



BBSRC-DBT LIVESTOCK HEALTH AND DISEASE WORKSHOP REPORT

**NATIONAL INSTITUTE OF IMMUNOLOGY
NEW DELHI, 6-8 FEBRUARY 2012**



INTRODUCTION

The Science and Innovation Network (SIN) and RCUK India sponsored a joint BBSRC-Department of Biotechnology (DBT) Livestock Health and Disease workshop. The workshop was held in New Delhi on 6-8 February 2012, hosted by the National Institute of Immunology, bringing together Indian and UK researchers with interest and activities in this area.

The scope of the workshop was broad, covering both BBSRC's and DBT's research interests in livestock¹ health including biological aspects of key infectious animal diseases, underpinning control measures and generic technologies (details at **Annex 1**). The aims and objectives of the workshop are as follows:

To gain an understanding of the **current research landscapes** in India and the UK in livestock health and disease research

To develop an **understanding of BBSRC's and DBT's current and future priorities** and research infrastructure for livestock health and disease research

To **identify areas of particular strength in livestock health and disease** in both countries and key challenges that would benefit from being addressed by collaborative proposals involving Indian and UK scientists

To **identify potential areas** of livestock health and disease research where additional expertise from scientists in India or UK would **add value to ongoing research** in the other country

To evaluate the **timeliness and perceived benefits** of future collaborative working between India and the UK

FORMAT OF THE WORKSHOP

The Programme of the workshop and a list of attendees are in **Annex 2** and **Annex 3** respectively. The first full day of the workshop was devoted to the UK and Indian scientists presenting the general landscape of research in the two nations under the following headings:

- Infectious animal diseases including bacterial endemic diseases, food-borne zoonoses, , parasitic, viral & vector-borne
- Transmission and epidemiology
- Genetics of livestock health
- Cross cutting issues - immunology, vaccinology and diagnostics
- Gut health

These presentations provided some detail of the work in the respective countries and current and future priorities. The main research needs highlighted in the presentation are in **Annex 4**.

¹ Livestock in this report refers to farmed animals including poultry.

The second day of the workshop involved intensive breakout group discussions based around three livestock species (Ruminants, Pigs and Poultry), with the objective of identifying key research topics where India-UK collaboration would add value and be of true joint benefit.

All delegates had the opportunity to be involved in discussions and provide input on research needs for all the livestock species under discussion. It became clear that the spread of skills was in many ways complementary and offered great potential for synergistic interactions. The summary of breakout group discussions is in **Annex 5, 6 and 7** for Ruminants, Pigs and Poultry sessions respectively.

CONCLUSIONS AND PRIORITIES

It became apparent during the workshop that there are a number of areas that present common challenges and opportunities to both countries and the spread of skills are in many ways complementary and offered great potential for synergistic interactions. Both countries have strong focus on livestock health and there is a need and ambition to combat infectious diseases.

A polling process was used to identify the areas of greatest common interest among the delegates. Ten UK and twenty three Indian delegates highlighted five areas of particular interest (in the order of priority):

1. **Novel Vaccines Development** (29 votes; 13 from the UK and 16 from India)

- Vaccines are pivotal to the control of many livestock diseases. Recent technological advances and detailed knowledge of immunology, molecular biology, microbiology and biochemistry can be exploited to generate novel vaccines. Subunit, recombinant, DNA and vectored vaccines are rapidly gaining scientific and public acceptance as the new generation of vaccines and are seriously considered as alternatives to current conventional ones. The research needs include:
 - Using genomic and proteomic approaches to design novel vaccines taking into account pathogen diversity
 - Research into developing thermo-stable vaccines and novel vaccine vectors
 - Novel and easy-to-use delivery systems
 - DIVA vaccines to differentiate infected from vaccinated animals and the potential for asymptomatic carriers to spread disease
 - Vaccines that induce an early onset of immunity, which are long lasting are needed in the case of emergency vaccination.
 - The development of multivalent vaccines to reduce the number of inoculations handling costs and avoid animal suffering
 - Basic and applied immunological research on target animal species to understand immunological differences in the host species

2. **Epidemiology and Modelling** (28 votes; 14 from the UK and 14 from India)

- Epidemiological surveillance and modelling contributes to mitigating the adverse effects of an animal disease outbreak or monitoring existing endemic diseases. Some of the research needs in this area include:
 - Predictive and real-time epidemiological modelling of zoonotic and endemic diseases, evolution of infectious agents and transmission dynamics (including infectivity and host range)
 - Conventional and molecular epidemiology to map pathogen flows and diversity

