Critical Needs for Research in Veterinary Science

Committee on the National Needs for Research in Veterinary Science, National Research Council

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Research in veterinary science is critical for the health and well-being of animals, including humans. Food safety, emerging infectious diseases, the development of new therapies, and the possibility of bioterrorism are examples of issues addressed by veterinary science that have an impact on both human and animal health. However, there is a lack of scientists engaged in veterinary research. Too few veterinarians pursue research careers, and there is a shortage of facilities and funding for conducting research. This report identifies questions and issues that veterinary research can help to address, and discusses the scientific expertise and infrastructure needed to meet the most critical research needs. The report finds that there is an urgent need to provide adequate resources for investigators, training programs, and facilities involved in veterinary research.

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Summary

Research in veterinary science is critical to the protection of public health and the advancement of science that benefits both humans and animals as individuals and populations. Veterinary research includes studies on prevention, control, diagnosis, and treatment of diseases and on the basic biology and welfare of animals. It transcends species boundaries to include the study of spontaneous and experimental models of both human and animal disease and research at important human-animal interfaces, such as food safety, wildlife and ecosystem health, zoonotic diseases, and public policy.

The rich history of veterinary research, which includes studies on infectious disease and in other biomedical sciences, is replete with seminal contributions to the improvement of animal and human well-being. The many contributions of veterinary research were the results of society’s recognition of its important role and society’s subsequent support in the form of human, fiscal, and infrastructural resources. The current level of support for veterinary research, however, has not kept pace with the challenges posed by new and emerging threats and the nation’s growing demands for knowledge in biomedicine and animal health. That society’s needs are outgrowing our knowledge base is seen in examples of missed opportunities to safeguard and improve human and animal health and welfare (Box S-1).

The capacity of veterinary research depends on the availability of human and financial resources, research facilities, and infrastructure. This report identifies some of the most critical research needs and outlines recommendations and strategies for meeting them. Failure to provide the necessary resources could have devastating effects on both human and animal welfare, impede biomedical advances, and harm the economy and society as a whole.
To prepare this report, the Committee on National Needs for Research in Veterinary Science analyzed national research needs in three fields of veterinary science—public health and food safety, animal health and welfare, and comparative medicine—and looked at a number of emerging issues that fit in two or more of those fields. The research needs include scientific investigation in domestic, wild,
companion, service, and laboratory animals. The committee’s analysis was based on a comprehensive review of published literature; information obtained from stakeholders, including the Association of American Veterinary Medical Colleges (AAVMC) and several veterinary specialty colleges; and comments provided by national experts at the committee-hosted Workshop on National Needs for Research in Veterinary Science. Current funding levels and sources also were analyzed. On the basis of workshop input and analyses of available data, the committee identified past and future research trends and gaps and the scientific expertise and infrastructure required to meet the most critical research needs. In accordance with its stated charge, the committee did not make specific budgetary or organizational recommendations. (See Appendixes A and B for complete statement of task and biographical information on committee members.)

CHALLENGES FOR VETERINARY RESEARCH

Veterinary research offers numerous opportunities for improving animal and human health, and unforeseeable challenges can be met best with a competent and properly equipped veterinary research community. Specific findings and critical research needs are detailed in Chapter 2 and summarized below.

Public Health and Food Safety

Foodborne disease is a major cause of morbidity and mortality in the United States. Animals—both domesticated and wild—are frequent reservoirs of foodborne pathogens that can cause human illness. Human public health is affected not only by foodborne pathogens but also by the security of our food animals. A new awareness of the need for research on food and agricultural biosecurity arose after September 11 and the “anthrax letter” attacks later in 2001 because biosecurity research is closely related to maintaining safe agriculture and the food supply. Veterinary research on public health and food safety can contribute to:

- Improving detection and surveillance of foodborne pathogens associated with livestock and poultry production.
- Developing interventions to reduce their dissemination.
- Understanding the development and mechanisms of antibiotic resistance among foodborne pathogens associated with animals in the food chain.
- Developing preharvest and postharvest surveillance systems, diagnostic and detection systems, vaccines, immunomodulating drugs, animal and product tracking systems, and ecologically sound means of disposal of animal carcasses.
- Improving our ability to detect and identify disease and pathogens in animal populations and our understanding of interactions between pathogens and hosts so that effective preventive measures and countermeasures can be developed.
A concerted research effort can reduce the recurrence of food pathogens associated with livestock and poultry and ensure the security of our food supply.

