donors and implementing agencies supporting and undertaking research on livestock production and health in the developing countries of the world. The objective of the meeting was to improve the collaboration between, and complementarity of, the different donor agencies in supporting what are generally common goals and aspirations shared by all of them (Hainsworth et al., 2001).

This was a truly remarkable gathering, for several reasons. First and foremost, it was remarkable in that it had not taken place earlier. While it is fair to say that there has been communication at various levels between many of the major donors supporting different aspects of livestock research and development, there has not been a formal joint synthesis of goals, policies and strategies, and collective consideration as to how complementarity might enhance efficiency and impact for all concerned. So the meeting was remarkable in terms of presenting a new opportunity for improving the performance of individual donors, and for a greater 'bang for the buck' of the total investment. In the development process, it is important that the donors provide a role model of cooperation and collaboration for others to follow.

The meeting was also remarkable in that it singled out and emphasised the overriding common goal of poverty reduction as the main focus of livestock research, and the needs to ensure orientation of research investment to this goal. Livestock are important to rural poor people (and increasingly to sectors of the urban poor), and they do provide an important vehicle for the pathway out of poverty.

The meeting resulted in a series of outcomes, including the development of a vision statement, i.e. *Poverty alleviation through improved livestock production facilitated through collaboration.* Another outcome served as the genesis of this report, and reads; *'Commission a study to identify major collaborative research opportunities with potential to achieve significant impact on livelihoods of the poor'*. Following the meeting, DFID prepared terms of reference for this study (see Appendix 1), and approached the Epidemiology and Disease Control Group at the International Livestock Research Institute (ILRI) to undertake the work. It was agreed that the major focus of the study should be on livestock health issues, and a work plan was developed (see Appendix 2) and approved. DFID also commissioned the Systems Analysis and Impact Assessment Group at ILRI to develop new spatial poverty surfaces for the developing world that could be used as a basis for the quantitative prioritisation components of this study.

Despite the high expectations that this study will, at last, provide some broadly acceptable animal health research priorities for greater impact on poverty alleviation, rather than on national economic development, it is important to recognise that, for many reasons, this is only one step in the direction of a greater poverty focus. To begin with, the time given for the study was just 5 months. When the World Health Organization (WHO) embarked on a similar exercise in the 1990s, and reviewed health research investments needed for future interventions (WHO, 1996), it deliberated for several years before producing its report.

What this study has achieved is to draw attention to the need for a poverty focus and to develop a semi-quantitative methodology for use as a basis for comparison with our intuitions and personal experiences as to where the priorities lie.

There were some important principles to this study. Firstly, that it should be completely independent, both of any particular donor and of the institution employing the scientists commissioned to undertake the study. It has therefore been essential to adopt a 'clean slate' approach to the different assessments of disease impacts, including consideration of all livestock species, all types of diseases, and all the regions of the world in which the major concentrations of poverty exist. With these principles in mind, and considerations of time and resources, this study has therefore focused on SSA, SA and SEA.

Another important principle was that the study should involve the widest possible consultation. It is estimated that all the different components of the short study have involved the expertise of almost 200 people, ranging from those at the front line of veterinary services, to those involved in upstream research institutions, drawn from most regions of the developing and developed worlds.

One of the original suggestions on the form of products developed by the study was a listing of the 'top five' in terms of animal diseases with highest impact, and with priority research opportunities. While there is a strong argument for focus, which this approach would most certainly provide, there is also the need to bear in mind that no single disease control method, nor any single technology, will alone solve the world's poverty problems. Furthermore, different donors have different interests in terms of the research they like to support, national capacities they like to support and spheres of influence that are important for them to exploit. This report will therefore present a basket of research opportunities, ranging from technology delivery and adoption, to epidemiology, to impact assessment, to technology development, with research priorities and best-bet options within each category. In this way, if vaccine research is your business, the priorities within this field have been identified, as they have with the more applied research supporting the delivery of animal health services. Furthermore, we have tried to identify which research options are likely to impact the different pathways out of poverty.

The body of this report is presented in the pages that follow. The commissioned appendices that support the document are presented on a compact disc, enclosed on the inside of the back cover of this book. Also on the compact disc is the companion study commissioned by DFID on the distribution of poverty and livestock prepared by Philip Thornton and colleagues.

Brian Perry, *OBE, BVM&S, DTVM, MSc, DVM&S, FRCVS*
Coordinator, Epidemiology and Disease Control,
International Livestock Research Institute (ILRI),
PO Box 30709,
Nairobi, Kenya.
Tel: +254-2-630743
Fax: +254-2-631499
Email: b.perry@cgiar.org
http://www.ilri.org

January 2002

Acknowledgements

We would like to thank the many people from different countries, organisations and institutions who have contributed to this study. They are listed below. We also thank Sarah Holden of DFID and Ian Maudlin of the University of Edinburgh for their enduring support and encouragement, and DFID's Animal Health Programme for funding the study. We thank Hank Fitzhugh, former Director General of ILRI, for his comments and support. Finally, we are most appreciative of the editing, typesetting and printing services provided by Sue Hainsworth and Pragati Offset Private Limited, in India, the cover graphic montage by freelance designer Rob O'Meara, in Nairobi, and at ILRI, the contributions of Ibrahim El-Habib, Tesfaye Jemaneh, Philip Kitala, Susan MacMillan and Leah Ndung'u

Authors of commissioned reviews

A. Catley, Kenya
P. Coleman, UK
A. McLeod and A. Wilsmore, UK
J. Rushton, C. Heffernan and D. Pilling, UK
A. Permin and M. Madsen, Denmark
J. Gibson, Kenya (ILRI)
T. Robinson, Kenya (ILRI)

Planning workshop participants
(ILRI, Nairobi, Kenya)

E. Camus, France
A. Permin, Denmark
J. Rushton, Bolivia
G. Thomson, Kenya
D. Pfeiffer, UK
A. Catley, Kenya
P. Roeder, Italy
C. Heffernan, UK
A. Shaw, UK
I. Maudlin, UK
R. Kruska, Kenya

Regional workshop participants
West Africa (Sikasso, Mali)

M. Kamuanga, Burkina Faso
D. Richard, Burkina Faso
O. Diall, Mali
Y. Yao, Côte d'Ivoire
O. Konaté, Burkina Faso
B. Diop, Mali
C. Ly, Senegal
K. Adomefa, Togo

Eastern, Central and Southern Africa
(ILRI, Nairobi, Kenya)

W. Asfaw, Ethiopia
A. Catley, Kenya
W. Olaho-Mukani, Uganda
M-L. Penrith, South Africa
G. Thomson, Kenya
D. Vink, Mozambique
J. Woodford, Tanzania
H. Nenkari, Kenya
A. Kondela, Tanzania
H. Kiara, Kenya
A. Omore, Kenya
A. Bishi, Zimbabwe

South-East Asia
(Bangkok, Thailand)

D. Hoffman, Thailand
R. Alders, Cambodia/ Mozambique
R. Holmes, Vietnam
F. Barwinek, Vietnam
E. Potter, Cambodia
Lai Thi Kim Lan, Vietnam
T. Daing, Myanmar
D. van Aken, Laos
W. Kalpravidh, Thailand
L. Gleeson, Thailand
T. Vannasouk, Laos
S. San, Cambodia
P. Poomvises, Thailand
T. Hutabaret, Indonesia
M. Maclean, Vietnam
N. Sohkim, Cambodia

South Asia
(ICRISAT, Hyderabad, India)

S. Ranawana, Sri Lanka
K. Fattah, Bangladesh
A. Mia, Bangladesh
B. R. Patil, India
R. Kumar, India
G. Butchaiah, India
N. P. S. Karki, Nepal
G. K. Sharma, India

Helminthosis workshop participants
(ILRI, Nairobi, Kenya)

D. Gray, The Philippines
P. Waller, Sweden
A. Lindberg, Sweden
L. Baker, Kenya
T. Krecek, South Africa
A. Nari, Italy
J. Mugambi, Kenya
L. Barnes, Australia
R. Dobson, Australia
E. Villar, The Philippines

J. Githori, Kenya
N. Maingi, Kenya

Research opportunities review workshop
(IAH, Compton, UK)
G. Davies, UK
F. Thiaucourt, France
I. Maudlin, UK
P. Jorgensen, Denmark
A. Willingham, Denmark
I. Morrison, UK
S. Houghton, UK
A. Donaldson, UK
M. Eisler, UK
J. Gibson, Kenya

Research opportunities review workshop
(ILRI, Nairobi, Kenya)
E. Taracha, Kenya
A. Musoke, Kenya
P. Majiwa, Kenya
R. Bishop, Kenya
J. Gibson, Kenya
D. Mwangi, Kenya
L. Baker, Kenya
R. Pelle, Kenya
P. Spooner, Kenya
J. Mugambi, Kenya

Report review meeting
(FAO, Rome, Italy)
S. Jutzi, Italy
M. Rweyemamu, Italy
J. Otte, Italy
H. Steinfeld, Italy
C. Delgado, USA
Y. Cheneau, Italy
F. Meslin, Switzerland
J. Pearson, France
M. Jeggo, Austria
I. Maudlin, UK
S. Holden, UK
M. Simeon, USA
D. Taylor, Kenya

Avian diseases review
Coordinator
P. Jorgensen, Denmark
D. Alexander, UK
P. Mbuthia, Kenya
E. Klopper, South Africa
J. Paweska, South Africa
B. Engström, Sweden
C. Ek-Kommonen, Finland
B. Lomniczi, Hungary
L. Ellis, Australia
A. von Krogh, Italy
P. Spradbrow, Australia
V. Palya, Hungary
T. van den Berg, Belgium
N. Eteradossi, France
V. Jestin, France
D. Todd, UK
Y. Saif, USA
I. Capua, Italy
G. Koch, Holland
R. Alders, Mozambique
M. Young, Mozambique
M. Jeggo, Austria
D. Hoffmann, Bangkok
M. Mashisi, South Africa
A. Fouchier, The Netherlands
M. Yongolo, Tanzania

Meat-borne and other parasitic zoonoses
Coordinator
A. Willingham, Denmark
D. Murrell, Denmark
D. McManus, Australia
M. Lightowlers, Australia
F. Zheng, China
D. Joshi, Nepal
A. Ito, Japan
S. Geerts, Belgium
P. Dorny, Belgium
M. Vang Johansen, Denmark
J. Magombo, Kenya

Trypanosomosis
Coordinator
M. Dávila, Brazil
A. Hassanali, Kenya
A. Fairlamb, UK
A. Husein, Indonesia
B. Namangala, Zambia
Bu-Jin Xu, China
D. Masiga, Kenya
D. Tuntasuvan, Thailand
D. Rogers, UK
D. Onha, Nigeria
D. Lamine, Burkina Faso
E. Authié, France
F. Njiokou, Cameroon
G. d'Ieteren, Kenya
H. Chitambo, Zimbabwe
J.R. Rao, India
J. Batolos, The Philippines
J. Enyaru, Uganda
J. Gibson, Kenya
K. Kappmeier, South Africa
K. Gull, UK
K. Sones, Kenya
M. Barrett, UK
M. Le Ngoc, Vietnam
N. Murphy, Ireland
P. Majiwa, Kenya
P. Buscher, Belgium
R. Saini, Kenya
R. Brun, Switzerland
R. Seed, USA
S. Black, USA
S. Aksoy, USA
S. Reid, Australia
S. Kemp, UK
S. Leak, The Gambia
S. Torr, UK
V. Singh, India
Z. Xichen, China

Dermatophilosis
Coordinator
D. Lloyd, UK
D. Taylor, Kenya
A. Bensaid, France
A. Masters, Australia
D. Martinez, France
F. Stachurski, Burkina Faso
I. Sidibé, Burkina Faso
J. Hermoso de Mendoza, Spain
J. Maillard, France
N. Ambrose, UK
P. Carnegie, Australia

Haemorrhagic septicaemia (HS)
Coordinator
M. de Alvis, Sri Lanka
S. Chandrasekeran, Malaysia
L. Natalia, Indonesia
N. Hasnain Shah, Pakistan

Peste des petits ruminants (PPR) and rinderpest (RP)
Coordinator
H. Wamwayi, Kenya
R. Kock, Kenya
T. Barrett, UK
A. Diallo, Senegal
T. Yilma, USA

African swine fever (ASF)
Coordinator
P. Wilkinson, UK
M. Salas, Spain
C. Martins, Portugal

East Coast fever (ECF) and *Theileria annulata*
Coordinator
D. McKeever, UK
D. Brown, UK
R. Spooner, UK
J. Ahmed, Germany
B. Shiels, UK
R. Hall, UK
I. Morrison, UK
A. Nichani, Morocco
G. Langsley, France
P. Preston, UK
E. Glass, UK
L. Innes, UK
S. Morzaria, Kenya

Gastro-intestinal (GI) helminthosis
Coordinator
R. Bains, UK
J. Boomker, South Africa
L. Gruner, France
J. van Wyk, South Africa
J. Vercruysse, Belgium
J. Zinsstag, Switzerland
A. Makundi, Tanzania
M. Knox, Australia
A. Vatta, South Africa
D. Gray, The Philippines
P.K. Sanyal, India
L. Baker, Kenya
G. Aumont, France
L. Le Jambre, Australia
M. Eysker, The Netherlands
C. Monahan, USA
P. Dorny, Belgium
F. Jackson, UK
T. Krecek, South Africa
P. Waller, Sweden
J. Kaufmann, Switzerland

Babesiosis and anaplasmosis
Coordinator
F. Jongejan, The Netherlands
S. de Echaide, Argentina
J. de la Fuente, USA
M. Saimo, Uganda
A. Bouattour, Tunisia
R. Mattioli, Italy
K. Kocan, USA

Anthrax
Coordinator
J. Woodford, Tanzania

Brucella abortus* and *B. melitensis
Coordinator
P. Elzer, USA

Bovine tuberculosis (TB)
Coordinator
R. Clifton-Hadley, UK

Contagious bovine pleuro-pneumonia (CBPP) and contagious caprine pleuro-pneumonia (CCPP)
Coordinator
F. Thiaucourt, France

Heartwater
Coordinators
D. Martinez, France, and
S. Mahan, Zimbabwe
D. McKeever, UK
B. Alsopp, South Africa
A. Barbet, USA

Lumpy skin, sheep and goat pox, and foot-and-mouth disease (FMD)
Coordinator
P. Kitching, Canada

Executive summary

In 2000 the donors supporting livestock research and development (R&D) in the developing world embarked on a new initiative to improve the communication, collaboration, and complementarity between them to enhance the impact of their investments. As part of this initiative, they commissioned the present study, with the objective of identifying major collaborative research opportunities with potential to achieve significant impacts on the livelihoods of the poor. The 5-month study was funded by the Department for International Development (DFID) of the Government of the United Kingdom. The Epidemiology and Disease Control Research Group at the International Livestock Research Institute (ILRI) in Nairobi, Kenya, was commissioned to carry out the study.

The major criteria for the study were that it should be independent (both of any particular donor and of the commissioned institution), involve the widest possible consultation, focus on Africa and Asia, and above all have a unique focus on identifying research opportunities that would have an impact on poverty alleviation.

There were seven major component processes to the study. These were:

- Describe and quantify the distribution and extent of poverty in South-East Asia (SEA), South Asia (SA) and sub-Saharan Africa (SSA)
- Determine the association of poverty with different agricultural production systems that involve livestock
- Determine the priority species to the poor in each region and production system
- Identify and quantify the disease constraints to these species, and rank them
- Review published literature on the impact of livestock diseases and of their control in the target regions
- Identify research opportunities to alleviate these constraints
- Synthesise the results of disease impacts on the poor and research needed to reduce them and identify priority research opportunities that will promote better donor coordination and greater impact on poverty alleviation.

Fundamental to the entire study was the need to describe and quantify the distribution and extent of poverty in the target regions. This was accomplished in a companion study made by the Systems Analysis and Impact Assessment Research Group at ILRI (Thornton et al., 2002). This study has resulted in the development of sets of maps and tables that locate significant populations of poor livestock keepers, and includes a very broad assessment of how poor livestock-keeping populations are likely to change over the next 3–5 decades. The results provided figures on the number of poor (people surviving on less than US$ 1 day^{-1}) in each of the 10 major livestock production systems of the world (building on the classification made by Seré and Steinfeld, 1996). These numbers served as a weighting factor in determining the importance of different livestock diseases to the poor.

The subsequent analysis of disease and research impacts had both quantitative and qualitative components. The quantitative approach to describing poverty continued into the evaluation of priority species to the poor, and to an assessment of the impacts on these species of the different diseases and syndromes. Workshops were set up in the following four regions: West Africa (in Sikasso, Mali), Eastern, Central and Southern

Africa (ECSA) (in Nairobi, Kenya), South Asia (SA) (in Hyderabad, India) and South-East Asia (SEA) (in Bangkok, Thailand). Participants (from 9–15 per workshop) were drawn from departments of veterinary services, non-governmental organisations (NGOs), research institutions, universities, animal health service development projects and international organisations.

Following a pre-determined structure and using selected criteria, workshop participants were asked to rank the livestock species of greatest importance to the livelihoods of the poor in each livestock production system occurring in their region. There were some clear patterns that emerged. In pastoral systems, several livestock species play an important role, but within these, sheep and goats are generally the most important, often playing a more important role than cattle. In the agro-pastoral (mixed) systems, cattle predominate, except in WA where sheep and goats are again the priority species to the poor. In peri-urban landless systems, poultry, sheep and goats, and pigs play the most important roles. Within these production system groupings, each region has a slightly different pattern to the priority species of the poor. In SEA, pigs and poultry were considered the most important species in both mixed rainfed and irrigated systems. Moving further west to SA, buffalo rank second after cattle, and yaks are important in the grassland humid systems. In ECSA, cattle ranked first in the mixed agro-pastoral systems, replaced in WA by sheep and goats, followed by poultry.

The workshops were also the setting for the identification and quantification of disease impacts. First, diseases and syndromes considered to negatively affect the livelihoods, productivity outputs and marketing of livestock products by the poor were identified and agreed by consensus. Then, three major impacts of each disease/syndrome were identified and scored. These were socio-economic impacts (primarily production losses and control costs incurred by the poor), zoonotic impacts (for those diseases transmissible from animals to humans) and national impacts (a combination of marketing impacts on the poor with public-sector expenditures on disease control). Each impact was scored for each disease, through discussion and the reaching of consensus, and scores were assembled. A weighting was applied to the scores for each disease relating to the importance of different impacts on the poor (socio-economic impact 85% and national impact 15%). Zoonotic diseases were ranked separately due to the difficulty of measuring the monetary value of human health impacts.

The composite disease impact scores derived were then adjusted to reflect both the relative importance to the poor of the species affected and the number of rural poor (adjusted to reflect the relative severity of poverty) in each production system. The aggregate scores so produced were then normalised to allow comparison of disease impacts between production systems and regions.

A total of 76 syndromes, general diseases, and specific disease entities were identified as having impact on the poor. These included all the disease categories (endemic, epidemic, zoonotic and food-borne). Whereas some diseases were reported from all regions, others had more limited distributions. Diseases were ranked by scored impacts. Thus a disease is likely to score highly if the impacts occur across the two main categories of impact scored (economic impact at the poor farmer level, and economic impact at the national level), occur in species that are ranked highly by the poor, occur in multiple species, and occur in multiple regions or production systems with high numbers of poor (particularly SA). Similarly, diseases that are confined to one species and one region are more likely to score low on the scale. This is clearly very important for inter-

pretation, and for this reason, regional, production system and species priority listings are presented. It must be emphasised that this is a ranking of diseases based on their impact on poor livestock keepers, and not a ranking of research priorities. In a subsequent section of this report research opportunities are discussed, and researchable issues linked to impact prioritisation.

On a global basis, the 20 highest ranked conditions with impact on the poor comprise three syndromes (neonatal mortality, reproductive disorders and nutritional/micronutrient deficiencies that all rank in the top 10), four general disease categories (gastrointestinal [GI] parasites, ectoparasites, respiratory complex and mastitis, the first two of which rank in the top 10), and 13 specific diseases (foot-and-mouth disease [FMD], liver fluke [fascioliasis], Newcastle disease [ND], anthrax, *Toxocara vitulorum* infection of buffalo [toxocariasis], followed by haemorrhagic septicaemia [HS], peste des petits ruminants [PPR], *Brucella abortus* infection [brucellosis], haemonchosis, African trypanosomosis, coccidiosis, *Trypanosoma evansi* infection, and rinderpest [RP]).

The presence of the three syndromes of neonatal mortality, reproductive disorders and nutritional/micronutrient deficiencies in the top 10 reflects the general recognition of production inefficiencies compounded by nutritional inadequacy across all of the species as being among the most important health impacts on the livestock of the poor. It is very interesting to note that these are syndromes that are generally no longer major constraints to livestock farming in the developed world. It is also interesting to note the remarkable similarity with human medicine. In the World Health Organization (WHO) study of research investment opportunities for human medicine, the group of three 'old enemies', responsible for more than half the disease burden in Africa, are listed as the diseases of childhood, malnutrition and poor reproductive health. There is a predictable homogeneity across the species barrier. Poverty is a predisposing factor for these conditions, in both animals and people, but is also a consequence of them (WHO, 1996).

The more qualitative components of the study were in the identification of research opportunities and in the synthesis of disease impacts and research opportunities to develop a listing of 'best bet' options for poverty alleviation.

First, research needs were evaluated from the end-users' perspectives. To do this, the participants in the regional workshops were asked to identify generic qualities of the following key tools for effective disease control:

- Vaccines
- Diagnostics
- Therapy
- Others (such as vector control, genetics)
- Epidemiology and economics (impact assessment)
- Delivery and adoption of services and technologies

Then, participants reviewed each of the diseases previously identified as a constraint to the poor and identified the most relevant category or categories of research priority.

Second, research needs were evaluated from the upstream perspective. International experts specialising in the different diseases were contacted and asked to assemble research priorities for a given disease in which they are leading experts. They were asked to contact other colleagues working in the field by e-mail and set up an electronic conference to identify research priorities in different categories. In addition to identifying relevant research opportunities in each of the categories listed above, the experts were asked to provide information about the cost, time frame, probability of success and available capacity to undertake such research.

To ensure that issues other than technology generation were addressed, additional reviews of research opportunities for the better delivery of animal health services were commissioned. A specific review of the role of research into the genetics of resistance to disease was also commissioned.

Research opportunities fell into three major categories.

- **Epidemiology, economics and impact assessment**
  From all sources of contributions to this study, it became apparent that there is a significant demand for epidemiology, economics and impact assessment research to meet different needs. In the field there is a demand for knowledge to better refine an understanding of what are the major constraints to the poor. Also in the field, there is a demand for knowledge on what are the economic effects of specific diseases, and more importantly, of the effects of different potential intervention options, for priority setting. And in the laboratories, there is a demand for information on how effectively new technologies will perform, and how they will affect the infection dynamics of the diseases they are intended to control.
- **Delivery of animal health services**
  The delivery of animal health services is seen as a major research opportunity. This broad area covers many different but related fields, such as better understanding of farmers' demands, better understanding of the economic viability of animal health services, including who benefits, who pays and how much, and a better understanding of the policies most amenable to the promotion of healthy livestock enterprises of the poor.
- **Specific technologies for the control of specific diseases**
  Research opportunities for the development of vaccines, diagnostics, therapeutics and other technologies were identified and tabulated, with estimated time frames, costs and probabilities of success, for approximately 40 diseases and disease syndromes.

Pulling disease impacts together with research opportunities, a conceptual framework matrix was developed to classify different types of disease-specific research (transferring knowledge and available tools, developing improved tools and strategies, better delivery and developing new tools and approaches) by the contribution the research product will make to poverty alleviation (by securing the assets of the poor, reducing the constraints to intensification or improving marketing opportunities).

When the desired outcomes of poverty alleviation approaches are combined with the R&D opportunity categories in a matrix, it becomes apparent that there are priority investment opportunities to suit different philosophical approaches to poverty alleviation. However it should also be noted that while some research opportunities are clearly associated with one category of approach, others could fall in more than one category. As examples, HS vaccines are considered particularly important to reduce buffalo and cattle mortalities, and improve the contributions of the species to traction at important times of year, e.g. sowing and harvest, so contributing to the 'securing assets' category. However, contagious bovine pleuro-pneumonia (CBPP) vaccines and diagnostics would contribute both to improving the performance of animals currently kept (securing assets), and also to reducing the constraints this disease brings to the movement of animals, so contributing to improving market opportunities.

The following criteria were applied to identify a 'basket' of research options and classify them within the conceptual framework matrix:

- The disease has a high impact on the poor. High impacts were generally derived from the high global or regional scoring
- The time frame for research products is within 15 years. Consequently, the shorter-term options were favoured
- The cost is compatible with the general donor expenditure on animal health research. As such, the low- to medium-cost options were favoured
- There was a medium to high probability of success
- There were significant opportunities identified by research experts based on the developments in the different fields of science
- There is research capacity to undertake the research

The selected basket of research opportunities in the conceptual framework matrix is presented in Table ES1.

Within these different categories of research, many funding opportunities are possible. The conceptual framework matrix presented allows the selection of different categories of sponsor for each of the different cells of the matrix. The funding opportunities depend on the type of research, the geographical area targeted, the species targeted and where else (other than by the poor) the benefits and impacts are felt.

In this report, a categorisation of research opportunities is presented according to the type of research and the likely impact the research product will have on different processes of poverty alleviation. This provides a framework for evaluating any animal health research proposal, and it also provides a basket of opportunities within the different groupings. What it does not do, at present, is rank them within any one 'basket'.

In this report, a broad consultative process has been employed to gather information from field personnel and expert reviewers on animal health constraints for the poor. This process has been very helpful in identifying new priority opportunities that would not necessarily have been highlighted in a more conventional prioritisation process. We have noted here opportunities over the next 15 years for improving the control of high-priority diseases within a vision of alleviating poverty through enhancing benefits from livestock. However, the limitations to quantifying or even qualitatively ranking research opportunities as to their expected poverty-alleviation benefits have been emphasised. In many cases, not only is little known about the incidence and impact of livestock diseases on the poor, particularly for livestock species other than cattle, for diseases that are difficult to diagnose and for populations in more remote areas, but even less is known about the expected benefit to the poor of specific interventions using the products of the research proposed. So yes, a set of priority research areas is proposed, but more data on their impact, among other key information, is necessary before they can be ranked.

A number of other tangible and intangible features will play a crucial role in deciding on the best investment options for a given donor.
These will include:

- Which of the options will other donors prefer, and why? Most agencies are able to offer relatively small amounts, but if there is collaboration in funding, significant amounts of money can be invested in priority issues, creating synergies and greatly enhancing the potential for research success, and therefore impact. This has been a key component of the 'Roll Back Malaria' programme, and could be applied to one or more of the priorities identified here.

Table ES1 Relationship between different contributions to poverty alleviation and different types of research opportunities[1], with examples of research for the control of selected diseases/pathogens and disease syndromes

Research and development categories	Contributions to poverty alleviation		
	Securing assets	***Reducing constraints to intensification***	***Improving market opportunities***
Transferring knowledge and available tools	Neonatal mortality (G) Reproductive disorders (G) Nutritional deficiencies/imbalances (G) Endo- and ectoparasite control (G)	Hygiene issues for the prevention of mastitis (G) Heat detection in cows (as an example of reproductive disorders) (G) Integrated control of gastro-intestinal (GI) parasites, including haemonchosis, fascioliasis and coccidiosis (G)	Hygiene issues for the prevention of cysticercosis and other parasitic zoonoses (G)
Improved tools, better strategies, better delivered	Development of a more efficacious haemorrhagic septicaemia (HS) vaccine (SA, SEA) Testing and evaluation of new peste des petits ruminants (PPR) vaccine (WA, SA) Evaluation of strategic therapy and management strategy for the prevention of toxocariasis (SA, SEA) Newcastle disease (ND) vaccine delivery strategies (G) Impact assessment of alternative control strategies for contagious bovine pleuro-pneumonia (CBPP) and contagious caprine pleuro-pneumonia (CCPP) (WA, ECSA) Impact assessment of PPR and alternative control options (WA, SA)	Development and evaluation of integrated control measures for trypanosomosis[2] (G) Development of integrated control packages for GI parasites (G) Development of strategies to manage resistance to anthelmintics (G) Development of brucellosis control strategies (G) Development of integrated health and nutrition packages for village poultry (G) Development of production system-specific integrated packages for tick and tick-borne disease (TTBD) control[2] (WA, ECSA)	Testing of vaccine for *Cysticercus cellulosae* (G) Improved FMD vaccines (duration of immunity and serotype cross- protection) (G) FMD control strategy and policy development (G) FMD diagnostics to support control (G) Rinderpest (RP) surveillance and control strategies in final pockets (ECSA, SA) Impact assessment and epidemiology of bovine TB (G) Spatial targeting of anthrax control to poor (G)
	Impact assessment of constraints to productivity, and of specific diseases and their control (G) Delivery and adoption of animal health services and technologies issues (G)		
New tools and approaches	Development of a new vaccine for Rift Valley fever (RVF) (WA, ECSA) Recombinant and marker vaccines for PPR (WA, SA) Vaccines for sheep and goat pox (WA, ECSA, SA) Vaccines for African swine fever (ASF) (WA, ECSA)	New vaccines for East Coast fever (ECF), heartwater, anaplasmosis, babesiosis, dermatophilosis (WA, ECSA) New therapeutics for trypanosomosis[2] (G)	Diagnostic for *Brucella melitensis* (Malta fever) (G) Vaccines for CBPP and CCPP[3] (WA, ECSA) Empty capsid vaccine for FMD (G) Diagnostics for bovine TB (G)

1. Research opportunities are identified as being of global (G) or regional significance (WA=West Africa; ECSA= Eastern, Central and Southern Africa; SA=South Asia; SEA=South-East Asia)
2. Placed in the intensification category, but also contributes significantly to asset security
3. Placed in the marketing category, but also contributes significantly to asset security

- Where are there supportive social and policy environments that could catalyse the research process and enhance its chances of success? These factors have greatly contributed to the important successes of the National Dairy Development Board (NDDB) in India and support to smallholder poultry in Bangladesh and other countries.
- The options presented have different geographical foci, different species focus and different price tags, which may all be important considerations in the choice made by a donor.

Thus, the research opportunities identified here need to be considered in a broader financial and socio-political context. The ultimate impact of the opportunities identified in alleviating poverty will very much depend on developing enabling circumstances in which they can succeed. This reality demands a coordinated approach by governments, civil societies, the R&D community and investors. The identification of priority animal health research opportunities in this report is the start of this process. The eventual benefits that these have for the poor will very much depend on coordinated and focused action by many.

This study emphasises the impacts that research in animal health has on poverty alleviation rather than on national agricultural development. Clearly these two goals are not mutually exclusive, but it is extremely important that poor nations, and the poor within any nation, are able to take advantage of their livestock enterprises so that the poor can more effectively contribute to national economies.

1 Introduction

It is generally recognised that poverty is the greatest constraint to global harmony and the well-being of the peoples of the world. Poverty is a problem of extraordinary proportion, with an estimated 2.8 billion of the world's 6 billion people living on less than US$ 2 day^{-1}, and 1.2 billion on less than US$ 1 day^{-1} (World Bank, 2001). But this is not a static situation, and during the next 25 years, the human population is predicted to grow by a further 2 billion, 97% of which will be in the countries of the developing world (World Bank, 2001). These are dramatic figures. And it is these figures and trends that have influenced the Development Assistance Committee (DAC) of the Organization for Economic Cooperation and Development (OECD) to produce a set of international development goals (sometimes referred to as development assistance criteria targets), centred around reducing the proportion of people living in extreme poverty by half between 1990 and 2015. An ambitious target.

Development assistance by governments and international organisations has placed considerable emphasis in the past on policies and strategies designed to strengthen national economies, in the belief that by supporting strong commodity sectors in a country, there would be a trickle-down effect to the poor. However, while the total number of people living on less than US$ 1 day^{-1} has decreased in East Asia (EA) and the Pacific region, it has increased in Latin America, SA and SSA (World Bank, 2001). In SSA alone, 46% of the population are believed to be in this category.

This lack of anticipated impact on poverty has resulted in much re-examination of the underlying causes of poverty, and of ways to alleviate it. There is now general agreement that measures targeted directly at the poor are those most likely to impact poverty alleviation (Randhawa and Sundaram, 1990; UNDP, 1997), although this view is not universally held. Recently the World Bank (2001) contributed to this process by recommending action in three areas.

- Promoting opportunity: expanding economic opportunities for poor people, building up their assets, and increasing their return on these assets by market and non-market actions
- Facilitating empowerment: making state institutions more accountable and responsive to poor people
- Enhancing security: reducing poor peoples' vulnerability to ill health, economic shocks, crop failures etc.

These areas emphasise a change in focus from development that supports the national economy to a direct focus on the poor of a country. Clearly, strength of national economies, markets and infrastructures are important, but it is increasingly argued that the time has come to develop policies and strategies that are more specific and of direct benefit to the poor themselves.

So where do livestock and their diseases fit into this picture? It has been estimated that livestock form a component of the livelihoods of 70% of the world's poor (LID, 1999). Livestock are important in supporting the livelihoods not only of poor farmers, but also of consumers, traders and labourers throughout the developing world. Animal diseases are an every-day occurrence to these people, as the animals of the poor are particularly vulnerable to disease (due to many reasons, including lack of knowledge

about their management and control, and lack of access to–and resources for–animal health and production inputs and services). Furthermore, poor farmers usually have few animals, so the loss of an individual animal has proportionally greater significance. They also have few reserves on which to survive during lean times, and which they can use for recovery.

Livestock have not always been the 'flavour of the moment'. Not so many years ago, much publicity was given in the media of the developed world to the woes of consuming meat, and the negative environmental and animal welfare impacts of keeping large numbers of pigs and poultry under intensive management. While these views might have been relevant to the conditions in many western nations, they totally misrepresented the conditions and demands of the poor in the developing world. In the consumer societies of the western world, per capita consumption of meat and many other livestock products is predicted to decline (Delgado et al., 1999), where high income levels, widespread availability of an enormous variety of food products, low levels of malnutrition and increasing levels of cardiovascular disease, diabetes and other complications of overindulgence have led to a negative view of animal protein. This has been coupled with concern over the environmental threats posed by the need to dispose of large amounts of animal effluent from large-scale and intensive poultry and pig production units.

Ironically, these two factors are reversed in much of the developing world. Malnutrition is rife in many regions, and livestock products, particularly meat and milk, provide an important opportunity to overcome this by providing protein, micronutrients and vitamins. The annual demand for meat is predicted to grow by 2.8% and for milk by 3.3%, dwarfing the growth rates of 0.6% for meat and 0.2% for milk predicted for the developed world (Delgado et al., 1999). Furthermore, livestock are a powerful means of enhancing the purchasing power of the poor through the sale of their products, income that can be used for the purchase of food, education and health care. When it comes to the environment, livestock are a most valuable asset, providing the essential fertiliser for crop production, unavailable or unaffordable in any other form.

The realisation of the starkly different roles of livestock in the developed and developing worlds, and the predictions as to how these differences are likely to continue and intensify, have reversed the negative attitudes to supporting agricultural development that involves livestock. This endorsement of livestock becomes even more appealing when the focus is poverty alleviation rather than national agricultural development, given the multiple roles played by livestock in the livelihood of poor communities around the world.

On a global basis, precise estimates of the numbers of poor livestock keepers, traders, labourers and consumers by region and system, and the types of livestock that contribute to their livelihoods have not been made. Thus, it is necessary to rely on crude aggregate estimates from summary reports. These do provide a picture of the relative importance of livestock to poor people. Livestock In Development (LID, 1999) developed global estimates of numbers of poor livestock keepers presented in Table 1.1.

Given the importance of livestock to the poor, the focus articulated by the World Bank on promoting opportunity, facilitating empowerment and enhancing security, and the high risk to the poor from diseases of their animals that impact livestock productivity and human health, it is argued that research on alleviating those diseases that are

Table 1.1 Number (in millions) of poor livestock keepers by livestock production system

Agro-ecological zone	Category of poor livestock keepers		
	Extensive graziers	Poor rainfed mixed farmers	Landless livestock keepers
Arid or semi-arid	63	213	_
Temperate (including tropical highlands)	72	85	_
Humid, subhumid and subtropical	_	89	_
Total	135	407	156[1]

1. Largely in irrigated systems but also in other high-population-density livestock systems
Source: LID, 1999

of priority to the poor will have direct and major impacts on poverty alleviation. Within populations of poor peoples, women are particularly likely to benefit from improved animal health. They are particularly vulnerable in poor communities, but with their primary responsibility for the management of livestock in most societies, and for the marketing of many livestock products, they stand to be major beneficiaries of improved animal health.

But what are the priorities? Many countries, institutions and international organisations have embarked on priority-setting exercises to ensure optimal impact, and appropriate levels of resource allocation in the face of inadequacies of funding to fulfil all their requirements. These exercises are often qualitative, and take into consideration the relative magnitudes of the different challenges faced, the comparative advantage of the institution addressing these challenges, and the predicted returns from investment in the different options. A few are quantitative. In the field of animal health, there are notable examples from several countries including Kenya (Mulinge and McLeod, 1998), and from international organisations such as ILRI (Thornton et al., 2000). However, as far as we are aware, there has been no priority-setting exercise in animal health research specifically targeted at its impacts on poverty alleviation. While poverty alleviation was a component of the ILRI study, there were also five other criteria included in the evaluation (expected economic impact, environmental impact, internationality of the problem and the solution, capacity-building outputs and comparative advantage of ILRI[1]). Why is this the first evaluation of the direct impacts on poverty?

There have been grossly inadequate data on the distribution and extent of global poverty. Fortunately, this is now receiving much attention, and we have been able to use in this study new global databases of poverty developed by ILRI and its collaborators (Thornton et al., 2002). These are not perfect, and will continue to be improved, but at least they have allowed us to make direct comparisons using the numbers of poor people in three regions of the world, SSA, SEA and SA to achieve an understanding of the scale of impacts of different diseases.