- Descriptive epidemiology of pathogens and their distribution
- Long-term studies of epidemiology of multi-species infectious diseases
- Epidemiological studies of risk factors e.g. ecological changes and other socio-economic factors
- Increasing integration of mathematics in biology

3. **Investigating Pathogen Biology at the Molecular Level** (25 votes; 11 from the UK and 14 from India)

➤ Basic understanding of the biology of *pathogens* by elucidating the molecular mechanisms underlying physiology, metabolism, stress adaptation, host interactions and virulence of *pathogens* is essential for development of effective prevention and intervention strategies. The following research needs were highlighted:

- Better knowledge of pathogens, their (intermediate) hosts, diversity and their virulence
 - Genomic approaches to understand the expression pattern and role of individual genes in colonisation, pathogenesis and transmission
 - Host's immune response
 - Transmission pathways and host specificity
- Host/Pathogen tool-boxes
- Research into mechanisms of amplification and persistence of pathogens in host and environment
- Basic immunology research to understand host species' susceptibility and resistance to infection

4. **Genetics of Host Disease Resistance** (22 votes; 8 from the UK and 14 from India)

➤ India has a broad spectrum of native breeds and immense global diversity. The UK has major expertise in genomics and host genetics. Exploiting current advances in genomic technologies would help dissect host variation and its role in incidence and impact of diseases. The following research needs were highlighted:

- Understand molecular basis and mechanisms of genetic resistance to disease
- Understand species and strain difference in disease resistance
- Distinguish resistant genotypes (by region)
- Translate genomic applications to develop tools (vaccines and diagnostics) for disease control
- Studies of genetic resistance to disease
- Technologies that enable creation and/or exploitation of resistant phenotypes and biomarker discovery

5. **Novel Diagnostic Tools** (16 votes; 6 from the UK and 10 from India)

➤ Effective disease control requires rapid and accurate detection coupled with fast and effective response to an outbreak. The use of effective diagnostic tests for surveillance purposes and for the rapid confirmation of disease outbreaks is essential. Research is needed to develop:

- Novel and effective tools, especially to monitor epidemiology of disease (simple and rapid tests (e.g. pen-side) for use in the field and regional laboratories to support clinical suspicion of disease)
- Rapid and sensitive methods for differential diagnosis (DIVA diagnostics - parallel development of vaccine and test)

- Multiple diagnostic platforms

The delegates also highlighted both capacity building and training needs, especially in the areas of epidemiology, reference laboratories and research methods. Doctoral training programmes and exchange programmes were highlighted.

While the 'voting' involved too small a number of experts to use with any precision, the overall view was that vaccinology with the focus on "better and cheap" vaccines and epidemiology were seen as valuable areas for collaboration. However, it was also clear that there were significant opportunities within the other priority areas.

SCOPE OF THE WORKSHOP

Biological aspects

- Key infectious animal diseases, including food borne zoonoses, and key animal species including pigs, chickens and cattle
- Transmission, vectors, epidemiology
- Host/infectious organism interactions – biology of the infectious organism (including, mechanism of infection/colonisation, survival, virulence), host response, immunology

Underpinning control measures

- Genetics of Livestock Health including:
 - Understanding genetic basis of disease resistance
 - Which diseases might be most amenable to genetic approaches
 - How genetic approaches might be incorporated into integrated approaches to disease management
- Vaccinology (also under technological aspects)
- Gut Health including:
 - Effect of the feed on the host-microbiota interactions (gut ecosystem, intestinal morphology, colonization by pathogens) and its impact on livestock health
 - Effect of feed-borne contaminants (fungal, bacterial, mycotoxins) on livestock health

Generic technological aspects

- Detection, identification and monitoring
- Vaccine development
- Genetic and genomic approaches, transgenics

BBSRC-DBT Livestock Health and Disease Workshop

Venue: National Institute of Immunology (NII), Delhi, 6-8 February 2012

WORKSHOP PROGRAMME

Monday 6th February 2012	
Time	Programme
1900-1945 hours	Pre-meeting briefing for UK delegates (By RCUKI and BBSRC)
2000-2200 hours	Networking Dinner for UK and Indian delegation