**Animal Health and Welfare**

The increasing demand for veterinary research in animal health and welfare has several underlying causes:

- The perspective of the role of animals in human society and in the ecosystem has changed.
- A secure supply of food animals—such as poultry, cows, and fish—depends on their health.
- Some food-animal diseases affect human health directly (for example, some strains of high-pathogenicity avian influenza virus).
- Companion and service animals have an important role in human welfare.
- Laboratory animals are integral to our understanding of basic biology and physiology and are crucial for biological and medical advances.
- Wildlife health is important for the maintenance of the ecosystem and for the economy.
- Some emerging infectious diseases are associated with zoonoses (animal diseases that can be transmitted to humans).

Veterinary research is poised to improve human and animal health further through advances in preventive medicine, enhanced treatment for animal diseases, and a better understanding of transmission of zoonotic and other emerging diseases between wild and domestic animals and humans.

**Comparative Medicine**

Comparative medicine is the field that compares medical and scientific discoveries and knowledge of more than one animal species, including humans. Research in comparative medicine is invaluable for the overall medical research enterprise and for the improvement of animal health. Animal models used in biomedical research provide a whole-animal perspective that cannot be achieved at the molecular, cellular, or organ-system level. With technological advances, many new fields are emerging in comparative medicine, for example:

- Comparative genetics, which aims to develop reliable molecular markers of specific genetic traits to identify carrier and affected animals.
- Genome and phenome research that identifies specific genotypes associated with phenotypes.
- Stem-cell research and cloning.
- Genetically engineered animal models.
- Biomaterial developed to treat human and animal diseases.
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Continuous progress in biomedical research will depend on our ability to develop and refine animal models to advance biomedical research, to preserve valuable models, and to improve methods for developing genetically engineered animal species other than the mouse to advance understanding of select diseases.

RESEARCH AGENDA AND STRATEGIES

The committee outlined a research agenda and recommended strategies for doing the research (Chapter 3) on the basis of the critical research needs described above. The especially compelling scientific opportunities to improve the quality of life of and minimize biological threats to animals and humans include the following:

- Implement the concepts of One Medicine and interdisciplinary and translational research in the broader biomedical research agenda.
  - Substantially improve the integration of molecular biology, genomics, immunology, whole-animal physiology, pathophysiology, and other disciplines in clinical disease research.
  - Encourage scientists, through grant-funding mechanisms and other means, to work collaboratively across disciplines, institutions, and agencies.
  - Encourage research institutions to foster research environments that nurture and reward successful team-oriented investigators and research.
  - Expand veterinary student involvement in ecosystem health and increase their opportunities to work collaboratively to study and understand complex systems and the intricate relationships between humans (individuals, cultures, and societies), animals (domestic and wild), and the environment.

- Set priorities for research to expand our knowledge, detection, and control of infectious diseases.
  - Emphasize classes of disease agents of the highest economic importance, including those most likely to cause massive epizootics or epidemics and new and emerging diseases and candidate bioterrorism agents.
  - Emphasize the study and eradication of laboratory animal diseases that adversely affect the quality of biomedical data.
  - Focus research on the molecular bases of virulence and on how pathogenic organisms replicate and survive in the environment, including studies of vector biology, wild-animal hosts and reservoirs, host defense factors, and host-pathogen interaction.
  - Develop and validate rapid, sensitive, reliable, and where possible quantitative systems for detecting and monitoring disease-causing organisms.

- Expand the study and use of bioinformatics and develop databases and other resources that are readily accessible to the scientific community to enable
  - A population-level view of disease and research on the interaction between wildlife, domestic animals, and humans.
– Tracking of pathogen prevalence in animals, including companion, food-producing, and laboratory animals.
– Tracking of foodborne diseases.
– Maximizing the sharing and efficiency of developing, preserving, and housing important rodent and other animal models.
  • Quantify critical, scientifically based measures of animal health and welfare to optimize efficient, effective, sustainable, and socially responsible food-animal production and laboratory animal research.
  • Expand research on the human-animal bond and the overall role of animals in society.