Secondly, there have been inadequate data on disease occurrence to determine the priority diseases to the poor. Animal health information systems exist in most of the developed world, particularly for the intensive livestock production systems in which they serve as a valuable aid to enhancing production efficiency. In the public sector, these are often well developed for the detection and monitoring of national priority

1. The traditional focus and historical comparative advantage of ILRI in ruminant diseases, and within these on vector-borne haemoparasite diseases, was a strong force against a dramatic change in the technology development component (particularly of vaccines and diagnostics) of its animal health research.

diseases undergoing programmes of control or eradication. In many developing countries, public sector animal health information on disease incidence, and particularly on disease impact in terms of morbidity, mortality, production losses etc., are often rudimentary. In many such countries, this situation has deteriorated over the last decade as public sector support to veterinary services has declined dramatically. Furthermore, with such limited resources, the majority of data on animal disease occurrence comes from the more commercial production systems or the more accessible areas, so data on the diseases of those livestock keepers with less than US$ 1 day^{-1} are very limited at best. One positive element has been a general increase in the use and quality of active surveillance and of specific field studies, that have resulted from greater sophistication and availability of epidemiological techniques, but these have unfortunately been very few and far between due to inadequacies of funding (Perry et al., 2001).

To develop a ranking of animal disease priorities to the poor in different production systems of the three regions of the developing world covered by the study, we have used a combination of information documented in the published literature, and information derived from groups of experts working in veterinary services, universities, research institutions, NGOs and international organisations. The latter group contributed to a scoring of disease impacts on the poor in different species and production systems, allowing a semi-quantitative evaluation to be carried out. Using the same set of experts, supplemented by another set of specific disease research experts, we then compiled a set of research opportunities for most of the diseases scoring the highest impact. The impact of diseases on the poor is just one side of the coin, but it must be weighed against the other side of the coin, the research opportunities to produce or deliver technologies to the poor to reduce current levels of disease. This has presented a methodological challenge. We have attempted to document the research opportunities from two perspectives, that of the field worker and that of the research scientist. Overall, these have proved to be remarkably similar, and complementary. From the research scientists we commissioned reviews of research opportunities in the diseases we expected to feature as constraints to the poor, and broadly speaking, these matched the messages we received from the field. The real challenge has been, and continues to be, determining the balance between disease impact and research opportunity. Ideally, if we could identify by how much any given research product, say a vaccine, could reduce the impact of a given disease, we could undertake an economic surplus and benefit cost approach (Alston et al., 1995). However, given the gaps in our knowledge, and the limited time, this was not considered realistic or feasible. So, we reviewed the different researchable options, and selected those that appeared to be addressing priority diseases, different research approaches, different species kept by the poor, and different regions, in order to present a set of priorities in each of these fields that might be attractive to different donors.

For some of the diseases with high impact on the livestock of the poor, the researchable issues relating to their control may be very limited, and on the other hand, some of those diseases lower down the impact list may have highly researchable opportunities that could have significant impact. It is also important to consider both short- and longer-term research opportunities. Currently, many donors favour investment in short-term projects that produce impacts in 3–5 years. While this may be productive where the research issue is to determine the best policy or strategy to deliver an available technology, it is not appropriate if new technologies, tailored for sustainable adoption

and use by poor livestock keepers, are required, and are demonstrated to have a significant pay-off, as such research can take many years, and should not be marginalised by short-sightedness in investment policy. We therefore present both short- and longer-term research opportunities.

Whatever the research opportunities are, it is important that the research products are specifically targeted at poor livestock keepers. In essence, this means they should be appropriate, affordable and accessible, and have direct positive benefits on human capital (improved health, nutrition and quality of life), social capital (improved status in society), and financial capital (improved income), as well as no negative impacts on natural capital (particularly the environment).

The world is in a constant process of change. The nature and extent of the problems it faces change, as do the nature of the potential solutions, with people's rapidly advancing knowledge and the availability of technologies. Thus, today's priorities may be vastly different in a few years' time. The predictive time-frame of this study was taken as 15 years, a planning horizon that conveniently coincides with the target date of 2015 by when the OECD aims to have reduced global poverty by half.

2 Study design

The overall objective of the study is to identify priority animal health research opportunities in terms of their potential benefits for the poor in developing countries. Achieving this objective requires, on the one hand, prioritising animal disease constraints according to their impact on the poor, and on the other, evaluating known research opportunities to address these constraints according to their resource requirements and probabilities of success.

Several factors influenced the approach adopted to answer these large questions. First was the very limited time frame for the study, and the need within that short period to develop a framework and acquire data that could permit comparing the impact of a wide range of disease constraints and possible research solutions across the target regions. Also, the review had to be totally independent, with no bias towards the institution of the consultants. Finally, it needed to be as widely consultative as possible.

The resulting study design integrated several different components. These include both qualitative and quantitative approaches, involving contributions from many different individuals, institutions and regions of the world. The major components were structured as a series of tasks that needed to be accomplished to achieve the overall objective, as follows:

- Describe and quantify the distribution and extent of poverty in SEA, SA and SSA
- Determine the association of poverty with different agricultural production systems that involve livestock[1]
- Determine the priority species to the poor in each region and production system
- Identify and quantify the disease constraints to these species, and rank them
- Review published literature on the impact of livestock diseases and of their control in the target regions
- Identify research opportunities to alleviate these constraints
- Identify priority research opportunities in different categories that take into consideration their likely impact on poverty reduction.

No databases currently exist that cover all diseases and all regions, nor are there many experts, if indeed any, having the requisite breadth of experience and knowledge, especially with the poverty orientation needed for this study. It was therefore clear that an objective, quantitative approach would be required for the first four tasks listed above to minimise bias resulting from our human limitations and individual subjectivities. A quantitative priority assessment framework developed and used for ILRI's strategy planning in 1999 had demonstrated the utility of such an approach.

The final three tasks are much more difficult to quantify and so a more qualitative approach was adopted for them. An initial workshop of experts with broad international experience, held at ILRI in Nairobi in January 2001, agreed upon the essential elements of the methodology and the strategies for both quantitative and qualitative components used during the study.

1. Livestock in this study include cattle, buffalo, yaks, sheep and goats (pooled for the quantitative analysis), camels, poultry, donkeys and horses. Micro stock such as rabbits, guinea pigs, bees, and silkworms kept by poor people in many regions, were not included due to a general deficiency in data.

This strategy translated into four general activities:

- A quantification of poverty by livestock farming system, carried out as a separate companion study by Thornton et al. (2002), using a poverty mapping approach.
- A series of consultative workshops with experts working at the front line of veterinary services, held in the target regions to collect information and agree by consensus on key inputs for the analyses. Participants were asked to contribute to four particular tasks: 1. Reconciliation of production systems classifications; 2. Prioritisation of livestock species important to the poor, by production system; 3. Scoring the impact of diseases and syndromes to the poor; and 4. Identification of major research opportunities to improve animal health for poor livestock keepers. These workshops were held in Sikasso, Mali (WA), Nairobi, Kenya (ECSA), Hyderabad, India (SA) and Bangkok, Thailand (SEA), with participants (from 9–15 per workshop) drawn from departments of veterinary services, NGOs, research institutions, universities, animal health service development projects and international organisations.
- Commissioned reviews of the literature on the impacts of diseases and their control, on the delivery of veterinary services, and on the links between livestock disease control and poverty.
- Commissioned reviews of relevant research opportunities specific to individual diseases, generally conducted by e-mail with leading researchers on specific diseases. The products of these were subsequently reviewed at two workshops, one of leading researchers in Europe (and held at the Institute for Animal Health [IAH], Compton, UK) and one of researchers at ILRI in Nairobi, Kenya.

A review of the overall study was carried out by other international organisations actively involved in animal health R&D (e.g. the Food and Agriculture Organization of the United Nations [FAO]; the Office International des Epizooties [OIE]; the World Health Organization [WHO]; and the International Food Policy Research Institute [IFPRI]) in a one-day meeting held at FAO Headquarters in Rome, Italy.

The following sections describe the specific approaches adopted to address each of the seven tasks and achieved through these four activities.

2.1 Defining and quantifying the location and extent of poverty, and its association with livestock farming systems

To assess the potential impact of animal health research on the poor, it is necessary to know where the poor are, and their association with livestock production. Key steps in this process were to decide upon, first, an appropriate definition of poverty and, secondly, a classification of livestock farming systems that could be applied consistently across the three regions. Theoretical considerations in making these decisions needed to be tempered by practical considerations of data availability. These decisions and the actual process of developing a global poverty map classified by livestock production systems are the subject of the separate companion study by Thornton et al. (2002), and in Appendix 4 (Robinson, 2002) are reviewed within the context of the present study, as summarised below.

2.1.1 Defining and measuring poverty

Poverty is multidimensional and is perceived differently by different groups, so no single definition captures all its aspects. The International Fund for Agricultural Development (IFAD), for example, currently uses a definition of poverty that includes eight

broad classes: 1. Material depravation; 2. Lack of assets; 3. Isolation; 4. Alienation; 5. Dependence; 6. Lack of decision-making power; 7. Vulnerability to external shocks; and 8. Insecurity (Jazairy et al., 1992).

To measure poverty, various types of single or multiple-component indicators have been developed that reflect economic, social, institutional and environmental dimensions of human welfare. Economic indicators based on household consumption and income are most common because the necessary survey data are usually available. For the present analysis, global poverty indicators were needed that could be comparable across the three target regions of SSA, SA and SEA. Two types of income-based measures were selected:

- **Number of rural poor:** defined as the headcount of rural population living below the rural poverty line, using poverty rates based on the latest household survey for each country (World Bank, 2001). It was considered that limiting the measure to rural poor rather than also including urban poor, would better represent populations that depend in some way on livestock keeping. The number of rural poor measures the extent of poverty.
- ***P*-adjusted number of rural poor:** defined as the headcount described above, multiplied by a country-specific poverty severity index (*P*). This index is estimated based on the gap between equity-adjusted average incomes and the poverty line in a given country, with the equity adjustment derived from a measure of the degree to which incomes are equitably distributed within the country (Gini Coefficient). Index values for *P* range from zero to one, with a value of one indicating severe poverty associated with a very highly skewed income distribution. This measure therefore captures both the extent and severity of poverty.

2.1.2 Livestock farming systems

Seré and Steinfeld (1996) produced the only currently existing global livestock production classification system associated with a detailed data set. For this reason, it has been widely used, and served as the basis for ILRI's recent priority-setting exercise (Thornton et al., 2000). Seré and Steinfeld used FAO's agro-ecological zoning classification and produced detailed country tables with disaggregated data by area, human population, livestock numbers, and livestock outputs for each livestock production system category. Thornton et al. (2002) refine and update the Seré and Steinfeld classification system and database. Four main production categories are identified: landless systems (typically found in peri-urban settings), livestock/rangeland-based systems (areas with minimal cropping, often corresponding to pastoral systems), mixed rainfed systems (mostly rainfed cropping combined with livestock, i.e. agro-pastoral systems), and mixed irrigated systems (significant proportion of cropping uses irrigation and is interspersed with livestock). All but the landless systems were further disaggregated by agro-ecological potential, as defined by the length of the growing period. Three different agro-ecological zones are used: highland/temperate, arid/semi-arid and humid/subhumid. In summary, the following ten livestock systems were defined and mapped across the globe:

LGA	Livestock only, rangeland-based arid/semi-arid
LGH	Livestock only, rangeland-based humid/subhumid
LGT	Livestock only, rangeland-based temperate/tropical highland
MIA	Mixed irrigated arid/semi-arid

MIH Mixed irrigated humid/subhumid
MIT Mixed irrigated temperate/tropical highland
MRA Mixed rainfed arid/semi-arid
MRH Mixed rainfed humid/subhumid
MRT Mixed rainfed temperate/tropical highland
LL Landless (peri-urban)

Thornton et al. (2002) map the geographical coverage for each livestock production system by applying the production system definitions to a series of ancillary global socio-environmental datasets.

2.1.3 Associating poverty to livestock production systems

Data for the selected poverty indicators are available at national level for most of the countries in the three target regions. To generate the selected poverty indicators by livestock production system, Thornton et al. (2002) use various statistical techniques to allocate human population numbers to the different livestock production systems within each country. National-level 'Rural %' poverty rates from the World Bank (2001) were then applied to estimate the numbers of rural poor in each livestock production system for each country (see data tables in Appendix 4). The resulting estimates serve as the basis for the quantitative analysis in the present study.

Among the various poverty measures estimated by Thornton et al. (2002), one attempts to refine further the 'number of rural poor' indicator in terms of livestock activities by recognising that the portion of livestock keepers varies by production system. Thus, Thornton et al. (2002) also estimate 'number of poor livestock keepers' by production system in each country based on very crude global proportions of livestock keepers among the rural poor in pastoral, agro-pastoral and landless systems reported by LID (1999). These estimates are only intended to be indicative, but do offer an alternative measure that is used in the present study to test the sensitivity of the disease-impact rankings.

2.2 Livestock and the poor: which species are most important to livelihoods?

To evaluate the impact on the poor of individual livestock diseases, it is necessary to understand the role of the affected species in the livelihood strategies of the poor. During the initial methodology workshop held in January 2001, a number of criteria were identified that could be used to evaluate the relative importance of different types of livestock to the poor in a given livestock farming system, with the roles of livestock as economic and social capital assets highlighted. A scoring system was proposed, but proved to be impractical during the regional workshops. Instead, a simple ranking by the workshop participants of the top five most important species, based on consensus and subjective evaluation of the proposed criteria, was used.

2.3 The poor, their livestock and the impact of diseases

During the initial methodology workshop, a quantitative framework was proposed for assessing the relative impacts of individual livestock diseases and syndromes on the poor inspired by ILRI's own research priority assessment exercise conducted in 1999 (Thornton et al., 2000). The framework consists of evaluating the impact of individual diseases on the affected livestock species within specific livestock farming systems in

each region using a scoring system, and then weighting these scores by the relative importance of the affected species to the poor (section 2.2) and by indicators of the relative poverty found in each production system (section 2.1), to generate aggregate rankings of the disease impacts across species, production systems, and regions. During the regional workshops, the participants applied the scoring system, reviewing each individual disease and scoring by consensus.

2.3.1 Scoring system used to assess the relative impacts of diseases within individual production systems

Four types of impacts were initially identified during the methodology workshop for evaluating disease constraints to the poor in individual production systems: 1. Economic; 2. Zoonotic; 3. Social; and 4. National. It became evident, however, that social and economic impacts are often difficult to distinguish and tend to be highly correlated, and so they were combined into a single measure within the scoring system. Specific criteria were identified for measuring the various impacts, and each criterion was evaluated on a scale of 0–5, with five representing the most severe type of impact.

Ideally, the various impact scores would be combined into a single composite index to permit ranking the diseases by their overall impact. To do so, though, requires devising a weighting system that explicitly assigns relative values to the socio-economic and human health impacts, saying, for example, that one unit of human mortality and illness is the equivalent of two units of livestock production value lost. Currently, no basis exists for such a value system, so two separate impact rankings were estimated, one for socio-economic impacts and one for human health impacts.

A composite score for the socio-economic impacts for each disease was calculated as the weighted sum of the economic and national impacts. The scoring system is summarised in Table 2.1.

Socio-economic impact was given the largest weight (85%) in the composite score to reflect its importance as often the most immediate, profound effect on the poor. In this context, economic impact refers primarily to production losses and control costs incurred by livestock keepers due to the disease. Difficulties arose over how to reconcile the nature of losses that occur continuously with endemic diseases, with the risk associated with epidemic diseases that occur only infrequently but nonetheless constrain further investment or intensification of livestock production, so the concept of *expected* losses was applied.

In the scoring system, economic impact is broken down into two sub-components: 1. Expected production losses, which are evaluated according to annual disease incidence (proportion of herds/flocks affected within the production system) and the severity of the impact within an affected herd/flock; and 2. Control costs incurred by livestock keepers, measured as the proportion of livestock health expenditures allocated to the specific disease. Although livestock keepers in some cases incur significant expenditures for their livestock health care, such as for controlling trypanosomosis and tick-borne diseases (TBDs) in cattle in pastoral areas in Africa, for the large majority of livestock diseases, the poor invest relatively little in controlling disease in such species as small ruminants and poultry that are important to them. Control costs are therefore assigned a weight of 15% versus 70% for production losses.

Table 2.1 System for scoring impacts on the poor of a non-zoonotic livestock disease within a production system

Criteria	Sub-components	Score and description	Weight (%)
	A What is the annual herd/flock incidence? (proportion affected)	**1** Endemic diseases What percentage of herds or flocks reared by poor people is affected by clinical disease in an average year?	**2** Epidemic diseases a. How often do epidemics occur? b. When an epidemic occurs, what proportion of herds or flocks is affected?
I Economic impact at the level of poor producers 85%	**B** What is the impact in affected herds/flocks? (the losses caused)	0= Negligible impact on livestock productivity 1= Moderate reduction in livestock productivity 2= Chronic/sustained or regularly repeated reduction in livestock productivity 3= Chronic lowering of productivity and occasional deaths 4= Some mortality plus serious reduction in productivity 5= High mortality and dramatic effect on productivity	70
	C What is the current cost of prevention and treatment to poor producers?	0= Negligible < 5% 1= 5–20% of annual expenditure on animal health for that species 2= 20–40% 3= 40–60% 4= 60–80% 5= > 80%	15
II National impact of disease 15% (indirectly affecting poor producers)	**D** What are the market effects on poor people? (the extent to which the disease blocks market opportunities)	0= None 1= Local movement restrictions, probably only one species affected 2= Movement restrictions, ban on exports from certain areas 3= Regarded as an important risk by neighbouring countries—multiple species affected 4= No trade in live animals from affected regions 5= Completely blocks all marketing of animals and livestock products	10
	E What are current levels of public expenditure?	0= Negligible < 5% 1= 5–20% of annual expenditure on animal health for that species 2= 20–40% 3= 40–60% 4= 60–80% 5= > 80%	5
Total score	**Endemic diseases S = [A1 · B · 0.7] + C · 0.15 + D · 0.1 + E · 0.05** **Epidemic diseases S = [A2 · b/a · B · 0.7] + C · 0.15 + D · 0.1 + E · 0.05**		

In addition to the economic impact to the individual livestock keeper, livestock disease can also have important impacts beyond the farm that also affect the poor. These are broadly termed as 'national' impact (accounting for the remaining 15% of the composite score), composed of the effects of the disease on livestock marketing opportunities and on public finances directed at the poor. In the case of market opportunities, stress was put on whether the market impacts truly affect the poor, or are concentrated primarily in the commercial sector.

Zoonotic diseases are ranked separately and evaluated based on the incidence of the disease in livestock (from Table 2.1, I [A]), the extent of human populations at risk from an outbreak of the disease, together with its severity in affected individuals. The scoring system is presented in Table 2.2.

Table 2.2 System for scoring impacts on the poor of a zoonotic livestock disease within a production system

Criteria	Sub-components	Score and description	Weight (%)
III Importance as a zoonosis	F Which incidence indicators apply? (describe the affected populations)	0= Not a zoonosis or negligible 1= Minor threat to livestock keepers 2= Significant threat to livestock keepers, minor threat to others 3= Major threat to those in contact with livestock or living in the area 4= Significant threat to consumers of certain products and/or major threat to those living near livestock and to livestock keepers 5= Threat to general public	50
	G How severe is the impact in affected individuals? (including the costs of treatment)	0= Not a zoonosis 1= Minor discomfort and/or easily treated 2= Unpleasant chronic illness, often undiagnosed 3= Serious problem, requiring expensive therapy, often undiagnosed 4= Very expensive to treat, probably requires hospitalisation, risk of death, often undiagnosed 5= High case fatality rate, expensive to treat, often undiagnosed	50
Total score	**Endemic diseases S = A1 · [F · 0.5 + G · 0.5]** **Epidemic diseases S = A2 · b/a · [F · 0.5 + G · 0.5]** **where A1, A2, b and a are described in Table 2.1**		

2.3.2 Implementing the scoring system

During the regional workshops, participants were prepared for the disease impact scoring exercise by first identifying the major livestock production systems in the region, and how these systems correspond to the Seré and Steinfeld classification. This also included a discussion about whom and where the poor are in each production system within their region, followed by ranking the species in each production system by their relative importance to the poor. These various discussions helped to ensure that the participants shared a common understanding of the target population and the production systems before beginning the scoring exercise.

To begin the disease impact scoring, a preliminary inventory of disease constraints drawn up during the initial methodology workshop was reviewed and modified as needed by the participants. Each disease in turn was discussed and scored by consensus. Once a disease was scored for one production system, the other relevant production systems for that disease were identified and whether the same scores applied or needed to be adjusted in the other production systems. Scoring was initially very slow in each workshop as participants worked toward a common understanding of the scoring criteria and at the same time questioned their ability to provide accurate answers. Participants quickly realised that the emphasis was on the relative scores across diseases, rather than estimating the correct exact score for any given disease, permitting the pace to pick up and the exercise to be completed in the allocated time.

Although the same process was followed at each regional workshop, each group of participants developed their own particular interpretation of the scoring system. Nonetheless, there do not appear to be dramatic differences between the results generated by each group, with the WA workshop tending to score a bit higher and the SA workshop a bit lower.

2.3.3 Ranking disease impacts: aggregating scores

Using the criteria scores provided by the regional workshops, composite disease impact scores were calculated following the formulae in Tables 2.1 and 2.2. To make the production loss component consistent in scale with the other components, the production loss value of (A•B) was first normalised by region to fit a 0–5 range.

Each composite disease impact score is specific to one disease and its impact on one species in one production system within a region. To aggregate over different combinations of species, production systems, and regions, the scores were adjusted to reflect both the relative importance to the poor of the species involved, and the relative poverty found in the indicated production systems. The species adjustment was made by multiplying the disease impact score by (6-*R*)/5, where *R* represents the ranking of the species in terms of its importance to the poor in the specific production system (*R*=1,2,3,4,5; 1=most important; species not ranked in the top five being valued as zero). Disease impact scores for the most highly ranked species were therefore multiplied by 1, those for the second highest were multiplied by 0.8, and so on. This adjustment serves to discount diseases that affect species of less importance to the poor.

The second adjustment for poverty was achieved by simply multiplying the species-adjusted disease impact score by the selected poverty indicator (section 2.1.1). This provides a poverty-adjusted, species-adjusted disease impact score (S^*_{dijk}) for each disease *d*, species *i*, production system *j*, and region *k*, that though has no direct intuitive interpretation, does provide a measure of the relative magnitude of how the disease impacts the poor in that production system.

Summarising:

$$S^*_{dijk} = S_{dijk} \cdot \frac{(6 - R_{ijk})}{5} \cdot P^*_{jk}$$

where P^* is the *P*-adjusted number of rural poor—the selected poverty measure. To rank diseases according to their impact on the poor, the values of S^*_{dijk} are simply summed over *i*, *j*, *k*, or any combination of these, to compute aggregate disease impact scores. The aggregate scores are then normalised so that the highest aggregate score has an index value of 100, and the others re-scaled accordingly.

2.3.4 Sensitivity analysis

To evaluate the robustness of the resulting disease impact rankings, various types of sensitivity analysis were conducted. First, the sensitivity of the disease rankings to different poverty indicators was tested. The global disease impact rankings were re-estimated using: 1. The number of rural poor unadjusted for the severity of poverty (see section 2.1.1), 2. The number of poor livestock keepers (see section 2.1.3) and 3. the *P*-adjusted number of poor livestock keepers.

As will be presented in Chapter 3, the adjustment for severity of poverty and shift from rural poor to poor livestock keepers both serve to reduce the relative importance of disease impacts from SEA and increase those from SSA. Nonetheless, the disease impact rankings remain relatively consistent regardless of which poverty measure is used, as shown in Table 2.3. In most cases, changing the poverty measure contributes to only minor changes in rankings in the immediate neighbourhood for each disease—for example, the 7th-ranked disease falling to 8th rank—but few major changes. This is evidenced by the small numbers of disease that fell from a given rank group (such as the top five), with typically the lowest–ranked disease slipping out.

Table 2.3 Impact of changes associated with poverty measure used

Poverty measure	Number of diseases compared to Base model no longer in Top: 5	10	15	20
Numbers of rural poor	0	1	1	1
Numbers of rural poor adjusted for severity of poverty (*P*-adjusted)–Base analysis	–	–	–	–
Numbers of poor livestock keepers	0	1	1	2
Numbers of poor livestock keepers adjusted for severity of poverty (*P*-adjusted)	0	1	1	3

Second, the impact of the disease impact score weighting system (the last columns of Tables 2.1 and 2.2) was evaluated by considering alternative weighting schemes. The sensitivity analysis indicates the rankings to be very robust to major changes in the weightings assigned to evaluating disease impacts. The results for the alternative weighting schemes for the socio-economic impacts are shown in Table 2.4. Once again, there are few major changes.

Table 2.4 Impact of changes in weighting scheme

Scenario	Weights assigned to each component: Production losses	Control costs	Market effects	Public finance	Number of diseases compared to Base model no longer in Top: 5	10	15	20
Base analysis	0.70	0.15	0.10	0.05	–	–	–	–
Higher control cost share, lower off-farm shares	0.60	0.35	0.04	0.01	1	1	1	1
Lower control cost and off-farm shares	0.85	0.10	0.04	0.01	1	1	0	1

A third sensitivity analysis was conducted to evaluate the impact of the normalisation of production losses across the four regions in the computation of the disease impact index. The normalisation is done for two reasons. The first is to avoid bias due to different approaches adopted by each regional workshop in applying the scoring system (e.g. one group of regional experts may have set their relative scoring higher than another). The second is to avoid an implicit discounting of the 0.70 weight assigned to the production losses component of the economic impact index. If the highest production loss score is only 3 out of a possible 5, then the 0.70 weight is automatically reduced by 40% unless the scores are first re-scaled to represent the full range up to 5. It may be argued, however, that different scoring ranges indeed reflect different degrees of importance of disease impacts rather than scoring biases, and so should be maintained in the index computation. To test the implications for the analytical results, the analysis was conducted without normalising the production loss scores in each region.

The results are summarised in Table 2.5. The experts from the Asian regions tended to be more conservative in their scoring of the most severe disease impacts compared to those in Africa. Overall, though, the normalisation changes the disease impact rankings only marginally.

A final sensitivity analysis was conducted to evaluate the impact of incorporating a vulnerability premium into the scoring system. It can be argued that for the poor, mortality is particularly catastrophic, whether it relates to animals as assets or to a household member. This is perhaps not adequately reflected in the scoring systems described in

Table 2.5 Impact of normalising regional production loss scores[1]

		Region[2]				
		Global	WA	ECSA	SA	SEA
Highest recorded production loss score[2]		4.0	4.0	3.5	3.0	3.0
Compared to Base model, number of diseases no longer ranked among Top:	5	0	0	0	1	0
	10	1	1	0	2	0
	15	1	1	0	0	1
	20	1	0	1	0	0

1. Out of a possible score of 5
2. WA = West Africa; ECSA = Eastern, Central and Southern Africa; SA = South Asia; SEA = South-East Asia

Tables 2.1 (subcomponent B) and 2.2 (subcomponent G), in which scores increase in a simple linear fashion from morbidity to mortality. Therefore, a scoring system that assigns proportionally higher scores to mortality was tested. Table 2.6 displays the revised system.

Table 2.6 Revised scoring system introducing vulnerability premium

Description	Assigned score	
	Base model	Revised
1 (B) Economic impact at the level of poor producers–impact in affected herd/flocks		
Negligible impact on livestock productivity	0	0
Moderate reduction in livestock productivity	1	0.5
Chronic/sustained or regularly repeated reduction in livestock productivity	2	1
Chronic lowering of productivity and occasional deaths	3	2
Some mortality plus serious reduction in productivity	4	3
High mortality and dramatic effect on productivity	5	5
III (G) Importance as a zoonosis–severity of impact in affected individuals		
Not a zoonosis	0	0
Minor discomfort and/or easily treated	1	0.5
Unpleasant chronic illness, often undiagnosed	2	1
Serious problem, expensive therapy, often undiagnosed	3	1.5
Very expensive to treat, probably requires hospitalisation, risk of death, often undiagnosed	4	3
High case fatality rate, expensive to treat, often undiagnosed	5	5

The Base model was re-estimated using the revised scoring system. The change in disease rankings is summarised in Table 2.7. Once again, there are only marginal changes in the disease orderings. Introducing a vulnerability premium for mortality produces little change in the final results.

Table 2.7 Impact of vulnerability premium

Index	Number of diseases compared to Base model no longer in Top:			
	5	10	15	20
Economic impact	0	2	1	1
Zoonotic impact	1	0	0	0

In summary, the impact rankings are quite robust, and not significantly sensitive to the poverty weighting factor used, the weighting of scores in different categories, the normalisation of production loss scores across the four regions studied, nor the linear ranking of disease impacts.

2.3.5 Limitations

The approach and process described above for ranking disease impacts should be recognised as a first and imperfect attempt. It is just a beginning, intended to provide a quick, preliminary assessment of how different diseases are likely to vary in their relative magnitude in terms of impact on the poor. In particular, the robustness of the reported rankings indicated by the sensitivity analyses should in no way be interpreted as certifying the underlying accuracy of the rankings. That accuracy ultimately depends on the quality of the information collected about each disease, and for now, lacking systematic, objective data collection across the developing world with respect to both disease and poverty incidence by livestock farming system, we have had to depend upon the very subjective and inevitably flawed opinions of a wide range of local and international experts. The sensitivity analysis simply tells us that, given those inputs, the ranking remains basically unchanged regardless of how we adjust the weighting and do the final computations. Beyond this general caveat, a few other limitations of the disease impact rankings need to be kept in mind when reviewing the results:

- **Misinterpretation of the rankings.** As stressed elsewhere in the study, the disease impact rankings should not be misconstrued as an indicator in and of themselves of priority research opportunities. Decision-makers will undoubtedly focus on the tables with the disease impact rankings to see which diseases have the largest impact and so merit the largest investments. This is wrong. Priorities need to be decided according to the extent to which the impact of a particular disease can be effectively addressed per research dollar (Perry and Randolph, 1999).
- **Comparability of disease definitions.** As described above, the diseases included in the scoring exercise were identified through a participatory process at each of the regional workshops. This was intended to avoid introducing bias by imposing a predetermined list of diseases. The drawback of this approach is that different workshops generated different disease definitions. In some cases, due to lack of information, participants in one region were more comfortable talking about gastrointestinal parasitism in general while in another region, they preferred to distinguish specific types of parasitism. Similarly, some diseases were identified as syndromes, such as neonatal mortality or reproductive failure, which due to lack of knowledge about the specific causes, could represent a number of different diseases. As a result, there are a number of inconsistencies in definitions of the diseases being compared. Some are inevitable, but others can be improved upon in future assessments.
- **Variable quality of information by disease.** Certain diseases have been the subject of more research or monitoring than others, and this was reflected in the degree of confidence that participants in the workshops exhibited when attempting to score the disease incidence and impacts. Incidence of disease was estimated for all diseases in all regions, but in many cases participants felt that inadequate data are available to provide reliable estimates. Individual impact scores—and hence the rankings themselves—are therefore associated with widely varying 'confidence intervals', and no mechanism was anticipated in the scoring system to account for this.
- **Accounting for 'lost potential'.** The criteria for assessing disease impacts concentrate on impacts associated with disease incidence. No attempt was made to evaluate the impact of disease risk, and which is often cited, for example, as the reason for

lower than expected use of cattle in the tsetse belt of SSA (see Chapter 5). The problem, of course, is how to evaluate the counterfactual scenario of 'what if' a given disease was effectively controlled. With what confidence could we say that the individual disease is the lone constraint to adoption of a different livestock species or management technology? If we do accept that it is the lone constraint, then how do we predict and measure the potential adoption of the species or technology and its benefits? To do so would require an in-depth analysis, such as that reported by Kristjanson et al. (1999) for trypanosomosis. This said, a simple scoring approach to address this gap should be explored in future assessments.

- **Changing production system coverage.** For the purposes of data collection during the regional workshops, the geographical extents of individual production systems used in guiding the scoring exercise were based upon data from Thornton et al. (2000). During the period of the present study, the production system data and geographical coverage have been updated and refined (Thornton et al., 2002), and it is these more-recent data that have been used in computing the disease impact rankings. The impacts of potential inconsistencies between the geographical coverage used for data collection and those used for the analysis are considered negligible.

2.4 What have been the constraints to delivering animal health services and technologies?

From the poor livestock keeper's point of view, his or her inability to manage a specific livestock disease is due to an appropriate (also meaning affordable) control technology or service not being readily available. In some cases, the needed technology has yet to be developed, but in other cases the livestock keeper may simply not have access to an already existing technology. Ineffective delivery of livestock health services also compromises the potential impact of new technologies as they are developed. To complete the evaluation of disease constraints, a review of those constraints related specifically to delivering animal health services was commissioned, and undertaken by A. McLeod and A. Wilsmore of the Veterinary Epidemiology and Economics Research Unit (VEERU), University of Reading, UK (see Appendix 11, McLeod and Wilsmore, 2002). Additional reviews, specific to small-scale and backyard poultry production, were commissioned, and undertaken by the Network for Smallholder Poultry Development, the Royal Veterinary and Agricultural University, Denmark (Permin and Madsen, Appendix 8, 2002a and Appendix 12, 2002b).

As noted earlier, ranking disease constraints by their impact on the poor is not sufficient to identify animal health research priorities for alleviating poverty and if used alone for such purposes, is likely to misguide research efforts (Perry and Randolph, 1999). It is essential that information on the impact of disease constraints be complemented by information on the potential opportunities for research to mitigate or eliminate those impacts. The following sections describe the approach adopted to collect this type of information.

2.5 Research opportunities in animal health

Research to improve livestock disease control benefiting the poor can potentially span a very wide range from achieving breakthroughs in basic science that generate new technologies, to the adaptive end of the research spectrum where simple tweaking of an existing technology or designing innovative service delivery strategies improve accessibility and uptake. To capture the full breadth of potential research opportunities, a two-pronged strategy was adopted.

2.5.1 Field perspectives of research priorities

First, research needs were evaluated from the end users' perspective. To do this, the participants in the regional consultations were asked to identify generic qualities of the following key tools for effective disease control:

- Vaccines
- Diagnostics
- Therapy
- Others (such as vector control, genetics etc.)
- Epidemiology and economics (impact assessment)
- Delivery and adoption of services and technologies.

Then, participants reviewed each of the diseases previously identified as a constraint to the poor, and identified the most relevant category or categories of research priority.

2.5.2 Disease expert perspectives of research priorities

Second, research needs were evaluated from the upstream perspective. A set of international experts was contacted and asked to assemble research priorities for a given disease in which they are leading experts. They were asked to contact other colleagues working in the field by e-mail, and to set up an electronic conference to identify research priorities in different categories (see Appendix 3). In addition to identifying relevant research opportunities in each of the categories listed in the preceding section, the experts were asked to provide information about the cost, time frame, probability of success and available capacity to undertake such research. A template was developed (see Appendix 3) to guide the types of information to be collected during the conference, and ensure comparability across different diseases.

2.5.3 Generic research opportunities in the delivery and adoption of animal health services and technologies

To ensure that issues other than technology generation were addressed, additional reviews of research opportunities for the better delivery of animal health services were commissioned and undertaken as part of the studies noted above in section 2.4. These reviews are reported in Appendix 11 (McLeod and Wilsmore, 2002) and Appendix 12 (Permin and Madsen, 2002b).

2.5.4 Genetics of disease resistance

A specific review of the role of research into the genetics of resistance to disease was commissioned from J. Gibson, ILRI (see Appendix 13, Gibson, 2002).

2.6 Pulling it all together: disease impact, research opportunities and poverty alleviation

To synthesise all of the many types of information collected or generated during this study, the following approach was adopted.

First, based on the results of ranking animal disease impacts, the top 20 candidate priority diseases and syndromes were identified globally, by region, by species and by production system. The results were also reviewed for a few select diseases that did not rank highly but are of traditional interest to donors, to gain a better understanding of their low ranking. Information about delivery and adoption constraints was also reviewed.

A framework was developed for the categorisation of research priorities based on the impact of the disease, and the different approaches to poverty alleviation (securing assets, reducing constraints to intensification, and improving market opportunities). This allowed consideration of the different philosophical approaches to poverty alleviation, and the different types of research.

Next, the research opportunities identified by both the regional and expert consultations were reviewed for each of the priority diseases, and categorised according to the generic area of research involved, the approach to poverty alleviation, the time horizon, and the likely sources of funding. This allowed a series of research priorities to be presented in different categories.

The listing of research opportunities for the disease priorities should not be considered exhaustive. Specific reviews of research opportunities were not commissioned for all the priority diseases, nor were the opportunities identified for those that were commissioned necessarily complete. However, the framework can allow donors of animal health research the opportunity to evaluate for themselves the significance of research proposals submitted, from the priority given to the disease and the type of research proposed.

3 Global poverty and its association with agricultural systems

The understanding of poverty and its many dimensions has steadily evolved in recent years as countries and organisations have grappled with the increasing scale of this global problem of human deprivation, and with a more structured and comprehensive approach being applied to reducing, even eliminating, poverty. As such, while material deprivation, in terms of income and assets, is still considered central to poverty, other factors such as health, education, vulnerability, voicelessness and powerlessness are now all considered key elements. Furthermore, many of these elements are closely interlinked. Broadening the causal dimensions of poverty allows greater opportunity for evaluating ways of reducing it.

As far as measuring poverty is concerned, income poverty, using monetary estimates of income or consumption, still dominates assessments (see World Bank, 2001, pp. 15–41 for a review of poverty assessment indicators). In this report, while a broader view of all the dimensions of poverty described above are taken into consideration in the evaluation of the benefits that research products to improve the health of animals may bring, all of the quantification of poverty (how many people, in which region, in which production system, and with which livestock species) was carried out on the basis of material deprivation in the form of income poverty (see Thornton et al., 2000; Thornton et al., 2002 and Appendix 4, Robinson, 2002).