Tuesday 7th February 2012			
Time/Venue	Programme		Speaker
0830 – 0900 hours	Registration		
0900 –1000 hours	0900- 0905	Compere	Dr Alicia Greated, Director, Research Councils UK- India
	0905-0915	Welcome and opening remarks	Dr Chandrima Shaha, Director, National Institute of Immunology
	0915-0930	Introduction to DBT's Livestock Health and Disease Research	Dr George John Senior Adviser, DBT
	0930-0945	Introduction to BBSRC BBSRC's Livestock Health and Disease Research	Dr Lesley Heppell (Head of Basic Bioscience Underpinning Health Sector, BBSRC) Dr Sadhana Sharma (Strategy and Policy Manager, BBSRC)
	0945-1000	Aims and objectives of the workshop and expectations	Prof Tom Humphrey and Dr Subeer Majumdar
1000-1020 hours	Tea/ coffee break		
1030-1200 hours	E-poster style introduction to participants' research interests 1 min each.1 slide covering: Name, institution, three key research interests, previous UK-India collaboration		

1200-1300 hours	<p>Landscape session: Infectious animal diseases (Food-borne zoonoses and Bacterial endemic diseases)</p> <p><u>10 minutes per speaker</u> Prof D Maskell Prof J Leigh</p> <p><u>10 minutes per speaker</u> Dr N Hegde Dr R Verma</p> <p>Q&A</p>
1300-1400 hours	Lunch and networking
1400-1500 hours	<p>Landscape session: Infectious animal diseases (Viral & Vector-borne diseases)</p> <p><u>10 minutes per speaker</u> Prof V Nair Prof I Morrison</p> <p><u>10 minutes per speaker</u> Dr V Suryanarayana Dr R K Singh</p> <p>Q&A</p>
1500-1545 hours	<p>Landscape session: Infectious animal diseases (Parasitic)</p> <p><u>10 minutes per speaker</u> Prof F Tomley</p> <p><u>10 minutes per speaker</u> Dr S Ghosh</p> <p>Q&A</p>
1545-1645 hours	<p>Landscape session: Transmission and Epidemiology</p> <p><u>10 minutes per speaker</u> Prof E Riley</p> <p><u>10 minutes per speaker</u> Dr H K Pradhan</p> <p>Q&A</p>
1645-1700 hours	Tea/Coffee Break

1700-1800 hours	Landscape session: Genetics of livestock health <u>10 minutes per speaker</u> Mr C Warkup Prof D Burt <u>10 minutes per speaker</u> Dr B P Mishra Dr SS Majumdar Q&A	
1800-1845 hours	Landscape session: Gut Health <u>10 minutes per speaker</u> Prof T Humphrey <u>10 minutes per speaker</u> Dr DN Kamra Q&A	
1845- 1900 hours	Closing remarks	Dr Alicia Greated
1930-2100	Special address: Dr Alex Morrow (DEFRA) STAR-IDAZ: Global Strategic Alliances for the co-ordination of research on the major infectious diseases of animals and zoonoses	

Wednesday 8th February 2012

Time	Programme	Moderators/Speakers
0900 -0905 hours	Welcome and opening remarks for day 2	Dr Alicia Greated
0905 – 1005 hours	Landscape session: Cross cutting issues – Immunology, Vaccinology and Diagnostics <u>10 minutes per speaker</u> Prof I Morrison Prof T Drew <u>10 minutes per speaker</u> Dr D Raj Dr R Bhatnagar Q&A	
1005- 1015	Introduction to breakout sessions	Dr Alicia Greated
1015-1045 hours	Tea/Coffee Break	

1045-1245 hours	<p>Breakout session</p> <p>Delegates will be grouped according to animal themes to discuss:</p> <ul style="list-style-type: none"> ➤ Challenges and Research Needs ➤ Strengths of UK and India ➤ Potential Areas of UK-India Collaboration <p>• Ruminant UK Delegates: Prof J. Leigh, Prof I. Morrison Indian Delegates: Dr MC Sharma, Dr S Ali, Dr MS Chauhan, Dr P Reddana, Dr G Prasad, Dr BP Mishra, Dr DN Kamra, Dr SS Majumdar, Dr AK Rawat</p> <p>Moderators: UK: Prof I Morrison India: Dr G John (DBT)</p> <p>• Poultry UK Delegates: Prof V. Nair, Prof F. Tomley, Prof T Humphrey, Prof D Burt Indian Delegates: Dr V Saxena, Dr D Raj, Dr N Hegde, Dr P Rao, Dr V Suryanarayana</p> <p>Moderators: UK: Prof F Tomley India: Dr HK Pradhan</p> <p>• Pigs UK Delegates: Prof D Maskell, Prof T Drew Indian Delegates: Dr G Saikumar, Dr K Kumanan, Dr R Verma, Dr S Ghosh, Dr RK Singh, Dr R Bhatnagar, Dr P Singh</p> <p>Moderators: UK: Prof D Maskell India: Dr S R Rao</p>	
1245-1330 hours	Lunch and networking	
1330-1430 hours	Discussion across groups An opportunity to comment on discussions in neighbouring breakout groups	
1430- 1515 hours	Tea/Coffee Break Moderators can use this time to visit neighbouring stations	
1515- 1545 hours	Moderators to feed back to the delegation as a whole	
1545-1615 hours	Prioritisation of research challenges identified in the context of a potential call for proposals	
1615-1630 hours	Summary of prioritisation	Prof Tom Humphrey and Dr Subeer Majumdar
1630-1645 hours	Next Steps and close of workshop	Dr Lesley Heppell, Dr George John