Although the different disciplines of veterinary research are grouped in three categories—public health and food safety, animal health and welfare, and comparative medicine—the disciplines are intertwined, and many of the committee’s recommendations apply to two or all three fields. For example, research in comparative medicine contributes to animal health through development of preventive medicine and treatment. Study of wildlife diseases contributes not only to wildlife health and conservation but also to public health because many human diseases are zoonotic. In short, veterinary research has interfaces with human and animal health and is interdisciplinary; therefore, collaborative and interdisciplinary research is crucial in translating scientific advances from one traditional discipline to another. However, such research may be hampered by administrative barriers, cultural barriers, and lack of economic resources. Agencies that support veterinary research have their own missions. When proposed interdisciplinary research is relevant to the mission of several agencies but does not perfectly fit the mission of any one agency, it can be difficult to get funding to support it.

Recommendation 1: The veterinary research community should facilitate and encourage collaborative research across disciplines, institutions, and agencies by reducing administrative barriers and by nurturing and rewarding successful team-oriented investigators. The community should encourage the development of a long-term national interagency strategy for veterinary research. The strategy could include a specific focus at the National Institutes of Health (NIH) on integrated veterinary research via the Roadmap initiative. NIH should consider having a veterinary liaison like the veterinary-medicine and public-health liaison at the Centers for Disease Control and Prevention (CDC) to help to ensure integration of veterinary and human medical research. Other federal agencies, state agencies, private foundations, and supporters of veterinary research should recognize and provide long-term support for collaborative, integrated veterinary research.

Addressing critical issues in veterinary science requires adequate human, infrastructure, and financial resources. The infrastructure and financial resources
for the conduct of veterinary research in institutions that play a major role were examined and compared with the resources needed to do the research proposed to meet societal needs (Box S-2).

The National Research Council report *National Needs and Priorities for Veterinarians in Biomedical Research* projected a deficit of 336 veterinary pathologists in the United States and Canada in 2007, and the American College of Veterinary Pathologists reported needs for 149 veterinary pathologists in 2004. Similar human resource needs have been reported by the US Department of Agriculture (USDA), CDC, and the American College of Laboratory Animal Medicine. The shortage of veterinary researchers is due partially to declining interests in research among veterinary students, which in turn could be attributed to the following:

- The long period required to attain a DVM, a PhD, and postdoctoral training.
- The substantial tuition debt accrued during DVM training.
- The sparse financial support for graduate students in veterinary science.
- The brief exposure of veterinary students to basic science and research throughout their academic curriculum and internships.

The extended training could be partially addressed by establishing more combined-degree programs, and financial incentives could be provided to veterinary students interested in research through grants, fellowships, and possibly a loan-forgiveness program. However, stimulating students’ interest in veterinary

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**BOX S-2**

Institutions and Organizations Considered in the Assessment of Resources for Veterinary Research in This Report

- Schools and colleges of veterinary medicine
- Colleges of agriculture
- Colleges of medicine and medical research institutions
- Wildlife and aquatic health institutions
- Zoological institutions
- National Institutes of Health
- U.S. Department of Agriculture
  - Agricultural Research Service
  - Cooperative State Research Education and Extension Service
  - Other subagencies
- Centers for Disease Control and Prevention
- Department of Defense
- Food and Drug Administration
- National Science Foundation
- Department of the Interior
- Private sector research resources
research may require a substantial change in the culture of colleges of veterinary medicine (CVMs). Academic faculties are driven to incorporate clinical learning processes into the early years of veterinary education and may not adequately integrate basic science and research in veterinary curricula. The capacity of academic veterinary curricula to incorporate and demand teaching of evidence-based medicine, including the use of research data and statistical analyses, will have a great impact on animal health and the mindset of those who support it. A consequence of failure to train the next generation of veterinary researchers adequately is that opportunities for veterinary science to address public-health needs and to improve animal and human health will be missed. A strong workforce of veterinary researchers is needed to provide the data required for informed decisions in matters that govern day-to-day activity in animal health and welfare—decisions that underlie the economic stability necessary for adequate national animal health care. Veterinary research is essential to informed decision-making by policy-makers who aim to develop effective legislation and regulations based on sound science.