According to a recent study on the global poor, more than 1.2 billion people are living in abject poverty on less than US$ 1 day^{-1}(World Bank, 2001)[1]. An additional 1.6 billion persons are only slightly better off, with an average income of between US$ 1 and US$ 2 day^{-1} (World Bank, 1997). Approximately one quarter of the above global poor are estimated to be livestock keepers. More specifically, 407 million persons are classified as farmers in rainfed zones, 135 million are pastoralists, and a further 156 million keep livestock in landless systems (LID, 1999). In many developing countries, livestock are one of the few means available to the poor for generating capital assets. Livestock products are also an important nutritional resource, and through gift-giving animals may act as a means of gaining social approbation and acceptance. Indeed, a recent study in Kenya demonstrated that although poor households are almost always involved in a wide array of livelihood activities, livestock took on increasing economic and social importance, the deeper the poverty of the household (Heffernan and Misturelli, 2000).

Nevertheless, livestock have been under-utilised as a weapon for poverty reduction. In general, livestock projects and programmes have not had a pro-poor focus (LID, 1999). Historically, the aim of most development activities has been on improving productivity and not on the health and welfare of the households involved (Heffernan and Sidahmed, 1999). The belief was that by supporting a strong livestock sector, there would be trickle-down benefits to the poor. Indeed, even today, arguments and justifications for livestock development most often centre on global food needs and the demand for meat and milk by wealthier consumers (Delgado et al., 1999). Thus, although new frameworks of development support a focus on the poor, old arguments

1. The following two paragraphs are based on Appendix 5 (Heffernan, 2002).

regarding the importance of a strong livestock sector and the secondary benefits to the impoverished stubbornly persist.

3.1 The distribution of poverty

The essential pre-condition for using livestock as a weapon for poverty reduction is a better understanding of where livestock play a role in the livelihoods of poor people. As noted in the preceding chapter, we have been fortunate in being able to draw upon the results of a concomitant study by Thornton et al. (2002) to map the distribution of poverty by livestock production system across the developing world. Based on their data, four poverty measures described in the preceding chapter were developed to represent the distribution and variation in intensity of poverty by livestock system across the four target regions: WA, ECSA, SA and SEA.

The regional distributions of the two poverty measures based on headcounts for the year 2000 are summarised in Table 3.1 and Figure 3.1. The first poverty measure is numbers of rural poor. Of the total 2.4 billion people living in the four target regions, 38% of this population, or 911 million, are considered rural poor. The second poverty measure is based on rough estimates of numbers of poor in livestock-keeping households among the rural poor (section 2.1.3 and Appendix 4). According to these estimates, livestock-keeping households account for approximately half of the rural poor in these regions. Each headcount poverty measure is subsequently adjusted to reflect the relative severity of poverty within each region by multiplying headcount figures by the *P* value described in section 2.1.1 and Appendix 4. The resulting number, which is used as a weighting factor when aggregating species/production system/region-specific disease impact scores, does not have any direct interpretation. The impact of this adjustment is

Table 3.1 Headcount (millions) poverty indicators, by region, 2000

	Region[1]				
Measure	WA	ECSA	SA	SEA	Total
Human population	240	315	1,360	501	2,416
Rural poor	100	149	503	159	911
(% of total population)	*41.6*	*47.4*	*37.0*	*31.8*	*37.7*
Poor livestock keepers	60	90	202	59	411
(% of total population)	*25.9*	*27.9*	*15.1*	*12.2*	*17.3*

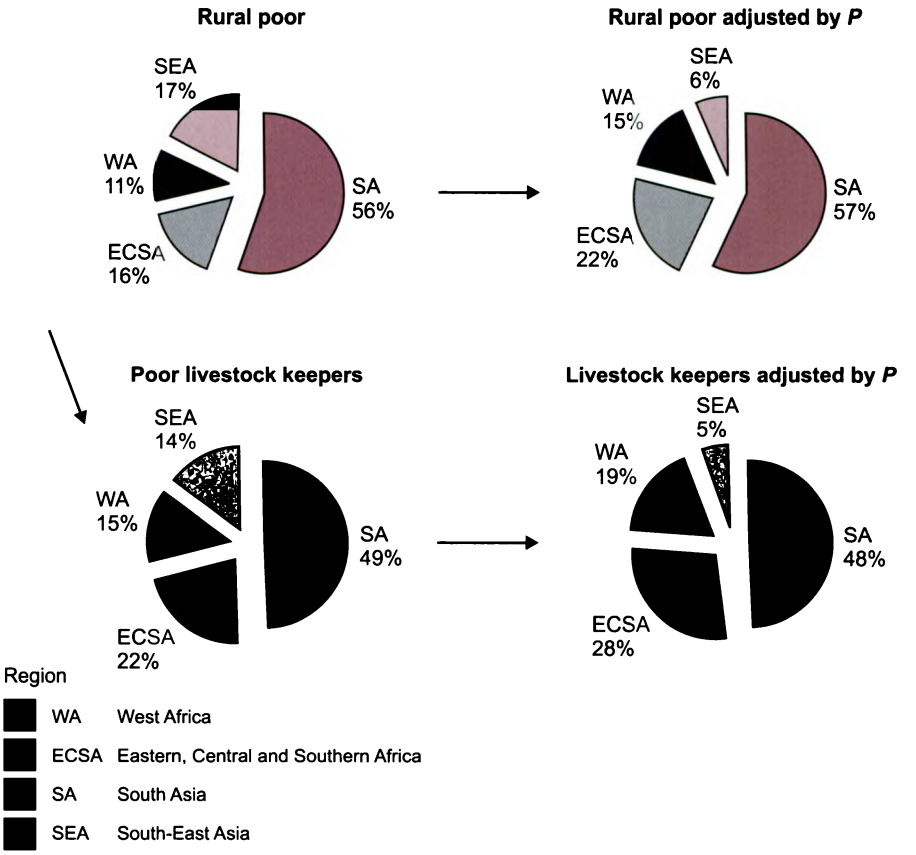
1. WA = West Africa; ECSA = Eastern, Central and Southern Africa; SA = South Asia; SEA = South-East Asia

shown, however, in the changes it generates in the regional poverty shares (Figure 3.1). The distribution of the *P*-adjusted number of rural poor by livestock production system is displayed in Figure 3.2.

The following points emerge from these results:

- **The great majority of poor associated with livestock are found in mixed crop–livestock systems.** Across the four regions being considered, 84% of the rural poor are located in mixed agro-pastoral systems, with two-fifths in irrigated systems and three-fifths in rainfed systems. Pastoralist systems account for only 5% of the rural poor.
- **The majority of the poor live in SA.** Over half (57%) of the poor associated with livestock are located in SA, SSA follows with over a third, and SEA with the smallest share of 6%. This means that diseases important to the poor in SA will necessarily rank highly among global disease impacts, and therefore research opportunities

Figure 3.1 Regional distribution of poverty for different poverty measures



that address diseases in SA are also likely to rank high in any priority list. SA will inevitably drive the results of any quantitative analysis.

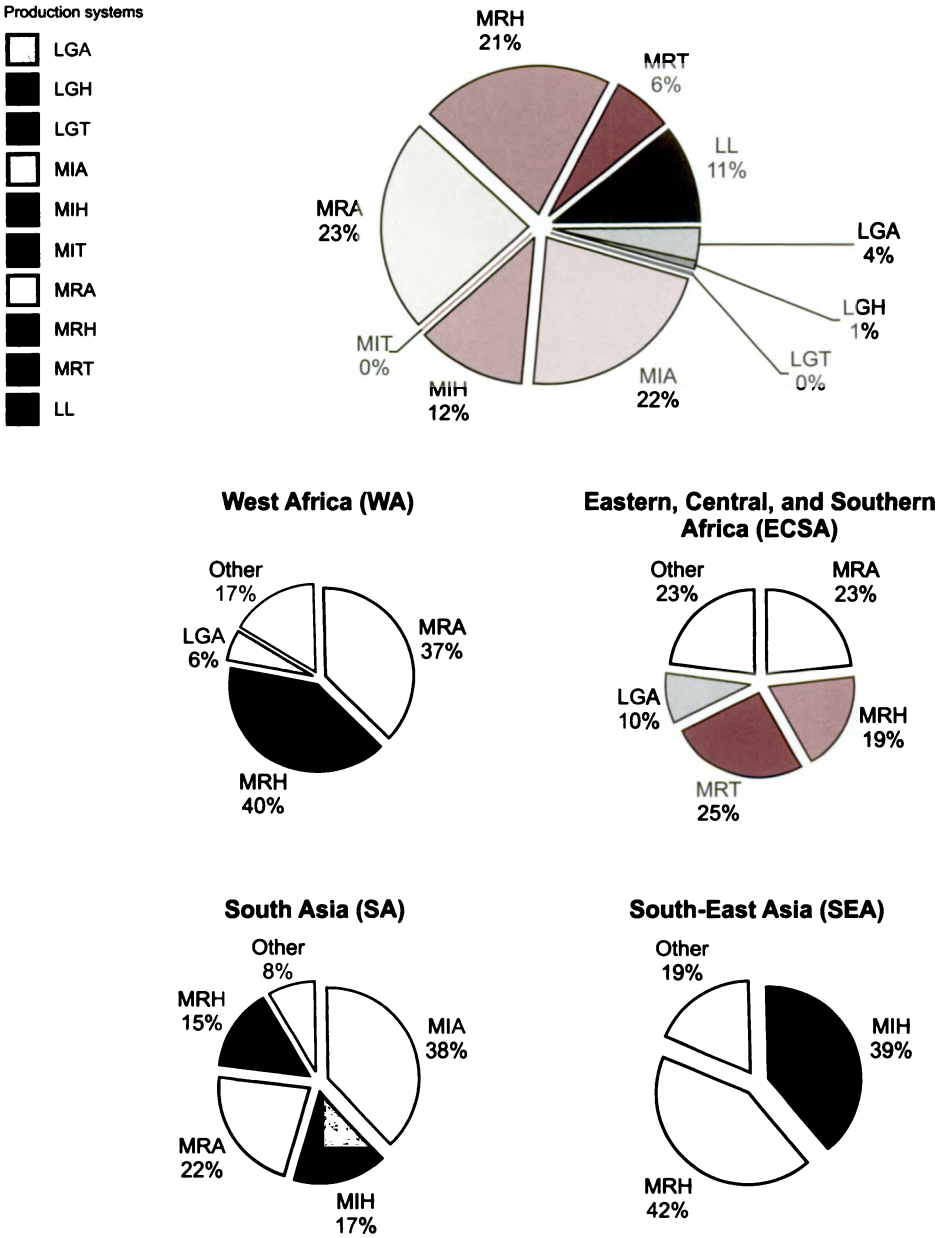
- **A larger share of poverty is found in SSA as the poverty measure is refined.** If only the simple headcount of rural poor is considered, 27% of the poor in the four regions are found in SSA. As the poverty measure is extended to include not only numbers, but also relative severity of poverty (*P*-adjusted numbers), the share of poverty in SSA rises to 37%. This captures the dimension that the average poor African is poorer than the average poor Asian. Similarly, if the poverty measure is further limited to only poor livestock keepers, the SSA share increases again to 37%, and after adjustment for relative severity of poverty (*P*-adjusted), to 47%.

3.2 Future trends

How may the patterns of poverty distribution be expected to change over time? Three trends can be identified.

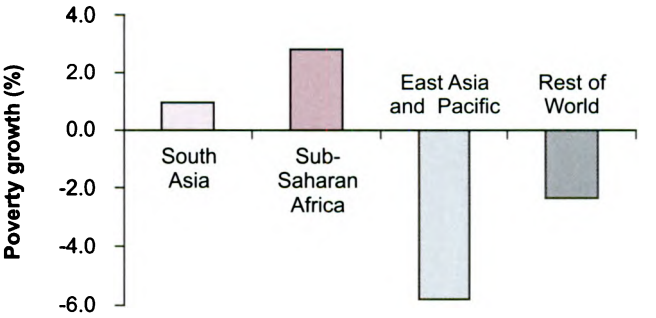
- **Poverty is growing most rapidly in SSA.** From 1987–98, poverty grew at the average rate of 3% per annum in SSA, versus 1% in SA, and negative rates in East Asia (EA) and the Pacific (not including China) and the rest of the world (Figure 3.3). Dismal projections regarding general economic growth in SSA mean that this region will continue to exhibit the fastest-growing poverty.

Figure 3.2 Distribution of poverty by livestock production system and by region (based on *P*-adjusted numbers of rural poor)



This suggests that investors with a longer horizon for impact should give additional weight when assessing priorities to those diseases identified as constraints in SSA.

- **Agro-pastoral production systems will expand at the expense of pastoralist systems due to population growth.** The companion study by Thornton et al. (2002) describes the impact of continued population growth in SSA. As population densities rise in current pastoral areas, available land for grazing livestock will become limited and farming systems are assumed to convert increasingly to agro-pastoralism. This trend will undoubtedly reduce yet further the proportion of poor people living in pastoralist systems. Landless livestock (LL) systems are similarly expected to expand.



1. Average per annum computed from data reported in World Bank, 2000, Table 1.1

- **Pastoralism will be replacing agro-pastoralism in some areas of SSA due to climate change.** Thornton et al. (2002) have also examined the potential impact of climate change to the year 2050. Their analysis indicates that higher temperatures will reduce the length of the growing period for crops across wide areas of Africa. As a result, the geographical range for crops will be reduced. In those areas where the growing period will no longer support crop cultivation, pastoralism may become the only sustainable source of food production. This is expected to occur by 2050 in relatively small areas on the semi-arid margins of current potential cropping zones, and so is likely to have less impact than the counteracting effects of population growth described in the preceding point.

These trends have important implications for identifying research opportunities for a much longer-term investment horizon beyond 2015. More and more of the poor will be living in agro-pastoral systems and in SSA. Research efforts focused on disease constraints to the poor in these systems will reap the highest long-term benefits for alleviating poverty.

4 The association of livestock species with the poor

4.1 How the poor use livestock

Each of the common livestock species is kept by the poor somewhere in the regions under study (with the exception of Andean species such as llama and alpaca). The principal species are listed in Table 4.1. Numbers of each species associated with the poor are unknown; no national or international services collect or report data on livestock numbers that are distinguished by income class.

Table 4.1 Animal species kept by the poor, and their contribution to household assets

	Contribution to household assets				
Species	**Financial**	**Social**	**Physical**	**Natural**	**Human**
Cattle, Buffalo, Yaks	Sales of milk, meat, hides, animals, draught power services, transport	Networking mechanism	Draught power for crop cultivation	Manure for maintaining soil fertility	Household consumption of milk, meat
	Savings instrument	Social status indicator	Draught power for transport		
Camels	Sales of milk, meat, hides, animal, transport services	Networking mechanism	Draught power for transport		Household consumption of milk, meat
	Savings instrument	Social status indicator			
Donkeys, Horses	Sales of animals, draught services, transport (esp. water)		Draught power for crop cultivation	Manure for maintaining soil fertility	Provision of household water supplies
			Draught power for transport (esp. water)		
Goats, Sheep	Sales of milk, meat, hides, animals	Networking mechanism		Manure for maintaining soil fertility	Household consumption of milk, meat
	Savings instrument	Social status indicator			
Pigs	Sales of meat, animals			Manure for maintaining soil fertility	Household consumption of meat
	Savings instrument				
Poultry	Sales of eggs, meat, fowl	Networking mechanism		Manure for maintaining soil fertility	Household consumption of eggs, meat

Two key points characterise the role of livestock for the poor:

- **The poor usually keep more than one species.** Poor households rarely specialise in a particular species, preferring to diversify into more than one to take advantage of the different types of roles each species can play, as well as to spread risk, including the risk of disease. Obviously, the ability of the poor to acquire livestock is constrained by the market value by species, which increases as one moves up the 'livestock ladder', as roughly approximated by the order of the species from bottom to top in Table 4.1.
- **Each species serves multiple roles for the household.** As described in Table 4.1, each species contributes in various ways to the different types of household assets. From the development perspective, we typically focus on livestock keeping in

terms of generating income for the household. In fact, poor households often have multiple objectives in keeping livestock, and some of the most common have been highlighted in the table.

4.2 What should be the species focus of animal health research?

Much of the previous investment by donors has been in the control of diseases of ruminant livestock, particularly cattle. Is this the most appropriate species for impact on the livelihoods of the very poor? Clearly in some regions, particularly the pastoralist regions of Africa and SA, cattle play a pivotal role to these communities. Recently there has been considerable discussion of the merits of investment in cattle diseases, and the possible advantages and disadvantages of diversifying into other species that are more closely associated with the poor, such as poultry and small ruminants. The arguments include:

- In the more receptive market environments of parts of Asia, pigs and poultry are much more important in terms of protein of animal origin for human consumption by the rural poor, and as a cash crop for local marketing and trade
- In many regions of the developing world, there is a hierarchy of livestock keeping, and livestock marketing, that mirrors the hierarchy of wealth. The poorest only keep poultry, the less poor also keep small ruminants and possibly pigs, and only the more affluent, in relative terms, keep cattle. This was described in one of the workshops as the 'livestock ladder', which can also operate within a species, with investment in improved breeds
- Furthermore, in poor communities in which a range of species is kept (as for example, poultry, goats, pigs, cattle and buffalo in certain areas of SEA), it is the poultry and small ruminants that provide the major contribution to cash flow on a weekly basis, with sale of cattle and buffalo only under special circumstances.
- The poultry industries (and in some cases the pig industries) of the developing world are changing and intensifying fast, and present a much better opportunity than ruminants for rapidly enhancing food production to feed the burgeoning human populations.
- Poultry are probably the most widely kept species by smallholder farmers of the globe, and thus could play a much broader role in poverty alleviation than cattle, for example.
- Improvement of ruminant survival and production efficiency places large demands on natural resources that have negative environmental implications.

The latter is a particularly convincing argument. However, the arguments for maintaining a focus on ruminants have won the day in the past, and these include:

- Ruminants serve multiple functions in the developing world, beyond just the supply of animal protein, so make a significant contribution to crop production for the poor in the developing world through traction, manure, nutrient cycling, social status and security etc.
- Ruminants can survive and thrive under many circumstances on diets that do not compete with food production for humans, such as pastures and cultivated forages.
- Ruminants in the tropics and sub-tropics suffer from particular diseases for which control technologies are not developed, and for which little research is carried out in the developed world.

- Technology development in the field of animal health is much more advanced for poultry due to the abundance of intensive systems in the developed world. Thus the research needs for poultry production may be small compared to the needs for greater commercialisation, delivery and adoption of available technologies and knowledge.

In general, in the three regions studied, livestock as a group play a very important role in the livelihoods of the poor. Also in general, the poor tend to diversify into several species of livestock, so spreading their risk, and optimising their options both in terms of human nutritional requirements, and in terms of market opportunities in village or community life. There are all sorts of regional variations on this theme. Firstly there are the obvious ones, such as no pig production in the predominantly Muslim countries of Bangladesh and Pakistan, and the Muslim communities of Malaysia and Indonesia, for example. Then there are production system-associated differences, with ruminant species predominating in the grasslands, and dairy cattle, pigs and poultry dominant in the peri-urban systems. The widespread mixed systems, in which livestock and crops work together to support family, village and community livelihoods, are those in which the widest range of species are found, with different priorities given in different regions depending often on agro-ecology, culture and the staple diet of the human population.

The role of cattle to the poor varies considerably. In the pastoralist communities, cattle are central to their societies, and the highest-valued animal species. Productivity, in traditional western terms, is usually not the predominant role of cattle, but herd size—and therefore survival—is, and hence these are almost exclusively indigenous breeds that can cope with the environment, the quality and quantity of available feed, the management and the prevailing diseases. In the mixed farming systems, cattle are also important but they take on multiple roles that include ploughing, transporting crops, providing manure as fertiliser to croplands, and in some cases providing fuel for cooking. For these functions, again it is the indigenous breeds that do best. However, it is in some of these mixed systems that the growing demand for milk, and to a lesser extent for meat, that the use of improved breeds appears attractive, but these are often highly susceptible to the effects of diseases, poorly palatable food and environmental stresses.

Buffalo are extremely important to the mixed farming systems of SEA and SA, and are strongly linked to the poor. They are central to these societies in the preparation of arable land for cultivation, for harvesting and marketing the crops and for nutrient cycling. In some countries of the region, such as Thailand, the economic growth of the last decade has seen a decline in overall buffalo numbers, as a result of a trend toward increased mechanisation, and increased migration from rural to urban areas. However, to the large numbers of rural poor, buffalo remain a crucial component of their survival.

Goats and sheep are also very important to the poor in all corners of the world. They take on the role of a cash crop, providing an easily liquidated resource that can be used for raising cash. These species are the ruminants most used for home and village consumption, and so frequently have active local markets. Goats have a reputation for environmental damage, as they forage on shrubs and small bushes, but the very positive role they play in recycling and fertilising ingested seeds is grossly undervalued (Reid and Ellis, 1995).

Table 4.2 Expert rankings of species in terms of their importance to the poor, by region and production system

Production system	Region[1] WA	ECSA	SA	SEA
Pastoral				
LGA Livestock only, rangeland-based arid/semi-arid	1. Sheep and goats 2. Horses, donkeys and mules 3. Camels 4. Cattle 5. Poultry	1. Sheep and goats 2. Cattle 3. Camels 4. Horses, donkeys and mules 5. Poultry	NA[2]	NA
LGH Livestock only, rangeland-based humid/subhumid	1. Sheep and goats 2. Horses, donkeys and mules 3. Camels 4. Cattle 5. Poultry	1. Cattle 2. Sheep and goats 3. Poultry 4. Horses, donkeys and mules	1. Yak 2. Sheep and goats 3. Cattle 4. Pigs 5. Poultry	NA
LGT Livestock only, rangeland-based temperate/tropical highland	1. Sheep and goats 2. Horses, donkeys and mules 3. Camels 4. Cattle 5. Poultry	1. Cattle 2. Sheep and goats 3. Poultry 4. Horses, donkeys and mules 5. Pigs	NA	NA
Agro-pastoral				
MRA Mixed rainfed arid/semi-arid	1. Sheep and goats 2. Poultry 3. Cattle 4. Horses, donkeys and mules 5. Pigs	1. Cattle 2. Sheep and goats 3. Poultry 4. Horses, donkeys and mules 5. Pigs	1. Cattle 2. Sheep and goats 3. Camels 4. Buffalo	NA
MRH Mixed rainfed humid/subhumid	1. Sheep and goats 2. Poultry 3. Cattle 4. Horses, donkeys and mules 5. Pigs	1. Cattle 2. Sheep and goats 3. Poultry 4. Pigs 5. Horses, donkeys and mules	1. Cattle 2. Buffalo 3. Sheep and goats 4. Poultry	1. Poultry 2. Pigs 3. Cattle 4. Buffalo 5. Sheep and goats
MRT Mixed rainfed temperate/tropical highland	1. Sheep and goats 2. Poultry 3. Cattle 4. Horses, donkeys and mules 5. Pigs	1. Cattle 2. Sheep and goats 3. Poultry 4. Horses, donkeys and mules 5. Pigs	NA	NA
MIA Mixed irrigated arid/semi-arid	NA	1. Sheep and goats 2. Cattle 3. Poultry	1. Buffalo 2. Cattle	NA
MIH Mixed irrigated humid/subhumid	NA	NA	1. Cattle 2. Sheep and goats 3. Poultry 4. Buffalo 5. Pigs	1. Pigs 1. Poultry 3. Buffalo 3. Cattle 5. Sheep and goats
Peri-urban				
LL Landless	1. Poultry 2. Sheep and goats 3. Pigs 4. Cattle 5. Horses, donkeys and mules	1. Poultry 2. Sheep and goats 3. Pigs 4. Cattle	1. Poultry 2. Pigs 3. Sheep and goats 4. Cattle 5. Buffalo	1. Poultry 1. Pigs 1. Sheep and goats 4. Cattle 5. Buffalo

1. WA = West Africa; ECSA = Eastern, Central and Southern Africa; SA = South Asia; SEA = South-East Asia
2. NA = Not applicable

Poultry, particularly chickens, are the most widely kept species by the poor in the world, and also the most numerous. They act as a cash crop, easily disposable in village markets. In SEA, ducks also play an important role.

There are many other species kept by the poor, including rabbits, guinea pigs, bees and silkworms that all play important roles in the diverse enterprises of the rural poor in different parts of the world. However, there is a general lack of available information on their management and use, and particularly on the disease constraints affecting them, and for these reasons, they are not included in this study.

4.3 Results of species prioritisation at the regional workshops

At each of the four regional workshops, participants prioritised the importance of different species of livestock to the livelihoods of the poor in each production system found in their region. This allowed the ranking illustrated in Table 4.2 to be developed.

There are some clear patterns that emerge. In pastoral systems, several livestock species play an important role, but within these, sheep and goats generally are the most important, often playing a more important role than cattle.

In the agro-pastoral (mixed) systems, cattle predominate, except in WA where sheep and goats are again the priority species to the poor. In the peri-urban landless systems, poultry, sheep and goats, and pigs play the most important roles.

Within these production system groupings, each region has a slightly different pattern to the priority species of the poor. In SEA, pigs and poultry were considered the most important species in both mixed rainfed and irrigated systems. Moving further west to SA, buffalo rank second after cattle, and yaks are important in the grassland humid systems. In eastern and southern Africa, cattle ranked first in the mixed agro-pastoral systems, replaced in WA by sheep and goats, followed by poultry.

5 Animal diseases and their impact on the poor

5.1 General considerations

Animal diseases continue to constrain livestock productivity, agricultural development, human well-being and poverty alleviation in many regions of the developing world in a variety of different ways. There are some diseases that affect all regions of the world and all sectors of the community, and there are some that are of particular importance, individually and collectively, to the very poor. These are diseases that affect the particular species of animals that have special importance to poor societies as security, as financial capital and social capital, as machines for cultivation, as fertiliser, and of course as nourishment. They include diseases that affect the human populations of these poor societies themselves, causing death, disability and suffering, and so creating a barrier to escape from poverty.

In the preceding chapter, the species important to the poor in a given livestock farming system were identified by putting aside traditional conceptions of which species predominate in the farming system and instead viewing the role of species through a special poverty lens. A similar approach is adopted in this chapter in which the wide variety of ways in which animal diseases affect the poor are reviewed. The chapter concludes by offering a novel typology of the three major pathways by which animal disease can thwart efforts to alleviate poverty, thus condemning the poor to remain poor.

5.2 Types of diseases

To facilitate the discussion on impacts, it is useful to distinguish four general groups of diseases: the endemic, the epidemic (or transboundary), the zoonotic and the food-borne (Perry et al., 2001).

- **Endemic diseases** include the vector-borne haemoparasitic diseases, the multitude of helminth diseases, the enteric bacterial diseases of the neonate, and the bacterial and viral causes of reproductive failure, among many others. They can be further divided for the purpose of priority setting for the world's poor into those that are 'tropical' and those that are 'tropical and temperate'. Many of the endemic diseases that still occur today in the temperate regions of the world represent one of the last hurdles to improving production efficiency there, and as a result many effective control technologies are available or under development through support from the public and private sectors of the developed world. Most of these technologies are not widely applied in much of the developing world, and certainly not in poor communities.

  Much less attention has been invested in the 'tropical' group of endemic diseases, as to the developed world with the money, they are 'somebody else's problem'. These include the vector-borne haemoprotozoan infections, for which effective control technologies appropriate for the majority of poor livestock keepers in the developing world are still lacking.

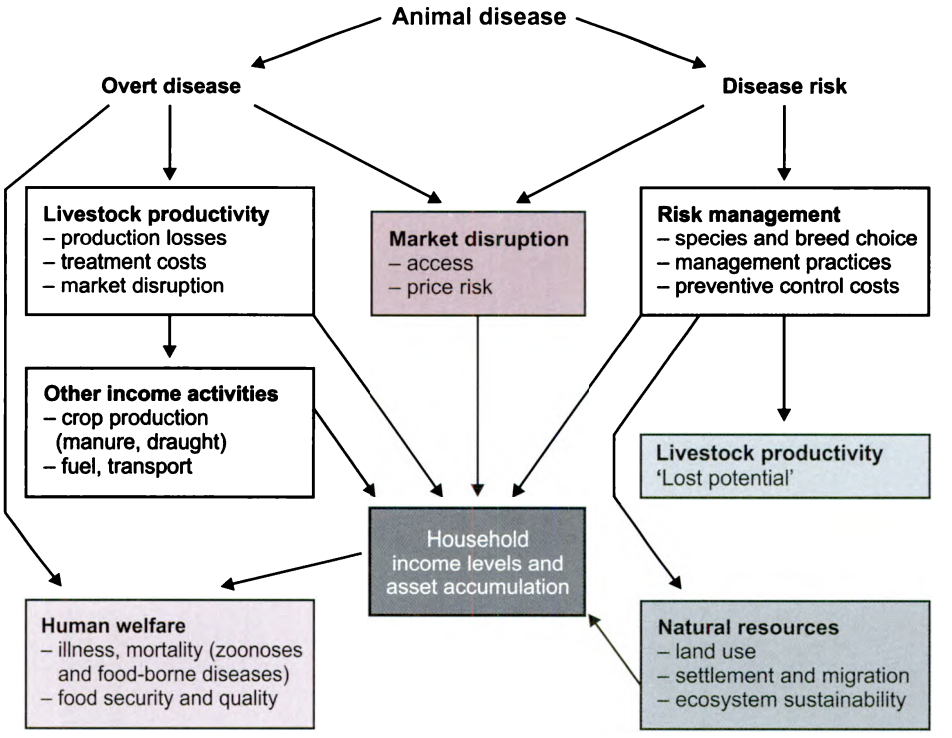
  Endemic diseases tend to be those that exert their greatest effect at the farm, village and community level, even though the aggregation of all the farm-level effects can of course be translated into national-level losses.

- **Epidemic diseases (sometimes termed transboundary diseases)** are those that characteristically occur at a frequency above the expected, are highly infectious and exert their influence at both farm and national level on local marketing and international trade. This group includes the virus infections of foot-and-mouth disease (FMD), rinderpest (RP), hog cholera (classical swine fever, CSF), Newcastle disease (ND) and the influenzas, among others. Some epidemic diseases can result in devastating shocks to the poor, by wiping out their entire livestock. Because of their potentially explosive nature, their tendency to cross international borders, and the need to protect valuable commercial livestock production systems and/or markets, public sector involvement in their control is common. This is particularly the case where lucrative export markets exist, and a country is trying to protect an existing or potential market by maintaining a certain level of disease control, or disease freedom. It is important to note that these diseases are endemic in some countries and production systems, particularly in the developing world. Thus they can also have considerable impact at the farmer level, in cases where they are widely distributed and occur frequently. For example, FMD can be considered epidemic when it appears in Europe, but is endemic in much of SEA, SA and SSA.
- **Zoonotic diseases** may cause significant productivity losses in livestock (or in other domestic or wild animal species), but their major impact is usually in causing human disease and suffering. Some can be characterised as endemic, such as many of the meat-borne helminth zoonoses, brucellosis and tuberculosis, and some are epidemic in nature, such as rabies and Rift Valley fever (RVF). Traditionally, donors of livestock research and development have not considered this group a high priority, partly due to the lack of good data on their impact in many regions. However, due to their particular importance to poor livestock keepers, their families and communities, there is a strong argument that better zoonotic disease control should be considered on a research agenda.
- **Food-borne diseases** such as cysticercosis and trichinellosis, can be particular problems to the poor due to poor hygiene and sanitation, and inadequate resources for cooking animal products. In addition, infections caused by *Escherichia coli* 0157 and *Salmonella* spp., are particular problems in more industrialised systems of the world, and thus their incidence is likely to increase in developing countries as livestock production and processing systems become more intensive. Food-borne diseases affect consumers, food processing workers and livestock producers.

5.3 Disease impacts

Animal diseases generate a wide range of biophysical and socio-economic impacts that may be both direct and indirect, and may vary from very localised to global problems. A particularly useful distinction can be made between those impacts associated with overt disease and those associated with disease risk (Figure 5.1; Swallow, 1997).

Figure 5.1 Disease impacts[1]



1. Adapted from Swallow (1997)

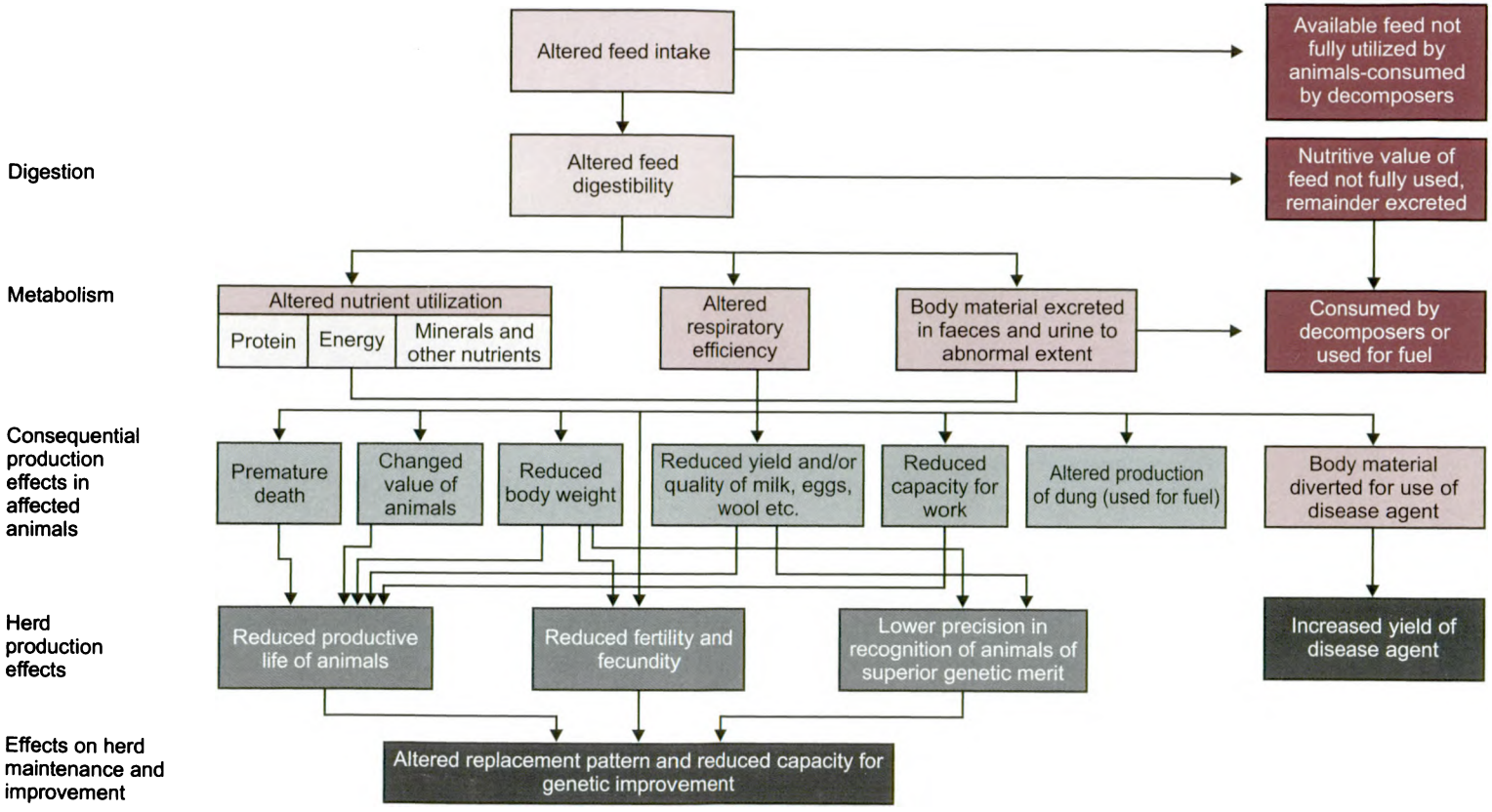
5.3.1 Impact of overt disease

When animal disease occurs, there are several different types of commonly recognised impacts:

- **Loss of livestock productivity.** The most important and readily measurable direct effects of diseases are manifest by losses in productivity. These include the effects of death, illness leading to condemnation, poor weight gain, poor milk yield, poor feed conversion, poor reproductive capacity and poor work capacity for ploughing or transport. The mechanisms and pathways of the effects of diseases on productivity are illustrated in Figure 5.2. Achieving effective control of them is difficult and long-term in the smallholder sector, with its limited resources and poor infrastructures, and extremely difficult for the poorest of the poor. Some of the causes of poor productivity in the livestock of the poor have yet to be fully elucidated. In addition, many of the constraints may not be researchable issues, but rather involve education, information and extension, for example:

  – **Treatment costs.** Assuming that an appropriate veterinary technology is available, livestock keepers, communities, and public services may incur direct financial and time costs in responding to animal disease by seeking or providing treatment. The increase in production costs these represent are expected to be compensated by reducing subsequent production losses, but this may not be the case if animal health care services are of poor quality and the treatment is not applied correctly.