LIST OF ATTENDEES

S No	Name	Organisation
1	Dr Sher Ali	National Institute of Immunology, New Delhi
2	Dr Rakesh Bhatnagar	Jawaharlal Nehru University, New Delhi
3	Professor David Burt	The Roslin Institute/University of Edinburgh
4	Dr Bryan Charleston	Institute for Animal Health, Pirbright
5	Dr MS Chauhan	National Dairy Research Institute, Karnal
6	Professor Trevor Drew	Animal Health and Veterinary Laboratories Agency
7	Dr S Gosh	Indian Veterinary Research Institute, Bareilly
8	Dr N Hegde	Ella Foundation, Hyderabad
9	Professor Tom Humphrey	National Centre for Zoonoses Research, University of Liverpool
10	Dr N Kamra	Indian Veterinary Research Institute, Bareilly
11	Dr JM Kataria	Indian Veterinary Research Institute, Bareilly
12	Dr Kumanan	TANUVAS, Chennai
13	Professor Jamie Leigh	School of Veterinary Medicine and Science, University of Nottingham
14	Professor Subeer Majumdar	National Institute of Immunology, New Delhi
15	Professor Duncan Maskell	Veterinary School, University of Cambridge
16	Dr BP Mishra	Indian Veterinary Research Institute, Bareilly
17	Professor Ivan Morrison	The Roslin Institute/University of Edinburgh
18	Dr Alex Morrow	Defra/STAR IDAZ Coordinator
19	Professor Venugopal Nair	Institute for Animal Health, Compton, Berks
20	Dr HK Pradhan	WHO, Delhi
21	Dr Gaya Prasad	Indian Council of Agricultural Research, Delhi
22	Dr Dhinakar Raj	TANUVAS, Chennai
23	Dr P Rao	Ella Foundation, Hyderabad
24	Professor P Reddanna	University of Hyderabad
25	Professor Eleanor Riley	London School of Hygiene and Tropical Medicine
26	Dr G Saikumar	Indian Veterinary Research Institute, Bareilly
27	Dr Vishesh Saxena	Central Avian Research Institute, Indian Veterinary Research Institute, Bareilly
28	Dr MC Sharma	Indian Veterinary Research Institute, Bareilly
29	Dr RK Singh	National Research Centre on Equines, Hisar
30	Dr VVS Suryanarayana	Indian Veterinary Research Institute, Bangalore
31	Professor Fiona Tomley	The Royal Veterinary College, University of London
32	Dr Rishendra Verma	Indian Veterinary Research Institute, Bareilly
33	Mr Chris Warkup	Biosciences Knowledge Transfer Network

ORGANISERS

S No	Names	Organisation
1	Dr George John	DBT
2	Dr SR Rao	DBT
3	Dr AK Rawat	DBT
4	Dr Padma Singh	DBT
5	Dr Lesley Heppell	BBSRC
6	Dr Sadhana Sharma	BBSRC
7	Dr Chandrima Shaha	National Institute of Immunology, New Delhi
8	Dr Alicia Greated	RCUKI
9	Sukanya Kumar-Sinha	RCUKI
10	Shalini Singh	RCUKI
11	Swati Saxena	Science and Innovation Network

LANDSCAPE PRESENTATION

1. INFECTIOUS ANIMAL DISEASES (FOOD-BORNE ZONOSSES AND BACTERIAL ENDEMIC DISEASES)

➤ UK:

- Bacterial Diseases: The major diseases include: Mastitis, Lameness, Bovine TB, Calf scours, Bovine Respiratory Diseases, Johne's and Foot rot. These endemic diseases reduce production efficiency and are an important welfare problem. The major research needs are tools for early detection, differential diagnostics, epidemiology and disease monitoring, genomics based approaches for vaccine development, and genomic analysis of host disease resistance variations. The continuing emergence, development and spread of pathogenic organisms that are resistant to antimicrobials are a cause of increasing concern.
- Food-borne Zoonoses: Major food-borne pathogens of concern to the UK are: *Campylobacter*, *Salmonella*, *E. coli* (VTEC) and *Listeria*. The need to use genomic approaches to understand pathogenesis, virulence, transmission, colonization and role of individual genes of the major food-borne pathogens was emphasised. Also, the impact of variation in genome repertoire, individual gene sequence or level of expression, host specificity and zoonotic or epidemic potential of pathogens was highlighted.