Recommendation 2: Additional veterinary researchers must be trained to alleviate the demands and to meet societal needs for veterinary research. A debt-repayment initiative similar to the NIH Clinical Research Loan Repayment Program could address concerns about the large debt burden faced by graduates of CVMs. If NIH’s Center for Cancer Research training initiative in comparative pathology and biomedical sciences and USDA’s Agricultural Research Service PhD training program for veterinarians prove to be successful in recruiting and retaining veterinary researchers, they could be expanded and used as models for other agencies and companies.

Recommendation 3: To meet the nation’s needs for research expertise in veterinary science, changes in recruitment and programming for graduate and veterinary students will be required. Changes would involve enhancing research cultures in veterinary colleges and strengthening of summer research programs, combined DVM/PhD degree paths, and the integration of basic science into clinical curricula. The AVMA Council on Education, which is charged to review colleges of veterinary medicine for accreditation and publishes guidelines for the process, should strengthen the guidelines for assessment of research in regard to opportunities for research experiences for veterinary students. Research scientists in training should be made aware of national problems in animal health and welfare, be given the opportunity to incorporate cutting-edge science into experimental design, and develop programs of high quality that compete nationally with other disciplines of science.

Increasing the veterinary research workforce requires an enlarged training capacity of educational institutions. The last major federal program to support
construction of facilities for CVMs ended nearly 40 years ago. AAVMC has documented that 1,641,000 ft² of new and 611,000 ft² of renovated facilities are needed to train additional veterinary and graduate students to meet the demands of public practice. Space for classrooms, teaching, and research laboratories at all biosafety levels and housing for research animals is needed. Existing funding sources, such as state and university funds and gifts from foundations and private donors, are unlikely to meet the needs of the nation.

Recommendation 4: AAVMC and its members should identify ways in which the CVMs’ facility needs can be met financially and logistically. They should consider mounting an extensive outreach effort to educate policy-makers in federal and state governments about the necessity of additional facilities to train adequate veterinary researchers. The committee did not find useful documentation on facility needs of federal or state agencies to fulfill their roles in veterinary research effectively, with the noted exception of the USDA Report of the Strategic Planning Task Force on USDA Research Facilities: A 10-year Strategic Plan. Report and Recommendations. The report recommended renovation of outdated facilities and noted that biocontainment facilities were required for research on high-risk pathogens. Although replacement facilities at the National Animal Disease Center in Ames, Iowa, were designed and the first phase was constructed in response to the report, not all the documented needs have been met. Expanded biocontainment facility space was one of the unmet recommended needs, which was also given high priority in Homeland Security Presidential Directive 9 (HSPD-9).

Recommendation 5: The recommendations of the 1999 Strategic Planning Task Force on USDA Research Facilities and the provisions of HSPD-9 should be implemented immediately. Biocontainment laboratories should receive special attention. Adequacies and shortfalls in facilities—both federal and nonfederal—needed to support veterinary research should be documented and quantified. Other research resources for veterinary research include libraries, databases, animal health monitoring and surveillance systems, electronic communication systems for sharing data and clinical information, specialized populations of animals, and collections of research materials, such as tissue samples. Effective communication among the various entities involved in veterinary research is needed to maximize the value of studies and to leverage the resources of the relatively small veterinary research community. In particular, databases with clinical records that can be exchanged among teaching hospitals, private practices, and diagnostic laboratories would provide data that could serve as valuable cost-efficient tools for retrospective and prospective research. Likewise, tissue samples and other specimens (for example, serum, DNA, and microorganisms) from both healthy and diseased animals offer exciting opportunities
to study animal diseases and epidemiology if they are archived properly for research with client or owner confidentiality protected and made available to the research community. Of equal importance, surveillance systems that effectively and efficiently integrate animal health, food-product safety, and human health monitoring findings into user-friendly and easily accessed networks are needed.