Figure 5.2 The ways in which diseases may affect the productive value of animals



Source: Redrawn from Morris and Marsh (1994)

- **Loss of farm productivity.** Through their effects on performance, diseases of livestock have additional indirect impacts on other agricultural enterprises, in particular crops. This is through the reduction in traction capacity for ploughing, the effect of reductions in manure output on soil fertility and nutrient cycling, and the reduction in traction for harvesting and marketing of crops, and for general transport, including essential water supplies, all of which can severely affect livelihoods of smallholder farmers[1]. This impact is often highly under-estimated, and has generally been poorly quantified. Interestingly, some of the endemic diseases, such as the TBDs, considered by many to be so important in their impact on productivity, may not be the priorities in traction animals, as these are generally indigenous cattle or buffalo, and so less susceptible to the effects of tick-borne infections for various reasons. In mixed farming systems in which cattle and buffalo are used for ploughing and other traction or transport functions, diseases that cause lameness, such as FMD, can have a major impact, whereas in pastoralist systems in which traction does not play such an important role, FMD may be considered much less important.
- **Reduction or elimination of market opportunities.** Outbreaks of infectious diseases in a community or a region may result in local market disruptions as movement restrictions are imposed, with farmers unable to market livestock and livestock products with optimal timing (such as moving fattener pigs to market) or at all (e.g. restricting milk collection), or they may face dramatically depressed prices. The mere occurrence of certain diseases can also severely constrain cross-border and other international trade, and is most commonly associated with the highly infectious diseases such as FMD, RP, hog cholera, ND and the epidemic zoonoses such as RVF. Restrictions on international trade typically affect primarily the larger-scale commercial sector, with potential multiplier effects on employment and other auxiliary sectors.
- **Disturbance of human health.** Illness in people associated with zoonotic and food-borne diseases leads to losses in their productivity and quality of life, as well as costs incurred for treatment. Productivity losses in people are more difficult to quantify than for livestock, where there are more readily measurable indicators such as production of meat and milk. Currently the unit of the disability-adjusted life year (DALY) has been adopted as the standard measure of impact on humans used by WHO (1996). In the evaluation of human health research priorities conducted by WHO, many of the zoonotic diseases were ranked individually as relatively low on the scale of DALYs. This group of diseases is addressed in more detail in Chapter 6 and in Appendix 9 (Coleman, 2002).
- **Impairment of human welfare.** Diseases of livestock have many additional direct and indirect impacts on human nutrition, community development and socio-cultural values (e.g. Curry et al., 1996). Animal disease can significantly reduce farm income, contributing to food insecurity and poor nutrition.

5.3.2 Impact of disease risk

Even if no disease occurs on a given farm or in a particular community, the threat of the disease occurring may already induce significant impacts. The most obvious are

1. When an outbreak of FMD crossed through central Laos in 1999, in a region inhabited entirely by poor livestock keepers, disease in buffalo and cattle, and their resulting lameness, complicated by secondary infections, had a direct impact on the capacity to plant rice (Perry et al., 2000).

economic losses from higher production costs or the public expenditures incurred in attempting to prevent disease. These are typically related to prophylactic control strategies (vaccination, chemo-prophylaxis) and monitoring and surveillance programs.

Less obvious, though, are the changes in behaviour or management in the face of disease risk that lead to sub-optimal production systems. At the extreme, disease risk may limit the use of susceptible species or high-productivity breeds. The low density of cattle in general, but especially of improved cattle, across the SSA tsetse belt, attributed primarily to the ever-present risk of trypanosomosis, illustrates this impact.[2] This represents economic losses from what is often referred to as 'lost potential' since farmers are discouraged from keeping cattle or trying dairy production, that otherwise might offer substantial financial rewards.

5.3.3 Impact of disease control

Disease control efforts are undertaken to minimise the various impacts of diseases described above. In doing so, however, disease control may spawn yet other unintended impacts. The example often cited is that of potential environmental impact resulting from effective control of trypanosomosis. It has been estimated that herds in areas under trypanosomosis risk are only 50–70% the size of herds of similar areas with no risk (Swallow, 2000), and so cattle numbers would be expected to increase substantially with better disease control. If not properly managed, such growth in cattle populations may contribute to degradation of the natural resource base. Realising the 'lost potential' noted in the preceding section may therefore be associated with negative impacts that partially offset the benefits of improved control. It should be stressed, however, that trypanosomosis is probably the only disease that so clearly limits the geographical extent of livestock production, and would be the one disease most likely to generate identifiable impacts.

Poor implementation of disease control may also contribute to localised negative impacts. Improper use of chemicals and drugs, in particular, can expose animals, humans and the immediate environment to possible toxic effects, either directly or through residues in livestock products. It can also lead to the emergence of resistance by parasites to control drugs, as has occurred for example, with trypanocides, anthel-mintics and acaricides.

5.4 The critical role of risk for the poor

The various types of impacts of animal disease outlined above are all likely to be proportionally greater for the poor. Focusing on *risk* is the key to understanding why this is true. The poor are exposed to more animal disease risk and have less capacity to cope with that risk than the better-off, and this combination reduces yet further their chances of escaping poverty.

5.4.1 Types and sources of risk

The recent World Development Report on poverty devotes a chapter to the role of risk in poverty and its alleviation (World Bank, 2001). A framework is presented of the types and sources of risk. This is shown in Table 5.1, modified to illustrate how animal disease is related to multiple sources of risk at several different levels from micro to

2. In parts of its distribution in which infection challenge is particularly high, the disease actually prohibits the keeping of most livestock species, including the indigenous breeds well-known for their hardiness.

Table 5.1 Sources of risks, including those related to animal disease

	Idiosyncratic	Covariant	
Type of risk	**Affecting an individual or household (micro)**	**Affecting groups of households or communities (meso)**	**Affecting regions of nations (macro)**
Natural		Rainfall (*RVF*) Volcanic eruption	Drought *(CBPP)* Flood
Health	Illness (⇐*Brucellosis,*[1] *cysticercosis*) Injury Death (⇐*Anthrax*)	Epidemic (⇐*Trypanosomosis*)	
Social	Crime (*cattle rustling*)[1] Domestic violence	Gang activity	War (*RP*)
Economic	*Livestock disease* Unemployment (⇐*FMD*) Harvest failure (⇐*Trypanosomosis*)	*Changes in food prices* (⇐*RVF*)	Terms of trade shock (⇐*FMD*)
Political		Riots	Coup d'état
Environmental		Pollution (⇐*Tsetse control*) Deforestation	

1. (⇐*disease*) Animal disease contributes to source of risk
(*disease*) Source of risk contributes to livestock disease leading to additional economic risk
2. Source: Adapted from World Bank (2001), Table 8.1

macro (termed idiosyncratic to covariant). The sources of risk cited here relate mostly to short-term shocks and epidemic and zoonotic diseases; they fail to reflect adequately the additional role of chronic long-term risk due to endemic diseases or the effects of certain trends, such as increasing movement of livestock, rising livestock densities in peri-urban areas, and the decline in public veterinary services.

5.4.2 Their much higher exposure to risk

The poor in the developing world face particularly high risk from animal disease. Firstly, there is more disease present.

- Much of the developing world lies within the tropical and subtropical regions of the world, where climates and ecosystems favour a wide range of parasitic infections and infestations, many of which do not occur in the temperate regions of the world.
- Unrestricted movement of animals for marketing, social and other reasons is widespread in and between many regions, and while it promotes market orientation for many poor livestock-centred communities (such as those in the Horn of Africa), it can also enhance the spread of certain diseases.
- Livestock production systems of the poor further enhance the risk of disease through such confounding factors as poor housing, multiple species and poor nutrition.

Secondly, there is less disease control.

- In many cases, appropriate control technologies do not exist, in part because many domestic funding bodies in developed countries do not even consider funding research into the control of animal diseases that occur outside their boundaries. Should international donors therefore focus on tropical animal diseases, and more specifically on parasitic diseases that do not exist in the developed world?
- Even if the appropriate technology exists, animal health services in developing countries, through financial, infrastructural, logistic and educational restrictions, often do not permit the optimal delivery and adoption of known disease control measures. Are there tangible research issues here that donors should be addressing?

- Poor delivery is exacerbated by the fact that markets for animal health inputs in the developing world, such as vaccines and pharmaceuticals, are relatively small, given the low incomes of the majority of the populations, so financial incentives for technology development and application by international pharmaceutical industries are severely limited. This is of particular significance for the very poor, who live on less than US$ 1 day^{-1}, and whose purchasing power will be considered insignificant by the pharmaceutical industries. This raises two issues; how to make available products for the control of priority diseases more affordable to the poor, and how to persuade pharmaceutical companies to invest in the development of new products whose major clients are the poor.
- Production systems are evolving rapidly with increasing human population growth and changes in the demands for livestock products, and many traditional disease-control strategies and policies are outdated and inappropriate. Examples include the need to consider how vaccines against endemic livestock diseases can best be delivered to the evolving peri-urban smallholder dairy sectors in many developing countries, and how rabies vaccines can be effectively delivered to an adequately high proportion of stray dogs in high-risk urban and peri-urban communities.

5.4.3 Their much lower capacity to bear risk

While exposed to a wide array of risks related to animal disease, the poor have yet less capacity to cope. Existing close to the survival threshold, the poor tend to be more risk-averse, and so less likely to 'take a chance' on preventive disease technologies. More importantly, low income and few assets mean that the poor have few options available for managing crises, are less resilient to shocks and are slower to recover. Livestock disease is particularly damaging since it threatens one of the few assets that the poor keep on hand for dealing with other shocks.

5.5 A framework for understanding disease impacts on the poor

As the preceding discussion suggests, the impacts of animal disease on the poor are complex, involving direct and indirect effects, multiple pathways, and at a variety of levels, depending on the particular disease or syndrome. The livelihoods approach (DFID, 2000), as outlined in Figure 5.3, offers a ready framework for handling these various dimensions and structuring the discussion[3]. The different components of the framework in an animal disease context are described in the following sections.

5.5.1 The vulnerability context

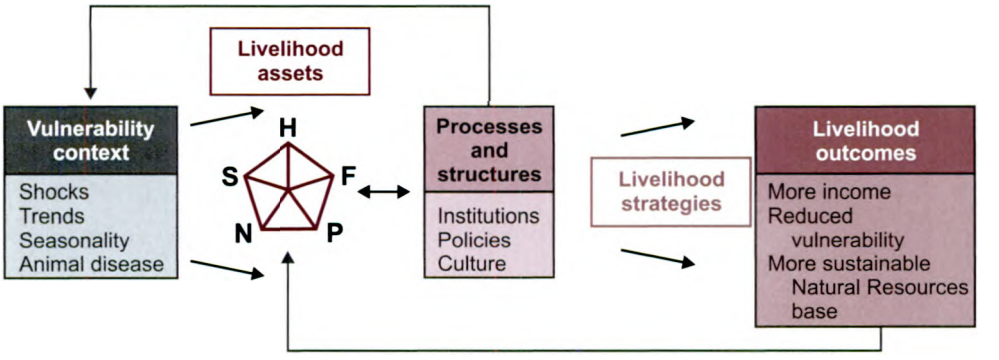
The vulnerability context (left-hand box in Figure 5.3) represents the environment in which the poor live, particularly as it translates into the various types of risk they face. As already discussed in section 5.4, the poor face risks from livestock disease directly, but also through the intermediary of a number of other different sources.

5.5.2 Livelihood assets

Within the livelihoods framework, the impact of animal disease can be described by the various ways it affects the poor household's asset base represented by the pentagon. Animal disease can threaten each of the five types of household assets.

3. Heffernan (2002, Appendix 5) presents an alternative livestock-based version of the livelihoods framework.

Figure 5.3 Sustainable livelihoods framework



1. (H = Human capital; F = Financial capital; N = Natural capital; S = Social capital; P = Physical capital)
Souce: DFID, 2000

- **Financial capital.** Livestock mortality and morbidity can directly reduce both income flows from livestock activities by cutting output, and more importantly, the financial investment value of the livestock assets themselves. It is also likely to raise production costs if control costs are incurred or production efficiency is lowered. Income from crop production or transport activities dependent on animal traction may also be affected. Remembering that we are considering those living on less than US$ 1 day^{-1}, even a small reduction in income flow is likely to have immediate impact on consumption for basic needs. The loss or depreciation of their livestock compromises one of their principal consumption-smoothing instruments and coping mechanisms for crises requiring liquidity.
- **Human capital.** Zoonoses and food-borne diseases can temporarily or permanently impair an individual's ability to work, and thus deprive the poor household of its principal income-generating asset. Other animal diseases may also indirectly affect the health of household members by reducing the supply and consumption of livestock products produced by the household (milk, eggs, meat), or through its affect on available income for food purchases and medical care. Chronic animal diseases have potential longer-term nutritional impacts, which for young children may jeopardise the quality of their future human capital. The relationship between pork-borne cysticercosis and epilepsy is a particular case in point.
- **Social capital.** In many societies, livestock serve as a mechanism for establishing relationships of trust within social networks. This may be particularly crucial for the poor to ensure an informal safety net in times of crisis, through the development of trusting relationships with others in the community. Disease lowers the number and quality of animals available for this purpose.
- **Natural capital.** In mixed crop-livestock systems, manure often plays a critical role in maintaining soil fertility, especially for the poor who are less likely to be able to invest in chemical fertilisers. Disease may reduce the availability of manure.
- **Physical capital.** Livestock can be considered production assets as farm 'tools', and disease lowers their productive quality or even wipes them out. Important to the poor, in particular, is the use of larger stock for ploughing or transport. Disease at critical periods during the crop year can reduce the area the household can successfully cultivate. Often forgotten, poor households often depend on animal

transport for their water supplies, and animal disease may therefore have indirect sanitary implications in terms of the quantity and quality of water supplies used by the household.

5.5.3 Transforming structures and processes

Poor households devise their livelihoods strategies depending on their asset base and the risks they face, but conditioned by the structures (public, civil, private sector) and processes (policies, legislation, institutions, culture) under which they operate. For animal diseases, these structures and processes refer primarily to the delivery of animal health services.

The general failure of animal health services to reach poor livestock keepers is commonly recognised as perpetuating the particular vulnerability of the poor in the developing world to animal disease and its impacts. The poor have limited access to preventive and curative treatment, animal breeding services, information and advice, and veterinary drugs. Inadequacy of animal health services has been attributed to the failure of centralised, publicly funded state services. Over the past two decades, declining public funding has led to some increase in the provision of health services by the private sector, but in most cases with little benefit to the poor. Currently, in many developing countries provision of animal health services to poor livestock owners is often non-existent. For example, animal health services in Ethiopia reach only an estimated 10% of livestock owners and in Zimbabwe, 80% of backyard poultry producers receive no veterinary or extension services.

McLeod and Wilsmore (2002, Appendix 11) identify four key characteristics that are required for animal health delivery to be effective from the perspective of the poor; these are: accessibility, affordability, acceptability and sustainability. Developing appropriate delivery systems to the poor that meet these criteria will require changes in nearly all of the relevant structures and processes. Much of the focus has been on privatisation and decentralisation of services, but the appropriate role for the public sector will also need better definition. Particular emphasis must be given to designing an enabling regulatory and legislative environment, especially to support innovative community-based approaches to service provision in marginal areas with thin markets. In many cases, though, it is not only the process, but also the product. As we will see in later chapters, participants in the regional workshops identified a number of opportunities for adapting existing animal health technologies to the particular circumstances of the poor.

5.5.4 Livelihood strategies and outcomes

Animal diseases reduce the already limited asset base of the poor livestock-keeping household, and currently existing structures and processes offer little assistance in helping the household to respond effectively and contain the often multiple impacts of disease.

The result is a livelihood strategy that must accommodate lower than expected productivity from the household's livestock, and often rules out—due to the risk-averse nature of poor households—adopting better management or more productive livestock activities. The outcome is continued low levels of income, asset accumulation and investment, and thus poverty is perpetuated.

5.5.5 The poor who do not keep livestock

The same type of analysis can be applied to poor households that do not necessarily keep livestock. First, for the poor who earn wages from working in off-farm livestock production or marketing enterprises, animal disease can put at risk one of their important sources of income (financial capital). Second, most poor—rural and urban—are consumers of animal products, and often can only afford low-quality products sold in informal, uncontrolled markets. They therefore face a higher chance of contracting zoonotic and food-borne diseases, putting at risk their key human capital (illness) and financial capital (wage losses and medical expenditures) assets. Poor consumers can also be affected by epidemic animal diseases when outbreaks disrupt markets, create product shortages and raise prices.

5.6 A novel typology of disease impacts on the poor

By looking at the impacts of animal disease through a poverty lens with the help of the livelihoods approach, a new way of grouping the impacts of diseases begins to emerge. Three general categories are proposed. The boundaries between the categories are certainly not distinct, and there is an inevitable degree of overlap. Nonetheless, the three categories provide a useful framework for organising appropriate R&D efforts.

5.6.1 Diseases that exacerbate asset insecurity

The first set of diseases includes those that threaten and degrade the asset base of the poor household under current conditions of use of livestock within the household. Whether the household keeps livestock for consumption or market, earns wages from off-farm livestock activities, or simply consumes livestock products, the focus here is on the impact of animal diseases in eroding the household's assets through the various pathways discussed above. These include many of the endemic diseases and production syndromes, as well as the common zoonoses. Through the continued high exposure to the wide array of risks associated with animal disease, and the lack of access to appropriate and effective means to manage those risks, poor households are forced to adopt risk-averse livelihood strategies that do not allow them to accumulate assets or invest in better technologies. These types of animal diseases help to keep the poor trapped in the poverty trap.

5.6.2 Diseases that limit market opportunities

The second set of diseases refers to those that restrict the poor from exploiting market opportunities for their livestock and livestock products. Poor livestock keepers generally have open access to local markets. In pastoral areas, livestock keepers have even been able to move animals across borders to markets in neighbouring countries. Their access to markets has in part been due to the lack of or lax application of animal sanitary controls, which has undoubtedly been appropriate for the needs of local markets and consumers. Where sanitary controls are applied, a parallel informal market usually exists, in which the poor can sell at lower prices their livestock goods that do not meet standards.

Market opportunities are changing rapidly for the poor. First, local demand for livestock products is expected to increase dramatically in developing countries as income levels improve in what has been termed the coming Livestock Revolution (Delgado et al., 1999). Most of these large increases in demand are expected to be

satisfied to a large extent through expansion of intensive commercial production systems. With appropriate policies, the response to increased demand could also be harnessed as a mechanism for alleviating poverty. This will require paying particular attention to enhancing the role of the poor, including smallholder livestock keepers, casual labourers and petty traders.

Secondly, globalisation is a reality that will also eventually revolutionise livestock markets in the developing world. For now, its impacts are being felt mainly in the large-scale, export-oriented commercial sector in those countries that satisfy the particular sanitary and phytosanitary (SPS) requirements of their trade partners. As globalisation gathers momentum, developing countries will be under increasing pressure to adopt a certain minimum of sanitary controls even within local markets if they are to continue participating in regional and international trade. If the poor are to avoid being further marginalised, they will need access to better monitoring and control of the diseases that restrict trade. This may require adapting monitoring and trace-back systems from the developed world, making them appropriate to the context of rural markets in the developing world, and will probably require an innovative mix of private and public action.

From this perspective, many of the zoonoses and epidemic and food-borne diseases can be seen to limit—now and increasingly so in the future—access to markets for livestock products from the poor. This works both to reduce their ability to reap full income value from their livestock activities by restricting them to informal markets and their lower prices, and to exclude them from participating in new market opportunities as they develop under globalisation.

5.6.3 Diseases that limit livestock-based intensification of farming systems

The first two categories have concentrated on the current livestock production activities undertaken by the poor, regardless of their relative importance within the household economy, even if it refers to the scavenging chicken kept in the backyard. The third category of diseases and their impacts turns the focus to those livestock activities that would require a specific effort and investment to be taken on by the poor because they involve upgrading an existing activity through a more productive management technique or adopting a wholly new, more-productive livestock activity. Increasing productivity is the classic pathway for intensification of farming systems by which households increase the value of output for their inputs, and is thus key to escaping poverty. Moving up the livestock ladder is a common form of intensification. But, as emphasised above, the poor tend to be risk-averse, and so are reluctant to invest in a new activity that may exacerbate their vulnerability and threaten their already constrained asset base. The possibility of livestock disease would obviously be an important consideration. Some diseases have had a major impact by discouraging certain livestock activities. A well-known example is that of trypanosomosis, which has been responsible for the under-utilisation of livestock across the tsetse belt of SSA. Similarly, the low adoption of improved dairy-grade cattle in the Great Lakes area of Central Africa has been largely attributed to the continuing threat of East Coast fever (ECF).

Box 5.1 Animals in harmony with their environment[1]

In much of Uganda and western Kenya, possibly the cradle of East Coast fever (ECF, caused by the parasite *Theileria parva* and transmitted by the brown ear tick [*Rhipicephalus appendiculatus*]), most of the indigenous cattle are solidly immune to this disease; young calves become infected early in life and rarely go on to develop clinical disease (a situation known as 'endemic stability', Norval et al., 1992; Perry and Young, 1995; Coleman et al., 2001). When poor farmers consider intensification through the introduction of a new breed, such as a Friesian to increase the meagre milk production of the local zebu, they generally die of ECF unless treated with acaricides on a weekly basis to kill the ticks, or vaccinated using the current live 'infection-and-treatment' vaccine. Research on ECF therefore, may not be a priority for securing the current assets, but will certainly be a priority for intensification. This situation is similar with the other tick-borne and tick-associated diseases (TBDs). Dermatophilosis, for example, may not present a serious constraint to many of the indigenous cattle in peri-urban areas of Nigeria, but it is devastating if a farmer is attempting to start milk production with a dairy breed that is severely affected by the disease.

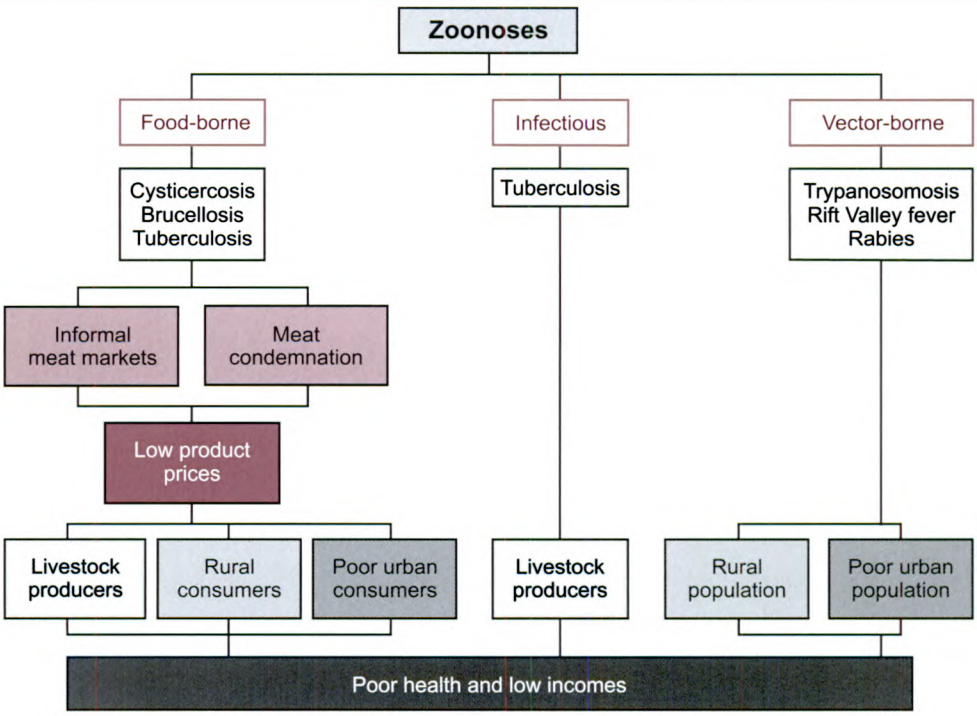
1. Generally it is the improved and exotic breeds of cattle that are most susceptible to the effects of all the TBDs, which can be highly fatal. Although endemic stability to many TBDs is common in indigenous breeds, this is by no means universal. For example, ECF may cause significant losses in indigenous cattle on the fringes of the distributions of the vector tick, where challenge levels are insufficient to maintain endemic stability, and in areas in which tick challenge is seasonal, such as in southern Africa.

6 Zoonotic diseases and their impact on the poor

Many infectious agents are quite host-specific, restricting their life as a parasite to one particular mammalian host. However, many are more catholic in their tastes, and enhance their chances of survival through a wide host range. For some of these, the hosts are all domestic animals, for some they are domestic and wild animals, and for some they are animals and humans, a group known as zoonotic infections (which may be manifest by zoonotic diseases).

The zoonotic diseases are a grouping that has a variety of mechanisms for transmission, and a variety of impacts. Some are directly infectious, such as anthrax, some are transmitted by bites (a form of direct transmission), such as rabies, some are indirectly transmitted through fomites, some are food- and water-borne, such as salmonellosis and cysticercosis, some are vector-borne, such as sleeping sickness and RVF, and some have multiple routes of infection, such as brucellosis and Q fever caused by *Coxiella burnetti* (Figure 6.1). Their impacts can be uniquely on human health, or affect both human health and livestock productivity, and be of varying severity to both. Some are very much associated with the developing world, such as rabies and sleeping sickness, and some are ubiquitous, such as cryptosporidiosis and salmonellosis. In the developing world, there is a dearth of good data on their occurrence and impact, even with the most devastating diseases. Rabies, for example, is highly fatal in humans who develop the clinical disease, but good data on its incidence and the mortalities it causes are scanty from many developing countries. Furthermore, avilable data are generally from cities and from hospitals, but not from the rural poor.

Figure 6.1 The zoonotic diseases and their impacts on the poor



Some of these are zoonoses in theory, and contribute to the long list of 868 pathogens documented in authoritative texts, but some of them are very much zoonoses in practice. Foot-and-mouth disease, for example, classifies as one of the former. It has been recorded in humans on extremely limited occasions as causing infections, and occasionally disease, but when considering the high infectivity of the virus, and the considerable interactions between infected animals and humans, its inclusion as a zoonosis is for textbook accuracy rather than for necessity. Compare that with RVF, a mosquito-borne virus affecting several species of domestic animals, including sheep, goats, camels and cattle, that can also spread to humans both through mosquito bites and direct contact with infected animals. Although this disease appears only cyclically every 5–10 years or so, and is currently restricted to Africa and parts of the Arabian peninsula, it causes devastation in many ways when it occurs, and has been associated with heavy loss of life in humans and animals, accompanied by restrictions in animal movements that limit or prohibit trade.

There are many features of the zoonotic diseases (reviewed in Appendix 9, Coleman, 2002) that render them particularly important to the poor, be they livestock keepers, labourers working with livestock, livestock owners consuming products from their animals or non-livestock owners consuming the livestock products of their neighbours or of other poor communities.

The first of these features is that many of these diseases produce fatal and disabling diseases in humans, the prevention of which is often through their control in animals. This feature is discussed in detail in Appendix 9. This requires the availability of appropriate animal health technologies, in place for these diseases, and their delivery to and accessibility by the poor. Human sleeping sickness caused by *Trypanosoma brucei rhodesiense* is an important example, in which the mass treatment of cattle significantly reduces the risk of disease in humans. Another important example is human epilepsy, in which neuro-cysticercosis (caused by the intermediate stage of the pork tapeworm *Taenia solium*) is considered the main cause (Anon., 1994). WHO estimates that at least 50 million people are infected with the parasite, that annually causes more than 50,000 deaths (Schantz et al., 1993).

The second of these features is that while there are some zoonotic diseases to which a large section of any given human population is equally susceptible, the poor are particularly at risk to many of them. Examples include cysticercosis in pigs, in which poor sanitation is the underlying cause, and for which knowledge and resources to adopt preventive measures are limited or absent in poor communities. Another example is leptospirosis, in which rats play an important role in the maintenance of infection; and rats often thrive in poor communities and in rice paddies.

The third, and possibly the most important of these features, is that the lower down the income scale, the more likely is the high risk of multiple zoonotic infections. Consider the landless peri-urban setting found in all of the regions studied, in which a cow, some pigs and goats, and the household dogs all co-exist with the family struggling for survival. There is a potential risk of human infection from brucellosis in the cow and Malta fever in the goats, as well as from tuberculosis (TB) and leptospirosis in the cow, cryptosporidiosis in a calf, cysticercosis and trichinellosis in the pigs, and rabies in the dogs. The risk of multiple zoonoses is a factor of poor hygiene, the purchase of cheap animals that may be the culls of others or have failed disease-screening tests, the purchase of cheap meat that has not undergone inspection, or has—but failed, and the lack of

resources or knowledge to protect their dogs against rabies. In such communities in Asia can be added the risk from pigs of Japanese B encephalitis and from poultry of influenza.

Although almost every one of these diseases appears on the annual reports issued by ministries of health in most developing countries, but as individual entities, they may not feature as priorities in the face of much more important individual human disease problems of these communities, such as malaria and human immunodeficiency virus (HIV) infections. However, in the contexts of poor livestock keepers, they assume a completely different role. The DALY's are higher for the zoonoses than for many other human diseases of the developing world, such as malaria. This is because many have a fatal outcome if not diagnosed and treated correctly. Thus, for example, it was calculated that in southeastern Uganda, there were 178 times as many recorded and treated cases of malaria as sleeping sickness, but these accounted for only three times as many DALY's lost (Odiit et al., 2000).

Livestock offer both a major contribution to the livelihood of the poor, and a pathway out of abject poverty, but also a risk to their own health, well-being and performance. Clearly, improved control of zoonotic diseases will require a coordinated effort by both human medical and veterinary research and service provision.

7 Animal disease impact on the poor: study results

A total of 76 syndromes, general diseases and specific disease entities were identified as having impact on the poor. These included all the categories discussed in the previous chapters (endemic, epidemic, zoonotic and food-borne). Whereas some diseases were reported from all regions, others had more limited distributions. The results of priority impact rankings, carried out globally, by region, by species and by production system, are provided in Table 7.1. This shows a summary of the diseases/syndromes that ranked in the 'top 20' either globally or in any of the regions.

Because of the difficulty in equating impacts on human health with impacts on livestock health, the zoonotic diseases that have no production impacts are not included in this ranking, but appear separately, and ranked within the group in Table 7.2. However, it is acknowledged that diseases that impact livestock productivity, the marketing of livestock and their products, and human health, have greater impacts on poverty than those impacting only one of these areas. The potential of using a composite index score that captures both the economic and zoonotic impacts is discussed in Box 7.1.

As described in the methodology (Chapter 2) the ranking is based on scored impacts. Thus a disease is likely to score highly if the impacts occur across the two main impact categories scored (economic impact at the poor farmer level, and economic impact at the national level), occur in species that are ranked highly to the poor, occur in multiple species, and occur in regions or production systems with high numbers of poor (particularly SA). Similarly, diseases that are confined to one species and one region are more likely to score low on the scale. This is clearly very important for interpretation, and for this reason, regional, production-system and species priority listings are also presented (Tables 7.3–7.5).

A further cautionary note must be sounded about the interpretation of these disease rankings for several reasons. Firstly, they are presented as a mixture of broad areas of production inefficiencies (such as neonatal mortality), as broad disease groupings (such as ectoparasites) and as very specific diseases. As such, some may not consider the comparisons valid, as they may not all be mutually exclusive. Some of the specific diseases may contribute to the areas of production inefficiency. However, we believe it is important to recognise the importance of these non-specific entities raised during the workshops, as they were often considered to be the major constraint to the poor, despite a lack of knowledge of the specific cause. Secondly, even within the specific disease categories, there is not necessarily homogeneity of knowledge on their impacts, particularly among the poor. Some diseases have been very well studied in some systems, but not necessarily with the poor, and others are poorly understood in all systems. Thirdly, and this must be emphasised, this is a ranking of diseases based on their impact on poor livestock keepers, and not a ranking of research priorities. In later chapters we discuss research opportunities, and try to link researchable issues with impact prioritisation.

Table 7.1 Top 20 diseases/pathogens globally or regionally, ranked according to their impact on the poor

Rank group[1]	Disease/pathogen (alphabetical within each rank group)	Global index[2]	Contribution to global index[3] (%)		Species role in global index[4]		Regional[5] ranking				Production system[6] ranking			Species ranking				
			Econ	Natl	Imp. to Poor (index)	Species number	WA	ECSA	SA	SEA	Past -oral	Agro-Past	Peri-urban	Cattle	Sheep Goats	Buffalo	Pigs	Poultry
A	Anthrax	46	49.5	50.5	78	4	A	D	B	B	E	A	B	A	A	A	–	–
	Ectoparasites	63	99.8	0.2	53	4	A	A	C	A	A	A	A	C	A	–	A	A
	Foot-and-mouth disease (FMD)	64	68.9	31.1	64	5	B	C	A	A	C	A	A	A	B	A	A	-
	Gastro-intestinal (GI) helminths	100	99.6	0.4	49	6	A	A	B	A	A	A	A	B	A	–	A	A
	Liver fluke (fascioliasis)	51	99.1	0.9	73	4	A	B	A	B	D	A	B	A	A	A	–	–
	Neonatal mortality	79	100.0	0.0	32	6	–	A	A	–	A	A	A	B	A	–	A	A
	Newcastle disease (ND)	58	93.7	6.3	51	1	B	A	B	A	B	A	C	–	–	–	–	A
	Nutrition/ micronutrients	46	100.0	0.0	67	4	–	A	A	B	A	A	B	A	–	B	–	A
	Reproductive disorders	50	100.0	0.0	82	2	–	B	A	–	B	A	A	A	–	A	–	–
	Toxocara vitulorum	45	100.0	0.0	65	2	–	–	A	A	B	A	A	A	–	A	–	–
B	*Brucella abortus*	38	66.8	33.2	79	3	C	D	A	–	A	B	A	A	–	A	–	–
	Coccidiosis	30	100.0	0.0	20	1	D	B	A	B	E	B	C	–	–	–	–	A
	Haemonchosis	42	100.0	0.0	57	2	C	A	B	–	C	B	B	–	A	–	–	–
	Haemorrhagic septicaemia (HS)	40	78.5	21.5	70	3	B	D	A	A	B	B	A	A	–	A	–	–
	Mastitis	23	79.2	20.8	84	2	–	C	B	–	E	B	A	B	–	B	–	–
	Peste des petits ruminants (PPR)	40	90.0	10.0	47	1	B	D	A	–	C	B	C	–	A	–	–	–
	Respiratory complexes	35	99.0	1.0	82	4	A	A	C	–	A	B	B	–	A	A	–	–
	Rinderpest (RP)	21	6.4	93.6	79	2	C	D	B	–	C	B	D	B	–	A	–	–
	Trypanosoma evansi	21	99.7	0.3	77	3	C	C	B	B	A	B	D	C	–	A	–	–
	Trypanosomosis (tsetse)	32	96.8	3.2	69	4	A	B	–	–	A	B	B	A	B	–	A	–
	Babesiosis	14	91.8	8.2	80	1	B	B	C	–	C	C	E	B	–	–	–	–
	Contagious bovine pleuro-pneumonia (CBPP)	19	77.3	22.7	72	1	A	B	–	–	A	C	D	A	–	–	–	–
	Contagious caprine pleuro-pneumonia (CCPP)	12	100.0	0.0	70	1	B	C	D	–	C	C	D	–	B	–	–	–
C	Diarrhoeal diseases	19	100.0	0.0	85	3	–	–	B	–	B	C	C	B	–	B	–	–
	Foot problems	12	91.5	8.5	88	1	B	B	–	–	C	C	D	–	B	–	–	–
	Heartwater	19	95.6	4.4	78	2	A	B	–	–	–	C	D	C	A	–	–	–
	Infectious coryza	12	100.0	0.0	56	1	–	A	–	–	B	C	C	–	–	–	–	–
	Rift Valley fever (RVF)	17	2.2	97.8	82	3	B	A	–	–	A	C	C	C	B	–	–	–
	Sheep and goat pox	17	85.7	14.3	58	1	B	–	C	–	C	C	C	–	A	–	–	–
	Theileria annulata	13	100.0	0.0	91	1	–	–	B	–	–	C	E	B	–	–	–	–

Rank group[1]	Disease/pathogen (alphabetical within each rank group)	Global index[2]	Contribution to global index[3] (%)		Species role in global index[4]		Regional[5] ranking				Production system[6] ranking			Species ranking				
			Econ	Natl	Imp. to Poor (index)	Species number	WA	ECSA	SA	SEA	Past -oral	Agro-Past	Peri-urban	Cattle	Sheep Goats	Buffalo	Pigs	Poultry
	Anaplasmosis	10	98.0	2.0	73	1	B	E	C	–	C	D	B	C	–	–	–	A
	Black-leg	11	87.1	12.9	61	2	A	E	D	B	–	D	E	B	–	B	–	–
	Dermatophilosis	11	88.7	11.3	62	1	A	C	–	–	D	D	E	B	–	–	–	–
	Duck virus enteritis (DVE)	8	89.5	10.5	73	1	–	–	E	A	B	E	–	–	–	–	–	A
D	East Coast fever (ECF)	9	88.5	11.5	97	1	–	A	–	–	–	D	A	C	–	–	–	–
	Fowl cholera	11	98.7	1.3	59	1	–	–	D	A	–	D	B	–	–	–	–	A
	Fowl pox	11	91.2	8.8	40	1	–	B	C	A	B	D	C	–	–	–	–	A
	Hog cholera (CSF)	9	98.1	1.9	24	1	–	–	C	A	D	D	B	–	–	–	A	A
	Infectious bovine rhinotracheitis (IBR)	10	100.0	0.0	89	1	–	–	B	–	B	D	E	B	–	–	–	–
E	Orf	3	100.0	0.0	39	1	–	–	D	B	–	E	E	–	B	–	–	–
	Tick infestation	6	77.0	23.0	92	2	–	B	–	–	–	E	B	C	–	–	–	–
G	*Brucella suis*	1	100.0	0.0	23	1	–	–	E	B	–	G	E	–	–	–	A	–

1. A = top 10 ranked diseases; B = 11-20; C = 21–30; D = 31–40; E = 41-50; F = 51-60; G = 61-70
2. Disease impact scores (weighted by region/production system-specific relative importance of the affected species, the number of poor, and the severity of poverty in the specific region) were normalised to an index of 0 to 100 with 100 representing the highest impact
3. Portion of disease impact score (weighted aggregate across all region/production systems) contributed by each of the two main components: economic impact (Econ: incidence and herd-level productivity impact) and national livestock sector impacts that indirectly affect the poor (Natl: trade impacts and public expenditures)
4. Region/production system-specific disease impact scores are adjusted to reflect the degree to which the disease affects species important to the poor. Imp. to Poor (importance to the poor) is the global weighted average importance of the species affected by the disease, where 1=all species affected by the disease are considered to be the most important to the poor in the relevant region/production systems and 0=all species affected by the disease are considered unimportant to the poor in those region/production systems. Species number indicates the number of different species affected by the disease. The nine categories of species include: cattle, buffalo, yaks, camels, horses, donkeys, pigs, sheep and goats, poultry
5. Regions: WA = West Africa; ECSA = Eastern, Central and Southern Africa; SA = South Asia, SEA = South-East Asia
6. Pastoral systems correspond to the rangeland-based systems (LGA, LGH, and LGT; which may include large-scale commercial beef production); agro-pastoral systems to the mixed crop-livestock systems (MRA, MRH, MRT, MIA, MIH, MIT), peri-urban systems to the landless farming systems (LL)

