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Emerging and Transboundary Animal Viruses

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The book is dedicated to all the eminent virologists who own not only inventiveness and creativity but also astonishing compassion. Their resourceful contribution helped in accomplishing this mammoth compilation involving important aspects on animal viral pathogens/diseases having emerging and transboundary description.

Preface

Even if the livestock sector has become a backbone to maintain the economy of many countries, the emerging and transboundary (crosses the national borders) animal viral diseases pose a serious risk to the animal farming sector and food and nutrition security globally. The epidemics and pandemics of a few infectious diseases of animals and/or humans during the past couple of decades have highlighted the significance of emerging infectious diseases (EIDs) due to their direct impact on the economy, welfare and public health. Even though Asia has been recognized as the epicentre of many EIDs and upcoming infections, several new pathogens have also appeared in the recent past in other parts of the world. Additionally, the emergence of new viral diseases/infections, such as Rift Valley fever, West Nile fever, SARS coronavirus, Hendra virus, avian influenza A (H5N1), Nipah virus, Zika virus and swine influenza A (H1N1) virus, from time to time is the flagrant examples threatening adversely both animal and public health globally. Therefore, the emerging, re-emerging and transboundary viral infections have become the prime choice of researchers and public health workers. The leading reason behind the increase in the number of viral diseases is the absence of safe and inexpensive prophylactics and therapeutics. Besides, the control and management procedures adopted for restricting viral diseases remain challenging and require expertise in capacity building for detection and differentiation of the pathogen; development of rapid, sensitive and cost-effective pen-side diagnostic tests/kits; regional and peripheral diagnostic laboratories; clinical and sero-surveillance of the disease in the susceptible and in contact animal populations; border control for transboundary diseases; quarantine facilities, vector control, and restrictions on the movement of animals from the affected areas; and other relevant general health control measures, such as disposal of carcasses, zoo-sanitary measures and management practices.

Currently, numerous research articles/news are available on several animal pathogens. Nevertheless, the book dealing with emerging, re-emerging and transboundary animal viruses is limited. Such a resource is essential for the research community to understand the latest knowledge and trends in this field so that it can be utilized for improving the counteractions. To overcome these issues and fill the gaps, we have come up with a compilation on *Emerging and Transboundary Animal*

Viruses to provide a conversant resource in this area. The significance of viral diseases in animals in the light of the adverse economic impact on the farmers and the livestock industry is also highlighted using appropriate examples. This book provides precise and up-to-date information on animal viral diseases that have emerged in the recent past or are re-emerging due to several complex environmental interplay factors and the ones which are not bounded in restricted national boundaries and have attained the transboundary status. Conclusively, the chapters define present-day information on the existence of emerging, re-emerging and transboundary animal viruses in a global context, with emphasis on the molecular state-of-the-art tools with special reference to the development of diagnostics, prophylactics and therapeutics.

The book covers important viruses/viral diseases of economic/public health concern in animals in various chapters written by more than 50 authors (researchers/academicians/young investigators) from different parts of the world. Additionally, throughout the book, tables and figures provide important clinical data and recommendations, with specific references at the end for readers who want to obtain further details of each topic. In this book, we have included 15 chapters on important animal viruses. The first chapter (Chap. 1) by Dr. Yadav and colleagues provides an overview of emerging and transboundary animal viruses, highlighting the significance of EIDs on public health. This chapter oveviews the experience gained in the control and management of a few important transboundary animal diseases and EIDs along with the successes, constraints, limitations and future research needs for developing better control approaches. Chapter 2 on African Swine Fever Virus by Dr. Alexander Malogolovkin and colleagues from Russia provides virus epidemiology, immunopathobiology and diagnostics with a brief overview of recent advances of virus vaccine development. Similarly, comprehensive information is provided on Classical Swine Fever Virus in Chap. 3 by Dr. Sarma. Coronavirus infections are a serious threat to the swine industry. In Chap. 4, Dr. Vlasova and colleagues discuss the progress on Transmissible Gastroenteritis Virus (TGEV), Porcine Epidemic Diarrhoea Virus (PEDV) and Porcine Deltacoronavirus (PDCoV) of swine. An overview of Torque Teno Virus of swine is given in Chap. 5 by Dr. Ghosh and colleagues. Dr. Malik and colleagues provide an overview of Teschovirus of swine in Chap. 6.

The burden of Flaviviruses has made the whole world vulnerable towards its infection. Animals play a crucial role in Flavivirus life cycle where pigs are the amplifying host for Japanese encephalitis virus, and migratory birds are reservoirs for West Nile virus. Dr. Saxena and team in Chap. 7 provide a detailed account of the Animal Flaviviruses. In Chap. 8, Orbivirus, the largest genus of the family *Reoviridae*, is discussed by Dr. Maan's team. Main emphasis of the chapter is on Bluetongue virus with elucidating taxonomic relationships, epidemiology, replication mechanisms and evolutionary process of these viruses. The next chapter (Chap. 9) by Dr. Virmani's group elaborates the equine influenza virus giving its current situation globally. In the subsequent chapter (Chap. 10), Dr. Sudhakar and team provide an overview of Schmallenberg virus. A tick-borne virus, classified as a BSL4 agent, the Crimean-Congo Haemorrhagic Fever Virus, is explained in Chap.