**Recommendation 6:** The American Animal Hospital Association, AAVMC, and AVMA should address the need for more effective communication among the federal, university, and private sector entities involved in veterinary research. The need for databases, animal health monitoring and surveillance systems, specimen collections, and other sharable research tools to support veterinary research should receive special attention. Organization of a working task force or national workshop to devise an operating plan for developing and managing these clinical and research databases and collections and to identify methods for their support would be an important first step toward the formation of national databases and archives (such as specimen banks and clinical databases) for veterinary research.

In addition to databases and tissue samples, many disciplines in veterinary research have benefited substantially from access to well-characterized animal colonies with known diseases. Preserving the genomes of those unique model animals is critical to facilitate research in animal diseases. The genetic similarity between humans and other animals is a compelling argument that studies with such animals would reveal both normal and abnormal pathways and mechanisms. Those animal colonies are imperative for integrative physiology and pathophysiology studies.

**Recommendation 7:** NIH and USDA should address the importance of engineered and spontaneous model colonies of animals and ensure that these valuable resources are not lost. This can be accomplished for some species by cryopreservation and preservation of their germ plasm in tissue banks until it is needed for funded, targeted research or by transfer of their genetic mutations into smaller laboratory species. For other species, maintenance of the whole animal may be necessary.

A review of the organizations that are most likely to fund veterinary research reveals that some research disciplines do not have an identifiable source of financial support from government agencies. Those disciplines include ecological research on zoonotic emerging diseases, dynamics of select agent, biodefense pathogens in wildlife, companion-animal and equine research, wildlife and conservation research, and zoo animal and exotic-pet research. Those disciplines contribute to animal health and welfare and to important elements of human health research or have direct human social impact, but they do not have depend-
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able, permanent financial resources that would ensure their continuing advancement in research.

Recommendation 8: The veterinary research community should actively engage NIH, USDA, the Department of the Interior, the National Science Foundation, and other federal agencies and urge them to recognize and address the need for financial support for the disciplines of veterinary research that lack identifiable sources of federal funding despite their contributions to public health, comparative medicine, and animal health and welfare.

SUMMING UP

In this age of reductionist research and the ascension of disciplinary endeavors, veterinary research stands apart because of its breadth and interdisciplinary orientation. The world today is full of unanticipated risks in the form of highly pathogenic avian influenza, foreign animal diseases, and transmissible spongiform encephalopathies, to name but a few examples. At the same time, unparalleled opportunities in biomedicine have been afforded by advances in molecular biology, genomics, and other disciplinary sciences. Veterinary research serves as the interface of basic science and animal and human health that is critical to the advancement of our understanding of and response to impending risks and to the exploitation of disciplinary advances in the pursuit of One Medicine. The urgent need to provide adequate resources for investigators, training programs, and facilities involved in veterinary research must be met to seize the opportunities to improve the well-being of humans and animals and to minimize risks to their health.
CRITICAL NEEDS FOR RESEARCH IN VETERINARY SCIENCE

Committee on the National Needs for Research in Veterinary Science

Board on Agriculture and Natural Resources

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.

www.nap.edu

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The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy’s purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Wm. Wulf are chairman and vice chairman, respectively, of the National Research Council.

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Preface

Veterinary research has historically played an important role in the improvement of health and welfare of all animals, including humans. Veterinary scientists are often at the forefront of research in human diseases because many human pathogens have their origins in animal hosts. Moreover, animal models of disease have been used to elucidate the underlying mechanisms of many diseases in humans and other animals. In addition to its many contributions to human health, veterinary research—by targeting the prevention and control of agricultural, domestic, wild and aquatic animal diseases—contributes to the quality of human life. Food-animal health, for example, secures a safe and economic food supply for the human population. Veterinary research is also essential to the health and increased longevity of service and companion animals and thereby reduces stress in both animals and owners. The events of September 11, 2001, have changed our lives in many ways and have greatly increased the need for research in human and animal health as bioterrorism threatens human health directly and indirectly through disruption of our food supply. Despite the increasing demands on veterinary research, however, its workforce has not increased. The types and priorities of resources dedicated to human and animal health must be reevaluated to address the greatly increased demands on research in the veterinary community.

The National Research Council’s Committee on the National Needs for Research in Veterinary Science—composed of specialists in pathology, laboratory animal medicine, infectious diseases, genomics, nutrition, food safety, biosecurity, and other subdisciplines of animal research—was charged to identify current needs and project future needs for research in three fields of veterinary science: public health and food safety; animal health; and comparative medicine. (The committee defines comparative medicine as the field of medicine that compares medical and scientific discoveries and knowledge of one or more animal species, including humans.) The committee was also asked to assess resources, infrastructure, and manpower available to meet those needs without making specific budgetary or organizational recommendations.
The committee met five times over a 10-month period, beginning in May 2004. To gather information, the committee hosted a workshop in which stakeholders and experts met to share data and opinions on current and future needs in veterinary research, on a vision for veterinary research from a government perspective, and on the integration of veterinary science into tomorrow’s research. Workshop speakers were selected in part to fill perceived gaps in the background and expertise of the committee.

We have organized our report into five chapters. We attempted to define the role of veterinary research in human society in Chapter 1, and to highlight historic achievements and identify trends and frontiers in veterinary research in Chapter 2. On the basis of the research needs described in Chapter 2, we suggest in Chapter 3 an implementation plan for each area of research with short-term, intermediate-term, and long-term goals. We describe the resources available for veterinary research in Chapter 4. In crafting Chapter 4, the committee encountered several instances in which desired information was not available for two reasons. First, veterinary research crosses disciplinary boundaries, so it is difficult to define resources and personnel that are dedicated strictly to veterinary research. Second, some desired information is available but cannot be extracted from databases. For example, the U.S. Department of Agriculture has a good database on individual grants, but it is difficult to determine whether some relevant awards are credited to veterinary research. The Association of American Veterinary Medical Colleges provided many of the needed data, but we were also seeking data on the time that faculty devote to research in colleges of veterinary medicine. Most important, there is no central source of data on infrastructure, human, and financial resources for other academic and research units relevant to veterinary science, such as departments of veterinary science, wildlife and fisheries, and comparative medicine; colleges of agriculture; and zoological institutions. In Chapter 5, we assess the adequacies of available resources to meet the challenges posed to veterinary research.

I am grateful to the committee of experts who gave their time and energy generously to a report they perceived to be timely and important. Each committee member participated in the writing, review, discussion, and revision of this report and eventually accepted it as a consensus interpretation of the status of and needs for research in veterinary science. I was impressed from beginning to end with the ability of this diverse collection of professionals to speak and listen, instruct and learn, agree and disagree, and ultimately reach an objective consensus on the issues posed in our charge. On behalf of the committee, I thank our study director, Dr. Evonne Tang, for providing direction, marshaling resources, and keeping this committee focused on its charge. The sometimes appropriate metaphor of herding cats is probably not lost on an audience drawn to veterinary research. We are also indebted to our administrative assistant, Karen Imhof, who, with Evonne made our work both productive and enjoyable.

James E. Womack, Chair
Committee on the National Needs for Research in Veterinary Science
This report is a product of the cooperation and contributions of many people. The committee would like to thank all the participants of the Workshop on National Needs for Research in Veterinary Science on July 19-20, 2004, and others who provided information and input.

This report has been reviewed in draft form by persons chosen for their diverse perspectives and technical expertise in accordance with procedures approved by the National Research Council’s Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards of objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following for their review of this report:

Ed Breitschwerdt, North Carolina State University
James Estep, Battelle Medical Research and Evaluation Facility
John M. Gay, University of Washington
Scott McEwen, University of Guelph, Canada
Michael Miller, Colorado Division of Wildlife
George Seidel, Colorado State University
Gary Sherman, USDA Cooperative State Research, Education, and Extension Service
John Sundberg, The Jackson Laboratory
Linda Toth, Southern Illinois University School of Medicine
Although the reviewers listed above have provided constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Dr. John G. Vandenbergh of the North Carolina State University. Appointed by the National Research Council, Dr. Vandenbergh was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the author committee and the institution.
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