Table 7.2 Ranking of zoonotic diseases/pathogens according to their impact on the poor

Rank group[1]	Disease/pathogen (alphabetical within each rank group)	Global index[2]	Contribution to global index[3] (%)		Species role in global index[4]		Regional[5] ranking				Production system[6] ranking			Species ranking				
			Incidence scope	Severity	Imp. to Poor (index)	Species number	WA	ECSA	SA	SEA	Past-oral	Agro-Past	Peri-urban	Cattle	Sheep Goats	Buffalo	Pigs	Poultry
	Anthrax	12	44.7	55.3	0.703	4	A	A	A	A	A	A	A	A	A	A	–	–
	Bovine tuberculosis	15	38.6	61.4	0.738	2	A	A	–	A	A	A	A	A	–	A	–	–
	Brucella abortus	100	60.9	39.1	0.799	3	A	A	–	A	A	A	A	A	–	A	–	–
	Brucella melitensis	30	63.1	36.9	0.488	1	A	–	–	A	A	A	A	–	A	–	–	–
A	Buffalo pox	8	50.0	50.0	0.691	1	–	–	–	A	–	A	B	–	–	A	–	–
	Cysticercosis	17	84.7	15.3	0.313	1	–	A	A	A	A	A	A	–	–	–	A	–
	Leptospirosis	12	50.0	50.0	0.432	3	–	–	–	A	–	A	–	A	–	A	–	–
	Rift Valley fever (RVF)	7	44.0	56.0	0.766	3	A	A	–	–	A	A	–	A	A	–	–	–
	Toxocara vitulorum	7	50.0	50.0	0.470	2	–	–	A	–	–	A	A	A	–	A	–	–
	Trypanosomosis	15	24.4	75.6	0.850	4	–	A	–	–	A	A	–	A	–	–	A	–
	Botulism	1	25.0	75.0	0.802	1	A	A	–	–	A	B	B	A	–	–	–	–
	Brucella suis	1	50.0	50.0	0.081	1	–	–	–	A	–	–	A	–	–	–	A	–
	Cysticercus bovis	2	50.0	50.0	0.868	1	–	A	–	–	A	B	B	A	–	–	–	–
B	Japanese B encephalitis	2	55.6	44.4	0.217	1	–	–	–	A	–	B	A	–	–	–	A	–
	Mange	1	50.0	50.0	0.600	1	–	A	–	–	A	–	–	–	–	–	–	–
	Orf	1	50.0	50.0	0.315	1	–	–	A	–	–	–	A	–	A	–	–	–
	Schistosoma japonicum	1	40.0	60.0	0.500	1	–	–	A	–	–	B	–	A	–	–	–	–
	Trichinellosis	1	66.7	33.3	0.081	1	–	–	–	A	–	B	A	–	–	–	A	–

1. A = top 10 ranked diseases; B = 11–20
2. Disease impact scores (weighted by region/production system-specific relative importance of the affected species, the number of poor, and the severity of poverty in the specific region) were normalised to an index of 0 to 100 with 100 representing the highest impact
3. Portion of disease impact score (weighted aggregate across all region/production systems) contributed by each of the two main components: scope of incidence (ranging from livestock handlers to general public) and severity of the disease on a person affected
4. Region/production system-specific disease impact scores are adjusted to reflect the degree to which the disease affects species important to the poor. Imp. to Poor (importance to the poor) is the global weighted average importance of the species affected by the disease, where 1=all species affected by the disease are considered to be the most important to the poor in the relevant region/production systems and 0=all species affected by the disease are considered unimportant to the poor in those region/production systems. Species number indicates the number of different species affected by the disease. The nine categories of species include: cattle, buffalo, yaks, camels, horses, donkeys, pigs, sheep and goats, poultry
5. Regions: WA = West Africa; ECSA = Eastern, Central and Southern Africa; SA = South Asia, SEA = South-East Asia
6. Pastoral systems correspond to the rangeland-based systems (LGA, LGH, and LGT; which may include large-scale commercial beef production); agro-pastoral systems to the mixed crop-livestock systems (MRA, MRH, MRT, MIA, MIH, MIT), peri-urban systems to the landless farming systems (LL)

Table 7.3 Twenty top diseases/pathogens ranked according to their impact on the poor, by region (listed alphabetically within each rank group)

	West Africa (WA)	Eastern, Central and Southern Africa (ECSA)	South Asia (SA)	South-East Asia (SEA)
T o P 10	Anthrax Black-leg Contagious bovine pleuro-pneumonia (CBPP) Dermatophilosis Ectoparasites Gastro-intestinal (GI) parasitism Heartwater Liver fluke (fascioliasis) Respiratory complexes Trypanosomosis	East Coast fever (ECF) Ectoparasites GI parasitism Haemonchosis Infectious coryza ND Neonatal mortality Nutritional/ micronutrient deficiencies Respiratory complexes RVF	*Brucella abortus* Coccidiosis FMD HS Liver fluke Neonatal mortality Nutritional/ micronutrient deficiencies PPR Reproductive disorders *Toxocara vitulorum*	Duck virus enteritis (DVE) Ectoparasites FMD Fowl cholera Fowl pox GI parasitism HS Hog cholera ND *Toxocara vitulorum*
Next 10	Anaplasmosis Brucellosis Contagious caprine pleuro-pneumonia (CCPP) Foot-and-mouth disease (FMD) Foot problems Haemorrhagic septicemia (HS) Newcastle disease(ND) Peste des petits ruminants (PPR) Rift Valley fever (RVF) Sheep and goat pox	Babesiosis CBPP Coccidiosis Foot problems Fowl pox Heartwater Liver fluke Reproductive disorders Tick infestation Trypanosomosis	Anthrax Diarrhoeal diseases GI parasitism Haemonchosis Infectious bovine rhinotracheitis (IBR) Mastitis ND Rinderpest (RP) *Trypanosoma evansi* *Theileria annulata*	Anthrax Black-leg *Brucella suis* Coccidiosis Cysticercosis Liver fluke Nutritional/ micronutrient deficiency Orf *Schistosoma japonicum* *T. evansi*

On a global basis, the 20 highest-ranked conditions with impact on the poor comprise three syndromes (neonatal mortality, reproductive disorders and nutritional/micronutrient deficiencies, which all rank in the top 10), four general disease categories (gastro-intestinal [GI] parasitism, ectoparasites, respiratory complex and mastitis, the first two of which rank in the top 10), and 13 specific diseases (FMD, liver fluke, ND, anthrax, *Toxocara vitulorum* infection, followed by HS, PPR, *Brucella abortus* infection, haemonchosis, African trypanosomosis, coccidiosis, *Trypanosoma evansi* infection and RP).

On a global basis, GI parasitism emerges with the highest global index as an animal health constraint to the poor. In the workshops, diseases and syndromes caused by GI parasites that can be distinguished clinically, or for which there are quite specific research opportunities, were separated out. As a result, the following entities were considered: haemonchosis, *Toxocara vitulorum*, and general GI parasitism. Haemonchosis was confined to sheep, goats and camels, *T. vitulorum* to buffalo and cattle, while GI parasitism was the general name given to the syndrome that occurs in all species and is caused by a variety of parasites including *Trichostrongylus*, *Ostertagia*, *Oesophagostomum* and *Strongyloides*. Thus its high score is a reflection of the wide geographical distribution of GI parasitism, the wide host species range, and the importance given to its high economic impact at the poor farmer level in all production systems, and particularly in camels, sheep, goats and poultry.

Table 7.4 Twenty top diseases/pathogens ranked according to their impact on the poor, by production system (listed alphabetically within each rank group)

	Pastoral systems (LGA, LGH, LGT)	Mixed crop–livestock systems (MRA, MRH, MRT, MIA, MIH, MIT)	Peri-urban systems (LL)
	Contagious bovine pleuro-pneumonia (CBPP)	Anthrax	Coccidiosis
	Ectoparasites	Ectoparasites	Ectoparasites
T	Gastro-intestinal (GI) parasitism	Foot-and-mouth disease (FMD)	FMD
o	Haemonchosis	GI parasitism	GI parasitism
p	Neonatal mortality	Liver fluke	Haemonchosis
	Nutritional/micronutrient	Neonatal mortality	Infectious coryza
10	deficiency	Neonatal disease virus (NDV)	Neonatal mortality
	Respiratory complexes	Nutritional/micronutrient deficiencies	ND
	Rift Valley fever (RVF)	Reproductive disorders	Nutritional/micronutrient
	Trypanosoma evansi	*Toxocara vitulorum*	deficiencies
	Trypanosomosis		Respiratory complexes
	Anthrax	*Brucella abortus*	Anthrax
	Contagious caprine pleuro-pneumonia (CCPP)	Coccidiosis	Fowl cholera
N	Foot problems	Haemonchosis	Fowl pox
e	Heartwater	Haemorrhagic septicaemia (HS)	Foot problems
x	Liver fluke (fascioliasis)	Mastitis	Heartwater
t	Mange	PPR	Hog cholera
	Newcastle disease (ND)	Respiratory complexes	PPR
10	Peste des petits ruminants (PPR)	Rinderpest (RP)	Reproductive disorders
	Sheep and goat pox	*T. evansi*	RVF
	Tick infestation	Trypanosomosis	Trypanosomosis

This result is therefore not surprising. However, it is important to note that a common theme from the literature, and particularly from the workshops, is the difficulty in quantifying the impact of GI parasitism in smallholder livestock systems.

The other general highly ranked disease category is ectoparasites, and this includes a range of parasites affecting cattle, pigs, sheep, goats and poultry, reported from all regions of the study. As with GI parasitism, there is extremely little documented evidence and quantification of their impacts on these species, but they are visible to poor livestock keepers, they are considered vermin by both the poor and their veterinary advisors, they are in abundance both in terms of species and absolute numbers in poor households with livestock, and as such are considered of significant impact.

The presence of the three syndromes of neonatal mortality, reproductive disorders and nutritional/micronutrient deficiencies in the top 10 reflects the general recognition of production inefficiencies compounded by nutritional inadequacy across all of the species as being among the most important health impacts on the livestock of the poor. It is very interesting to note that these are syndromes that are generally no longer major constraints to livestock farming in the developed world. It is also interesting to note the remarkable similarity with human medicine. In the recent WHO study of research investment opportunities for human medicine, the group of three 'old enemies' which are responsible for more than half the disease burden in Africa are listed as the diseases of childhood, malnutrition and poor reproductive health (WHO, 1996). A predictable homogeneity across the species barrier. Poverty is a predisposing factor for these conditions, in both animals and people, but is also a consequence of them (WHO, 1996).

Of the five specific diseases in the top 10, some were predictable, and some were less so. Among the more predictable is ND, prevalent in all regions, and always identified as the major disease of village poultry. The high ranking of poultry to the poor appeared to outweigh the poultry-specific characteristics of the disease.

Table 7.5. Top-ranked diseases/pathogens according to their impact on the poor, by species (listed alphabetically within each rank group)

	Buffalo	Cattle	Sheep/Goats	Poultry
	Anthrax	Anthrax	Anthrax	Coccidiosis
	Brucella abortus	*Brucella abortus*	Ectoparasites	Duck virus entritis (DVE)
T	Foot-and-mouth disease (FMD)	Contagious bovine pleuro-pneumonia (CBPP)	Haemonchosis	Ectoparasites
o	Haemorrhagic septicemia (HS)	FMD	Heartwater	Fowl cholera
p	Liver fluke (fascioliasis)	HS	Helminthosis	Fowl pox
	Reproductive disorders	Liver fluke	Liver fluke	Helminthosis
10	Respiratory complexes	Nutritional/micronutrient deficiency	Neonatal mortality	Infectious coryza
	Rinderpest (RP)	Reproductive disorders	Peste des petits ruminants (PPR)	Neonatal mortality
	Trypanosoma evansi	*Toxocara vitulorum*	Respiratory complexes	Newcastle disease (ND)
	Toxocara vitulorum	Trypanosomosis	Sheep and goat pox	Nutritional/micronutrient deficiency
	Black-leg	Babesiosis	Blue tongue	Duck virus hepatitis (DVH)
N	Bovine tuberculosis (TB)	Black-leg	*Brucella melitensis*	Gumboro
e	Buffalo pox	Dermatophilosis	Contagious caprine pleuro-pneumonia (CCPP)	Mycoplasmosis
x	Diarrhoeal diseases	Diarrhoeal diseases	Clostridial diseases	Salmonellosis
t	Mastitis	Helminthosis	FMD	
	Nutritional/micronutrient deficiency	Infectious bovine rhinotracheitis (IBR)	Foot problems	
10		Mastitis	Orf	
		Neonatal mortality	Para-TB	
		Rinderpest (RP)	RVF	
		Theileria annulata	Trypanosomosis	
	Pigs	**Camels**	**Donkeys**	**Yaks**
	African swine fever (ASF)	Acute respiratory syndrome	Helminthosis	FMD
	Brucella suis	Camel pox	Trypanosomosis	HS
T	Cysticercosis	Haemonchosis	Wounds/injuries	Liver fluke
o	Ectoparasites	Helminthosis		Neonatal mortality
p	FMD	Mange		
	Helminthosis	Neonatal mortality		
10	Hog cholera	Respiratory complexes	**Horses**	
	Japanese B encephalitis	Rift Valley fever (RVF)		
	Neonatal mortality	*T. evansi*	African horse sickness (AHS)	
	Trypanosomosis	Tick infestation	Lymphangitis	
		Anthrax		
		Rabies		

Many may be surprised at the high global ranking of FMD to the poor. The disease ranked within the top 10 globally, and in both SA and SEA, but in rank group B in WA, and C in ECSA. Its importance in several species, the importance of cattle in SA and the high population of poor in that region all contributed to this high global ranking. The disease can certainly have significant economic impacts to poor livestock keepers, and affect their local marketing. FMD scores relatively highly in agro-pastoral systems (rank group A) where cattle and buffalo play an important role in traction, but relatively lower on the scale (rank group C) in pastoral systems, in which livestock also play an important—but quite different—role.

Some might be surprised to see anthrax scoring so highly on a global scale. This is probably due to the multiple impacts (productivity impacts on the poor and national expenditures to control it), the multiple species involved, and its particular importance in SA and WA. However, it is an example of a specific disease entity for which accurate incidence figures were lacking in most regions.

Also unexpected to some might be the high global ranking given to *T. vitulorum*, particularly due to its impact in young buffalo and cattle in Asia. However information provided from a variety of sources from that region suggests that it is clearly a very important cause of productivity losses and mortality there. Its presence and impact were not reported as so significant in Africa, despite having been identified in different regions of the continent. Its importance in Africa possibly deserves further investigation.

Some of the perennials that have received long-standing support from research funding do not feature so high up the lists as some might have expected, and some of them hardly feature at all. The ranking of African trypanosomosis as group A in WA, and group B in ECSA seems consistent with conventional wisdom, putting it in group B on the global impact. There are two key points here. Firstly, these differences in ranking emphasise the significant regional differences there are in disease impacts and priorities for poverty alleviation. It would appear that support to the improved control of trypanosomosis in Africa as a means of alleviating poverty is justified, but if priorities are made on the basis of where the maximum number of poor can be touched at a global level, the control of other diseases may take priority. However, the second point is that trypanosomosis has only received significant research funding in Africa, where it is clearly an important problem, but the full impact of *T. evansi* in Asia has not been adequately quantified.

All the TBDs were ranked as priorities, but were not amongst the highest ranked. Those TBDs that affect more than one species, and occur over a wide geographic distribution tended to score higher. ECF is without doubt an important disease in ECSA, and heartwater is probably the most important TBD in southern Africa, and is also important in WA. However, even in the regions in which these diseases are known to be important, they both ranked as group B on the priority scale, while at the global level ECF ranked as group D and heartwater as group C. There are many reasons for this.

For ECF, its low ranking is probably due to the fact that it occurs in just one species, cattle, and whereas that species ranks highly in the ECSA, it is usually the indigenous zebu and sanga breeds that play the most important role in poor households in the mixed agro-pastoral systems of that region, rather than the more susceptible European breeds; in many circumstances (but certainly not all, see Box 5.1), the indigenous breeds were considered to suffer less in terms of economic losses, due to the presence of endemic stability to the TBDs. Furthermore, ECF does not occur outside the one

Box 7.1 Developing a single composite index to capture the economic and zoonotic impacts of animal diseases

As noted in section 2.3.1, separate rankings of disease impacts were developed based on economic and zoonotic impacts, because of the difficulty of measuring the monetary value of human health impacts. However, a composite ranking using both criteria can be constructed if in lieu of self-weighting based on a common monetary value, the various criteria are combined using explicit, but inevitably arbitrary, weights.

Such a weighting system was tested to assess the impact on the rankings of zoonotic diseases.

The proposed weighting system is given by:

Economic impacts (80% total)

- 60% value of production losses
- 10% control costs incurred
- 7% market and trade effects
- 3% public-sector control expenditures

Zoonotic impacts (20% total)

- 10% scope of human population affected
- 10% severity of impact in affected individual

Table 7.6 Effect of combining economic and zoonotic impacts into single composite index

	Change in rank groups from	Global ranking based on composite index[2]		Original global ranking from Table 7.1		Original global ranking from Table 7.2	
Disease/pathogens	**Table 7.1**	**Group[1]**	**Index**	**Group[1]**	**Index**	**Group[1]**	**Index**
Anthrax	0	A	100	A	45	A	12
Brucella abortus	+1	A	76	B	38	A	100
Toxocara vitulorum	0	A	47	A	45	A	7
Bovine tuberculosis	+3	B	30	E	5	A	15
Leptospirosis	+5	B	26	G	0	A	12
Rift Valley fever (RVF)	+1	B	40	C	17	A	7
Trypanosomosis (tsetse)	0	B	37	B	32	A	15
Brucella melitensis	+2	C	19	E	4	A	30
Botulism	+2	E	6	G	0	B	1
Buffalo pox	+1	E	7	F	2	A	8
Cysticercosis	+1	E	8	F	2	A	17
Cysticercus bovis	+1	E	6	F	1	B	2
Japanese B encephalitis	+1	F	3	G	0	B	2
Orf	-1	F	4	E	3	B	1
Schistosoma japonicum	0	F	2	F	2	B	1
Trichinellosis	+2	F	2	H	0	B	1
Brucella suis	0	G	1	G	0	B	1
Mange	-1	G	1	F	1	B	1

1. A = top 10 ranked diseases (1–10); B = 11–20; C = 21–30; D = 31-40; E = 41–50; F = 51–60; G = 61-70
2. Composite Index weights: 60%=economic impact in affected herds/flocks; 10% = control costs; 10% = incidence as a zoonosis; 10% = zoonotic impact in affected individuals; 7% = trade effects; 3% = public expenditures

The results are summarised in Table 7.6. Of the 20 zoonotic diseases scored, eleven increase their ranking substantially (jumping to a higher rank group) compared to Table 7.1 in which their economic production impacts alone are considered. Particularly dramatic increases are registered for leptospirosis and bovine tuberculosis.

It can be argued that a composite index is more appropriate for decision-makers than maintaining two separate indexes. In many instances, decision-makers will likely be forced to set priorities from amongst both production diseases and zoonoses as a single group, and individuals will inevitably assign their own set of subjective weights to the criteria upon which they base their decision. Constructing a single composite index, even if identifying a common unit of measure is problematic, requires analysts and policy-makers to agree upon the criteria and the weights, promoting transparency and consensus. Moreover, as demonstrated above, certain diseases may not rank particularly high in either of the separate indexes, but do rank higher when their economic and human health impacts are combined. Consider the examples of anthrax, bovine tuberculosis, leptospirosis, and trypanosomosis in the table above. Constructing a composite index ensures that such additive effects are captured.

region, further affecting its priority status on a global basis. During the data collection and analysis of disease impacts on the poor, the various tick and tick-borne diseases (TTBDs) were considered individually as anaplasmosis, babesiosis, ECF, heartwater, dermatophilosis and tick infestation. It has been argued that doing so fails to evaluate TTBDs as a disease complex similar in nature to other syndromes that have been scored, resulting in their being under-ranked. To test the impact of considering TTBDs as a syndrome, each of the individual TTBDs was recoded as TTBD, and the rankings re-estimated. Whereas in the original ranking, the single highest ranked TTBD was only in group C (heartwater), the TTBDs amalgamated additively as a group rank very high in group A—globally among the production diseases. This result must be interpreted with extreme caution, however, since this adjustment permits TTBDs to be double-, triple-... up to sextuple-counted for a given species in a given regional production system, so that scoring TTBD as a syndrome is not the same as scoring, for example, neonatal mortality, that can be counted only once.

A second approach is to simply assign TTBD the single highest score of the six individual TTBDs for any given species by regional production system combination. Following this more reasonable approach, TTBD is ranked globally in group B.

In the zoonotic diseases, infection caused by *Brucella abortus* in cattle and buffalo ranked highest overall by a considerable margin, followed by the related *B. melitensis* in sheep and goats. With the exception of bovine tuberculosis, infection caused by *B. abortus*, and anthrax, there appeared to be significant regional differences in the priority rankings. Thus sleeping sickness ranked as third globally, but is only present in Africa, and even there only in limited parts of the distribution of the tsetse fly (*Glossina* spp.).

One zoonotic disease not scored in the table is rabies, as it is not primarily a disease of food-producing livestock. Nevertheless, it was considered to be of considerable public health importance in all of the regions. It is the cause of considerable human suffering, particularly among the poor, and in many countries there is public expenditure to produce and deliver vaccines to dogs, the major reservoir in most of the developing world.

To conclude, several points must be re-emphasised. Firstly, while this ranking has been carried out by focused questions on impact, and a scoring system to help quantify and standardise the responses, it has been carried out by groups of people with different experiences and expertise, and inevitably different opinions. An example is in the comparison of the ranking of three parasitic diseases (pork-derived cysticercosis, fascioliasis and haemonchosis) by workshop participants and by a group of parasitologists. For cysticercosis and fascioliasis, the parasitologists generally put the incidence, the herd losses and the zoonotic impacts higher than did the workshop participants, whereas for haemonchosis the rankings of the two groups were similar. On the one hand, the parasitologists likely have greater knowledge of the impacts of the parasites they deal with, but at the same time may bias the scores of their favourite diseases. On the other hand, the field staff are likely to have a broader perspective on the relative impact of one disease vis-à-vis the multitude of other problems affecting livestock.

Secondly, the global rankings are weighted by the number of poor, and as a result are strongly influenced by priorities in SA. Not taken into consideration are the dynamics of the changes in poverty rates, which as discussed in Chapter 4, might favour SSA where poverty rates are predicted to increase relative to those in SA.

Thirdly, in many cases the incidence and impacts of specific diseases and disease syndromes are not known, in particular to how they affect poor farmers.

And fourthly, and most importantly, these are simply rankings of disease and disease syndrome importance to the poor, not of research or development priorities. These are dealt with in Chapter 10.

Finally, the identification of the disease constraints, and the scoring of their impacts, reflects their current status. Not taken into consideration is how these might change in both the short and long term as a result of direct and indirect factors. Among the direct factors could be the emergence of new diseases, or the changing distribution of existing diseases, associated with climate change or other phenomena. Among the indirect factors are the dynamics of evolving productions systems, responding to change in population growth, changing markets and changing access to technologies.

8 The role of research in alleviating poverty through improved animal health

8.1 What role does research play in alleviating these impacts?

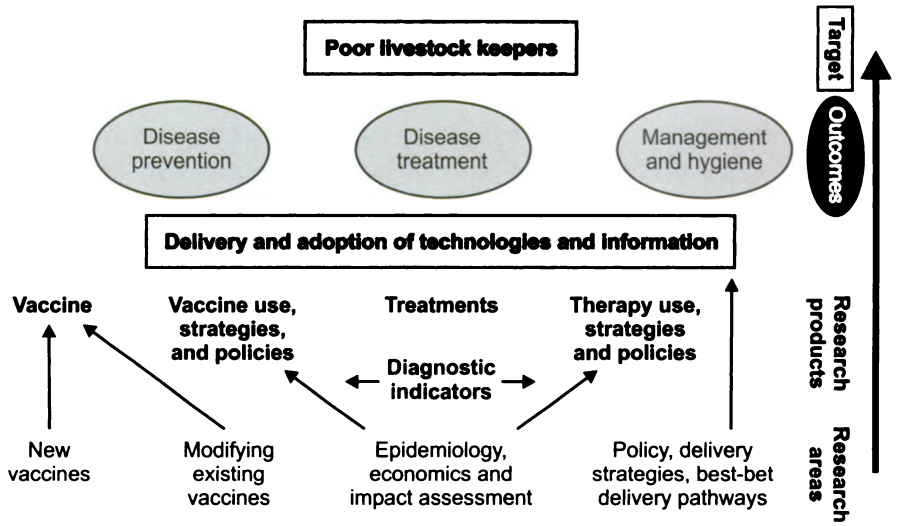
So many of today's advances in health and agriculture are a result of yesterday's research. Many fundamental qualities of the livelihoods of the majority of people in the developed world, now taken completely for granted in everyday life, are the products of previous investments in research. We have a responsibility to first examine what research would help to bring these advances to the poor in the developing world, and secondly to evaluate how the rapid developments in science can help create new research products that are tailor-made to solve the problems of the poor. In the animal and human health fields, research thus plays a crucial role in providing a strong and internationally recognised scientific base to many aspects of disease prevention and control operations of today, and in developing new technologies to improve the quality of disease control in the future.

Both of these general areas need to attract significant funding, and levels of funding have been far from adequate in recent years. Luckily, the increasing awareness in the West of the responsibility for, and desirability of, alleviating poverty in the developing world, should bode well for the future.

There are many areas of research in animal health that can provide major contributions to the development and transfer of disease control technologies. These include vaccine development to prevent diseases, the development of therapeutics to treat diseases that are susceptible to drugs, the development of diagnostic tests to ensure that the appropriate vaccines and therapeutics are used, the better use of genetically resistant breeds of livestock to reduce the impacts of diseases, the use of epidemiology and economics to evaluate priorities for action and help design appropriate technology-use strategies and policies, and the development of appropriate policies, pathways and strategies for the delivery of effective animal health services to the poor in different production systems and regions of the developing world. These are shown in Figure 8.1.

Examples of successful research products controlling diseases are most abundant from the field of human health, in which the greatest investment in research and development has taken place, and has had greatest impact in the developed world. These successes include the global eradication of smallpox, and the dramatic improvements in the control of measles, polio, diphtheria, pertussis and hepatitis B through the development and deployment of vaccines. But there are also impressive examples from the animal field. On a large scale they include the near eradication of RP through vaccination; the near elimination of wildlife rabies in northern Europe through vaccination; and on a farm scale they include the eradication of brucellosis, foot rot and ND, and the effective control of GI parasitism, the clostridial enterotoxaemias of sheep, and mastitis, to name but a few. Not all research products with impact have been vaccines. Epidemiological techniques have developed substantially over the last 30 years, and have played an important role in identifying risk associations where clear-cut causality has been difficult to determine, or where risk reduction, through management practices for example, is more feasible than vaccine development. An example in the human field is the identification of the association between smoking

Figure 8.1 The link between different research areas, the products of research and the outcomes to the poor



and lung cancer, and in the animal field of the dramatically reduced risk of ECF (*Theileria parva* infection) in dairy cattle kept under stall-feeding management. In addition, developments in cost: benefit and cost: effectiveness analyses have allowed predictive methodologies for analysing and comparing the potential benefits of different control and eradication options.

As far as the global potential for impact on poverty through animal health research is concerned, the evidence is certainly there, but most of these impacts have been in the developed world. With the multitude of constraints still operating in the developing world, it is important to tease out those diseases of greatest impact, and match them with the research options in different fields. If poverty reduction (or elimination) is the target, it is important to select the research that will have the greatest contribution to this goal. Thus there is a need to consider the importance of any particular disease constraint to the poor, the size of the potential impact achieved by controlling it, the probability of achieving that impact and the availability of resources to undertake the work through to completion.

In the following sections the major categories of disease prevention, treatment and control approaches within which research opportunities lie are presented, and their merits discussed.

8.2 Improved prevention of disease through artificially induced population immunity

In animals and in humans, and in sharp contrast to plants, the mechanism of rapidly induced immunity in individuals through immunisation with vaccines is a unique tool, which when applied to populations becomes one of the most effective and sustainable measures for preventing disease losses. There are many success stories in both human and animal fields of successful vaccines that have dramatically reduced the impacts of diseases, in some instances eradicated them from countries and regions, and in one

instance (smallpox), eradicated a disease from the globe. It is hoped that the same success might be just around the corner with RP. Vaccines have been developed to prevent diseases caused by a wide range of infectious organisms, including viruses, bacteria and parasites. However, there are some diseases for which effective vaccines have not been developed, and these include some of the parasitic diseases widely prevalent in the developing world. The ability to develop vaccines is very variable and dependent on the nature of the host/parasite interaction and of the host immune response. For some diseases, such as malaria, trypanosomosis and *Theileria parva* , the development of any vaccine has been problematic. For some, such as influenza, FMD and HS, vaccines exist, but the short duration of the immunity induced is a major constraint to their efficacy in the field. For some, such as ND of poultry, the challenge has been to develop a vaccine that can be easily administered to scavenging village poultry without the need for injections. For many diseases, the need to maintain vaccines in a cold chain at around 4°C also complicates delivery and availability, especially to the poor. To summarise, the major problems associated with development of population immunity through the use of vaccines that might be subject for research are:

- Lack of vaccines against certain priority infectious diseases
- Poor efficacy of currently available vaccines
- Poor thermostability of currently available vaccines
- Inadequate access to current and future vaccines

Research into the development of new vaccines is a long-term commitment that requires multidisciplinary research teams having critical mass (either inbuilt or from collaboration, and usually comprising molecular biology, immunology, biochemistry, parasitology—and increasingly—genomics), adequate laboratory facilities, adequate funding, good research management and secure political and institutional support. Increasingly, with the rapid technological advances taking place, such research requires extraordinary levels of collaboration between institutions and groups, very often in different countries, to be effective.

Research into enhancing the efficacy and stability of existing vaccines may appear less demanding, but also requires effective collaboration between different groups, as well as access to facilities for field-testing improved vaccines.

There is much opportunity for research into ways to improve the access by target farmers and service providers to current and new vaccines. This is particularly important with regard to a wide range of available vaccines that have been developed, and for which there is a demand, but that are not widely available to the poor in the developing world.

8.3 Improved prevention of disease through genetic resistance

The prevention of diseases through enhanced genetic resistance of livestock breeds is an attractive option because of its potential for sustainability and selection of multiple production and health traits (see Gibson, 2002, Appendix 13). The increased disease resistance of indigenous cattle in many tropical environments has been demonstrated and exploited. The best-known and documented examples are the trypanotolerant cattle breeds (e.g. N'Dama, Baoule) (Shaw and Hoste, 1987; d'Ieteren et al., 1999). In WA, cattle herders actively use breed selection as a disease risk management tool along with chemotherapy, grazing management and vector control. Trypanotolerant breeds are used almost exclusively in high-risk areas. Another example of exploiting

genetic resistance to disease is the tolerance of Red Maasai sheep to GI parasitism (Baker, 1999).

A number of research opportunities exist that could play a role in improving animal health through genetic resistance (see review by Gibson, 2002, Appendix 13). The most usefully exploited livestock genetic option in the developed world has been in breeding programmes that allow for the selection of both production and health traits. For tropical settings, specific breeding programmes for disease tolerance have been proposed. The advent of tools to identify genetic loci and even genes has opened up the prospect for marker-assisted genetic selection. However, understanding how organised breeding and selection programmes can be delivered and adopted by poor farmers is a major constraint that needs to be addressed.

The application of modern genomic and proteonomic research for enhancing genetic resistance to disease has interesting potential in the long-term. Beyond identifying genes or genetic markers for selection programmes, these tools are likely to greatly improve the understanding of parasite-host interactions and provide useful information that is just as likely to be exploited in guiding the development of new vaccines and therapeutics.

8.4 Improved therapy of diseases

The front line of impact reduction throughout the developing world is through the treatment of sick animals, and this is the procedure adopted most by farmers and service providers. It generally excludes viral diseases, and is particularly important for those diseases for which treatment is known to be effective and is known to reduce disease losses. The major problems associated with failures in therapy, which might be subjects for research are:

- Poor efficacy of chemotherapeutics
- Resistance to chemotherapeutics
- Poor access to therapeutics

Research into the development of new chemotherapeutics is an expensive and specialist operation, requiring the screening of a wide variety of potential products, with a high investment and a low rate of return. As such, commercial pharmaceutical companies seeking products that will have high economic returns traditionally carry out this activity. These are therefore targeted at the intensive livestock production systems of the developed world, and their use in the developing world is often a fortuitous 'spin-off'. Thus, anthelmintic products for the control of GI parasites are widely available in the developed world, due to the importance of intestinal parasitism as a constraint to production efficiency there, but new trypanocidal products, for example, are not being developed due to the demand being located exclusively in the impoverished developing world.

For three of the widely prevalent parasitic infections/infestation in tropical regions, resistance to therapy is a major problem. The products in question are anthelmintics, trypanocides and acaricides. It would appear that this is an issue that deserves research, but what are the prospects for progress, what type of research is required, and who has the capacity and comparative advantage to lead it? The clear identification of the existence of resistance, the better understanding of the mechanisms of resistance, and the determination of how best to manage resistance in the field through integrated disease control strategies would all seem to be valid areas of research.

Poor access to therapeutics is also considered to be important, and there would appear to be opportunities to improve this through the determination of best-bet delivery pathways appropriate for evolving priority production systems.

8.5 Improved recognition and evaluation of disease constraints through diagnostic indicators

One of the major constraints to effective treatment and control of diseases in the developing world is the inability to correctly recognise and identify conditions, and so instigate the appropriate intervention, either treatment or control. This has often been oversimplified into the development of laboratory diagnostic reagents and kits, which can form an important component of this process, but are only one of a broader set of indicators that will guide decisions on choice of intervention. Improved diagnostics are required to:

- Develop appropriate strategy for interventions
- Initiate appropriate treatment or control measures
- Confirm infection status prior to animal movement
- Differentiate between vaccinated and naturally infected animals
- Conduct research.

Research into the development of disease-indicator systems requires adequate financial, human and laboratory resources, in combination with good access to the production systems in which the diseases in question occur. It also requires good collaboration on a wide scale for indicator validation in many countries, and it requires credibility in terms of quality control, possibly endorsed by recognition from a reference centre. One of the major research opportunities to address the issues of appropriate treatment interventions and control strategy is the better integration of laboratory and non-laboratory indicators for more effective decision support to farmers and service providers.

8.6 Improved understanding of the dynamics, impacts and relative importance of diseases: epidemiology and economics

Epidemiology and economics have played a major role in the development of strategies and policies for animal disease control, and general health management, at all levels, from smallholder, to large farm, to national and regional programmes (Perry et al., 2001). With the improvement of animal health for poor livestock keepers in mind, these tools have two important roles in impact assessment. The first is to help quantify and prioritise disease burdens and the opportunities for their control, in a more localised (national or production–system level) version of this study. The combination of epidemiological data on disease occurrence and effect, economic data on the impacts of these effects, together with a review of the potential returns from research or development, all carried out in a quantitative framework, is a powerful tool for decision making on what needs to be tackled. Then, the next step is to evaluate the alternative policies and strategies that could be used to control the identified priority disease, using the same combination of disciplines. To date, these tools have been used mostly at national levels, such as in the evaluation of heartwater control in Zimbabwe (Mukhebi et al., 1999) and FMD control (Perry at al., 1999), but they could easily be adapted to focus on poverty, or on specific poor regions or communities.

8.7 Improved delivery and adoption of disease-control technologies

The mere availability of technologies and published knowledge does not guarantee effective interventions. Furthermore, with most diseases, no single technology or activity is likely to achieve the goals of reducing disease impact. Thus the last frontier for animal health research is arguably the effective synthesis of available technologies and knowledge into appropriate strategies and decision support at the farm, service provider, national and regional levels. The major problems associated with failure to deliver integrated disease control strategies and programmes are:

- Inappropriate decisions on interventions at farmer and service-provider levels
- Inappropriate or inadequate use of available technologies of knowledge
- Inappropriate or inadequate policies and strategies developed at national or regional levels
- Inadequate economic incentive for service providers.

Research into improving the application of appropriate disease control strategies is a specialist multidisciplinary activity, requiring appropriate critical mass and human resources in the areas of epidemiology, economics, sociology, impact assessment, decision and risk analysis techniques and policy analysis.

8.8 Identification of research opportunities for impact on poverty

Research opportunities to improve the human and animal health of poor livestock keepers were identified in the following four general categories, and these are described in Chapter 9.

- **Epidemiology, economics and impact assessment.** This covers a wide range of activities, including the development of an understanding of the dynamics and impact of a given disease on productivity and poverty, the evaluation of alternative intervention options on the dynamics and impact, and thus on productivity and poverty, and support to the development of appropriate strategies and policies for controlling the diseases, at village, production system and national levels.
- **Delivery, adoption and impact of animal disease control interventions.** This category considers how to take all of the three more technical areas described above, and translate them into the realities of different countries, different production systems, different institutional capacities for the delivery of services, different cultural perceptions etc., to ensure that good ideas, good vaccines, and good control programmes are translated into major impacts on the target beneficiaries.
- **Technology development and modification.** This category includes vaccines, therapeutics and diagnostics. Within these groups of technologies, there are some research opportunities for the modification of existing products (for example, improving the immune response through better antigen presentation, or the development of an oral vaccine to avoid injectable products), and some for the development of completely new products (such as moving away from live or inactivated vaccines to sub-unit or naked DNA products). The latter approach may also require some basic research such as genome sequencing of the causal organism, in order to lay the groundwork for the development of a new vaccine or diagnostic.