11 by Dr. Raut and colleagues. In the next chapter (Chap. 12), Dr. Rajkhowa has given a detailed account of an economically important swine disease named Porcine Reproductive and Respiratory Syndrome Virus.

Dr. Balamurugan's team has dealt with Peste-des-petits ruminants virus, a small ruminant morbillivirus (SRMV) belonging to the family *Paramyxoviridae* in Chap. 13. It is highly contagious, OIE notifiable and economically important transboundary animal viral disease of domestic and wild small ruminants, known as 'Plague of Small ruminants'. An overview of Sapelovirus in swine is provided in Chap. 14 by Dr. Malik and team. The last chapter (Chap. 15) is on hepatitis E virus by Dr. Kumar and colleagues. This viral disease is considered highly significant on account of its predominance in both developed and developing nations due to poor sanitation and low-grade drinking water.

We believe that owing to the in-depth knowledge of important animal viruses with high-quality contributions by experts, the present book will be an excellent source of information for the reader. The chapters published could be useful for veterinary professionals, clinicians, public health experts, researchers, students/scholars, animal producers, faculty and students with an interest in virology, viral diseases, epidemiology of viral diseases, viral zoonoses and management of viral diseases and epidemics, the pharmaceutical industry and biomedicine experts and pave the way towards designing and adapting effective and safer therapeutics from clinics to the laboratory for countering important animal viral diseases.

We, the editors, would like to express our gratitude to all the contributors for their support and hard work to make this book compilation a reality. We also extend special thanks to all the peer reviewers whose able expertise and rigorous reviewing of the manuscripts submitted for this book helped the authors to reach publication stages. We are grateful to Springer Nature for accepting our book proposal and extend our special thanks to Dr. Bhavik Sawhney, Associate Editor-Biomedicine, Springer Nature, for providing all the editorial help and high cooperation while processing the manuscripts for its successful publishing.

Izatnagar, India Yashpal Singh Malik
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"Emerging and Transboundary Animal Viruses": A Publication from World Society for Virology

About World Society for Virology

The World Society for Virology (WSV) is a nonprofit organization, 501c3-ID No. 001303257, that was established in 2017 with the mission to strengthen virology research on different viral diseases of humans, animals, plants, and others.

The main objectives of WSV include but not limited to:

1. Gather the virologists worldwide in the main society that does not require a fee for its membership [a great obstacle for many virologists in many countries] and provide help to all whenever possible.
2. Build up a network of scientific collaborations among virologists worldwide.
3. Build international bridges for virology laboratories worldwide.
4. Help virologists worldwide to advance their careers and obtain awards.
5. Provide educational resources free of charge and freely available to all members.
6. Help and facilitate getting scholarship and vacancies for virologists worldwide.
7. Build up databases of virologists based on their field of specialization for remote assistance and guide in case of the existence of any disease outbreak.

For details, visit www.ws-virology.org

About the Book

This book illustrates the prominence and implications of the emerging, re-emerging, and transboundary animal viruses which have become researchers' and public health workers' top precedence to triumph over the last few decades due to the consequential losses in animals as well as the unprecedented threats to the public. Even if the livestock sector has become the backbone to maintain the economy of many countries, the emerging and transboundary (crosses the national boarders) animal viral diseases possess a serious risk to the animal-agriculture sector and food security globally. The research outcomes of twenty-first century are transfiguring our capacity to respond to these animal healths defies swiftly and commendably through advent of urbane diagnostics tools, new generation prophylactic vaccines and therapeutic antimicrobials, and delivery systems. This book is comprised as an integrated approach to encompass comprehensive knowledge by a large team of more than 50 authors (researchers/academicians/young investigators) from different parts of the world. This book describes the precise and up-to-date information on animal viral diseases which have emerged in the recent past or are re-emerging due to several complex environmental interplay factors and the ones which are not bounded in restricted national boundaries and attained the transboundary status. The chapters provide information pertaining to the important viruses of livestock, emphasizing developments in the frontier research areas in studying emerging and transboundary animal viruses. Additionally, throughout the book, tables and figures comprehend the important clinical data and recommendations, with specific references at the end for readers who want to obtain further details of each topic. The significance of viral diseases in animals in the light of economic impact to the farmers and the livestock industry is also highlighted using apposite examples. Conclusively, the chapters define present-day information on existence of emerging, re-emerging, and transboundary animal viruses in global context with emphasis on the molecular state-of-the-art tools with special reference to the development of diagnostics, prophylactics, and therapeutics. As the chapters provided in this compilation are serious concern globally and suggestive of serious consideration at decision-making level, the book also explicitly describes the challenges imposed by the emerging and transboundary viral infections and our preparedness to counter them.