➤ India:

- Bacterial Diseases: Major endemic diseases are Bovine TB (including its zoometric potential); Brucellosis (cattle, buffaloes, sheep and goat), Anthrax (endemic in certain states in India), Q-fever (endemic), animal Listeriosis (database on Indian *listeria* culture collection is under construction). The research thrust is on the development of novel biosensors e.g. electronic nose, nano-finger and nano-bioluminescence. The need for national level surveillance for these diseases to understand the burden in different parts of India, and enhancing diagnostic capabilities was highlighted.
- Food-borne Zoonoses: Pathogens of interest include – *Salmonella* and *E.coli* (EHEC). Food-borne zoonoses are an important issue in India and it is likely that much is undetected. The focus areas of research need are: rapid pen/bed side diagnostics; surveillance programme for carrier status (a national food-borne disease surveillance system needs to be developed in India in order to enable effective detection, control and prevention of food-borne disease outbreaks), vaccines and antimicrobials for use in food animals; understanding host genetics (susceptibility/resistance for disease carriage) and disease pathogenesis. The need for "one health" approach was highlighted. India's main strength in this area is network of district laboratories for diagnosis and vaccine production.

2. INFECTIOUS ANIMAL DISEASES (VIRAL & VECTOR-BORNE)

➤ UK

- Viral Diseases: Viral pathogens are a major threat with implications for human health and bioterrorism. The main thrust of research in UK is to prevent diseases from entering the country. The major research focus on animal viral diseases for the UK is on livestock viral diseases (including Foot & Mouth Disease, Classical Swine Fever, Peste des Petits Ruminant, Bovine Respiratory Syncytical, and Porcine Reproductive & Respiratory Syndrome); avian viral diseases (Avian Influenza, Marek's Disease, Infectious Bronchitis, Pox, Avian Leukosis, and Inflammatory Bowel Disease) and vector-borne viral diseases and zoonoses (West Nile, Rift Valley Fever, African Horse Sickness, African Swine Fever, Blue Tongue etc.). Many of these diseases are endemic in India. There is a need to address fundamental research challenges using systems approaches e.g. mechanism of viral pathogenesis, immune response to pathogens/vaccines; virus-host interactions and novel vaccines using new approaches (e.g. recombinant DNA technology, novel vaccines using siRNA).
- Vector-borne Diseases: A few economically important endemic diseases in the UK are tick-borne: Babesiosis (cattle and sheep), Louping ill viral encephalitis and Lyme disease but the major economic threat from vector-borne disease is from exotic incursion e.g. associated with animal movement and global warming. The major research focus for the UK is on: vector biology and ecology; epidemiology and mathematical modelling to predict transmission and spread of disease; host-pathogen interactions; immunology and vaccine development. The UK has strength in vector control through genetic modification and basic research on virus structure to underpin vaccine design.

➤ India

- Viral Diseases: A summary of current research status and need for viral disease research spanning a range of livestock species was presented. The major focus is on developing vaccines and vaccination strategies, novel diagnostics, screening assays and DIVA technologies. The need for surveillance and epidemiology was highlighted for disease e.g. Japanese encephalitis, and swine influenza. Some interesting differences in diseases in various species was highlighted e.g. there is no fulminating Blue Tongue disease in cattle and buffaloes in India; Foot and mouth disease virus behaves differently in pigs. Reverse genetics to study differential immune response to Foot and Mouth disease in indigenous cattle breed and DNA vaccines for Foot & Mouth Disease was described.
- Vector-borne Diseases: The presentation focused on tick-borne diseases and Trypanosomiasis. There are 106 tick species and often there is multi-tick infestation. Acaricides are used for vector control but growing multi-acaricide resistance and lack of new generation insecticides is a concern. India's research capabilities include two susceptible and three resistant tick lines for monitoring of acaricidal resistance. Anti-tick vaccine is under development. There is a macroschizont vaccine available for tropical theileriosis and diagnostic tools are also being developed. Trypanosomiasis is wide spread in a variety of species – camel, horse, cattle, buffaloes, dog etc. Epidemiological evidence suggests that buffaloes act as a reservoir. The main research focus is on immunoprophylaxis and diagnosis of *T.evansi*.

3. INFECTIOUS ANIMAL DISEASES (PARASITIC)

- UK
 - The prevalence of worms (nematodes, cestodes), flukes (trematodes), protozoa and external parasites varies between livestock species. However, disease prevalence due to worms, flukes and protozoa is high in cattle, sheep and poultry respectively. The main factors underpinning increased incidence of diseases include increased anthelmintic, flukicide, anticoccidial and acaricide resistance combined with lack of vaccines, and climate change to warmer wetter conditions. The gaps and future needs include new drug targets, and lead anti-parasitics; defining precise requirements for protective immunity, *in vitro* assays and culture systems; methods for genetic manipulation and novel vaccines/adjuvants.
- India
 - The talk focused on two parasitic pathogens - *Fasciola gigantica* and *Hemonchus contortus*. The current focus of *Fasciola gigantica* research is on identifying immuoprophylactic targets, role of proteases as a transmission blocking agents. Also, cathepsin-L-cystein proteinase has been tried as the potential target antigen in immunodiagnosis. There is an increased concern about anthelmintic drug resistance in *Hemonchus contortus*. Research is focussed on mapping the drug resistance in *Hemonchus contortus* and development of ethno-veterinary drugs for GI parasites.

4. TRANSMISSION AND EPIDEMIOLOGY

- UK
 - UK research strengths are: pathogen genomics and molecular epidemiology; methodological research to underpin mathematical modelling of infectious diseases and modelling human, livestock and wildlife diseases and their control including relevance to policy. The major research need is preparedness for large-scale epidemics which requires understanding of basic demographic information, descriptive epidemiology of pathogens and their distribution. There is also a need for improved preparedness for emerging and exotic diseases which requires risk pathway identification to define the frequency and risks of pathogen flow across species, long-term studies of epidemiology of multi-species infectious diseases, insights into drivers and effective surveillance. A number of areas of collaboration were identified: studies of cost-effective control techniques aimed at vectors of pathogens of human and animal populations - thus improving links between veterinary and medical research (One Health approach); linking occurrence and intensity of monsoon conditions to vector-borne disease to provide general models for disease prediction; establishing reference laboratories for emerging pathogens; understanding the context of single diseases in a wider impact framework; understanding social factors driving vaccination campaigns; understanding the role of wildlife and biodiversity in disease transmission.
- India
 - The talk described transmission and epidemiology of two diseases: anthrax which is endemic in India and avian influenza which is exotic. The talk concluded that epidemiology of infectious disease in animals is a complex issue dependent on various

factors and variable across diseases. In-depth studies on transmission and epidemiology are a pre-requisite for disease intervention and eradication. Epidemiology was highlighted as an area for potential collaboration as there is a major research gap in India in this area.

5. GENETICS OF LIVESTOCK HEALTH

➤ UK

- Heritable host variation plays an important role in the incidence and impact of animal disease and current advances in tools and technologies can help dissect host variation at the genomic level. High density SNP genotyping tools and other technological advances were highlighted. Some of the major gaps include reliable and affordable phenotyping tools, definition of disease state and access to large diseased populations. There are also gaps in biological understanding of host-pathogen interactions and pathways of infection that are protective to the host, understanding multi-factorial diseases, disease resistance implications of selection for productivity, and variation in host response to vaccination and disease resistance. The need for immunological tools and reagents was highlighted.

➤ India

- There are a number of ICAR funded projects based on genetics/genomics approaches and research initiatives on animal health including genetic studies in indigenous livestock breeds. There is an immense global diversity and broad spectrum of native breeds in India which are very distinct and provide a valuable resource. The current issues and future needs include: availability of appropriate and reliable phenotypes (including health records); refining quantitative population genetic studies to define usable markers including biomarkers for health status; the host's whole genome responses to environment, nutrition and disease state; understanding molecular pathways of host and pathogens that are involved in transmission, survival, virulence, innate and adaptive immune responses, and protective immune response to natural infection and vaccination; use of omic-technologies for biomarker discovery studies; availability of resources (genomic resources etc.); easy to use diagnostic platforms; applications of genome-enabled technologies in drug and vaccine development and translating genomic information to tools for controlling diseases. Novel transgenic technology using testicular stem cells was described which can have potential applications in livestock, but biosafety issues remain to be resolved and public engagement is important.