- **Strategic field testing and evaluation of new vaccines, diagnostics and therapeutics.** Once a candidate product is developed, it requires field evaluation for efficacy and acceptability under the conditions of its proposed use. For convenience, this has in the past, often meant trials carried out under controlled circumstances for convenience of logistics, but while such an approach might evaluate efficacy under close supervision, it does not evaluate the much more important issues of administration and efficacy that are specific to the production systems of the poor.

9 Research opportunities for the development and adaptation of disease control technologies targeted at the poor, and for their delivery, adoption and impact

As described in the methodology (Chapter 2) the four major areas of research opportunity summarised at the end of Chapter 8 were assembled by many different people in a series of processes.

1. Generic areas of research to improve the quality of animal health services to the poor were identified by the participants of the four workshops
2. The same participants identified specific areas needing improvement through research for the sets of diseases and disease syndromes they had identified as important constraints
3. Generic research opportunities in the field of delivery of veterinary services were identified through a commissioned report
4. Research scientists were commissioned to assemble summaries of the major research opportunities for specific diseases and disease syndromes.

The results of these processes can best be synthesised into the following three major groupings of research opportunities that represent the priority areas identified in these different processes.

1. Epidemiology, economics and impact assessment
2. Delivery of animal health services
3. Specific technologies for the control of specific diseases.

9.1 Epidemiology, economics and impact assessment

From all sources of contributions to this study, it became apparent that there is a significant demand for epidemiology, economics and impact assessment research to meet different needs. In the field there is a demand for knowledge to better refine an understanding of what are the major constraints to the poor. Also in the field, there is a demand for knowledge on the economic effects of specific diseases, and more importantly, of the effects of different potential intervention options, for priority setting. And in the laboratories, there is a demand for information as to how effectively new technologies will perform, and how they will affect the infection dynamics of the diseases they are intended to control.

Interestingly, the requirements for such information tended to be greater in Asia than Africa. This is borne out in the literature review, where there is more published information available on the impact and dynamics of diseases in Africa than the other areas covered in this study. However from all regions, there is clearly a great shortage of information on constraints to systems involving small ruminants, small-scale pig production and village poultry.

The different stakeholders placed different emphases on the specifics of these research options (Tables 9.1 and 9.2). The voices from the field identified a wide range of data needs on disease epidemiology and impact, while the research scientists were more specific to certain diseases.

Table 9.1 Research opportunities identified through commissioned expert reviews (ER) and regional workshops (WS): all diseases/pathogens ranked in the top 20 for all production systems

Disease/pathogen	Global rank group[2]	New vaccine		Modified/ test vaccine		Diagnostic		Therapeutic		Epidem- iology		Delivery extension		Other
		ER	WS	ER	WS	ER	WS	ER	WS	ER	WS	ER	WS	
Anthrax[1]	A					✔				✔	✔	✔	✔	
Ectoparasites	A												✔	
Foot-and-mouth disease (FMD)[1]	A	✔	✔			✔		✔			✔		✔	
Gastro-intestinal (GI) helminths[1]	A							✔		✔		✔	✔	Genetic resistance
Liver fluke (fascioliasis)[1]	A	✔				✔	✔	✔	✔		✔	✔		
Neonatal mortality	A						✔				✔		✔	
Newcastle disease (ND)[1]	A			✔	✔						✔	✔	✔	
Nutritional/micronutrient deficiency	A						✔				✔		✔	
Reproductive disorders	A										✔		✔	
Toxocara vitulorum[1]	A											✔	✔	
Brucella abortus[1]	B	✔		✔	✔		✔				✔	✔		
Coccidiosis	B													No research opportunities identified.
Haemonchosis[1]	B			✔		✔	✔		✔	✔		✔		Fungi against larvae (ER); breeding for resistance(WS)
Haemorrhagic septicaemia (HS)[1]	B		✔	✔			✔				✔			
Mastitis	B						✔		✔		✔		✔	
Peste des petits ruminants (PPR)[1]	B		✔	✔		✔	✔			✔	✔	✔		
Respiratory complexes	B										✔		✔	
Rinderpest (RP)[1]	B			✔	✔	✔				✔	✔	✔		
Trypanosoma evansi	B								✔		✔			
Trypanosomosis[1]	B	✔				✔			✔		✔	✔	✔	Trypanotolerance (WS)
Babesiosis[1]	C	✔	✔			✔			✔	✔	✔			
Contagious bovine pleuro-pneumonia (CBPP)[1]	C	✔	✔			✔	✔	✔	✔	✔	✔		✔	
Contagious caprine pleuro-pneumonia (CCPP)	C		✔				✔				✔			
Diarrhoeal diseases	C										✔		✔	
Foot problems	C										✔		✔	
Heartwater[1]	C	✔	✔			✔	✔				✔			
Infectious coryza	C													No research opportunities identified
Rift Valley fever (RVF)	C						✔							
Sheep and goat pox[1]	C			✔	✔	✔	✔						✔	
Theileria annulata[1]	C	✔				✔		✔						

Disease/pathogen	Global rank group[2]	New vaccine		Modified/ test vaccine		Diagnostic		Therapeutic		Epidem- iology		Delivery extension		Other
		ER	WS	ER	WS	ER	WS	ER	WS	ER	WS	ER	WS	
Anaplasmosis[1]	D	✔	✔			✔	✔		✔					
Black-leg	D										✔			
Dermatophilosis[1]	D	✔	✔						✔	✔				Markers of (ER) and exploitation for (WS) resistance
Duck virus enteritis (DVE)	D		✔				✔							
East Coast fever (ECF)[1]	D	✔	✔			✔	✔			✔	✔			
Fowl cholera[1]	D				✔	✔	✔				✔	✔	✔	
Fowl pox[1]	D				✔	✔						✔		
Hog cholera (CSF)	D		✔				✔				✔			
Infectious bovine rhinotracheitis (IBR)	D													No research opportunities identified
Orf	E													No research opportunities identified
Tick infestation	E										✔			
Brucella suis[1]	G				✔		✔				✔			

1. ER for research opportunities only commissioned for these diseases
2. A = top 10 ranked diseases; B = 11–20; C = 21–30; D = 31–40; E = 41–50; F = 51–60; G = 61–70

Table 9.2 Research opportunities identified through commissioned expert reviews (ER) and regional workshops (WS): zoonotic diseases

Disease/pathogen	Global rank group[2]	New vaccine		Modified/ test vaccine		Diagnostic		Therapeutic		Epidem- iology		Delivery extension		Other
		ER	WS	ER	WS	ER	WS	ER	WS	ER	WS	ER	WS	
Anthrax[1]	A				✔					✔	✔	✔	✔	
Bovine tuberculosis[1]	A	✔	✔			✔				✔	✔		✔	
Brucella abortus[1]	A	✔		✔	✔		✔				✔	✔		
Brucella melitensis[1]	A	✔					✔				✔	✔		
Buffalo pox	A		✔											
Cysticercosis[1]	A			✔						✔	✔	✔	✔	
Leptospirosis	A										✔			
Rift Valley fever (RVF)	A						✔							
Toxocara vitulorum[1]	A											✔	✔	
Trypanosomosis[1]	A	✔				✔			✔		✔	✔	✔	
Botulism	B													No research opportunities identified
Brucella suis[1]	B	✔		✔	✔		✔				✔	✔		
Cysticercus bovis[1]	B			✔		✔		✔		✔		✔	✔	
Japanese B encephalitis	B										✔			
Mange	B								✔					
Orf	B													No research opportunities identified
Schistosoma japonicum	B													No research opportunities identified
Trichinellosis[1]	B									✔			✔	
Myiasis	NR[3]													No research opportunities identified
Rabies	NR				✔								✔	

1. ER for research opportunities only commissioned for these diseases
2. A = top 10 ranked diseases; B = 11–20; C = 21–30; D = 31–40; E = 41–50; F = 51–60; G = 61–70
3. NR =Not ranked (i.e. did not receive a score in any regional workshop)

9.1.1 Generic issues identified from the workshops

9.1.1.1 Lack of basic data

There is a lack of basic data on the epidemiology and impact of many diseases and syndromes that are important to poor livestock keepers. There is a need for better information on disease distribution, dynamics and impact that would allow more effective disease forecasting and risk factor identification, which in turn can support the development of appropriate strategies and policies.

9.1.1.2 Need to measure impact on poverty

The impact of animal disease control needs to be measured, not only in terms of productivity gains in the traditional sense, but also in terms of improved human welfare.

9.1.1.3 Role of livestock owners in identifying and prioritising constraints

It was considered most important to consult livestock owners as to what their problems are—probably described in terms of clinical signs rather than in specific disease terms—and concentrate on those conditions.

9.1.1.4 Involvement of farmers in research

It was also considered important to involve farmers in research (participatory methods), and to feed back information to farmers.

9.1.1.5 Need for intervention packages tailored for different production systems

A common theme from all workshops was the need to synthesise and apply current knowledge and technologies to the development of intervention packages for the control of diseases that were specific to the major production systems of different regions.

9.1.2 Disease/syndrome-specific issues identified from the workshops by research scientists

As Tables 9.1 and 9.2 illustrate, there were a wide variety of disease-specific research opportunities identified in the general area of epidemiology, economics and impact assessment. These are dealt with more specifically in section 9.3.

9.2 Delivery of animal health services

The delivery of animal health services is seen as a major research opportunity. This broad area covers many different but related fields, such as better understanding of farmers' demands, better understanding of the economic viability of animal health services, including who benefits, who pays and how much, and a better understanding of the policies most amenable to the promotion of healthy livestock enterprises for the poor.

9.2.1 Generic issues identified from the workshops

From the workshops a few very specific common themes were identified.

9.2.1.1 Delivery of therapeutics and vaccines to the poor

The availability of therapeutic products in packaging, especially in terms of number of doses, appropriate to the poor and with clear labelling and instructions in local languages is still a major issue.

The question of who should have access to the different classes of drugs was raised in several workshops as a policy issue.

Standardised registration of drugs within a region would be cost-effective, avoiding repeating the process under different sets of rules in each country.

Drug-usage protocols are required for some products that minimise the risk of emergence of drug resistance, and are highly desirable to maximise the effective life of the available products.

There is little incentive for pharmaceutical companies to develop new products to treat diseases that primarily affect livestock of the poor, and this is an issue that needs to be addressed.

9.2.1.2 Technology transfer/adoption/delivery

Governments have traditionally provided much of the animal health services to poor livestock farmers, but this has often proved to be inefficient and unsustainable, and has been severely affected by structural adjustment programmes in many countries.

Existing delivery systems may not be as strong as required, for example, in the provision of a cold chain to the end-user.

Alternative service providers could be NGOs, the private sector (including farmer groups), co-operatives, milk processors and local entrepreneurs, but research is needed to determine the 'best bet' option in different situations.

It is vital to translate research results into policies, strategies, extension messages and products.

Stakeholder participation is necessary in the development of strategies and policies.

Technologies need to be simple, acceptable and easily implemented and take into consideration socio-economic issues, including cultural factors.

9.2.2 Disease/syndrome-specific issues identified from the workshops and research scientists

Tables 9.1 and 9.2 illustrate the disease-specific issues relating to the delivery of animal health services that were raised in the workshops. These are considered further in section 9.3.

9.2.3 Summary of the commissioned review of research opportunities for the better delivery of animal health services

Reviews of research opportunities in the area of animal health service delivery were commissioned. These comprised both a general overview, and a poultry-specific review, and can be found in full in Appendices 11 (McLeod and Wilsmore, 2002) and 12 (Permin and Madsen, 2000b). The major findings of these reviews are summarised below.

Animal health service delivery is a cross-cutting issue that represents both a subject of its own (what is the best institutional framework? how should service organisations be managed?) and a component of other research (what is the best way to deliver technology x?; what is the delivery potential of a technology?). The following list emphasises the institutional and organisational elements, and applies to many of the specific diseases identified in the workshops for which delivery and adoption of available technologies were identified as priorities.

9.2.3.1 Possible research areas: institutional and organisational

- **Sustainability of para-professionals.** Widespread experience in Africa and Asia suggests that para-professionals enhance the access of the poor to drugs, treatment

and advice. However, they are very much dependent on the support of specific projects, rather than the communities they serve. How can their financial and institutional sustainability be assured after the withdrawal of specific project support?

- **Organisational models for private clinicians.** What models have private clinics adopted to ensure their survival, how successful have they been, and how do developing and developed country experiences compare? What has been the drop-out rate and what are the implications in terms of private and public costs?
- **The new role of district veterinary officers (DVOs).** In a privatised and decentralised veterinary service, what will be the necessary resources and skills of the remaining members of the state veterinary services. Issues might include costs and logistical constraints of establishing a 'networked' veterinary service, modes of interaction and partnership between public and private, vet and para-professional.
- **Appropriate indicators for animal health delivery.** Data on impact are extremely variable—this has been said many times before—and in spite of many well-argued research papers and current projects there is still no real agreement on how to assess the potential or impact of a delivery service. Could a system be proposed that draws together the most commonly available data (quantitative and qualitative) and encourages donors to standardise? This would need to be a multi-collaborator project to overcome the problem of small projects in reaching a wide audience.
- **Cross-sectoral comparison of animal and human health.** Holden et al. (1996) pointed out that there were hard indicators to assess the impact of human health services reform but very little hard evidence on the impact on non-state organisations in animal health. In carrying out the present review, the authors found interesting information and methodology in the human health literature that had not 'travelled' into animal health. The World Bank Public Sector Management project, investigating links between public sector financing and poverty alleviation, would be a useful cross-reference (www.econ.worldbank.org/view.php?type=20andid=1613andtopic=21). Linked with this might be a closer examination of holistic provision of human and animal healthcare at the grassroots, following on from suggestions by Ward et al. (1993), the FARM-Africa approach described by Field (1991) and comments by McCorkle and Mathias in the FAO Electronic Conference, 1997.
- **Policy research** In addition to policy research related to the structure of animal health delivery systems (e.g. the role of para-professionals), a number of other policy issues need to be addressed to better support decision-making on the implementation of disease control strategies. Of particular interest is the role of animal disease as a constraint to the globalisation of livestock trade.

9.2.3.2 Possible research areas: technology

- **Development or adaptation of technology to fit a prevailing delivery system.** This has already been done for RP by developing the thermostable vaccine. Another application that immediately springs to mind is TBD immunisation, where the protection level achieved by a dose of vaccine may be of less importance than the ease and total cost (over the animal's life) of delivering it: a dual stratum approach may even be appropriate.

9.2.3.3 **Possible research support areas**

- **Guidelines for assessing the 'deliverability' of technology.** It is becoming increasingly important for technical research proposals to include an assessment of the potential for technology dissemination, yet there are no widely accepted guidelines for how this assessment could be made. Box 9.1 suggests an approach.
- **An animal health delivery databank.** This would be directly accessible to development workers around the world, and would speed up preparation of research proposals, make them more relevant, and encourage researchers from other sectors, e.g. human health, to participate. The Livestock Environment and Development Initiative (LEAD) (www.fao.org/LEAD) is a multi-donor initiative doing something of a similar—although more ambitious—nature for livestock and the environment.

Box 9.1 Deliverability checklist for animal health technology research

Expected effect on the economic cost to poor livestock producers by reduction of incidence, impact and cost of prevention or treatment

- **Accessibility**
  Reduced time/distance/inconvenience for producers to obtain service. Technology is designed to be delivered through service providers most likely to be available to poor livestock owners, or through a range of providers who may be available; dissemination information is designed to be easily distributable to appropriate providers.
  Outcome: *Increased uptake, leading to reduced incidence or impact*
- **Acceptability**
  Technology is designed to be easy to use; or the dissemination method is designed to increase provider and producer understanding of its use; or provided in a size, packaging or with a storage life that closely fits what poor livestock owners want; or the means of promotion uses the most appropriate knowledge source.
  Outcome: *Increased uptake, technology delivered 'fresh', leading to reduced incidence or impact*
- **Affordability**
  Cost of the technology is reduced, for example, by appropriate package sizes; or it is designed to require minimal visits from a healthcare provider; or it is designed not to be too time-critical, so that use can be made when money is available.
  Outcome: *Increased uptake, leading to reduced incidence or impact; also, reduced cost to livestock owners*
- **Sustainability**
  Shelf life and storage requirements provide appropriate flexibility for the service providers who are likely to distribute the technology; or provision of the technology is done in a way that reduces risk for private providers.
  Outcome: *Increased uptake, technology delivered 'fresh', leading to reduced incidence or impact*

9.3 Research opportunities for specific technologies for the control of specific diseases

9.3.1 Generic issues identified from regional workshops

9.3.1.1 Vaccines

No vaccines exist for some diseases of importance to the poor, and the efficacy of existing vaccines, in terms of length of immunity afforded, is often inadequate.

Thermostable vaccines would be highly desirable particularly in areas where transport of vaccines is carried out under difficult conditions with frequent delays.

The route and ease of administration is most important to facilitate use by such non-veterinary staff as community-based animal health workers (CAHWs).

The issue of who should be permitted to have access to vaccines was also raised. There is often a conflict between the need for professional supervision of biological products, and the more practical aspect of achieving the highest coverage and best services to the poor that involves the lower cadres of animal health workers and farmers themselves. There is a need for pragmatic policies for the delivery of vaccines that do not constrain effective disease control.

9.3.1.2 Diagnostics

For many livestock diseases of importance to the poor, there are currently no appropriate diagnostic tests available. This can be a major constraint to effective disease control. A general lack of information on the incidence/impact of some diseases is compounded by a lack of adequate and appropriate diagnostics. Cheap, rapid, sensitive and specific pen-side tests are desirable for many diseases.

One of the constraints to the availability of diagnostics, and services to go with them, is cost, and who bears that cost. This is considered to be an area that deserves research. It clearly depends on for whose benefit the diagnosis is being made—for individual farmers or for national benefit, among other things.

9.3.2 Specific research opportunities identified by research scientists

The format requested for data assembly on research opportunities is shown in Appendix 3. The overall responses were very good, particularly given the short time frame and the need for wide consultation, but not all contributors followed the format provided, and there was some variability in the quality and level of detail provided. Some contributors paid particular attention to the relevance of recommended research to the poor, while some provided broader, more generic recommendations. There was also wide variation in the number of scientists contributing to the assembly of research opportunity data. In general, the research costs were not well defined, and probably tended to be underestimated. To address these deficiencies, the products of these consultations were subsequently reviewed at two workshops, one of leading researchers in Europe (held at the Institute for Animal Health (IAH), Compton, UK) and one of researchers at ILRI in Nairobi, Kenya. In addition, a review of the overall study was carried out by other international organisations actively involved in animal health R&D (FAO, OIE, WHO, IFPRI), in a one-day meeting held at FAO headquarters in Rome, Italy.

It must be emphasised that this listing of research opportunities for specific diseases is not exhaustive, either in terms of the diseases it covers (reviews of research opportunities were not commissioned for some of the syndromes that emerged as high priority,

such as neonatal mortality), or in terms of research opportunities. Furthermore, given the bias to laboratory research of many of the research scientists involved in this process, there is generally a greater emphasis on technology development, such as vaccines and diagnostics, than on delivery and adoption research.

9.4 Synthesis of research opportunities

A synthesis of the research opportunities in the major categories identified by the different groups (technology development or modification, epidemiology and impact assessment, delivery and adoption) are presented below for those diseases for which expert assessments were commissioned. This brings together, for each of the priority diseases, the research issues raised by all the different groups participating in the study[1].

Gastro-intestinal (GI) parasitism

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Development of vaccines to GI helminths	L	M–H	F
Therapeutic	New drugs	L	H	L
	Medicated feed	S	L	E
	Ethnoveterinary medicines	S	L	G
Other	Host genetic resistance	L	M–H	F
	Biocontrol (larvicidal fungi)	S–M	L–M	F–G
Epidemiology	Integrated control options			
	Minimising resistance	S–M	M	G
Delivery and adoption	Delivery system analysis			
	Delivery field trials (including information)	S–M	L–M	G

The major research opportunities rest in the area of development, delivery and adoption of measures that can be implemented by and are effective for poor farmers. Technologies are generally available, but methodologies for their use, and access to them at appropriate cost for poor farmers, are urgently required. Anthelminthic resistance is not thought to be a major problem at present among poor farmers, but with increased use of anthelmintics and adoption of improved animals from commercial system sources it could become more widespread.

Genomics studies can provide new insights to guide both drug and vaccine development. Vaccines probably need to be considered very carefully, as anthelmintic resistance has proved to be a major developing global problem.

Basic diagnostic tools are generally available to support the assessment of control programmes (impact, delivery and adoption).

Neonatal mortality

Research opportunities to reduce neonatal mortality lie principally in delivery and adoption of appropriate well-tested management practices, and the determination of specific causes of mortality in species and systems where it is unduly high. During the SA regional workshop, emphasis was put on health and production management systems

1. For all the tables in section 9.4
Time frame (years): Short (S) ≤3; Medium (M) 4–10; Long (L) >10
Annual cost (US$): Low (L) <100,000; Medium (M) 100,000–1,000,000; High (H) >1,000,000
Probability of success (%): Excellent (E) >90; Good (G) 60–90; Fair (F) 30–60; Limited/low (L) <30
? = not estimated by expert panel; Blank = research opportunity not proposed

and epidemiology (including information) for poor farmers and improved availability of available vaccines and drugs. No expert research opportunity assessment was commissioned.

Foot-and-mouth disease (FMD)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Refinement of available vaccines for longer immunity (12-month target), greater cross-immunity, and greater thermostability	M	H	E
	Better inactivation methods to improve vaccine safety, without compromising efficacy			
Diagnostic	Rapid pen-side diagnostics	S	M	E
	Strain identification	S	M	E
	Distinguishing vaccine versus natural infections	S	M	E
Epidemiology	Efficacy of vaccines in water buffalo	S	L	E
	Strategies for enhancing vaccination coverage	S–M	M	E
	Surveillance and movement information	S–M	M–H	G
	Assessing transmission (carrier states, wildlife reservoirs)	S–M	M–H	G
Delivery and adoption	Delivery system analysis (selective use in high producing animals)	S	L–M	E
	Cost-benefit studies on alternative intervention options			
	Who benefits and who pays ?			

There are many research opportunities for FMD control and eradication. The need for better and safer vaccines, with longer immunity, diagnostics with the ability to differentiate vaccinated animals from those suffering from natural infection, pen-side diagnostics, and better strategies and policies based on sound epidemiology and economics. The time frame and costs of epidemiological studies will depend on the spatial scale covered.

Ectoparasites

Identified as a priority in the WA, SA and SEA regional workshops. Main research opportunities were seen to be in the delivery and adoption of available control measures and advice for poor farmers. In SA the need for cheaper but efficacious drugs was noted. No expert research opportunity assessment was commissioned.

Liver fluke (fascioliasis)

There is some disagreement about whether vaccines are a research opportunity that should be pursued. Technically, there are significant opportunities, but the adoption of vaccines by the poor for what is often a sub-clinical condition is questionable. Major research opportunities include: identifying high-impact areas and improving the delivery, adoption and impact of control programmes for poor farmers. Better diagnostics are needed for these assessments. Cheaper drugs, efficacious for all parasite stages in the host, are required.

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Vaccine development	L	H	F–G
Diagnostic	Improve tests for field use	S–M	M	G
Therapeutic	Medicated feeds, Cheaper drugs	S	L	G
Other	Biological control, Molluscides, Host genetic resistance	M–L	M	G
Epidemiology	Integrated control options	M	M	G
	Incidence and impact	S	M	G
	Study cross-resistance with schistosomiasis	M	M	G
Delivery and adoption	Delivery system analysis	S–M	L–M	G
	Delivery field trials (including information)			

Reproductive disorders

Research opportunities were identified in all regional workshops. Reproductive disorders were recognised to be multifactorial as was the fact that epidemiological studies are required to identify the most important factors (infectious, nutritional, management) in high-priority systems. Enhanced diagnostic capacity appropriate for use by the poor would help in this. No expert research opportunity assessment was commissioned.

Newcastle disease (ND)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Modification of current vaccines to enhance delivery and adoption	M	L–M	G
	Combination with vaccines against other diseases			
Diagnostic	As part of general poultry disease diagnostic capacity	M	M–H	G
	Simple diagnostic tools			
Epidemiology	General assessment of incidence and impact of ND and other diseases in smallholder poultry	M	M–H	G
	Assessment of transmission dynamics and risk			
Delivery and adoption	How to deliver as part of a more general integrated support to smallholder poultry farmers	M	L–H	G

Thermostable live vaccines for ND have been developed that can be administered in feed or by eye-dropper providing an excellent control technology. The major research opportunity is in how to improve delivery and adoption of the vaccine to poor poultry producers and, once the vaccine is adopted, how to capture its full benefits by helping farmers to cope with other major disease, nutrition and management constraints in intervention packages. The cost of delivery and adoption studies will vary with the scale of the geographic coverage required.

Anthrax

See research opportunities for zoonoses.

Toxocara vitulorum

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Epidemiology	Integrated control options based on pyrantel use	S–M	L–M	E
Delivery and adoption	Delivery system analysis Delivery field trials (including information)	M	M	G

The major research opportunity is to evaluate available drugs and management strategies to improve the delivery and adoption of control programmes on poor farms. An effective protocol has been developed that requires testing, accompanied by an analysis of why it is not in more widespread use at present. Research should first focus on buffalo calves in Asia where losses are highest. Experts did not support research into vaccines or diagnostics.

Nutritional and micronutrient deficiencies

With respect to animal health, two research areas were proposed during the SA regional workshop. The first was to map areas of micronutrient deficiencies. The second and major one was to include some elements of nutritional research into the assessment of other health and health management programmes. Improved diagnostic 'tests' for deficiencies are needed to support such studies.

Haemorrhagic septicaemia (HS)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	New adjuvants	M	L	E
	Better production methods	M	L	G
	Enhanced immunogenicity (1-year target)	M	L	F
Diagnostic	Improved diagnostics to support field studies	M	L	G
Epidemiology	Incidence and impact Carriers and transmission Association with vitamin A	M	M	G
Delivery and adoption	Delivery system analysis Delivery field trials (remote areas)	M	M	G

Four major research opportunities exist. The first is to conduct field studies to better estimate the incidence and impact in different production systems, and to better define factors affecting disease transmission. Improved diagnostics would aid this, and are a major requirement. Modifying available killed vaccines to improve their efficacy and achieve a longer duration of immunity are also major research opportunities. The delivery and adoption of vaccines is considered more of a problem in remote areas and research should be linked to more generic delivery research in pastoral and agro-pastoral areas.

Peste des petits ruminants (PPR)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Develop recombinant and marker vaccines	M	M	G
	Develop combined vaccines incorporating PPR			
	Field testing of recombinant vaccines			
Diagnostic	Better field tests	S–M	L	G
Epidemiology	Incidence and impact	M	M	G
	Transmission/reservoirs	S	M	G
	Community surveillance	M	M	F–G
Delivery and adoption	Community-based and other delivery	M	L–M	F–G

PPR is a poorly recognised disease problem, thus one important research requirement is to estimate the incidence, impact and transmission dynamics under different production systems. Better diagnostic tests and community surveillance systems are considered as important tools for this. The efficacy of the newly available vaccines needs to be better evaluated under a range of different conditions. The development of a molecular vaccine that can be delivered nasally, marked to distinguish vaccinates from naturally infected sheep and goats, was identified as an opportunity. The ability of new vaccines to provide long-term immunity needs to be assessed. For enhancing vaccine delivery and coverage, community-based and other delivery systems need to be assessed.

Brucella abortus (Brucellosis)

See research opportunities for zoonoses.

Haemonchosis

Technology development was not stressed as a research opportunity required for poor farmers, even though there are several opportunities in the areas of vaccine development and the use of anti-larval fungi. Continued study of anthelminthic resistance and genetic resistance of some tropical breeds in the context of integrated control programmes was stressed. Targeting such programmes and enhancing their adoption and impact through epidemiological and delivery and adoption field studies and modelling is seen as a crucial research opportunity.

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	New vaccines	M–L	H	F–G
Therapeutics	New drugs	L	H	G
	Medicated feeds	S	L	G
	Ethnoveterinary medicines	S	L	G
Other	Host genetic resistance	L	?	?G
	Biocontrol (use of larvicidal fungi)	S–M	L–M	F–G
Epidemiology	Incidence and impact	M	M	G
	Integrated control options	M	M	G
	Minimising resistance	M	M	G
	Test current vaccines	S	L	L
Delivery and adoption	Delivery system analysis	S	L	G
	Delivery field trials (including information)	S	L	G

Respiratory complex

Better diagnosis and improved knowledge of the epidemiology of this cluster of disease entities were the only research opportunities noted. No expert research opportunity assessment was commissioned.

Trypanosomosis

(see also research opportunities for zoonoses)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Vaccine development			
	–Anti-infection	L	H	L
	–Anti-disease	S–M	M	F
Diagnostic	Molecular diagnostics for research			
	Parasite characterisation	M	M	G
	Drug resistance	M	M	G
Therapeutic	Identify new drugs	L	H	G
	Ethnoveterinary drugs	M	L–M	L
Other	Vector control / eradication	M–L	H	G
	Vector genomics	L	H	?
	Repellants and baits	M	M	G
	Trypanotolerance	M–L	H	L
Epidemiology	Integrated control options	M	M	G
	Minimising resistance	S–M	M	G
	Transmission	S–M	M	E
Delivery and adoption	Willingness to pay	S	L	G
	Community-based vector control	M	M	L

Priority research opportunities for trypanosomosis are controversial. Research opportunities for much-needed technologies are complex, long-term and expensive for vaccines, drugs and host genetics, but rapid advances in genomics and proteonics may provide new options. It is generally considered that the probability of developing a successful anti-infection vaccine is low. The capacity to develop new drugs is in the hands of the pharmaceutical industry, reluctant to embark on such a process in the face of limited financial viability. However, commitment to develop drugs for human trypanosomosis could have a major positive impact for animal trypanosomosis.

Large-scale vector control and eradication programmes are operationally complex and expensive.

Enhancing farmer-based integrated control is seen as the main opportunity in the short to medium term, incorporating drugs (used at reduced levels), management of emerging resistance, vector control, use of tolerant animals and management options. Research into the economics and strategies for delivering integrated trypanosomosis control to poor farmers needs further attention.

Mastitis

Research opportunities for mastitis were identified in the ECSA and SA regional workshops. These include determining the incidence and impact in different circumstances and helping farmers to diagnose and treat clinical cases as cheaply and efficaciously as possible. There are no new technology development opportunities, rather getting what is currently known and available applied. No expert research opportunity assessment was commissioned.

Coccidiosis

Coccidiosis was considered an important problem in many species in the regional workshops but participants were unsure of its incidence and impact. Thus, incidence and impact studies are a clear research opportunity. Available drugs and vaccines for poor farmers need to be assessed. No expert research opportunity assessment was commissioned.

Trypanosoma evansi (Surra)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine Diagnostic Therapeutic	These research opportunities would be linked to research under the other trypanosomoses. However, there are indications of greater opportunities with *T. evansi* that could affect time frames and probabilities of success.			
Epidemiology	Incidence and impact Drug resistance	S–M	M	G
Delivery and adoption	Advice and delivery for drugs and other integrated control	S–M	M	F–G

The major research need is to obtain a better understanding of the incidence and impact of *T. evansi* infections. In areas where this disease might be considered of priority, research is required on optimising control strategies for poor farmers and how they can be delivered and adopted. Other research into technologies (except for tsetse control) can be linked to other trypanosomosis research. Developing a vaccine for *T. evansi* infection is considered more likely than for tsetse-transmitted trypanosomes, as the parasite has a much smaller repertoire and there is evidence of population immunity resulting from field infections. The efficacy of drugs and development of resistance in different host species is not well known.

Rinderpest (RP)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Greater thermostability	M	M	F
Diagnostic	Modify tests	S	L–M	G
Epidemiology	Role of wildlife	S	M	G
	Surveillance	M	M	G
	Community factors in transmission	S	M	G
Delivery and adoption	Delivery systems (community-based)	S–M	M	G

The research opportunities for RP control are to consolidate the progress that has been made over the past two decades. These centre around the eradication of RP in cattle in its last foci, and require a better understanding of the local epidemiological issues in the relevant pastoralist areas. Whether RP virus will persist in wildlife in East Africa is another remaining research need. As the incidence of RP decreases further, good diagnostics for surveillance will become increasingly important.

Contagious bovine (and caprine) pleuro-pneumonia (CBPP and CCPP)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Develop new vaccines	M	M	G
	Field test vaccines			
	Improve freeze drying	S	L	F
Diagnostic	Enhance performance/develop better tests	M	M	G
Therapeutic	Evaluate role of therapy in transmission (including effect on carriers)	S	M	G
Other	Assess host immunology (poor performance of current vaccines)	M	M–H	F
	Assess genetic resistance	L	H	F
Epidemiology	Impact	S	L	G
	Transmission dynamics (outbreak factors)	M	M	G
	Risk assessment of introduction	S	L	G
Delivery and adoption	Delivery system analysis	S	M	G

The two major areas in which research opportunities exist are in technology development and epidemiology. Better vaccines (improved protection and thermostability) and diagnostics are required if CBPP is to be better controlled in the field. Vaccine development will require short-term research on current vaccines to lengthen and enhance their protection, and improve their thermostability. It will also require longer-term development of better recombinant vaccines. Higher-quality epidemiological information is required in order to target control measures and support the delivery of control efforts. Models can play an important role in strategy development.

For CCPP, the vaccines are inactivated (versus live vaccines for CBPP). Given the lower value of small ruminants, combined vaccines have great attraction. The research opportunities in technology development were virtually identical to those with CBPP except for technical variations in vaccine. The incidence and impact of the disease is unknown, and the delivery and adoption issues with small ruminants are somewhat distinct from those with CBPP.

Diarrhoeal diseases

As for respiratory syndromes and other general categories, better understanding of the causation and epidemiology, and the use of available technologies and knowledge for optimal delivery/adoption were considered most important in the regional workshops. No expert research opportunity assessment was commissioned.

Rift Valley fever (RVF)

See research opportunities for zoonoses.

Heartwater

Technology development research is a major opportunity as new vaccines are required. Larger-scale production methods for previously developed inactivated vaccines are needed. The incidence and impact of heartwater is well known for some areas and production systems, and study methods could easily be transferred to other areas where the incidence and impact is relatively unknown. More specific diagnostic tests are needed to support this. Delivery and adoption to farmers needs to be considered in conjunction with the other TTBD discussed below (anaplasmosis, babesiosis, theileriosis and dermatophilosis).

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Field testing of inactivated vaccines	M	M	G
	Recombinant vaccine development	M–L	H	G
Diagnostic	More specific molecular tests	S–M	M	G
Therapeutic	Field evaluation of slow release therapeutics	S	L	G
Other	Test tick decoys	S	L	G
Epidemiology	Impact and incidence	S–M	M	G
	Transmission studies	S	M	G
	Integrated control strategies	M	M	G
Delivery and adoption	Delivery system analysis	M	M	G

Sheep and goat pox and lumpy skin disease

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Vaccine development: recombinant, multi-pathogen	S–M	M	G
	Modify current vaccines and diagnostics	S–M	M	G
Diagnostic	Develop polymerase chain reaction (PCR) tests for research studies	S–M	M	G
Other	Genetics	L	M	F
Epidemiology	Molecular epidemiology and transmission studies	M–L	M	G
	Impact assessments and epidemiology	S–M	M	E
Delivery and adoption	Impact of control in the field	M	M	G

There is general consensus that better vaccines are required and are possible. This might be linked to pox virus infections in other species (camels, buffalo). Currently, severe adverse reactions often occur in immunogenic vaccines. There are opportunities to better understand the transmission using new molecular tools. As with other diseases, research into delivery and adoption options for the poor has not been done and is required.

Babesiosis

Major research opportunities are similar to the other TBDs (see heartwater).

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Develop a recombinant vaccine	M–L	H	G
Diagnostic	Differentiate *B. bovis* from *B. bigemina*	S–M	M	G
Other	Anti-tick vaccines	L	H	F
Epidemiology	Incidence and transmission studies	M	M	G
	Integrated control strategies	M	M	G
Delivery and adoption	Delivery system analysis Delivery field trials (information)	M	M	G

Tropical theileriosis

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Inactivated vaccines	M	M	G
	Recombinant vaccines	M–L	H	G
Diagnostic	Molecular assays for research			
	Pen-side tests	M	M	G
Therapeutic	Identify less-costly drugs (including ethnoveterinary)	M–L	M–H	G
Other	Breed susceptibility/tolerance	L	H	F
Epidemiology	Transmission dynamics	S–M	M	G
	Defining epidemic states	S–M	M	G
	Integrated control options	M	M	G
Delivery and adoption	Delivery system analysis	M?	M	G

Major research opportunities are similar to the other TBDs (see heartwater).

Black-leg

No expert research opportunity assessment was commissioned. Regional workshop participants felt that the current vaccine was good, but that the epidemiology, and thus disease control targeting, was poorly understood and therefore the main research opportunity at present.

Dermatophilosis

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Evaluate available vaccine	M	M	G
	Develop recombinant vaccine	L	H	F–G
Other	Genetic markers and selection studies	M	M	F–G
	Diagnostic tools for genetic markers	S	L	G
Epidemiology	Study risk factors	M	M	G
Delivery and adoption	Integrated control with trypanosomosis and TBDs	M	M	G
	Delivery system analysis			

The main research opportunity in technology development is to better understand the mechanisms of host immunity/resistance that could provide a future recombinant vaccine or genetic selection tools. Epidemiology (incidence, impact and risk factors) and delivery and adoption issues are another major opportunity as these are relatively unknown. Research into how the control of dermatophilosis can be linked to the control of trypanosomosis and TBDs is considered important.

Foot problems

No expert research opportunity assessment was commissioned.

Infectious bovine rhinotracheitis (IBR)

No expert research opportunity assessment was commissioned.