Contents

Editors and Contributors

About the Editors

Yashpal Singh Malik is presently working as "ICAR National Fellow" at the premier Veterinary Institute of the country—Indian Veterinary Research Institute (IVRI), Izatnagar, India. His major research achievements include contributions in viral disease epidemiology, virus-host interactions, microbial biodiversity, characterization, and diagnosis. He acquired advanced training in Molecular Virology from the University of Minnesota, Saint Paul, USA; Division of Virology, Ontario Research Institute, University of Ottawa, Ontario, Canada; and Wuhan Institute of Virology, Wuhan, China. He is a recipient of several prestigious national, state, and academy awards/honors including ICAR Jawaharlal Nehru Award (2001), Young Scientist Award of the Association of Microbiologists of India (2000), and Young Scientist Award from Uttarakhand Council of Science and Technology (2010). He is an active member of noted scientific and professional societies of international and national repute. He has been bestowed with several honors in the form of distinguished Associateships/Membership viz. Associateship of National Academy of Agricultural Sciences (2010); Membership—National Academy of Veterinary Sciences (2010); CSIR—Senior Research Fellowship (1997–2000); ICAR—Junior Research Fellowship (1995–1997); and Academic Merit Scholarship in bachelor's degree (1990–1995). He is an elected Fellow of the Indian Virological Society, Indian Association of

Veterinary Public Health Specialists, Indian Society for Veterinary Immunology and Biotechnology, and National Academy of Biological Sciences. Dr. Malik is a member of the International Committee on Taxonomy of Viruses (ICTV) on Birnaviridae and Picobirnaviridae study group and a managing committee member of the World Society for Virology. He has supervised 3 Ph.D. and 17 M.V.Sc. students. Over the years, he has developed several technologies and diagnostic kits and also has filed two national patents. He has authored 5 books, 25 book chapters, and published 2017 scientific research and review articles in peer-reviewed national/international journals of high impact factor. Dr. Malik has been the editor-in-chief of the *Journal of Immunology Immunopathology* and also edited a special issue of the Springer journal *VirusDisease* on "Enteric Viral Infections in Humans and Animals"; a special issue on "Emerging and Zoonotic Virus Challenges of Developing Nations" in Bentham's *The Open Virology Journal*; a special issue on "Therapeutic Advances and Their Biomedical Perspectives" for the *Journal of Current Drug Metabolism*; and a special issue on "Biomedical Perspectives of Advances in Disease Diagnosis and Therapeutics (BPADDT)" edited for the *Journal of Experimental Biology and Agricultural Sciences*.

Raj Kumar Singh is currently the Director-cum-Vice-Chancellor of the ICAR-Indian Veterinary Research Institute, Izatnagar. Dr. Singh is a noted scientist of high repute with specialization in veterinary microbiology, biotechnology, molecular epidemiology, diagnostics, and vaccinology. He has served as the Head of the Division of Virology, Station-in-Charge at IVRI, Mukteswar campus, Uttarakhand, and later as Director of the NRC on Equines and VTCC, Hisar. Dr. Singh has 10 national patents (granted—2 and filed—8), developed >8 live attenuated vaccines/vaccine candidates, and >26 diagnostic tests/assays/kits. He has authored 2 books, 23 book chapters, and published over 245 scientific research papers, 52 reviews, 15 lead papers, and 24 guest editorials/compendium chapters. Dr. Singh has supervised 8 doctoral and 11 master's students. He received several prominent awards including prestigious ICAR Rafi Ahmad Kidwai Award and Team

Research Award, DBT Tata Innovation Fellowship Award, Agriculture Research Leadership Award, FAO Fellowship for training at the University of California Davis, USA, and many others. He serves as the President of ISVIB and has several distinguished fellowships and life memberships of prestigious professional societies.

Mahendra Pal Yadav former Director, IVRI, Izatnagar, and Vice-Chancellor, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, is among the most renowned scientists working in the field of virology. The major research contributions to his name include the development of indigenous vaccines against equine influenza, infectious laryngotracheitis and colisepticemia in poultry, isolation and characterization of animal viruses, and development of several animal diseases diagnostic kits. Dr. Yadav has served as Professor of Virology (1981–1982) and Professor and Head of the Division of Virology at IVRI Mukteswar (1982–1987), Principal Scientist and In-charge of the Animal Health Unit (1987–1993), and Director of the National Research Centre on Equines, Hisar (1993–2000). He has also served as Director-cum-Vice-Chancellor of IVRI, Izatnagar (2000–2006), and later as Vice-Chancellor of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (2006–2009). As an eminent scientist, he is a recipient of several prestigious awards and fellowships including Fellow—National Academy of Veterinary Science (FNAVS); Fellow—National Academy of Agricultural Sciences (FNAAS), New Delhi, India; Fellow—Indian Association for Advancement of Veterinary Research (FIAAVR); President of Indian Association of Veterinary Microbiologists, Immunologists and Specialists in Infectious Diseases (IAVMI); Fellow—Indian Virological Society (FIVS); Fellow—Indian Society of Veterinary Immunology and Biotechnology (FISVIB); Fellow—Society for Immunology and Immunopathology (FSIIP); and Fellow—Royal Society of Crop Sciences (FRSCP). Dr. Yadav has received many prestigious awards including Chancellor's Medal 1966; Lance Award, 61 Cavalry, India 1996; ICAR Special Award 1998; Major (Mrs.) Malika IAAVR Award 2001; OIE International Meritorious Award (2000); Distinguished