6. CROSS CUTTING ISSUES - IMMUNOLOGY, VACCINOLOGY AND DIAGNOSTICS

➤ UK

- Vaccinology: Vaccination aims to contain new outbreaks, reduce the pathogen burden and support eradication programme (in conjunction with diagnostics to distinguish infected from vaccinated animals). Most current vaccine development is based on selection of attenuated strains to use in live vaccines; use of inactivated pathogens or their products incorporated in adjuvants. The focus of future vaccine research is on novel approaches such as engineering viral particles to generate protective antibodies; engineering novel live attenuated organisms; use of defined antigens in subunit vaccines. There is a need for immunological and genetic tools and immunological reagents that underpin vaccine

development. The UK is strong in developing immunological and genetic tools underpinning vaccine development including: immunological reagents for veterinary species; studies of the innate immune response; high throughput sequencing and bioinformatic tools.

- Diagnostics: Accurate diagnosis is essential in disease control. Some of the novel diagnostic technologies include real-time PCR, isothermal amplification (LAMP, TwistDX); biosensors, DIVA diagnostics (parallel development of vaccine and test) and arrays.

➤ India

- Vaccinology: There are 26 veterinary vaccine production units in India (19 in public and 7 in the private sector). However for general use, a vaccine would need to be too cheap to provide a commercial return. The current efforts in vaccine research are focussed on developing vaccines for Classical Swine Fever, Blue Tongue, Bovine Herpes virus, Nano-biomarker Newcastle disease vaccine; foot-rot, Johne's disease and FMD etc. Future research needs are - vaccines for chronic infections such as paratuberculosis; combination vaccines; nanotechnology-based vaccine delivery systems; aerosol / oral delivery systems especially for poultry; marker vaccines; new adjuvants – targeted and specific immune bias – (Toll-like receptor ligands, adjuvants for mucosal immunity); assays for vaccine efficacy assessment - *in vitro* potency and assays for protective immunity, mucosal immunity, cytotoxic lymphocytes etc. Current research includes study of host/pathogen interactions to develop vaccines for anthrax, brucellosis, rabies, and bovine TB.
- Diagnostics: Currently there are few user-friendly and affordable diagnostic kits for field use and most are restricted to poultry sector. For few diseases (Avian Influenza, FMD, Morbilli virus, Bluetongue, CADRAD and PD-ADMAS) there are reference lab and other diagnosis is done at State Biological Units and University labs. Farmers are only interested in diagnostics if there is an available treatment. The future needs in diagnostics are: use of standardized reagents to ensure reproducibility; nucleic acid-based tests, multiple diagnostic platforms.

7. GUT HEALTH

➤ UK

- The importance of gut health in food animals was described using *Campylobacter* as an example. The effect of rapid growth rate in chickens and its potential deleterious effect on gut health and disease resistance were presented.

➤ India

- Gut microbiology has been neglected in India as it is a low priority area for microbiologists, biotechnologists and molecular biologists and there is a lack of coordination between nutritionists and microbiologists. This is combined with the fact that the gut microbes are difficult to cultivate and there is a lack of microbial culture collections. A number of gaps were identified: culturing technologies for gut microbes; the microbial/enzyme profile for optimal fibre degradation in the rumen; mechanism of competitive exclusion of pathogenic microbes by the probiotic microbes; meta-genomics to understand the gut microbiota.

Research challenges identified includes understanding calf diarrhoea in cattle and buffalo; relationships among the microbes, gut health and clinical outcomes; diet composition and gut health; effect of feed quality/variation in the diet on the immune system and physiology of the gut (including the gut microbial ecosystem); understanding of the mechanisms of the interactions; microbial diversity of calf stomach and large intestine and role of specific microbes in gut health; effect of feed-borne contaminants (fungal, bacterial and myco-toxins) on gut health and animal's performance; microbial diversity of the gut of domestic and wild animals; selective stimulation of indigenous microbes in the gut; meta-genomics of the rumen eco-system; clinical nutrition. The main research strength is manipulation of the gut/rumen microbial population to improve health.

RUMINANTS: BREAKOUT GROUP DISCUSSION

RESEARCH STRENGTHS

India

- Diagnostics and test development
- Diversity of animal populations and genetic information
- Diversity of production environments
- A large well-trained workforce
- Species-specific institutes (Central Institute for Research on Buffaloes, and Goats),
- Large pool of mathematically literate Biology students
- Vaccine development (**Complementary strength: translational research**)

UK

- Immunology and vaccinology (**Complementary strength: basic research**)
- Genomics
- Epidemic viral diseases
- Mastitis (Research need for India)
- TB research
- Epidemiology and mathematical modelling (**Research need for India**)
- Structural biology
- Genetics of disease resistance
- FMD and vaccines to combat it

RESEARCH NEEDS

India

- Mastitis (**Strength of UK**)
- Bovine TB and para TB (**joint research need**)
- 'Pen side' diagnostic tools
- Molecular epidemiology (**Strength of UK**)
- Gut health
- Disease modelling using transgenic animals and gene knockout techniques
- Genetics of disease resistance (**joint research need**)
- New generation vaccines

UK

- Bovine TB and para TB (**joint research need**)
- Build up capacity in Bioinformatics (by training more people)
- Studying livestock diseases in endemic setting
- Drug resistance in pathogens
- Generation of biological data
- Measurement of disease phenotypes
- Genetics of disease resistance (**joint research need**)
- Infection models in target animal

Agreed areas of potential collaborative research for ruminant species are:

- Molecular epidemiology and mathematical modelling
- Genetics of disease resistance
- New generation vaccines
- "Pen-side" and DIVA diagnostic tools
- Characterisation of pathogen diversity and virulence

PIGS: BREAKOUT GROUP DISCUSSION

RESEARCH STRENGTH

India

- Classical Swine Fever (CSF) Network: ICAR funded projects
- All India Coordinated Research on Pig on Classical Swine Fever (CSF)
- National research centre on pigs. Nationally coordinated projects for breeding and extension to industry
- Willingness of companies to develop and market new vaccines (**Research need for UK**)
- Critical mass of relevant scientists

UK research strengths are:

- A good and productive interaction with industry
- Pig sector is well structured and organised
- Research on trans-boundary diseases, endemic bacterial diseases, CSF, African swine fever, EMD and PRRS
- National knowledge and capability for pathogen identification
- National control programmes for zoonotic agents such as *Salmonella*

RESEARCH NEEDS

India

- Vaccines and diagnostic tools for CSF
- Thermo-stable vaccines
- Capacity building (**joint research need**)
- Building strengths in research of Pig respiratory diseases (**joint research need**)
- Epidemiology of swine diseases
- Engagement with the 'unorganised' sector of the industry, which currently comprises 80% of production
- Infrastructure and resources

UK

- Investigation of syndromic diseases
- Piglet mortality which is currently 8% but was 4% 15 years ago
- Capacity building in endemic viral diseases (**joint research need**)
- Building strengths in research of Pig respiratory diseases (**joint research need**)
- Coordinated use of Animal facilities
- *Salmonella* and its control
- Porcine immunology (Immunology Toolbox)
- Greater interaction with industry (**Strength of India**)
- Repository of immunological reagents

Agreed areas of potential collaborative research for pigs are:

- Epidemiology of zoonotic and endemic diseases
- Training and capacity building
 - Epidemiology

- Reference centres
- Research methods
- Classical Swine Fever research needs: epidemiology, novel diagnostics and vaccines
- Basic research projects on pathogen biology and immunology
- Academia and industry collaboration for knowledge transfer and product development

POULTRY: BREAKOUT GROUP DISCUSSION

RESEARCH STRENGTHS

India

- Diagnostics (**joint strength**)
- Structured nature of most of the industry (~70% of production).
- Biodiversity of 'backyard' production (~30% of production) and of poultry resources (**UK Research Need**)
- Avian influenza (**joint strength**)

UK

- Diagnostics (**joint strength**)
- Good knowledge of disease patterns and good interaction with industry
- Highly integrated industry
- IBV, Marek's disease, APEC, Coccidia, IBDV and red mites
- Generic research skills
- Avian influenza (**joint strength**)
- FBZ
- Host genetics
- Vaccine vector technology
- Immunological tools (**Research Need for UK**)

RESEARCH NEEDS

India

- Vaccinology
- Immunological tools (**Strength of UK**)
- Diagnostics
- Epidemiology and modelling of animal diseases, including training
- Understanding impacts of host and pathogen diversity (**joint research need**)

UK

- Access to well-characterised and genetically diverse host populations
- Pathogen diversity for vaccine development (**Strength of India**)
- Immunosuppression
- Co-infection and pathogen interactions

Agreed areas of potential collaborative research for poultry are:

- Generic vaccine production technologies for next generation vaccines (subunit and/or vector) including mass vaccination methodologies
- Host resistance
- Diagnostics
- Immunological tools
- Molecular pathogen tool box
- Epidemiology and modelling of pathogen populations, to include surveillance