Fowl cholera

No disease-specific research opportunities for fowl cholera were identified by the expert group on poultry diseases. Its incidence, impact and potential for control on smallholder farms would be investigated under the generic smallholder poultry research opportunities

proposed in Appendices 8 and 12 (Permin and Madsen, 2002a; 2002b). General research into smallholder poultry was also considered a priority in the regional workshops.

Anaplasmosis

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Recombinant vaccines	M–L	H	F–G
Diagnostic	Molecular assays and pen-side tests	S	M–H	G
Epidemiology	Incidence and transmission studies	M	M	G
	Integrated control strategies	M?	M	G
Delivery and adoption	Delivery system analysis	M?	M	G

Major research opportunities are similar to the other TBDs (see heartwater).

East Coast fever (ECF)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Recombinant vaccine	M	H	G
Diagnostic	Molecular assays for different strains	M	M	G
Therapeutics	Identify less costly drugs (including ethnoveterinary)	M–L	M–H	G
Other	Molecular epidemiology and genomics	M	M	G
Epidemiology	Integrated TBD control options for different production systems that include vaccines	M	M	G
Delivery and adoption	Delivery system analysis	M?	M	G
	Delivery of current live vaccine	S	L–M	G

Major research opportunities are similar to the other TBDs (see heartwater). ECF offers an animal model for research into certain aspects of the efficacy of vaccines for malaria in humans.

Infectious coryza and fowl pox

As for fowl cholera above.

Hog cholera (Classical swine fever, CSF)

No expert research opportunity assessment was commissioned. Research opportunities highlighted in the SEA regional workshop included a better understanding of virus strains circulating and the efficacy of vaccines against those strains.

Tick infestation

No expert research opportunity assessment was commissioned. Research opportunities linked to integrated control of TBDs.

Duck virus enteritis (DVE)

No expert research opportunity assessment was commissioned. Better vaccines and vaccination strategies considered a priority.

Orf (Contagious pustular dermatitis)

No expert research opportunity assessment was commissioned.

***Brucella suis* (Brucellosis)**

See under research opportunities for zoonoses.

Zoonoses

Brucella abortus (Brucellosis)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Modified vaccine (either subunit or killed)	M	H	E
	Oral vaccines	M	H	E
Diagnostic	Modified direct binding assays			
	Improved agglutination assays for humans	S	H	E
Therapeutic	Low-cost therapy regime	M	M	G
Epidemiology	Differential diagnosis in humans	S–M	M	G
	Surveillance methods	S–M	M–H	G
	Impact assessment	S–M	M	E
	Transmission dynamics	S–M	M–H	E
Delivery and adoption	Vaccine field trial	M	H	E
	Delivery system analysis	S	M	G
	Delivery field trials	S	M	E

Brucellosis due to *Brucella abortus* has been controlled or eradicated in most developed countries but is essentially uncontrolled in the developing world, despite some previous successes (e.g. Mongolia et al., 2001). Thus, key research opportunities revolve around identifying the opportunities for greatest impact (in many systems the incidence and importance is unknown) and developing control strategies to maximise adoption and impact for the poor. Improved vaccines and diagnostics would aid this process.

Brucella melitensis (Malta fever, Brucellosis)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Modified vaccine (either subunit or killed)	M	H	E
	Oral vaccines	M	H	E
Diagnostic	Modified direct binding assays			
	Improved agglutination assays for humans	S	H	E
Epidemiology	Differential diagnosis in humans	S–M	M	G
	Surveillance methods	S–M	M–H	G
	Impact assessment	S–M	M	E
	Transmission dynamics	S–M	M–H	E
Delivery and adoption	Vaccine field trial	M	US$ 2,000,000	E
	Delivery system analysis	S	US$ 1,000,000	G
	Delivery field trials	S	US$ 500,000	E

Brucellosis due to *Brucella melitensis* has similar research opportunities to *B. abortus,* but the incidence and importance are less well known. Field studies could investigate both species in many production systems. Uptake of animal vaccines is less likely than for *B. abortus*

Trypanosomosis

The main research opportunity is for control of sleeping sickness due to *Trypanosoma brucei rhodesiense* in eastern and southern Africa. The zoonotic transmission of *gambiense* sleeping sickness is considered less important in most areas, particularly in the high-incidence areas of central Africa. Current drugs for treating humans are expensive, difficult to access and toxic; thus new drugs are one research priority. Control of *rhodesiense* sleeping sickness through control in the cattle reservoir is considered a

cost-effective alternative, as are livestock policies to prevent the spread of infection beyond traditional foci. Impact assessment as proposed by Coleman (2002, Appendix 9) is necessary.

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	See comments under production diseases			
Diagnostic	Tests to differentiate species within the *brucei* group	S	M	E
Therapeutic	Development of new drugs	L	H	G
Epidemiology	Surveillance methods	S–M	M	G
	Impact assessment	S–M	M	E
	Transmission dynamics	S–M	M	E
Delivery and adoption	Delivery system analysis	S	M	E
	Delivery field trials	S	M	G

Bovine tuberculosis (TB)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Immune responses	M	M–H	G
	Vaccines for cattle and wildlife reservoirs	M–L	H	F
Diagnostic	Sensitive/specific field tests	S–M	M	G
	Strain typing	S	M	E
	Distinguish vaccination from natural infection	M	M	G
Therapeutic	Slow-release antibiotics	M	M	G
Other	*M. bovis* genomics	M	H	G
	Pathogenesis	M	M	G
Epidemiology	Incidence estimation	S	M	E
	Risk models	S	M	E
	Wildlife studies	S	M	G
	Interspecies transmission	S	M	G
	Economic impact	S	M	E
Delivery and adoption	Field trials of control	M	H	G
	Impact of control options	S	M	G
	Delivery system analysis	S	M	E

A critical research opportunity is to define the incidence, impact and epidemiology of bovine TB in different settings, as this is highly variable. The importance of bovine TB in humans needs to be better quantified in most systems. The diagnostic tools available are poor and thus improved tests would be a major assistance in field studies. Once target systems are identified delivery and adoption issues to the poor will be a priority. Current vaccines are not considered efficacious. Human tuberculosis, primarily due to *M. tuberculosis,* is increasing and the focus of considerable research. Aspects of drug resistance in *M. bovis* would be linked to this research.

Leptospirosis

No specific research opportunities were mentioned except in the SA workshop. In that workshop, research opportunities proposed were: studies on the incidence and impact and better vaccines and diagnostic tools. No expert research opportunity assessment was commissioned.

Anthrax

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Longer-term immunity and immunity to multiple strains	?	?	?
Epidemiology	Incidence estimation	M	US$ 1,000,000	G
	Economic impact	M	US$ 500,000	G
	Risk models	M	US$ 750,000	G
Delivery and adoption	Efficacy of control	M	US$ 1,000,000	G
	Delivery system analysis			

Major research opportunities are spatial/epidemiological studies for targeting high-risk areas (the incidence is not well known) and developing vaccine and information delivery strategies for poor farmers. Useful vaccines exist but are not well deployed. Developing a vaccine providing immunity for longer than a year would ease vaccine delivery. There has been considerable military research on anthrax vaccines.

Cysticercosis (*Cysticercus cellulosae* and *C. bovis*)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Confirmation of protection in experimental trials	S	M	E
	Vaccine	S	M	E
	Development of a vaccine delivery system suitable for developing-country use	M	M	G
Diagnostic	Adapt tests to user-friendly format	S	M	E
Therapeutic	Field trials	S	M	E
Epidemiology	Surveillance systems	S	M	E
	Transmission dynamics			
Delivery and adoption	Strategies to enhance community education, food hygiene and other interventions	M	M	E

The main research priority is to investigate the potential of recent breakthroughs in vaccine development to determine if this will represent a major new strategy for the prevention of cysticercosis in pigs. As far as development is concerned, better community education and food hygiene interventions to prevent human infections are important, particularly for *C. cellulosae*. This will require adaptation of food hygiene strategies to make them appropriate in local settings. Information is required on the incidence in pigs, and if other species involved. Better diagnostic tests would facilitate these epidemiological studies, see review by Willingham (2002, Appendix 10).

Buffalo pox

Development of a vaccine was identified as a research need in the SA workshop. Based on other pox vaccines, this should not be difficult. No expert research opportunity assessment was commissioned.

Toxocara vitulorum (Toxocariasis)

See research opportunities for production diseases.

Rift Valley fever (RVF)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Vaccine development based on current and new antigens (no current human vaccine and animal vaccines are teratogenic)	M–L	M	F
Diagnostic	Field/pen-side test	S–M	M	E
Epidemiology	Understanding RVF epidemiology and entomology	M	M	G
	Transmission models	M		G
	Geographic information system (GIS) risk models	S	M	E
	Economic impact models	S	M	E
Delivery and adoption	Delivery of vaccines and diagnostics to support trade	S	L	G

The two main research opportunities are to improve the ability to predict RVF outbreaks in order to target prevention and control programmes, and to develop efficacious and safe vaccines for animals and humans. The RVF virus is in the haemorraghic group of viruses and thus any handling of the virus must be done in a high-security laboratory facility. It is expected that much basic research will be carried out in developed countries based on the potential of RVF virus as a biological warfare agent.

Japanese B encephalitis

No specific research opportunities were mentioned except in the SA workshop during which assessing impact of control in pigs versus humans was proposed. No expert research opportunity assessment was commissioned.

Schistosomosis japonicum

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Identify candidate antigens and develop a vaccine	L	H	G
Diagnostic	Develop field/pen-side test	M	M	E
Therapeutic	Optimise treatment protocols in animals	S	M	E
Epidemiology	Agricultural risk factors Impact of human therapy Transmission/reservoirs Spatial risk	M	M	E
Delivery and adoption	Community intervention programmes	M	M	E

A key research opportunity is to develop community intervention programmes based on local agricultural and social practices and disease epidemiology. Vaccines, if they can be developed, could play an important role in community-based control.

Botulism

No research opportunities were proposed in any of the regional workshops and no expert research opportunity assessment was commissioned.

Trichinellosis

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Development of a larval vaccine	L	M	G
Diagnostic	User-friendly field test	S	M	E
Therapeutic	Field testing of drugs and protocols	S	M	E
Epidemiology	Incidence estimation Economic impact	S	M	E
Delivery and adoption	Strategies to enhance community education, food hygiene and other interventions	M	M	E

As with cysticercosis, the main research priority is to develop better community education and food hygiene interventions to prevent human infections. This will require adaptation of food hygiene strategies to make them appropriate in local settings. The role of vaccines and therapy in these programmes will need to be assessed. Information is required on incidence and impact. Adaptation of current diagnostic tests for developing countries would facilitate these epidemiological studies.

Mange

Research to enhance farmer education on management and treatment of mange were proposed in the SEA and SA regional workshops. No expert research opportunity assessment was commissioned.

Brucella suis (Brucellosis)

See *Brucella abortus* and *Brucella melitensis* for research opportunities.

Orf (Contagious pustular dermatitis)

No research opportunities were proposed in any of the regional workshops and no expert research opportunity assessment was commissioned.

Unranked but with expert research opportunity assessments

Hydatid disease (hydatidosis)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Field trial of sheep and goat vaccine	S	M	E
	Development of canine vaccine	L	M	G
Diagnostic	Develop user-friendly tests	S	M	E
Therapeutic	Field trials and protocols	S	M	E
Epidemiology	Incidence estimation Economic impact	S	M	E
Delivery and adoption	Strategies to enhance community education, food hygiene and other interventions	M	M	E

African swine fever (ASF)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Vaccine	Attenuated vaccine	M	M	G
	Recombinant vaccines	L	H	F–G
Diagnostic	PCR tests	M	M	G
	Strain-specific tests	M	M	G
Other	Molecular epidemiology and genomics	L	H	F–G
	Genetic resistance of warthog and bushpig	L	H	?
Epidemiology	Basic epidemiological information on carriers, transmission	S–M	M	G
	Track strains associated with outbreaks	M	M	G
Delivery and adoption	Delivery system analysis	M	M	G

Research opportunities are in four broad areas: The first is to better understand the epidemiology of the disease and how to target control efforts to assist resource-poor farmers. Improved diagnostic tests will be important for this. The second area is in vaccine development. Vaccines are unlikely to be used in the developed world, where slaughter policies would likely be used if the disease is introduced into ASF-free countries, but they could be of significant impact to smallholder pig producers in endemic areas of Africa. Linked to this would be a third area of investigating variations in host genetic resistance. The final area is in the assessment of strategies to deliver available control more effectively, particularly to control outbreaks.

Gumboro disease (Infectious bursal disease, IBD)

Research opportunity	Type of research	Time frame	Annual cost	Probability of success
Diagnostic	Adapt tests to support general poultry diagnosis	M	M	E–G
Epidemiology	Incidence and impact for poor farmers	M	M	G
Delivery and adoption	Delivery system analysis	M	M	G
	Willingness to pay	S	L	G

There was broad support by poultry experts for research targeted at adapting existing tests and control programmes for developing-country and poor-farmer circumstances. This was envisaged as a broad programme of support into poultry disease management for poor farmers rather than targeting specific diseases in isolation. The role of genetic diversity of poultry and its association with disease resistance merits consideration.

9.5 Research opportunities in genetic resistance of livestock to disease

Most of the disease-specific research opportunities identified both in workshops and by research scientists gave greatest attention to vaccines, diagnostics, therapies, epidemiology and economics, and the delivery of veterinary services. The role of research into the genetics of disease resistance was not prominent due to the perceived long-term gestation period before impact on the farm can be achieved. Nevertheless, this area could play an extremely valuable role in the future, given the fast pace of scientific progress, and as illustrated below, there are some short-term research opportunities. A review of the broad research opportunities into the genetics of disease resis-

tance was therefore commissioned, and is provided by Gibson (2002) in Appendix 13. The key features are summarised below.

9.5.1 The better use of indigenous and exotic disease-resistant livestock

It is considered that virtually all indigenous livestock breeds have varying degrees of resistance to the long-standing endemic diseases present within their environment, and their use by the poor has many advantages. In addition, evolution of resistance in one geographic area may provide opportunities for exploitation in another. Examples are the use of trypanotolerant N'Dama cattle outside their original range, and of tick-resistant zebu *(Bos indicus)* cattle breeds in areas of northern Australia.

9.5.2 The use of disease resistance in crossbreeding

The genetic potential of using two breeds with complementary characteristics can often be captured for cross breeding, producing a new self-sustaining population. Thus one or both parents may provide disease-resistant characteristics.

9.5.3 Genetic selection for improved disease resistance

Over the past 50 years or so, the productivity and efficiency of dairy cattle, pig and poultry production in the developed world has been dramatically increased as a result of private, co-operative and public-sector genetic selection programmes. Such improvement programmes have generally focused on production and reproductive traits. Inclusion of disease resistance in selection objectives has only taken place in the past 20 years or so, and remains limited. This lack of attention to disease resistance in the developed world was quite logical, given that the impact of disease was relatively minor in most species due to the protection from disease afforded by modern production methods, prophylaxis and vaccination against infection, and cheap therapies for treatment of disease. The modern move to pay increased attention to disease resistance in selection objectives is driven by a combination of failing drug therapies as pathogens evolve resistance, and concerns about the impact on human health of widespread use of antibiotics as prophylactics and livestock growth enhancers.

Advanced statistical, data and project management tools for selection within populations are now routinely applied in the developed world, and use of molecular genetic information is increasingly being incorporated.

9.5.4 Genetic modification of disease resistance

Techniques for germ-line genetic modification of livestock have progressed markedly over the past decade. Techniques that deliver random insertion of gene constructs into genomic DNA are routine for cattle, sheep and pigs, and are being rapidly developed for poultry. Techniques based on homologous recombination allowing gene constructs to be inserted at target locations are under development, based on the embryo stem cell-like properties of somatic cell cultures used for generation of clones.

With the tools for genetic modification now available for several of the most important livestock species, the primary limitation to application to control of livestock disease is lack of sufficient knowledge about gene function to be able to design gene constructs with high probability of success in livestock. Existing techniques of biological research coupled with the rapidly expanding suites of genomic and post-genomic methodologies provide powerful tools for identifying potentially useful genetic mechanisms of disease resistance. A major advantage of genetic modification is that

Table 2.7 Research priority areas in genetic resistance to disease

Research opportunity	Areas of application	Years to completion	Years to application	Cost[1]
Documentation of disease resistance/tolerance characteristics of indigenous breeds globally, based on existing experimental, field and anecdotal information	Identification of key breeds for utilisation and conservation and further research	3	0	H[2]
Documentation of molecular genetic diversity to infer genetic relationships among breeds globally	Diversity information can be used to pick 'best bets' of breeds for detailed investigation[5]	5	0	M
Field and experimental studies to determine levels of resistance to key diseases of key indigenous breeds locally	Recommendation for retention of use of local breeds and for management interventions required if exotic breeds are utilised	1–5	0	L/M[3]
Epidemiological/genetic/management trials to assess impact of genetic resistance of available breeds on disease transmission and efficacy of non-genetic intervention strategies.	Design of appropriate integrated control strategies and recommendations for appropriate breed use and promotion	1–5	0–5	L–H[4]
Comparative international trials of selected breeds and their crosses, involving importation of two or more breeds to two or more potential regions of application and testing them and their crosses for disease resistance, survival, production and reproduction under controlled conditions.	Exploitation of breeds/crossbreeds in regions outside their centre of origin	3–10	1–10	L–H[4]
Mapping and characterisation of genes controlling disease resistance in livestock	Development of molecular markers for marker-assisted selection. Identification of genes and mechanisms involved for use in selection, and in development of therapeutics or vaccines	5–20	5–20	M/H
Mapping and characterisation of genes controlling disease resistance in mice	Identification of genes and genetic mechanisms to assist gene identification in livestock, to develop novel interventions and to design genetic modifications of livestock	5–10	0	L/H
Identification of genes controlling disease resistance in wildlife species, based on functional genomic tools developed for livestock.[6]	Design of genetic modification of livestock and development of novel intervention strategies.	5–15	0	
Studies of genetic variation within populations	Genetic improvement programs exploiting genetic variation within populations	3–10	5–20	L–H[4]
Design of applied breeding programs, with emphasis on long-term sustainability and dissemination of product, and determining impacts on disease impact and integrated management strategies	Genetic improvement programs exploiting genetic variation within populations	3–5	5–20	L/M
Genetic modification of livestock to enhance disease resistance and/or adaptation and production traits[7]	Dissemination of stocks with novel suites of disease resistance or introduction of resistance existing elsewhere into otherwise well-adapted stocks	5–15	5–20	M/H

1. Cost is per annum, per disease per breed (or per species for model species) unless otherwise indicated. Costs grouped as low (L = US$ 100,000), medium (M = US$ 100,000–500,000) or high (H = over US$ 500,000). Costs are estimated cost to donors, utilising existing global infrastructure
2. Cost is per livestock species for a global survey
3. Costs would generally be low, but could be medium for larger species (cattle/buffalo) and difficult diseases
4. Costs would depend on species, disease and size of trial. In most cases, costs would be low to medium
5. E.g. several breeds of sheep exhibit resistance to intestinal helminths. Diversity information could be used to select two or three breeds globally that have desirable characteristics, yet are genetically distinct and therefore have maximum chance of having evolved different genetic mechanisms of disease control. This maximises the chance of producing an outstanding new crossbreed/synthetic for minimum expenditure
6. Such tools will become available within the next couple of years for several livestock species
7. Initiation of genetic modification first requires prior knowledge to develop gene constructs with high probability of useful impact. Such knowledge is likely to start becoming available 2004 to 2006

genetic mechanisms of disease resistance can be transferred across species. Thus, elucidation of disease resistance mechanisms in wildlife species or in model organisms such as mice could lead directly to genetic modification of livestock.

9.5.5 Summary of researchable issues in genetics of disease resistance

In Table 9.3 are summarised broad areas of research into genetics of livestock disease, their potential areas of application, the relative cost of the research, the time from initiation to completion of the research and the time from completion of the research to application in the field (or the next research step in some cases). The categories of research are very broad, and diseases and species are neither identified nor prioritised. The researchable issues in Table 9.3 are intended only to indicate in the broadest sense where information is lacking and where researchable issues lie.

10 The balance between diseases with the highest impact and the opportunities for research on their better control: a synthesis of research priorities

10.1 A conceptual framework for classifying different research opportunities for poverty alleviation

Building on the typology of disease impacts on the poor developed at the end of Chapter 5, it follows that to have a sustained effect on the alleviation of poverty, there are three necessary, and quite obvious, outcomes of improved animal health. Each of these may be matched to a particular development philosophy. These are:

- **Secure the current assets (human, financial, social) of poor people who keep livestock, who consume livestock products, market livestock and livestock products, and who work as wage labourers with livestock, by reducing the risks they experi-ence through animal and zoonotic diseases.**

The review of the impact of diseases on the poor has shown that there is a wide range of diseases, disease syndromes and non-specific performance inhibitors to the production cycle that affect their livelihoods. These provide a barrier to their pathway out of poverty. Before the poor can contemplate taking on development activities to enhance the performance of their animals and reduce the health threats to and from their animals, it is important *to protect the assets they have.* In most cases, these are small numbers of animals, of a varying diversity of species, almost all of which are indigenous breeds and kept under traditional management practices. Improvements in the health of these animals, and of those people that keep and use them, is fundamental to all the major pathways out of poverty, regardless of whether they are livestock-based.

- **Enhance the marketing opportunities of the poor by controlling the diseases that affect the movement and marketing of livestock and animal products, primarily locally, but also regionally and internationally.**

Virtually all the poor of the world participate in marketing, be it in their labour services, in selling newspapers and cigarettes, or in the sale of livestock products such as eggs, meat, milk and skins. The pathway out of poverty involves improving the volume of the product marketed, and/or the quality of product, so increasing the revenue obtained. Access to this pathway is thus dependent on the control of diseases that either limit the movement of livestock or their products, or constrain the potential purchasers investing in them due to their poor quality with respect to food safety.

- **Reduce the constraints experienced by the poor to livestock-based pathways out of poverty through intensification (improved productivity and performance efficiency through the use of inputs).**

Having secured or protected current assets, improvement in the performance of livestock through the use of inputs (a new breed, more feed, better management, improved animal health services) provides a further perspective to the pathway out of poverty. This often involves having to deal with new disease constraints that did not compromise the original assets. The best example of this is the vastly different susceptibilities to the quality of feed and to animal diseases between indigenous and improved (exotic) breeds of livestock.

Behind each of these three outcomes, there are certain diseases that play a particularly important role, and these have been identified and ranked within the impact prioritisation

process. The next step is to review what can be done about these diseases, where research can play a role, and what type of research is necessary.

Reviewing the rankings of animal disease impact on these three outcomes, and the research opportunities elicited from different quarters, there are three major research and development categories of response to the three outcomes described above. These are:

- **Transferring knowledge and available tools to attack the classic performance inhibitors.** The development of improved livestock management, hygiene and preventive medicine practices for the production systems of the poor *through the transfer of available knowledge and technologies.*

It is clear that the poor are not able to take advantage adequately of the technological and knowledge advances in human and animal health made over the last 50 years or so. So the major constraints to the performance of their animals are still those that have been conquered in the developed world, such as the neonatal mortalities, the reproductive inefficiencies, the nutritional imbalances and deficiencies, and the ecto- and endoparasites. In theory, great progress could be made on all of these with the transfer of knowledge and some of the affordable technologies in what might be generally termed 'management packages'. In practice, that is not easily achieved. Furthermore, most of what is required is not research, but community development, and community involvement. The few research areas include a better understanding, in different priority systems in which the poor are very abundant, of how to best promote the uptake and sustained use of such packages, and of which technological components to include.

- **Making existing technologies more effective and appropriate for the poor.** Improved tools for animal disease control, better strategies for their use, better delivered to the poor.

There is a cluster of health constraints for which—although available technologies are there to help treat, control and prevent them—they, or their delivery, are imperfect, or even inappropriate. For trypanosomosis, for example, there are a selection of treatment and control methods, but which combination of methods fits which set of circumstances? For HS, as another example, prevention through vaccination before the monsoons is widespread, but how much more effective in reducing losses sustainably at this critical time would it be if the vaccine could induce a longer immunity? And for many diseases, how much more effective would their control be if the animal health services delivering technologies and information were better designed to serve needs and the pockets of their clients? This category contains a significant number of research opportunities, particularly in the areas of epidemiology and economics, impact assessment and the delivery and adoption of services, but also in the category of laboratory research. The prime example, also applicable to the human health field, is how can we reduce the reliance on the cold chain in the delivery of vaccines to the poor in tropical and subtropical environments?

- **Capitalising on developments in science—the next frontier.** The development, through research, of new tools and approaches appropriate for the priority constraints of the poor.

There are a few diseases in which clearly technologies that make a meaningful impact are just not available, but exciting new progress in science provides an opportunity for their development. The next 15 years could see much significant capitalising on the current widespread mapping of pathogen genomes and dissecting of immuno-

logical responses, with the aim of identifying protective antigens, and then presenting them in such a way that they successfully stimulate long-lasting immune responses.

If the desired outcomes of poverty alleviation approaches are then combined with the research and development opportunity categories in a matrix, it becomes apparent that there are priority investment opportunities to suit different philiosophical approaches to poverty alleviation (Table 10.1 [ES1]). Certain donors will prefer to have immediate impact on improving the conditions of the poor by focusing on securing their assets. Others are committed to supporting livestock-based intensification, while still others see improving access to markets as the longer-term key to development. The more one focuses on a specific production system, the clearer the divisions between these different contributions of disease control to poverty alleviation are, although certain diseases constrain all three pathways out of poverty, regardless of the scale of resolution. Therefore it should also be noted that while some research opportunities are clearly associated with one category of approach, others may fall in more than one category. As examples, HS vaccines are considered particularly important to reduce buffalo and cattle mortalities, and improve the contributions of these species to traction at the important time of year, so contributing to the 'securing assets' category. However, CBPP vaccines and diagnostics would contribute both to improving performance of animals currently kept (securing assets), but also to reducing the constraints this disease brings to the movement of animals, thus contributing to improving market opportunities.

10.2 Criteria for the inclusion of research opportunities in the conceptual framework matrix

The following criteria were applied to identify a basket of research options and classify them within the conceptual framework matrix:

- The disease has a high impact on the poor. High impacts were generally derived from the high global or regional scoring
- The time frame for research products is within 15 years. Consequently, the shorter-term options were favoured
- The cost is compatible with the general donor expenditure on animal health research. As such, the low- to medium-cost options were favoured
- There was a medium to high probability of success
- There were significant opportunities identified by research experts based on the developments in the different fields of science
- There is research capacity to undertake the research.

It must be stressed that these criteria were applied in a group synthesis of data presented, and not in a strictly quantitative manner. The options presented in Table 10.1 therefore do not represent a definitive list of research priorities, but are intended to illustrate how the framework can be used to select research opportunities that contribute to different pathways of poverty alleviation.

10.3 Synthesis of animal health research opportunities

The research opportunities considered examples of best-bet investments within each of the three research and development categories will be examined in some more detail. These comprise disease-specific research opportunities, and two broad categories that cut across all three poverty alleviation pathways.

Table 10.1 (ES1) Relationship between different contributions to poverty alleviation and different types of research opportunities[1], with examples of research for the control of selected diseases/pathogens and disease syndromes

Research and development categories	Contributions to poverty alleviation		
	Securing assets	*Reducing constraints to intensification*	*Improving market opportunities*
Transferring knowledge and available tools	Neonatal mortality (G) Reproductive disorders (G) Nutritional deficiencies/imbalances (G) Endo- and ectoparasite control (G)	Hygiene issues for the prevention of mastitis (G) Heat detection in cows (as an example of reproductive disorders) (G) Integrated control of gastro-intestinal (GI) parasites, including haemonchosis, fascioliasis and coccidiosis (G)	Hygiene issues for the prevention of cysticercosis and other parasitic zoonoses (G)
Improved tools, better strategies, better delivered	Development of a more efficacious haemorrhagic septicaemia (HS) vaccine (SA, SEA) Testing and evaluation of new peste des petits ruminants (PPR) vaccine (WA, SA) Evaluation of strategic therapy and management strategy for the prevention of toxocariasis (SA, SEA) Newcastle disease (ND) vaccine delivery strategies (G) Impact assessment of alternative control strategies for contagious bovine pleuro-pneumonia (CBPP) and contagious caprine pleuro-pneumonia (CCPP) (WA, ECSA) Impact assessment of PPR and alternative control options (WA, SA)	Development and evaluation of integrated control measures for trypanosomosis[2] (G) Development of integrated control packages for GI parasites (G) Development of strategies to manage resistance to anthelmintics (G) Development of brucellosis control strategies (G) Development of integrated health and nutrition packages for village poultry (G) Development of production system-specific integrated packages for tick and tick-borne disease (TTBD) control[2] (WA, ECSA)	Testing of vaccine for *Cysticercus cellulosae* (G) Improved FMD vaccines (duration of immunity and serotype cross- protection) (G) FMD control strategy and policy development (G) FMD diagnostics to support control (G) Rinderpest (RP) surveillance and control strategies in final pockets (ECSA, SA) Impact assessment and epidemiology of bovine TB (G) Spatial targeting of anthrax control to poor (G)
	Impact assessment of constraints to productivity, and of specific diseases and their control (G) Delivery and adoption of animal health services and technologies issues (G)		
New tools and approaches	Development of a new vaccine for Rift Valley fever (RVF) (WA, ECSA) Recombinant and marker vaccines for PPR (WA, SA) Vaccines for sheep and goat pox (WA, ECSA, SA) Vaccines for African swine fever (ASF) (WA, ECSA)	New vaccines for East Coast fever (ECF), heartwater, anaplasmosis, babesiosis, dermatophilosis (WA, ECSA) New therapeutics for trypanosomosis[2] (G)	Diagnostic for *Brucella melitensis* (Malta fever) (G) Vaccines for CBPP and CCPP[3] (WA, ECSA) Empty capsid vaccine for FMD (G) Diagnostics for bovine TB (G)

1. Research opportunities are identified as being of global (G) or regional significance (WA=West Africa; ECSA= Eastern, Central and Southern Africa; SA=South Asia; SEA=South-East Asia)
2. Placed in the intensification category, but also contributes significantly to asset security
3. Placed in the marketing category, but also contributes significantly to asset security

10.3.1 Transferring knowledge and available tools

10.3.1.1 Securing assets

This grouping (upper left cell in Table 10.1) comprises the classic performance inhibitors, including the three major syndromes of neonatal mortality, nutritional deficiencies/imbalances, and reproductive disorders, and the endo- and ectoparasites. To a greater extent, these are the syndromes of the past in much of the developed world, where knowledge and technologies have largely elucidated their causes and brought them under control, but at a cost. The challenge here is to transfer, and adapt, available knowledge and technologies and tailor them for the world's poor as part of rural development programmes throughout the developing world. Much of what is required centres around information and technology translocation. Success will depend on a strengthening of the appropriate institutions responsible for extension, product marketing and rural service provision. For this it will be necessary to determine how to develop their capacity, and how they might develop a sustainable working relationship with the poor that involves the poor themselves. There are several role models of this, including the Network for Smallholder Poultry Development, funded by Danida.

While this grouping is largely a challenge for development, there are some research issues. From this consultancy it has become very clear that the poor have not been the targets for these rudimentary health management practices, so whereas this is a monstrous task, it is conceivable that quite rapid progress could be made merely by providing a specific focus on the poor. The research required is technical, socio-economic and political. From a technical point of view, a better definition is required of what these general problems are, what disease, nutritional and management factors are contributing to them, with a view to determining how appropriate is current knowledge and conventional wisdom, and what are the unique features compared to the developed world, or to more commercial systems in the same countries for which data and technologies are available, and how to respond to these features. From a socio-economic point of view, a better understanding of the demands of the poor themselves will be crucial, and an evaluation of how service provision can be made to work, and to endure to the benefit of all stakeholders. Finally from the political standpoint, it will be important to translate the outcomes of the other research areas into policies that will genuinely benefit the poor.

10.3.1.2 Reducing constraints to intensification

Intensification, and its effects on improving productivity and production efficiency, has many dimensions, and the opportunities for intensification are different with different production systems and different species. Intensification also implies increasing capacity by livestock keepers to invest in health services and products, and so broadens the scope of possible control strategies. Three examples in this category for which the transfer of knowledge and available tools are required can be taken from the smallholder dairy sector, increasingly a feature of the peri-urban poor and rural poor in SA and some high-potential areas of eastern Africa. The intensification mode is the change from one or more indigenous cattle (or the adoption for the first time) of a cross-bred or improved cow for milk production, so increasing cash income from milk sales and food security in the family. The problems of heat detection, of mastitis and of leptospirosis then potentially appear on the health agenda. These were not problems with the indigenous cow. She was grazed extensively, whereas the new cow is kept tied up in a

stall near the house. Leptospirosis is a zoonosis, ranked as very important in cattle and buffalo in SA. When under extensive management, the risk of human infection is low, but when exposed to urine in a stall setting it is considerably higher. These three health and management issues may be easily handled in the developed world, but for a poor farmer with one cow, they may result in having to abandon dairy production. The challenge here is to make available the simple and relatively inexpensive tools so widely available in the developed world to support such efforts in intensification.

Also in this category is the transfer of available knowledge and technologies to better control GI parasitism in its broadest sense (including haemonchosis, fascioliasis and coccidiosis), considered of significant importance in most regions, particularly in small ruminants. There are very effective approaches to the early diagnosis and management of this syndrome, such as the use of the FAMACHA© technique for haemonchosis control[1], which could have significant impact if effectively applied.

10.3.1.3 Improving market opportunities

Certain diseases are a constraint to better marketing of livestock products, and pork-borne cysticercosis is a prime example particularly associated with the poor in many regions of the world. Although there are technology development research opportunities for this disease (see section 10.3.2.3), there are also more immediate approaches to address the problem, such as the role of personal hygiene, and avoiding contact between pigs and human faeces. This requires the transfer of knowledge, and the application of this knowledge to the many differing circumstances of the poor. Not an easy task, but one with many examples of successful application.

10.3.2 Improved tools, better strategies, better delivered

In this category, there are two general research categories identified as most important in terms of achieving greater impact on poverty that cut across the three poverty alleviation pathways. These are 'Impact assessment of health constraints to productivity and marketing, and of measures to alleviate them', and 'Delivery and adoption of animal health services and technologies'. These come from the clearly identified need to better understand and quantify the constraints on the poor in all regions, and to evaluate best-bet pathways for the delivery of services to them.

10.3.2.1 Securing assets

In this grouping, there are several examples.

- **Evaluation of strategic therapy and management strategies for the prevention of *Toxocara vitulorum* infection in buffalo calves.** *Toxocara vitulorum* is a significant cause of mortality and productivity losses in calves, in particular buffalo, and was ranked as the priority constraint in that species. There is a significant research opportunity for improving its control through targeted therapy at a specific time. This comprises the use of pyrantel on day 10 post partum, combined with certain management practices to avoid reinfection. This opportunity was highlighted as a 'best bet' for evaluating a known technology package on a wider scale, and it could have rapid and significant impact. It is also an important opportunity for private-sector partnerships involving the pharmaceutical industry.

1. FAMACHA© is a farmer-friendly colour chart system developed by the Livestock Health and Production group of the South African Veterinary Association to diagnose the level of anaemia in small ruminants based on visual inspection of the animal's eyes, and used to recommend appropriate intervention with anthelmintics.

- **Development of a more efficacious vaccine for HS.** Haemorrhagic septicaemia remains a very significant constraint to the livelihoods of the poor in Asia, particularly in buffalo that play such an important role in traction. The disease is not at the top of the rankings, but the research opportunities are considered very good at reasonable cost, and improved vaccines with greater efficacy could have a major impact. Efforts should focus on the improvement of adjuvants, the evaluation of live vaccines, the mechanisms of immune response and the delivery and timing of vaccination to achieve maximum protection.
- **Testing and evaluation of new PPR vaccines.** PPR ranked within rank group B globally, and in group A in sheep and goats. It is of particular importance in SSA and SA. It does not occur in SEA, but it does occur in Bangladesh, and could spread east. There are good research opportunities in the vaccine development area, through the field testing of current recombinant vaccines.
- **Evaluation of delivery and adoption strategies for ND vaccine.** ND is without doubt the major infectious disease constraint to poultry kept by the poor in all the regions studied, ranking highly in most regions. It is generally considered that a good vaccine now exists, and in general terms is appropriate for poor livestock keepers. There is a significant research opportunity to evaluate the delivery and adoption of this vaccine, in particular the suitability of different routes of administration (oral and intra-ocular) for different systems. It was recommended that in such evaluations, consideration should be given to the delivery of a 'package' of poultry health interventions, as although ND is the most important, there are many others, such as fowl cholera and helminthosis, that should not be ignored.
- **Impact assessment of alternative control strategies for CBPP and CCPP.** CBPP ranked in group A for WA, as well as for pastoral systems and cattle, although in the global ranking it was in group C. Clearly it, and CCPP, are important constraints to asset security and to market opportunities in Africa. A major research option is to better define the impact of these two diseases, and of alternative control strategies. There are also opportunities for vaccine development (see section 10.3.3.3).
- **Impact assessment of alternative PPR control options.** The impact of PPR and of its control are very poorly defined, and these areas of research deserve considerable attention.

10.3.2.2 Reducing constraints to intensification

- **The development and evaluation of integrated control measures for trypanosomosis.** Trypanosomosis is a disease of high impact in Africa where poverty numbers are significant, and rates of poverty are predicted to increase. Continued research into the control of this disease that severely constrains both securing assets (in particular the zoonotic effects in some regions) and intensification must be a priority. Most of those consulted considered that, while a vaccine is highly desirable, vaccine research has a low probability of success within the 15-year time frame considered by this study, and will have a high cost. The major research opportunity is seen to be the better integrated use of available control technologies, of which there is a selection. This includes research on the development of diagnostic aids to strategy development. Some research into new and improved therapeutics should also be considered (see section 10.3.3 New tools and approaches).