Veterinarian Award 2002 of IAAVR; Dr. P. Richard Masillamony Oration Award 2003; Vocational Education and Development Award 2003; Higher Education and Development International Award 2004; Order of Merit Award in Management 2004, Swadeshi Vigyan Puruskar of Vigyan Bharti, India (2004); Dr. P. Bhattacharya Memorial Award of NAAS (2004); World Intellectual Property Organization (WIPO) Geneva Award (2005); NRDC Meritorious Invention Award (2005); Vigyan Gaurav Award of U.P. Council of Science and Technology (2005); Dr. C.M. Singh Samman 2005; IAVPH Life Time Achievement Award 2006; Society of Plant Research Eminence Award 2007; World Institution Building Programme Life Time Achievement Award, 2008; Lakhi Ram Memorial Award 2008; Lalbahadur Shashtri Honor 2008; Padma Vibhushan Dr. M.S. Swaminathan Agricultural Scientist Award 2009; IAVMI Dr. P. G. Pandey Oration Award 2010; ISACP Life Time Achievement Award, 2011; Dr. A. Lingard Memorial Award, 2012, by the Indian Academy of Environmental Sciences; Dr. M.R. Dhanda Memorial Oration Award, 2012, by IAPH; and Excellence in Virology Award of Indian Virology Society (2013). Dr. Yadav served as President, Indian Virological Society (1996–2003); President, IAVMI (1999 to date); President, IAUA (2006–2007); President NAVS(I) (2011–2013); FAO National Consultant; and Consultant, Haryana Farmers' Commission. He has expertise in areas such as veterinary virology, bacteriology, infectious diseases, vaccinology, biotechnology, and equine infectious diseases.

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Chapter 1
Emerging and Transboundary Animal Viral Diseases: Perspectives and Preparedness

Mahendra Pal Yadav, Raj Kumar Singh, and Yashpal Singh Malik

Abstract The epidemics and pandemics of a few infectious diseases during the past couple of decades have accentuated the significance of emerging infectious diseases (EIDs) due to their influence on public health. Although Asia region has been identified as the epicentre of many EIDs and upcoming infections, several new pathogens have also emerged in the past in other parts of the world. Furthermore, the emergence of new viral diseases/infections, such as Rift Valley fever, West Nile fever, SARS coronavirus, Hendra virus, avian influenza A (H5N1), Nipah virus, Zika virus and swine influenza A (H1N1) virus, from time to time is a glaring example threatening adversely both animal and public health globally. Infectious diseases are dynamic and concerning due to their epidemiology and aetiological agents, which is manifested within a host, pathogen and environment continuum involving domestic animals, wildlife and human populations. The complex relationship among host populations and other environmental factors creates conditions for the emergence of diseases. The factors driving the emergence of different emerging infectious disease (EID) interfaces include global travel, urbanisation and biomedical manipulations for human EIDs; agricultural intensification for domestic animal EIDs; translocation for wildlife EIDs; human encroachment, ex situ contact and ecological manipulation for wildlife–human EIDs; encroachment, new introductions and 'spill-over' and 'spill-back'; and technology and industry for domestic animal–human EIDs. The concepts of sanitary and phytosanitary (SPS) measures and biosecurity have gained recognition globally in almost all the realms of human activities, including livestock health and production management. This chapter provides the experience gained in the control and management of a few important

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TADs and EIDs along with the successes, constraints, limitations and future research needs for developing better control approaches.

Keywords Transboundary animal disease · Infectious animal diseases · Emerging diseases · Biosecurity and biosafety · Animal virus diseases · Disease management

1.1 Preamble

A 'disease' may be defined as a condition of the living human, animal or plant body or one of its parts that impairs normal physiological functioning and is typically manifested by clinical symptoms and signs. Animal and human diseases are classified in several ways depending on the criteria, such as infectious and non-infectious diseases, contagious and non-contagious diseases, zoonotic and non-zoonotic diseases, and acute and chronic diseases. The infectious diseases are caused by virus, bacteria, mycoplasma, fungi or rickettsia depending on the nature of the etiological agent involved. Among the infectious diseases, viral diseases are most devastating and difficult to control as they usually spread very fast and unlike other infectious diseases have no cost-effective or safe antiviral antibiotics/drugs for the treatment. A new disease occurring in an area/host population spread further and get established in want of awareness, lack of diagnostic facility, expertise or other factors is termed as 'emerging disease'. While disease of past, re-appearing in an area having a susceptible host population(s), is termed as 're-emerging disease' (Lederberg et al. 1992; Daszak et al. 2000). Example of the latter is the re-emergence of human tuberculosis in many countries which earlier had negative status as a result of judicious control measures adopted; it re-appeared subsequently due to the spread of immunosuppressive human AID's virus, namely human immunodeficiency virus (HIV). Introduction of susceptible animal populations/breeds from abroad for crossbreeding to upgrade the local breeds in India and other developing countries has resulted in the re-emergence of protozoon parasitic infections, such as theileria, babesia and anaplasma in the imported stock or their crossbreeds. The disease which is introduced from abroad into a country is termed as 'exotic'.

The infectious diseases are dynamic concerning their epidemiology and etiological agents which is manifested within a host, pathogen and environment continuum involving domestic animals, wildlife and human populations. The complex relationship between these host populations and other environmental factors creates conditions for disease emergence. The spill-over of the new emerging disease may be from 'domestic animals to wild life', 'wildlife to humans' or 'domestic animal to human' or in all categories. The factors driving the emergence of different EID interfaces include global travel, urbanisation and biomedical manipulations for human EIDs; agricultural intensification for domestic animal EIDs; translocation for wildlife EIDs; human encroachment, ex situ contact and ecological manipulation

for wildlife–human EIDs; encroachment, new introductions and 'spill-over' and 'spill-back'; and technology and industry for domestic animal–human EIDs.

1.2 Emerging Diseases

The term 'emerging disease' is used to refer to changes in the disease dynamics in the population. Emerging infectious diseases (EIDs) are those which have moved recently into a new host or have enhanced incidences or geographic range or are caused by evolving pathogens (Lederberg et al. 1992; Daszak et al. 2000). This general definition covers a range of infectious diseases of man and animals which pose a significant threat to both medical and veterinary public health. Among the OIE-listed diseases of viral aetiology, major changes have been experienced in the occurrence of rinderpest, peste-des-petits ruminants (PPR), foot-and-mouth disease (FMD), African swine fever (ASF), lumpy skin disease and Rift Valley fever (RVF). Of these, rinderpest presents a success story from the 1990s to 2011 as a result of FAO, OIE, EU and IAEA (International Atomic Energy Agency) guided and co-ordinated programmes including the Pan African Rinderpest Campaign (PARC), NPRE and NREP in India (Yadav 2011), Global Rinderpest Eradication Program (GREP) of the FAO and other national governments where the disease was endemic. These exemplary efforts led to the historic declaration of global rinderpest eradication by the FAO on June 28, 2011.

1.3 Transboundary Diseases

The terms 'exotic disease' and transboundary animal diseases (TADs) are often used interchangeably. Though all transboundary diseases are of exotic origin, all exotic diseases are not included in TAD listing. Many EIDs are also transboundary diseases. The TADs are defined as highly contagious and transmissible epidemic diseases of livestock which have the capability for rapid spread to new areas and regions regardless of national borders and have serious socio-economic and public health consequences. Nearly all diseases affect livestock, poultry, fishes and other animals and adversely impact the quality and quantity of food and other products, such as hides and skins, bones, fibres, wool and animal draft power for tilling, transport and traction. The reduction in animal production, productivity and profitability due to TADs affect the human livelihood. In the present scenario of fast-increasing globalisation, TADs represent a serious threat to the economy and welfare of the public and affected nations as they drastically reduce production and productivity; disrupt trade and travel and local and national economies; and also threaten human health through inferior food quality and zoonotic diseases/infections. As such, consequences of TADs could have a significant detrimental effect on the economy and public health of not only the affected nations but also the whole of the world.

1.3.1 Source of the Pathogens of EIDs and TADs

Possibly the infectious agents which cause emerging and transboundary diseases are already present in the environment and get the opportunity to cause disease under certain altered circumstances. The transmission of the infectious agent could occur between animal and human; between wildlife, human and domestic animals; or between wildlife, domestic animal(s) and human. However, the main source for maintenance and transmission of the infectious agents in nature is determined by the zoonotic pool and spill-over and spill-back mechanisms.

1.3.2 Transboundary Diseases as Potential Threats

TADs have become of great concern due to the risk for national security on account of their economic significance, zoonotic nature and ever-growing threat of newer TADs in future. Among the TADs having zoonotic manifestations, a number of infectious diseases, such as highly pathogenic avian influenza (HPAI), BSE (Mad cow disease caused by prion), West Nile fever, Rift Valley fever, SARS coronavirus, Hendra virus, Nipah virus, Ebola virus, Zika virus and CCHF, to name a few, adversely affecting animal and human health have been in the news in recent times (Malik and Dhama 2015; Munjal et al. 2017; Singh et al. 2017, 2019). The direct and indirect costs due to the FMD outbreak in the UK in 2001 were assessed to be over US$9 billion. Over 150 million chicken died or were destroyed in Southeast Asia in 2004 to control HPAI (H5N1). The Netherlands suffered an economic loss of $2.5 billion due to classical swine fever in 1997–1998. As per the estimates of FAO nearly one-third of the world meat trade was facing import bans on account of BSE, HPAI and other animal diseases. There is evidence to suggest that threats from TADs have increased over the years. The risk of animal disease outbreaks is likely to further grow in future as the higher incomes of people in developing countries will generate more demand for animal protein and products (milk, meat, egg, chicken and fish). The number of animals raised for meat is growing rapidly. During 1990s poultry production in East Asia has increased by about 12% per year to double every 5–6 years. Similar to TADs, new human viral diseases have emerged like Ebola, SARS, Zika, CCHF, Nipah and BSE as well as there is the emergence of new antigenic forms or new biotypes of the existing infectious diseases, such as a hypervirulent strain of IBD in poultry in Europe and highly virulent strain of Newcastle disease in the USA (Riemenschneider 2005; Singh et al. 2017). Vector-borne pathogens, namely, bluetongue, African horse sickness, Rift Valley fever and West Nile fever, have the potential to spread in epidemic forms. Riemenschneider (2005) has deliberated over several issues relevant in the control of TADs as proposed in the Institute of Medicine (IOM) Report (Anonymous 2003). Some of the points which could be responsible for the increased threat of TADs are briefly discussed below.

1.3.2.1 Globalisation and Trade

In the present-day world, higher quantitative levels of animal origin foods, as well as faster trade, new trade routes and air travel, have led to higher risks for contracting new infections and diseases. As it is now possible to reach any part of the world within 24 h which is less than the incubation period of most of the infectious diseases, animals or people carrying the infectious agents go undetected in want of clinical disease/symptoms. Fresh commodities vis-à-vis processed foods that have witnessed an increased trade are more likely to carry the pathogens to distant parts of the world—countries and continents.

1.3.2.2 Intensive Animal Production Systems to Meet the Rising Demand for Animal Protein

Recent decades are witnessing higher demands for animal protein and other nutrients through meat and meat products, milk and milk products, eggs, and fish and fish products as a result of rising incomes in the developing countries and elsewhere which leads to the intensification of production systems and overcrowding of animals. This increased production is often required in peri-urban areas, having large human populations, under suboptimal husbandry practices. In such high-production areas, disease outbreaks affect a greater number of animals at a faster rate and speed, leading to heavy economic losses. Drastic control measures are taken, such as the slaughter of infected and in-contact animals followed by burning or burial is not acceptable to the society at large. For example, the mass slaughter of pigs in the Netherlands in 1997–1998 for the control of CSF virus led to objection from the non-farm population which might influence the application of the stamping-out policy as a disease control approach in future.

1.3.2.3 Impact of Changes in Forest Ecology

Exposure of the domestic animals to forest niches due to deforestation and transformation of tropical rainforests for livestock grazing exposes the domestic livestock to a completely new range of pathogens and vectors which previously circulated in wildlife reservoir niches only. With the domestic livestock being fully susceptible and naïve to these infectious agents, the disease spreads more rapidly and severely in want of lack of diagnostic tests and vaccines against these new pathogens resulting in heavy morbidity, mortality, trade restrictions and economic losses.

1.3.2.4 Influences of Increased Conflicts and Unrest

Nowadays many countries face prolonged civil unrests besides inter- and intra-country conflicts, which may lead to enhanced threat of TADs. Civil disorders are known to disrupt enforcement of quarantine and other control measures due to refugee and army deployments/movements. Breakdown in the institutional support for quarantine and difficulty in gaining access to border area due to landmines make disease surveillance more difficult. Inflows of more food aids for such areas also pose additional risks as the food items may have contaminants.

1.3.2.5 Effect of Climate Change, Global Warming and Microbial Evolution

Climate change and global warming seem to be altering rainfall and weather patterns. Rising temperatures in the northern hemisphere are likely to shift the distribution of insect vectors of bluetongue, African horse sickness, Rift Valley fever and similar vector-borne diseases. The bluetongue virus (BTV) having 27 serotypes occurs in many parts of the world. However, until recently it was never reported from Europe. The sudden incursions of some serotypes into Spain, Italy, Greece, Portugal and the Balkan countries since 1998, followed by Germany, and the recent incursion of BTV serotype 8 in several farms in the Netherlands, Germany and Belgium since August 2006 as well as serotype 1 are also believed to be due to climate change as European weather has become hotter in recent decades. The BTV serotype 8 revealed that this serotype is closest to the Nigerian strain. The incursion is believed to have been caused by the importation of an infected zoo animal or an infected midge. An upsurge of Rift Valley fever was observed in East and West Africa due to climatic changes.

1.3.2.6 TADs as a Serious Threat to National Security

Many factors discussed above make the TADS as a serious threat to national and international security. The developing countries are usually the worst sufferers. Among other factors, veterinary public health services in developing countries are usually much behind than the medical public health services. Moreover, unlike human disease reporting, animal disease reporting systems are usually based on passive reporting rather than active disease surveillance. A few other factors are also responsible for greater threat due to TADs, namely (1) lack of awareness of the farmers about the high-threat epizootic animal diseases; (2) lack of diagnostic facilities for exotic diseases, and under-reporting of animal diseases like HPAI due to the fear of loss of internal and export market till the country gets infection-free status as per OIE-laid-down criteria; and (3) poor and faulty compensation schemes.

1.4 Threat of Bioterror/Biowarfare

In the technological advances made in today's world, there is always a real risk of deliberate misuse of certain infectious agents/pathogens by terrorists as a means of biowarfare between nations to harm the people and/or livestock, poultry and other animals. Potential for pathogenic disease agents not reported previously in a country and being misused or mishandled for bioterrorism is likely to threaten the ecosystem on a large scale. Even new pathogens can be engineered as novel infectious agents. The animal diseases could even be a greater threat than human diseases as these may result in significant economic disruptions, besides causing food poisoning and deterioration, and zoonotic diseases in human beings. As animal diseases get less priority than human infections/diseases in undertaking immediate disease control measures, the threat scenario with the use of animal pathogens for bioterrorism or biowarfare will have many serious consequences. Some of the viruses having significant bioterror potential for humans and or animals include HPAI (H5N1), monkeypox virus, FMD virus, yellow fever virus, Spanish flu virus, poliovirus, AIDS virus (HIV), measles virus, Hendra virus, Nipah virus, SARS coronavirus, BSE prion agent and unknown agent(s) created through biotechnology and gene editing.

1.5 Handling of New Viral Disease Outbreaks

When an exotic viral disease strikes a country for the first time, it may initially affect one animal, few animals or a large number of animals. The strategy to be adopted for containing the outbreak will depend on the nature of the virus, speed of its spread, role of vectors, risk assessment, communication and management, response time and country legislation on disease control and prevention. Thus, there is a need to develop strategic plans for the prevention and control of exotic and TAD on a case-to-case basis. Examples of such viral diseases from Indian perspective include African swine fever (ASF), transmissible gastroenteritis (TGE), and swine vesicular disease in pigs, Rift Valley fever, African horse sickness (AHS), West Nile fever, Eastern equine encephalomyelitis (EEE), Western equine encephalomyelitis (WEE), and Venezuelan equine encephalomyelitis (VEE), FMD virus types 'C', 'SAT I', 'SAT II' and 'SAT III', Nipah virus, Hendra virus, SARS coronavirus, and prion diseases—bovine spongiform encephalopathy (BSE), and scrapie.

1.6 Biosecurity and Biosafety Measures to Combat Viral Infections

Institution of appropriate and timely biosecurity measures is an important instrument for the protection and improvement of animal health. Breach in biosecurity due to ignorance and avoidable lapses in the adoption of timely biosecurity and

biosafety measures in the management of livestock, poultry and fish minimise the risks from infectious diseases including EIDs and TADs. Breach in biosecurity in livestock management is often an important reason for the high incidence of zoonotic and other infectious diseases of animals. This is more so in case of the viral diseases of livestock and poultry. Closer contact between wildlife, animals and humans and rearing of livestock and poultry in close association with people promote spread of viral and other infectious diseases which have the potential for threatening health, economies and food security around the world. The emergence of new viral diseases/infections, such as Rift Valley fever, West Nile fever, SARS coronavirus, Hendra virus, avian influenza A (H5N1), Nipah virus, Zika virus and swine influenza A (H1N1) virus, from time to time is a glaring example of zoonotic disease threats adversely affecting both animal health and public health, national economies and food and nutrition security globally. Due to a lacuna in the biosecurity, viral diseases like the FMD had reoccurred in countries where these had not been reported for many decades, including the UK, a developed country.

1.6.1 Biosafety and Biosecurity

Biosafety and biosecurity are interrelated terms but used in different contexts. The guidelines are developed by WHO, FAO and OIE. Biosafety aims at the protection of person(s) at work and the facilities which are dealing with the biological agents, against their exposure to a disease agent, and prevents unintentional exposure to pathogens/toxins or their accidental release. Thus, biosafety is the application of knowledge, techniques and equipment to prevent personal, laboratory and environmental exposure to potentially infectious agents or biohazards. Biosecurity, unlike biosafety, has divergent meanings in different contexts in which it is used. It deals with the protection of microbiological assets from spill-over, theft, loss, diversion or intentional release from laboratories, preventing the import of certain organisms/toxins. Biosecurity is a set of preventive measures designed to reduce the risk of intentional transmission of infectious diseases to safeguard the facilities containing sensitive biological materials with the potential of a biological weapon. In brief, biosecurity means bio-risk management. Once a disease is eradicated globally, the policy for keeping the wild and vaccine strains of the virus along with vaccine stocks for emergency use and their subsequent destruction is decided by international agencies like FAO, WHO and OIE based on the recommendations of experts in the area.

1.6.2 Biosecurity Policies, Protocols and Action Plans

These include risk assessment; communication and management; quarantine of imported animals at seaports, dry ports and farm; establishment of check posts and vaccination stations at international and interstate borders for clinical surveillance; creation of immune belts at international borders; and planning and conducting

structured disease surveillance including clinical surveillance and serosurveillance. Biosafety and biosecurity need to be observed at all levels beginning from farm to national and international levels. For handling the most dangerous transboundary disease pathogens, BSL III and BSL IV laboratories are required to ensure biosafety, biosecurity and biocontainment. Proper zoo sanitary measures, such as quarantine; rodent and vector control; disinfection of animal sheds and premises; proper disposal of dung, urine, feed and fodder wastes; and proper carcass disposal, need to be adopted religiously for effective management of EIDs and TADs.

1.6.2.1 Biosecurity at International Borders

Every country needs strict and foolproof biosecurity mechanism at its international borders as a safeguard against the entry of exotic infectious agents/diseases from abroad along with the import of livestock and other animals and their products. For example, India has contiguous and porous borders with countries like Nepal, Bhutan, Pakistan and Bangladesh, besides free trade with Nepal and Bhutan. Since all these countries are vulnerable to TADs, there is a need for regional biosecurity plan to ensure a biosecure region. It would never be possible to have a biosecure country if the bordering countries do not have effective biosecurity in place.

Different countries are at risk for a number of TADs like anthrax, plague, glanders, Lyme disease, contagious equine metritis, *Salmonella abortus equi*, HPAI virus, FMD virus (SAT 1–3), Lyssavirus, rabies, Hendra and Nipah viruses, West Nile virus, highly pathogenic ND virus, rabbit haemorrhagic disease virus, bovine spongiform encephalopathy (BSE), African horse sickness (AHS), equine encephalomyelitis (EEE, VEE, WEE), equine infectious anaemia, chicken infectious anaemia, equine influenza, vesicular stomatitis, Rift Valley fever, malignant catarrhal fever (MCF) and other TSEs of sheep, goat and deer. Biosecurity measures are required for preventing and containing the ingress of these diseases through international trade. The OIE has facilitated safe trade in animals and animal products by developing effective standards to prevent the spread of animal diseases across the globe. Prevention of transmission of pathogens across intra- and inter-country borders warrants devising of biosecurity measures at par with international standards. Adequate infrastructure comprising check posts and quarantine facilities at seaports, airports and porous international land border are must to check the ingress of viral and other pathogens from across the borders. Diagnostic facilities with trained human resource, and well equipped with instruments and pen-side diagnostic tests/kits, should be in place for ensuring the pathogen-free status of imported livestock and livestock products.

1.6.2.2 Biosecurity Measures at National Level

Biosecurity measures at national level incorporate the components of ‘external biosecurity’ preventing the ingress of exotic and transboundary animal diseases and ‘internal biosecurity’ within the country encompassing zonal, compartmental and farm-level biosecurity. Regulations for animal movement through interstate borders

in India are in place but need strict implementation. Modern detection systems can be used for identification and tracking of animals and animal products to provide information regarding the origin of the animal, and environmental practices used in production and food safety.

1.6.2.3 Farm Biosecurity

For effective disease prevention and control, integration of biosecurity into every operation at the farm is essential. Farm biosecurity should be inclusive of both 'bio-exclusion' (measures for preventing a pathogen from being introduced to a herd/flock) and 'biocontainment'. The latter addresses the events after the introduction of the pathogen and its ability to spread among susceptible groups of animals at the farm or further spill-over to other farms.

Strict implementation of biosecurity at farm level has played a crucial role in preventing the spread of diseases. A suitable plan addressing important issues, such as location and layout of the farm, animal health practices in place and general management on the farm, needs to be chalked out. It should be flexible to include new knowledge, concepts and technology. A wide range of biosecurity practices have been recommended for different livestock species and production systems, both for specific infection risks or for disease prevention in general. Biosecurity practices have been recommended for cattle, sheep, pig, poultry and fish production systems.

General biosecurity practices and interventions that can be applicable across species and farms include:

1. Maintaining a closed herd procurement/purchase of animals from known sources
2. Minimising the number of animals purchased/transferred/exchanged and the number of herds from which the animals are introduced
3. Avoiding purchases from markets or dealers
4. Appropriate quarantine and testing of animals upon introduction or reintroduction in farm premises
5. Discouraging farming practices such as hiring a bull or stallion and returning it after the breeding season
6. Avoiding the introduction of biological material of uncertain health status
7. Health and vaccination records should be obtained for all the newly introduced animals

Isolation/quarantine of such animals for 2–8 weeks in a separate quarantine facility should be practiced and the animals during this period should be observed for illness/symptoms and screened for important diseases before mixing with other stock at the farm. Laboratory testing of appropriate samples collected during quarantine against important infectious diseases is recommended. The incoming stock can also be given vaccine against the endemic disease prevalent in the area at least 2 weeks before release from quarantine to boost their protective immunity.

Animal diseases can spread from farm to farm resulting in animal sickness, death and economic losses. Visitors to the livestock farm, disease laboratory, birds,