- **Development of integrated control packages for GI parasites.** While GI parasites are a major constraint to asset security, their importance takes on a different and often more severe face in the intensification process, particularly if that involves the use of exotic breeds of livestock, more susceptible to the effects of GI parasitism. Furthermore, in this category, it may not necessarily be the simple application of currently available knowledge that is required, but rather the development of specific integrated packages to suit different production systems, that make use of anthelmintics, age resistance, grazing management etc. This high demand area of research would offer good opportunities for collaboration with the pharmaceutical industries.
- **The epidemiology, dynamics and impact of resistance to anthelmintic drugs.** Where intensification involves the increased use of anthelmintic drugs, and/or the increased adoption of improved breeds of sheep, in particular, that have come from commercial farms on which anthelmintic drugs have been used intensively, there is a significant risk of anthelmintic resistance complicating integrated helminth control strategies and programmes. There is an urgent need for a better understanding of the mechanisms, dynamics and impact of anthelmintic resistance and its development in smallholder systems in the tropical developing world. Such research is considered to be of high priority, with a high probability of success in the medium term.
- **Development of brucellosis control strategies.** Reasonably effective brucellosis control technologies are available in much of the world, on the basis of which the disease can be brought under control. However, it is necessary to apply available tools to develop suitable control strategies for the evolving smallholder dairy systems in agro-pastoral and peri-urban settings in which the disease presents a constraint both to reproductive performance and human health.
- **Development of integrated health and nutrition packages for village poultry.** It is recognised that ND is the single most important health constraint to smallholder poultry, and much emphasis has been put in this report on the more effective delivery of vaccines to control the disease. However, it is important that this disease not be considered in isolation, as the continued impacts of other health and nutritional constraints will limit the degree to which benefits from better ND control will be felt. As such, it will be necessary to develop system and region-specific packages that will optimise the benefits from reduced incidence of infectious diseases in village poultry. An appropriate vaccine for ND could serve as a 'product leader' in the introduction of this package.
- **Development of production system-specific integrated packages for TTBD control.** Research on the TBDs, important as constraints to asset security and intensification, particularly in Africa, has tended to focus on the control of individual diseases. As the trend to use less acaricides continues, their control relies increasingly on integrated control, and packages of integrated techniques that accommodate the TTBD disease complex, rather than individual diseases, are urgently required. These need to be tailored for different production systems, in which the combinations of TBDs, and of appropriate options to control them, differ.

10.3.2.3 Improved market opportunities

Again there is a series of 'best bet' options within this category. Many of those in this category address the zoonotic diseases, and the diseases that constrain movement and marketing of animals and animal products.

- **Testing and evaluation of vaccines for *Cysticercus cellulosae*.** In the better control of the pork tapeworm, a major zoonotic disease of significant importance to the poor, there are two opportunities. The first is transferring knowledge on its spread and prevention, mentioned above, but there is also the opportunity of testing new vaccines to prevent the disease. A recombinant vaccine has been developed for use in pigs (see Willingham, 2002, Appendix 10), and could have a major impact if appropriately delivered. This is seen as an excellent research opportunity with potential for high impact on public health and marketing opportunities of the poor.
- **Improved vaccines and diagnostics for FMD.** FMD is an important global constraint to improving market opportunities, and ranked highly, particularly in the mixed crop–livestock systems of Asia. The recent European outbreak of FMD has illustrated the need for improved vaccines that provide longer immunity, and greater cross protection across strains, and for pen-side diagnostics that differentiate field from vaccine strains of virus. In the developing world, and in particular with the very poor, these new technologies are unlikely to have major impact without the more fundamental elements important in controlling such an infectious disease, such as movement control and quarantine. As such, while there are good research opportunities for the development of these new technologies, with high probabilities of success within reasonable time frames, it will likely be the developed countries wishing to maintain their freedom from FMD, and the livestock marketing organisations of the developed world, that will take the lead in securing funding for such research.
- **Improved strategies for FMD control and eradication.** FMD will remain very difficult to control in much of the developing world, given the inadequacies of resources to purchase and deliver vaccines effectively, and the difficulties in controlling animal movement. Given its high impact, it will be very important to develop appropriate national and regional strategies and policies for its optimal management, based on good epidemiology and economics-based impact assessments, in order that maximum opportunity can be made of local and international markets. This is a very low-cost research opportunity with an excellent chance of success, and with high impact.
- **Better understanding of the epidemiology and impact of bovine TB.** Bovine tuberculosis does not rank highly based on its productivity impacts, but it is one of the cluster of zoonotic diseases that has high potential impact on securing assets of the poor (human health) and on enhancing market opportunities (through the sale of meat and milk). Of particular importance to the poor is a better understanding of the epidemiology and impact in different systems. For this priority research, improved diagnostic tools will be essential. There is also a need for new vaccine technologies, and it will be important to link this with research into new vaccines against the human form, *M. tuberculosis*.
- **Better understanding of the incidence and impact of anthrax.** Anthrax ranks highly to the poor in many regions, in particular in WA, both as an economically important disease and as a zoonosis that impacts both asset securing and marketing. However, the data on anthrax occurrence and impact are very sparse, so a better definition of anthrax incidence and impact was considered a priority research area, that would have a high probability of success at relatively low cost within a medium-term time horizon.

- **Spatial targeting of anthrax control measures for the poor.** There are good vaccines available for anthrax, so the development of new vaccine technologies was not considered a priority. However, it was considered that they need to be better targeted, which will require a stronger understanding of risk factors, geographical and others, and optimal pathways for the sustained delivery of anthrax vaccines. Funds applied to bio-terrorism weapons may provide support to such research.
- **RP surveillance and control strategies in final pockets of the disease.** The global programme to eradicate RP has made great progress, and the disease is now restricted to limited areas of eastern Africa and SA. The disease can have a devastating effect on the livelihoods of the poor, so it will be important to consolidate the successes made so far, and complete the eradication programme. Key to this will be a good understanding of virus dynamics in the regions in which it still exists with a view to eliminating these foci, and maintaining a sophisticated surveillance to ensure that the disease does not return.

10.3.3 New tools and approaches: capitalising on developments in science

10.3.3.1 Securing assets

- **Intra-nasal recombinant and marker vaccines for PPR.** PPR has a significant impact on asset security, given the high importance of small ruminants to the poor. It was ranked as particularly important in SA. Notably it is currently absent from SEA, but it is a severe threat to that region and could be introduced, whereupon it would have devastating impact. While there are vaccines undergoing evaluation, the possibility of developing new intra-nasal recombinant and marker vaccines, that would be important in making clear distinctions with RP infections, easily delivered to small ruminants and also effective in protecting areas in which the disease does not yet occur, has a good probability of success in the medium term.
- **Vaccines for sheep and goat pox.** Sheep and goat pox ranked in group C, but are important in all the regions. Here there is a real opportunity for the development of new and effective technologies to control these diseases, and there may be strong linkages between this research and that for other pox viruses appearing on the list, such as camel pox, buffalo pox, lumpy skin disease and orf.
- **Development of a new vaccine for RVF.** RVF occurs in limited regions of Africa at infrequent intervals, but when it does occur, it has a high impact on the livelihoods of the poor in many different ways, including human disease with mortality, loss of livestock productivity, and severe disruption in the movement and marketing of animals. There is scope for better vaccines for both animals and humans.
- **Vaccines for ASF.** ASF did not rank highly in this study, but the disease has had significant impact in recent outbreaks in WA, and in the past when it has been translocated from Africa to other continents. There is a need for a safe and effective vaccine for use to prevent losses in pigs kept by the poor in Africa. The research opportunities were considered quite good, of medium to long term, and at medium to high cost.

10.3.3.2 Reducing constraints to intensification

Intensification is an important pathway out of poverty. When it involves the use of improved breeds in tropical and subtropical environments in which disease vectors flourish, it opens up new disease constraints that may not have been of high priority in

indigenous breeds kept in the same environment. In this category are the vector-borne haemoparasites, within which grouping there are many research opportunities.

- **New vaccines for ECF.** The ability of cattle to develop natural and long-lasting immunity to ECF, and the technical successes of the live parasite 'infection and treatment' method of vaccination, has led researchers to conclude that new improved vaccines against ECF are a real possibility. New technology for genome mapping as an aid to antigen identification is helping this process. ECF remains a constraint to the intensification of cattle production in the region of its distribution, and it also constrains the securing of assets for some of the pastoral and agro-pastoral systems of the region. Research into ECF vaccines, particularly in the presentation of antigens to elicit cell-mediated immune responses, has strong implications for the development of efficacious vaccines against human malaria.
- **New vaccines for babesiosis, anaplasmosis, heartwater and dermatophilosis.** The other tick-borne and tick-associated infections are also constraints to intensification, with some having much wider global distributions. Vaccines against these diseases, particularly if developed as multivalent products (as many of these diseases occur simultaneously), could have major global impact. A strong research base for TBD exists.
- **New therapeutics for trypanosomosis.** With vaccine development for trypanosomosis considered technically complex and expensive, but with the unmistakable impact this disease has on the poor in Africa, there is a need for some new technology development research. Therapy is the most widely used at present, but with serious complications of resistance. New therapeutics for both human and animal trypanosomosis would be highly desirable within the 15-year time frame, allowing greater use of livestock in agro-pastoral systems of SSA.

10.3.3.3 Improving market opportunities

There are some new tools and approaches required to improve the market opportunities of the poor, and examples are provided below.

- **New vaccines against CBPP and CCPP.** These two diseases are very important in Africa, both as constraints to securing assets as well as improving market access. If they are to be effectively controlled, there is a need for new and improved vaccines and diagnostics. It is considered that there is a good chance of developing such vaccines within the time frame considered in this study. An important component of this research will be a better understanding of the immune responses involved.
- **New diagnostics for *Brucella melitensis*.** *Brucella melitensis* is an important member of the zoonotic disease complex affecting the poor keeping small ruminants, and its effective management and control is constrained by the lack of good diagnostic tests. These have an excellent chance of development within a short time frame.
- **New generation FMD vaccine.**
- **Improved diagnostics for bovine TB.**

10.4 Research funding opportunities

Within these different categories of research, there are many different possible funding opportunities. The conceptual framework matrix presented allows the selection of different categories of sponsor for each of the different cells of the matrix. The funding opportunities depend on the type of research, the geographical area targeted, the species targeted, and where else (other than by the poor) the benefits and impacts are felt.

10.4.1 Type of research

Some donors prefer to support 'front line' development activities (the 'transferring knowledge and available tools' category) rather than applied or upstream research. In this group are the NGOs who can be significant players in this field. A good example of this has been the Danida support to smallholder poultry development. Other donors or sponsoring organisations only support upstream science, and within this category fall the Wellcome Trust and the US National Institutes of Health (NIH), for example. There is a large group of donors, including DFID, IFAD and the Australian Centre for International Agricultural Research (ACIAR), for example, that supports the 'development of improved tools, better strategies, better delivered' category. The challenge is to link the appropriate type of research with the most receptive sponsor.

10.4.2 Geographical area and species

Several donors have specific target countries for their technical cooperation programmes that are linked to historical, political and trading connections.

10.4.3 Who, other than the poor, benefit?

Also important to consider when evaluating potential sponsors is whether the research needed might be considered a valuable 'spin-off' for a particular investor. There are several examples. Considerable investment is being made into the control of certain diseases considered to be potential bio-terrorist weapons, such as anthrax, for example. A potential spin-off of this investment could be in improving the control of anthrax in developing countries, such as the impact assessment and improved control targeting opportunities identified as necessary in this study.

The pharmaceutical industry invests large amounts of money into research, but the clients for most of the products are found in the developed world, where people can afford to pay for them. Some research opportunities identified above require the use of available pharmaceutical products (such as the evaluation of pyrantel for the control of *T. vitulorum*), and this provides an opportunity for public/private partnerships in sponsoring research, that could bring both income and goodwill to the pharmaceutical sector.

An illustration of these points for a few key opportunities is provided in Table 10.2.

Table 10.2 Funding strategies

Disease/pathogen	Research opportunity	Other beneficiaries	Possible funding source
Foot-and-mouth disease (FMD)	Vaccine development Pen-side diagnostics	International traders in livestock products from the developed world	Public sector of FMD-free trading countries Livestock commodity importers in FMD-free developed countries
	National strategy and policy development for developing nations	Developed-world livestock sectors	FMD-free developed country governments
Toxocara vitulorum	Evaluation of therapy and management protocol	Drug sales and good public relations	Pharmaceutical industries/ donor partnerships
Anthrax	Impact and intervention targeting strategies	Countries susceptible to bioterrorism	Funders of anti-bioterrorism
Trypanosomosis	New therapeutic drug	Humans requiring sleeping sickness control	Link with pharmaceutical industry, and spin-off from sleeping sickness drug development

10.5 How can research opportunities be ranked?

In this chapter, a categorisation of research opportunities has been presented by the type of research, and by the likely impact the research product will have on different processes of poverty alleviation. This provides a framework for evaluating any research proposal in animal health, and it also provides a basket of opportunities within the different groupings. What it does not do, at present, is rank them within any one 'basket'. Should that be done, and if so how?

In this report, a broad consultative process has been employed to gather information from field personnel and expert reviewers on animal health constraints for the poor. This process has been very helpful in identifying new priority opportunities that would not necessarily have been highlighted in a more conventional prioritisation process. In this chapter, we have noted opportunities over the next 15 years for improving the control of high-priority diseases within a vision of alleviating poverty through enhancing benefits from livestock. However, the limitations to quantifying, or even qualitatively ranking, research opportunities as to their expected poverty alleviation benefits have been emphasised. In many cases, not only is little known about the incidence and impact of livestock diseases on the poor, particularly for livestock species other than cattle, for diseases that are difficult to diagnosis and for populations in more remote areas, but even more difficult is being able to estimate the expected benefit to the poor of specific interventions using the products of the research proposed. So yes, a set of priority research areas are proposed, but more data on their impact, among other key information, are necessary before they can be ranked.

A number of other tangible and intangible features will play a crucial role in deciding on the best investment options for a given donor. These will include:

- **Which of the options will other donors prefer, and why?** Most agencies are able to offer relatively small amounts, but if there is collaboration in funding, significant amounts of money can be invested in priority issues, creating synergies and greatly enhancing the potential for research success, and therefore impact. This has been a key component of the 'Roll Back Malaria' programme, and could be applied to one or more of the priorities identified here.
- **Where are there supportive social and policy environments that could catalyse the research process, and enhance its chances of success?** These factors have greatly contributed to the important successes of the NDDB in India and support to smallholder poultry in Bangladesh and other countries.
- **The options presented have different geographical focuses, different species focus, and different price tags.** These may all be important considerations in a donor's choice.

Thus, the research opportunities identified here need to be considered in a broader financial and socio-political context. The ultimate impact of the opportunities identified in alleviating poverty will very much depend on developing enabling circumstances in which they can succeed. This reality demands a coordinated approach by governments, civil societies, the research and development community and investors. The identification of priority animal health research opportunities in this report is a start at this process. The eventual benefits that these have for the poor will very much depend on co-ordinated and focused action by many.

References

Alston J.M., Norton G.W. and Pardey P.G. 1995. *Science under scarcity*. Cornell University Press, Ithaca, USA. 585 pp.

Anon. 1994. Communicable tropical diseases, International League Against Epilepsy: Relationship between epilepsy and tropical diseases. *Epilepsia* 35:89–93.

Baker R.L. 1998. *Genetic resistance to endoparasites in sheep and goats. A review of genetic resistance to gastrointestinal nematode parasites in sheep and goats in the tropics and evidence for resistance in some sheep and goat breeds in sub-humid coastal Kenya.* FAO/UNEP Animal Genetic Resources Information 24. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy. pp. 13–30.

Catley A. 2002. *Appendix 6, Notes on pastoral livelihoods in Africa.* In: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K., *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 3 pp.

Coleman P.G. 2002. *Appendix 9, Zoonotic diseases and their impact on the poor.* In: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K., *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 21 pp.

Coleman P.G., Perry B.D. and Woolhouse M.E.J. 2001. Endemic stability—A veterinary idea applied to human public health. *The Lancet* 357:1284–1286.

Curry J., Huss-Ashmore R., Perry B. and Mukhebi A. 1996. A framework for the analysis of gender, intra-household dynamics, and livestock disease control with examples from Uasin Gishu District, Kenya. *Human Ecology* 24(2):161–189.

Delgado C., Rosegrant M., Steinfeld H., Ehui S. and Courbois C. 1999. *Livestock to 2020: The next food revolution.* Food, Agriculture, and the Environment. Discussion Paper 228. IFPRI (International Food Policy Research Institute), FAO (Food and Agriculture Organization of the United Nations), and ILRI (International Livestock Research Institute). IFPRI (International Food Policy Research Institute), Washington, DC, USA. 72 pp.

DFID (Department for International Development). 2000. *Sustainable livelihoods guidance sheets.* Institute of Development Studies. www.livelihoods.org

Field C. 1991. FARM-Africa camel improvement and community health project. *Pastoralist Development Newsletter Set no. 31.* Overseas Development Institute (ODI), London, UK.

Gibson J.P. 2002. *Appendix 13, Role of genetically determined resistance of livestock to disease in the developing world: Potential impacts and researchable issues.* In: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K., *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 14 pp.

Hainsworth S.D, Godfrey S.H., Matthewman R.W. and Richards J.I. (eds). 2001. *Linkages, livestock, and livelihoods—Promoting co-ordination in livestock research for poor people: Proceedings of the first interagency meeting on livestock production and animal health, 6–7 December 2000, Imperial College at Wye, Kent, UK.* Natural Resources International Limited (NRIL), Chatham Maritime, UK. 188 pp.

Heffernan C.L. 2002. *Appendix 5, Livestock in a sustainable livelihood context.* In: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K., *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 6 pp.

Heffernan C. and Misturelli F. 2000. *The delivery of veterinary services to the poor: Preliminary findings from Kenya.* Report of the DFID-funded study R7357. Veterinary Epidemiology and Economics Research Unit (VEERU), Department of Agriculture, University of Reading, Reading, UK. 81 pp.

Heffernan C. and Sidahmed A. 1998. Issues in the development of veterinary services to the rural poor: a framework for analysis. Invited paper at the DSA Conference: Provision of Livestock Services, 12 June 1998, University of Reading, Reading, UK. 19 pp.

Holden S., Ashley S. and Bazeley P. 1996. *Improving the delivery of animal health services in developing countries: A literature review.* Livestock In Development (LID), Crewkerne, UK. 96 pp.

d'Ieteren G.D.M., Authie E., Wissocq N. and Murray M. 1999. Trypanotolerance: An option for sustainable livestock production in areas at risk from trypanosomosis. *Revue Scientifique et Technique de l'Office International des Epizooties* 17:1–32.

Jazairy I., Alamgir M. and Panuccio T. (eds). 1992. *The state of world rural poverty: An inquiry into its causes and consequences.* IFAD (International Fund for Agricultural Development), New York University Press, New York, USA. 514 pp.

Kristjanson P.M., Swallow B.M., Rowlands G.J., Kruska R.L. and de Leeuw P.N. 1999. Measuring the costs of African animal trypanosomosis: The potential benefits of control and returns to research. *Agricultural Systems* 59:79–98.

LID (Livestock In Development). 1999. *Livestock in poverty-focused development.* LID, Crewkerne, Somerset, UK. 95 pp.

McCorkle C.M. and Mathias E. 1997. *Paraveterinary healthcare programs: A global overview. Paper contributed to the FAO electronic conference on principles for rational delivery of public and private veterinary services, January–March 1997.* www.fao.org/waicent/faoinfo/agricult/aga/agah/vetsl/default.htm

McLeod A. and Wilsmore A. 2002. *Appendix 11, The delivery of animal health services to the poor: A review.* In: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K., *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 29 pp.

Morris R.S. and Marsh W.E. 1994. The relationship between infections, diseases and their economic effects. In: Perry B.D. and Hansen J.W. (eds), *Modelling vector borne and other parasitic diseases. Proceedings of a workshop organised by ILRI in collaboration with FAO, Nairobi, Kenya, 23–27 November 1992.* ILRAD (International Laboratory for Research in Animal Diseases), Nairobi, Kenya. pp. 192–213.

Mukhebi A.W., Chamboko T., O'Callaghan C.J., Peter T.F., Kruska R.L., Medley G.F., Mahan S.M. and Perry B.D. 1999. An assessment of the economic impact of heartwater (*Cowdria ruminantium* infection) and its control in Zimbabwe. *Preventive Veterinary Medicine* 39: 173–189.

Mulinge W. and McLeod A. 1998. Priorities for animal health research in KARI: Report for stakeholders. KARI (Kenya Agricultural Research Institute), Nairobi, Kenya. 35 pp. (unpublished).

Norval R.A.I, Perry B.D. and Young A.S. 1992. *The epidemiology of theileriosis in Africa.* Academic Press, London, UK. 481 pp.

Odiit M., Coleman P.G., Fèvre E.M., Magona J. and McDermott J.J. 2000. Incorporating the burden of human sleeping sickness in an economic impact assessment of trypanosomosis. In: *Proceedings of the ninth international symposium on veterinary epidemiology and economics, 7–11 August 2000.* Breckenridge CO, USA. (CD-ROM). Abstract ID 350.

Permin A. and Madsen M. 2002a. *Appendix 8, Literature review on disease occurrence and impact (smallholder poultry).* In: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K., *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 13 pp.

Permin A. and Madsen M. 2002b. *Appendix 12, Literature review of disease control delivery, adoption and impact (smallholder poultry).* In: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K., *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 6 pp.

Perry B.D., Gleeson L.J., Khounsy S., Blacksell S. and Bounma P. 2000. The economic impact of foot and mouth disease and its control on smallholder farming systems in Savannakhet Province of the Lao Peoples Democratic Republic. (ILRI International Livestock Research Institute), Nairobi, Kenya. 13 pp. (unpublished).

Perry B.D., Kalpravidh W., Coleman P.G., Horst H.S., McDermott J.J., Randolph T.F. and Gleeson L.J. 1999. The economic impact of food and mouth disease and its control in South East Asia: A preliminary assessment with special reference to Thailand. *Revue Scientifique et Technique de l'Office International des Epizooties* 8(2):478–497.

Perry B., McDermott J. and Randolph T. 2001. Can epidemiology and economics make a meaningful contribution to national animal-disease control? *Preventive Veterinary Medicine* 48:231–260.

Perry B.D. and Randolph T.F. 1999. Improving the assessment of the economic impact of parasitic diseases and of their control in production animals. *Veterinary Parasitology* 84:145–168.

Perry B.D. and Young A.S. 1995. The past and future roles of epidemiology and economics in the control of tick-borne diseases of livestock in Africa: The case of theileriosis. *Preventive Veterinary Medicine* 25:107–120.

Randhawa N.S.and Sundaram K.V. 1990. *Small farmer development in Asia and the Pacific: Some lessons for strategy formulation and planning.* FAO Economic and Social Development Paper 87. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy. 104 pp.

Reid R.S. and Ellis J.E. 1995. Livestock-mediated tree regeneration: Impacts of pastoralists on dry tropical woodlands. *Ecological Applications* 5(4):978–992.

Robinson T. 2002. *Appendix 4, Global poverty mapping for livestock research.* In: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K., *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 25 pp.

Roth F. and Zinsstag J. 2001. *Economic analysis of brucellosis control in Mongolia—Improvement of human health through the veterinary sector—The case of animal brucellosis control.* Swiss Tropical Institute, Basle, Switzerland. 57 pp.

Rushton J., Heffernan C.L. and Pilling D. 2002. *Appendix 7, A literature review of livestock diseases and their importance in the lives of poor people.* In: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K., *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 129 pp.

Schantz P.M., Cruz M., Pawlowski Z. and Sarti E. 1993. Potential eradicability of taeniasis and cysticercosis. *Bulletin of the Pan American Health Organization* 27:397–403.

Seré C. and Steinfeld H. 1996. *World livestock production systems: Current status, issues and trends.* FAO Animal Production and Health Paper 127. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy. 82 pp.

Shaw A.P.M. and Hoste C.H. 1987. *Trypanotolerant cattle and livestock development in West and Central Africa. Vol. 1. The international supply and demand for breeding stock.* FAO Animal Production and Health Paper 67/1. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy. 184 pp.

Sones K.R., Perry B.D., Randolph T.F. and McDermott J.J. 2002. *Appendix 14, Identifying priority areas for international action for the development of livestock technologies: reports of four regional workshops.* In: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K., *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 71 pp.

Swallow, B.M. 1997. Impacts of trypanosomosis on African agriculture. In: *Proceedings of the 24th International Scientific Council for Trypanosomiasis Research and Control Meeting, 29 September–4 October 1997, Maputo, Mozambique.* Organization of African Unity (OAU), Scientific, Technical and Research Commission (STRC), Nairobi, Kenya. pp. 515-536.

Swallow B.M. 2000. *Impacts of trypansomiasis on African agriculture.* PAAT (Programme Against African Trypanosomiasis) Technical and Scientific Series 2. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy. 52 pp.

Thornton P.K., Randolph T.F., Kristjanson P.M., Omamo W.S., Odero A.N. and Ryan J.G. 2000. *Assessment of priorities to 2010 for the poor and the environment.* ILRI Impact Assessment Series 6. ILRI (International Livestock Research Institute), Nairobi, Kenya. 120 pp.

Thornton P.K., Kruska R.L., Henninger N., Kristjanson P.M., Reid R.S., Atieno F., Odero A. and Ndegwa T. 2002. *Mapping poverty and livestock in developing countries.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 132 pp.

UNDP (United Nations Development Programme). 1997. *Human development report 1997.* Oxford University Press, New York, USA. 256 pp.

Ward D.E., Ruppanner R., Marchot P.J. and Hansen, J.W. 1993. One medicine—Practical application for non-sedentary pastoral populations. *Nomadic People* 32:55–64.

Willingham A.L. 2002. *Appendix 10, New research opportunities in meat-borne and other parasitic zoonoses.* In: Perry B.D., Randolph T.F., McDermott J.J., Sones K.R. and Thornton P.K., *Investing in animal health research to alleviate poverty.* ILRI (International Livestock Research Institute), Nairobi, Kenya. 22 pp.

World Bank. 1997. *World development report 1997: The state in a changing world.* Oxford University Press, New York, USA. 265 pp.

World Bank. 2001. *World development report 2000/2001: Attacking poverty.* Oxford University Press, New York, USA. 335 pp.

World Health Organization. 1996. *Investing in health research and development. Report of the* ad hoc *committee on health research relating to future intervention options.* WHO (World Health Organization), Geneva, Switzerland. 278 pp.

Disease name	Species affected	Causative agents
General syndromes		
Acute respiratory syndrome	All livestock species	Various causes both infectious and non-infectious
Diarrhoeal diseases	All livestock species	Various causes both infectious and non-infectious
Foot problems	All livestock species	Various causes both infectious and non-infectious
Haematuria	All livestock species	Various causes both infectious and non-infectious
Mastitis	All livestock species	Various causes both infectious and non-infectious
Meningitis	All livestock species, humans	Various infectious causes
Neonatal mortality	All livestock species	Various causes both infectious and non-infectious
Nutritional/micronutrient deficiencies	All livestock species	
Reproductive disorders	All livestock species	Various causes both infectious and non-infectious
Respiratory complexes	All livestock species	Various causes both infectious and non-infectious
Wounds/Injuries	All livestock species	
Bacterial (including Mycoplasmal and Rickettsial) diseases		
Anthrax	All livestock species (not poultry), humans	*Bacillus anthracis*
Black-leg	Cattle, sheep	*Clostridium chauvaei*
Botulism	All livestock species, humans	*Clostridium botulinum*
Brucellosis	All livestock species (not poultry), humans	*Brucella abortus, B. melitensis, B. suis* and *Brucella* spp.
Calf diphtheria	Calves	*Fusobacterium necrophorum*
Chlamydial infections	All livestock species, humans	*Chlamydia* spp.
Clostridial diseases	All livestock species (not poultry)	*Clostridium* spp.
Contagious bovine pleuro-pneumonia (CBPP)	Cattle	*Mycoplasma mycoides mycoides*
Contagious caprine pleuro-pneumonia (CCPP)	Sheep, goats	*Mycoplasma mycoides capri*
Dermatophilosis	Cattle, sheep, goats	*Dermatophilus congolensis*
Fowl cholera	Poultry	*Pasteurella multocida*
Fowl typhoid	Poultry	*Salmonella pullorum, S. gallinarum*
Haemorrhagic septicaemia (HS)	Cattle, buffalo	*Pasteurella multocida*

Infectious coryza	Chickens (and other poultry)	*Haemophilus gallinarum*
Leptospirosis	All livestock species (not poultry) humans	*Leptospira* spp.
Listerosis	All livestock species, humans	*Listeria monocytogenes*
Malta fever	Sheep, goats, humans	*Brucella metitensis*
Mycoplasmosis	All livestock species	*Mycoplasma* spp.
Paratuberculosis (Johnes disease) (Para-TB)	Cattle	*Mycobacterium paratuberculosis*
Pullorum disease	Poultry	*Salmonella pullorum*
Salmonellosis	All livestock species, humans	*Salmonella* spp.
Tetanus	Herbivores, humans	*Clostridium tetani*
Tuberculosis (TB)	Cattle, humans	*Mycobacterium bovis*
Fungal diseases		
Epizootic lymphangitis	Horses, donkeys, mules	*Cryptococcus farciminosa*
Mycoses	All livestock species	Various fungal spp.
Parasitic diseases		
Babesiosis	Cattle	*Babesia bigemina, B. bovis*
Cerebro-spinal nematodiasis (CSN)	Cattle	*Setaria* spp.
Chagas disease	Dogs, cats, humans	*Trypanosoma cruzi*
Coccidiosis	All livestock species	*Coccidia* spp.
Cryptosporidiosis	All livestock species (not poultry), humans	*Cryptosporidium* species
Cysticercosis (beef tapeworm)	Humans, cattle	*Taenia saginata (Cysticercus bovis)*
Cysticercosis (pork tapeworm)	Swine, humans	*Taenia solium (Cysticercus cellulosae)*
East Coast fever (ECF)	Cattle	*Theileria parva*
Ectoparasites	All livestock species	Various species of mites, lice, ticks, flies (maggots) etc.
Gastro-intestinal (GI) parasitism (helminthosis)	All livestock species	Various helminth species (e.g. *Haemonchus, Ostertagia, Onchocerca, Ascaris, Trichostrongylus, Bunostomum, Cooperia, Strongyloides, Nematodirus, Toxocara, Trichuris* etc.)
Haemonchosis	Cattle, sheep, goats	*Haemonchus contortus*
Hookworm infection (cutaneous larva migrants)	Dogs, cats, cattle, humans	*Ancylostoma* spp.
Hydatidosis (hydatid disease)	All livestock species, humans	*Echinococcus granulosus, E. multilocularis* and other *Echinococcus* spp.
Fascioliasis (liver fluke)	Buffalo, cattle, sheep, goats	*Fasciola hepatica, F. gigantica*
Filariasis	All livestock species	*Dirofilaria immitis*
Leishmaniasis	Dogs, humans	*Leishmania donovani, L. chagasi*

Lungworm	Cattle, sheep, goats	*Dictyocaulus viviparus, D. filaria*
Mange	All livestock species (not poultry)	*Sarcoptes* spp.
Myiasis	Cattle, sheep, goats	Lucilia spp. and *Chrysomyia* spp.
Q-fever	Sheep, goats, cattle, humans	*Coxiella burnetii*
Schistosomiasis (schistosomosis japonicum)	Cattle, humans	*Schistosoma japonicum*
Tick infestation	All livestock species	Various species of ticks
Toxoplasmosis	All livestock species, humans	*Toxoplasma gondii*
Toxocariasis	Buffalo, cattle	*Toxocara vitulorum*
Trichinellosis	Pigs, humans	*Trichinella spiralis*
Surra	Buffalo, cattle, camels, horses, donkeys, mules	*Trypanosoma evansi*
Trypanosomosis (tsetse-transmitted)	Cattle, sheep, humans (*T. brucei*)	*Trypanosoma congolense, T. vivax, T. brucei*
Tropical theileriosis	Cattle	*Theileria annulata*

Rickettsial diseases

Anaplasmosis	Cattle, sheep, goats	*Anaplasma marginale*
Heartwater	Cattle, sheep, goats	*Cowdria ruminantium*

Viral diseases

African horse sickness (AHS)	Horses	Orbivirus
African swine fever (ASF)	Pigs	Iridovirus
Aujeszky's disease (pseudorabies)	Pigs	Herpes virus
Avian influenza	Poultry	Orthomyxovirus
Blue tongue (BT)	Sheep, cattle, goats	Orbivirus
Bovine viral diarrhoea virus (BVD)	Cattle	Pestivirus
Buffalo pox	Buffalo	Pox virus
Camel pox	Camels	Pox virus
Duck virus enteritis (duck plague, DVE)	Ducks	DVE virus
Duck virus hepatitis (DVH)	Ducks	DVH virus
Foot-and-mouth disease (FMD)	Cattle, sheep, goats, pigs	Rhinovirus (various serotypes)
Fowl pox	Poultry	Pox virus
Gumboro disease (infectious bursal disease, IBD)	Poultry	IBD virus
Hog cholera (classical swine fever, CSF)	Pigs	Pestivirus
Infectious bovine rhinotracheitis (IBR)	Cattle	Herpes virus
Infectious bronchitis (IB)	Chickens	Coronavirus
Infectious laryngo-tracheitis (ILT)	Poultry	Herpes virus
Japanese B encephalitis	Pigs, horses, humans	Flavivirus
Lumpy skin disease	Cattle	Pox virus
Malignant catarrhal fever (MCF)	Cattle	Herpes virus

Marek's disease	Poultry	Herpes virus
Nairobi sheep disease	Sheep, goats	Ganjam group virus
Newcastle disease (ND)	Poultry	Paramyxovirus
Orf (contagious pustular dermatitis, CPD)	Sheep, goats	Parapox virus
Peste des petits ruminants (PPR)	Sheep, goats	Morbillivirus
Rabies	All livestock species (not poultry), humans	Lyssavirus
Rift Valley fever (RVF)	Sheep, cattle, goats, humans	Bunyavirus
Rinderpest (RP)	Cattle	Morbillivirus
Sheep and goat pox	Sheep, goats	Pox virus

Note: This list does not include certain zoonoses mentioned in Appendix 9 such as Hanta virus infections, plague and leprosy that do not affect livestock.

Acronyms

ACIAR	Australian Centre for International Agricultural Research
AHS	African horse sickness
ASF	African swine fever
CAHW	community-based animal health worker
CBPP	Contagious bovine pleuro-pneumonia
CCPP	Contagious caprine pleuro-pneumonia
CSF	Classical swine fever
DAC	Development Assistance Committee (OECD)
DALY	disability adjusted life year
Danida	Danish International Development Agency
DFID	Department for International Development (UK)
DNA	deoxyribonucleic acid
DVE	Duck virus entiritis
DVH	Duck virus hepatitis
DVO	district veterinary officer
ECF	East Coast fever
ECSA	Eastern, Central and Southern Africa
ER	expert review
FAO	Food and Agriculture Organization of the United Nations (Italy)
FARM-Africa	Farm and Agricultural Research Management-Africa (UK)
FMD	Foot-and-mouth disease
GI	gastro-intestinal
HIV	Human immunodeficiency virus
HS	Haemorrhagic septicaemia
IAEA	International Atomic Energy Agency (Austria)
IAH	Institute for Animal Health (UK)
IBD	Infectious bursal disease
IBR	Infectious bovine rhinotracheitis
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (India)
IFAD	International Fund for Agricultural Development (Italy)
IFPRI	International Food Policy Research Institute (USA)
ILRI	International Livestock Research Institute (Kenya)
LEAD	Livestock Environment and Development Initiative (FAO)
LG	livestock only, rangeland-based
LGA	livestock only, rangeland-based arid/semi-arid
LGH	livestock only, rangeland-based humid/subhumid
LGT	livestock only, rangeland-based temperate/tropical highland
LID	Livestock In Development (UK)
LL	landless (peri-urban)
MIA	mixed irrigated arid/semi-arid
MIH	mixed irrigated humid/subhumid
MIT	mixed irrigated temperate/tropical highland
MRA	mixed rainfed humid/subhumid

MRT	mixed rainfed temperate/tropical highland
ND	Newcastle disease
NDV	Newcastle disease virus
NDDB	National Dairy Development Board (India)
NGO	non-governmental organisation
NIH	National Institutes of Health (USA)
OECD	Organization for Economic Community Development (France)
OIE	Office International des Epizooties (France)
P	poverty severity index
PCR	polymerase chain reaction
PPR	Peste des petits ruminants
R&D	research and development
RP	Rinderpest
RVF	Rift Valley fever
SA	South Asia
SEA	South-East Asia
SSA	sub-Saharan Africa
TB	Tuberculosis
TBD	tick-borne disease
TTBD	tick and tick-borne disease
UNDP	United Nations Development Programme (USA)
VEERU	Veterinary Epidemiology and Economics Research Unit (UoR)
WA	West Africa
WHO	World Health Organization (Switzerland)
WS	workshops

The artwork on cover and inside pages are composites of drawings held in the national collections of British art at the Tate Gallery, UK.

The artists and works depicted on the cover are:

Top row, left to right:

Thomas Gainsborough (1727–88), Study of a Cow

British School, from Album of Drawings Mainly by Flaxman

British School, from Madeira and India Sketchbook (1833)

Henry Moore, Head [of a sheep] (1974)

Henry Moore, Sheep with Lamb IV (1972)

British School, A Goat

Robert Hills (1769–1844), detail from Studies of Cows

Henry Moore, Sheep and Lamb (1974)

Bottom and middle rows, left to right:

Robert Hills, detail from Studies of Cows

Robert Austin, Woman Milking Goat (1925)

Robert Hills, detail from Studies of Cows

Eric Gill, The Good Shepherd (1927)

Robert Hills, details from Studies of Cows

Sir Sidney Nolan, Rinder Subject I (1969)

Joseph Highmore (1692–1780), Side View of a Bull's Head

Sir Sidney Nolan, Rinder Subject III (1969)

Eric Gill, Swineherd (1925)

British School, Indian Coolie, Carrying a Basket

Joseph Highmore (1692–1780), Front View of a Bull's Head

INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE