Engaging scientists and veterinarians in strengthening biosecurity systems

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Summary
The engagement of both scientists and veterinarians in strengthening biosecurity systems is of paramount importance to ensure resilience and sustainability. Such commitment from scientists and veterinarians begins during their university education, is nurtured by the examples set by their mentors, and continues into their careers through professional development and the wisdom gained from experience. Resilient and sustainable biosecurity systems also require an organisational culture that encourages, recognises and rewards scientists and veterinarians who are committed to biosecurity education, research, outreach and preparedness. At present, such involvement is complicated by the range of definitions of biosecurity used in the life sciences and veterinary medicine, and by the various international organisations with biosecurity responsibilities.

Biosecurity represents both a public and a private good. However, the priority given to biosecurity education, research, outreach and implementation differs widely among the public, private and academic sectors. The public sector has the broadest engagement and the broadest mandate for biosecurity. The private sector’s approach to biosecurity is governed by business decisions and whether or not they produce consumer goods. In the academic sector, although biosecurity education is gaining increased attention in universities, there are disincentives to research in this field. Strategies for encouraging greater involvement from scientists and veterinarians include agreeing on an inclusive definition of biosecurity, developing teaching materials and experiential learning approaches for use in undergraduate curricula and postgraduate professional development, train-the-trainer programmes, increased involvement of government scientists and veterinarians in university education and professional development, and the fostering of public–private–academic partnerships around shared interests in biosecurity education, research, outreach and implementation.

Keywords
Biosecurity – Capacity-building – Scientific training – Veterinary education.

Introduction
The engagement of both scientists and veterinarians in strengthening biosecurity systems is of paramount importance if we are to ensure resilience and sustainability. Biosecurity systems are designed from our current knowledge. However, resilience requires more; it requires active research, regular reviews and continuous improvement of our biosecurity systems in the face of new information and the emergence of new biothreats. Despite consensus on the importance of sustainable biosecurity, engaging the commitment of scientists and veterinarians remains a daunting task.

Biosecurity, in its broadest meaning, encompasses effective risk management of the natural, accidental and intentional spread of biological agents that can adversely affect humans, animals and the ecosystem. The spread of biological agents is a continuous threat. Strengthening biosecurity and resilience is a global priority with direct implications for animal health, food security and public health, as well as economic vitality and political stability.

Engaging scientists and veterinarians begins during their university education, is nurtured by the examples set by their mentors, and continues on into their careers through professional development and the wisdom gained from experience. Resilient and sustainable biosecurity systems
also require an organisational culture that encourages, recognises and rewards the commitment of scientists and veterinarians to biosecurity education, research, outreach and preparedness. This paper examines biosecurity as a unifying concept, considers it in the context of public and private goods, and discusses the priority given to biosecurity by institutions in the public, private and academic sectors, all of which have a stake in it. The author reviews the determinants of university curricula for science and veterinary science, along with the drivers of continuing professional education. Strategies are presented to encourage the greater involvement of scientists and veterinarians in biosecurity education, research, outreach and preparedness.

The need for a unifying definition of biosecurity

One of the underlying challenges of engaging scientists and veterinarians in the full range of biosecurity opportunities is the ongoing confusion caused by competing definitions (1, 2). Animal health professionals use the term ‘biosecurity’ to describe the implementation of measures to reduce the introduction, establishment and spread of disease agents to, within and from populations (3, 4). Laboratories tended to use the terms ‘biosafety’ and ‘biosecurity’ almost interchangeably until the terrorist events of 2001, when security professionals (i.e. law enforcement) added their perspective. Concern over the intentional use of bioterrorism agents and the potentially negative, unintended impact of ‘dual use research’ (legitimate research that can be used for both benevolent and harmful purposes) led to a 2006 report from the United States National Academy of Sciences. This report used the term ‘biosecurity’ to mean security against the inadvertent, inappropriate, or intentional malicious or malevolent use of potentially dangerous biological agents or biotechnology, including the development, production, stockpiling or use of biological weapons, as well as natural outbreaks of newly emergent and epidemic diseases (5).

The same year, the World Health Organization (WHO) presented biosecurity as a complement to biosafety in laboratory risk management; the former focused on containing potential unintentional and accidental exposure to pathogens and toxins, and the latter focused on preventing access to laboratory pathogens and toxins for terrorist use (6). Subsequently, in 2010, the International Food Safety Authorities Network (INFOSAN), a joint effort of WHO and the Food and Agriculture Organization of the United Nations (FAO), suggested that biosecurity represented an integrated risk management approach covering human, animal and plant life and health (7). However, this risk management definition of biosecurity failed to mention protection against intentional biothreats.

Most recently, the 2015 Global Conference on Biological Threat Reduction, hosted by the World Organisation for Animal Health (OIE), focused on the theme: ‘Building cooperation for efficient health and security systems worldwide’. The term ‘biosecurity’ was avoided in the final report. Instead, the phrase ‘biological threat reduction’ was used to encourage the animal health, public health, ecosystem health and security sectors to work together (8).

Biosecurity – both a public and private good

In general, biosecurity represents a global public good, as efforts to successfully reduce or eliminate biothreats benefit all. Public goods are considered to be non-exclusionary and non-prejudiced. In other words, public goods benefit many people, not just those who paid for them, and individuals cannot be excluded from their benefits. For example, more effective laboratory biosafety, preventing intentional bioterrorism, and more effective screening of imported animals and animal products benefit the whole country by reducing the likelihood of catastrophic animal diseases and zoonoses. Everyone in the country benefits, regardless of whether they contributed financially to support these activities or the science behind them. (Neighbouring countries also benefit, since pathogens do not recognise borders.)

Some biosecurity activities may be considered private goods when their benefits only accrue to those who pay. For example, an individual who chooses to pay for additional vaccinations for themselves or their animals may be protected against certain types of biothreat, whereas those who do not have protection. Similarly, a farmer or company may choose to pay for additional biosecurity measures to decrease their risk, while their competitors accept greater risk should a biothreat occur.

The public good/private good distinction has a potential influence on individual behaviour and on the willingness of scientists and veterinarians to become involved with biosecurity research and implementation. Considering biosecurity as a public good may create a moral hazard. While the individual scientist or veterinarian may acknowledge the importance of biosecurity, they may not place a high priority on their own involvement, in the belief that others or ‘the government’ will take care of it and they will enjoy the benefits regardless. In addition, the curse of good biosecurity programmes at the institutional level is complacency and decreased attention. If no biothreats materialise for a long time (i.e. biosecurity is successful) then individuals and institutions may decide that further resource commitments are not needed. When biosecurity
breaks down and a biothreat occurs, lax biosecurity and decreased budgets are the first lapses to come under criticism.

Understanding workplace priorities and reward systems

Most scientists and veterinarians work in one of three different sectors: the public sector (government), the private sector (i.e., businesses for profit), and the academic sector (universities and other educational institutions). The priority placed on biosecurity differs in each of these sectors as do the reward systems for the scientists and veterinarians employed there.

The public sector

The public sector focuses principally on public goods, those areas that benefit the nation or significant segments of the population. The public sector likely has the greatest appreciation of biosecurity, given that it often has the primary responsibility for responding to biosecurity breaches. Governments typically regulate laboratories, medical facilities and food and drug manufacturers, protect borders, establish biosecurity standards for domestic processes and maintain a response capacity in the event of biothreats. However, these responsibilities are spread across multiple government institutions at the national, regional and local levels, which may complicate the efficient and effective functioning of the public-sector biosecurity system.

The government may also bear the brunt of the responsibility for biosecurity research and translational science. Basic science research into the nature of biothreats and countermeasures to prevent and respond to them carries a considerable financial risk, in that the results may not immediately cover the costs of the research itself. Hence, the private sector is less willing to pursue these areas of investigation, despite their importance. Much of the basic research into the mechanisms of biological threats, and biosecurity interventions to reduce their consequences, is carried out by public-sector research institutions or in government-sponsored research at universities.

Research into the reduction of biothreats often requires high-security laboratories or special facilities that are expensive to build and costly to maintain. Laboratories with the strictest security requirements in each country are often government facilities. Access to these high-security laboratories, and to the biothreat agents and reagents necessary for biothreat research, may be restricted so that government facilities are the only places where this research can be conducted.

The priorities for biosecurity education, research, outreach and implementation at public-sector establishments are usually set centrally and may be driven by national priorities or political necessity. Government research agendas may take stakeholder input into consideration, as well as current events. Political will and funding often reflect the issue of the moment, so biosecurity may get less attention when prevention has been successful.

The private sector

The private sector focuses on overall business objectives and makes decisions based on anticipated profits; in other words, the projected return on investment or total projected sales compared to the cost of research and development. Most private-sector businesses focus on private goods and services, whose value is enjoyed only by those willing and able to pay. Business decision-making seeks to reduce uncertainty by focusing on those ventures with the greatest certainty of profit.

The private sector is interested in providing the specialised equipment and supplies needed for routine biosecurity practices. Routine biosecurity measures, such as cleaning and disinfection, require supplies. These goods represent a known demand and attract private-sector engagement and new product development. Preparing for a biothreat response presents a very different case, especially for new and emerging diseases, because the market size is uncertain. Companies are hesitant to invest in developing a new vaccine for an issue that emerges in only one part of the world unless a significant risk exists, so as to create a long-term market for that product.

Priorities in the private sector are set by business management. These priorities may be affected by shareholders in a publicly held business where ownership shares are freely traded. Many publicly held businesses seek more rapid returns on investment than some privately held businesses, and are therefore hesitant to invest in research and development for projects that have a long time horizon. Some businesses may invest for longer-term returns on their investment if the government promises a guaranteed return. Examples would include a government guarantee programme that supports the development of an urgently needed vaccine or high-priority treatment.

Biosecurity is a high priority for private-sector businesses because their own products, such as foodstuffs or medicines, are at risk. Catastrophic animal disease or human illness that can be traced back to contamination of their products is not ‘good for business’.

While most scientists work for government, large private-sector companies or academia, most veterinarians are
clinical practitioners working for themselves or for a small veterinary practice in the private sector. Small-business decisions are made in a similar way as in other segments of the private sector but private veterinary practitioners tend to think more about their local market, whereas the feed, food and pharmaceutical industries consider regional, national and global markets and trends. The attention given to biosecurity by the private practitioner is directly linked to their ability to charge for their services or for products associated with biosecurity.

The academic sector

Universities and other educational institutions represent a unique type of organisation whose stated priorities are education, research and, in some cases, outreach, while also maintaining attractive facilities and competent faculty members in order to attract government support and/or fee-paying students.

A university’s strategic priorities (education, fields of research, outreach, facilities and faculty) are influenced by a number of factors, including the priorities of its funders (the public and/or private sector), the university’s accreditation standards and/or degree programmes, and student demand. Accreditation standards vary among countries, and there is no global accreditation of universities or of most academic programmes within universities. Regional accreditation has emerged for some professional programmes, such as veterinary medicine. Furthermore, the OIE has developed ‘Recommendations on the Competencies of Graduating Veterinarians (“Day 1 Graduates”)’ to assure National Veterinary Services of Quality’ (9).

Biosecurity research at universities may be driven by government mandate, with associated funding. In the absence of such a mandate, and its funding, individual faculty research is driven largely by the initiative and interests of individual researchers, not by central administration, strategic planning or business decisions, such as returns on investment. University researchers fund their work from a variety of intramural and extramural sources. Intramural funds (university funds distributed to their own research faculties) may target the university’s own strategic priorities, such as seed money for new researchers, or may be competitively awarded to further the development of research centres of excellence on campus. Some government research funds may also be distributed through intramural competitive grants programmes.

Individual faculty researchers may also compete with researchers from other universities for extramural funds from government agencies and non-governmental organisations (NGOs). Extramural funding comes from the government, NGOs and private-sector companies, who most commonly solicit proposals for specific types of research that are of particular interest to them and related to their business priorities. Some governments support applied research through competitive grants programmes, although applied research on animal health, food security and agricultural subjects is far surpassed by the amount of government funding for medical and military research.

Community outreach programmes remain a strategic priority for some university systems, such as the land grant university system in the United States. Originally conceived as a method for sharing agricultural and engineering knowledge from the university to the community, ‘extension’ programmes employ community educators who deliver content through various types of programmes and consultation.

Faculty researchers may also be contracted to do proprietary research on behalf of private-sector businesses or ‘sensitive’ research for government agencies. These arrangements commonly include restrictions on the ability of the researcher to share the results, which may have a chilling effect on researchers’ interest. If university promotion and tenure for researchers is linked to their work appearing in scientific publications, then a prohibition on publishing results may act as a deterrent. Finally, some universities have internal policies that preclude proprietary or sensitive research.

Since the advent of the ‘hybrid university’, academic institutions have placed additional priority on the intellectual property generated by faculty research. Universities see the opportunity to license inventions and market them to the private sector as a potential profit centre. Thus, university research enterprises may end up looking more like the private sector, even though the research itself was funded for the public good.

Universities develop physical plants (infrastructure) to support education and research. The development of such facilities may be driven by public investment or by the wishes of philanthropic donors. High-biosecurity laboratory facilities are extremely expensive, so relatively few universities are willing or able to afford these investments. Infrastructure maintenance also represents a major constraint for biothreat agent research as the cost of operating a high-security laboratory may be prohibitively expensive. While private philanthropy or corporate donations may support the construction of new laboratories or buildings, similar support is rarely channelled into operating budgets for these facilities.
Challenges of engaging scientists in biosecurity programmes

Ensuring biosafety in the laboratory, reducing accidental and intentional biothreats both domestically and at international borders, and ensuring rapid response and recovery are daunting challenges which are largely underappreciated by most life scientists and veterinarians. The day-to-day maintenance of a sustainable and resilient biosecurity system involves a portfolio of biosecurity practices, many of which are labour-intensive but not technically difficult. Biosecurity assurance is without high visibility, high priority or high reward in many institutions until a breach occurs. Often these responsibilities are relegated to junior staff or contractors with little supervision or engagement from scientists and veterinarians.

Engaging scientists and veterinarians in biosecurity is challenging. Most scientists have neither the education nor the training to be fully engaged. Surveys of life scientists in Europe and Japan concluded that many found biosecurity (in the context of concern over dual-use biotechnology research fostering biological weapons) to be irrelevant (10). Biosecurity is not a regular part of life science education, although some biosafety principles are frequently taught alongside technical laboratory skills. Increased concern over the risks of dual-use biotechnology research has increased attention on the subject in the past decade (1).

Veterinary education typically focuses on biosecurity in the context of preventing and controlling the spread of infectious diseases in animals and zoonoses in humans. Veterinary curricula are influenced by international guidelines, regional or national standards (if they exist), university priorities and the career objectives of the students. The OIE has published recommendations for the core competencies of Day 1 veterinary graduates related to the public good responsibilities of national Veterinary Services (9). While ‘biosecurity’ is not mentioned explicitly, several of the specific competencies include learning objectives related to biosecurity in the context of preventing disease spread, such as controlling transboundary animal diseases and disease prevention and control programmes. Neither laboratory biosafety/biosecurity nor biothreats of intentional origin are addressed in the OIE recommendations for veterinary education.

A review of the accreditation standards in the Americas (11) and Europe (12) shows that biosecurity knowledge is included in the curriculum requirements for both. Veterinary students learn by observation, as well as by the formal curriculum. In that context, the European standards (12) also mention biosecurity as a requirement for veterinary education facilities: ‘The Establishment’s livestock facilities, animal housing, core clinical teaching facilities and equipment must… ensure relevant biosecurity and bio-containment’. Although no specific surveys have been identified that looked at curricular coverage of the reduction of intentional biothreats per se, the lack of experience of many faculty members suggests that these topics receive scant coverage in the curriculum.

The shift of veterinary medicine’s primary focus from food-producing animals and their products to the care of companion animals – a shift in emphasis from public good to private good – has seen a corresponding change in curricula, especially in developed countries. Veterinary students who want to become companion animal specialists exert considerable pressure for more instruction in the clinical sciences, medicine and surgery, while arguing for less coverage of those subjects linked to public goods, such as epidemiology and public health.

Research on biological threats, mechanisms for reducing those threats, and biosecurity is critically important, given the complex nature of these threats, both natural and human-made. Scientific research provides key evidence on which to build biosecurity systems and ensure sustainability and resilience in the face of new and existing biological threats. Translation research is also needed to take laboratory findings and apply them to practical problems.

Biosecurity represents an important investment for those private companies involved in raising animals, producing feed and food, and manufacturing vaccines and pharmaceuticals. However, biosecurity is a production cost and does not add to the profit margin per se. Biosecurity lapses may negatively affect consumer perceptions of the company and its products and, in litigious societies, attract lawsuits. Therefore, much of the private sector’s approach to biosecurity takes the form of risk management strategies to protect their products and brand against catastrophic consequences. Practically speaking, biosecurity may be lumped into the larger function of quality assurance in many private-sector, consumer-product companies. Scientists may be involved in supervising quality assurance programmes, although such involvement by veterinarians is less likely.

Although many argue that biosecurity is a shared responsibility and should not be used as a competitive advantage, the biosecurity efforts of a single private-sector company may be considered proprietary, privileged information. Anti-monopoly laws may also restrict private-sector collaboration and information-sharing. Finally, private-sector acknowledgement of biosecurity failures may precipitate regulatory action by government agencies. Consequently, sharing best practices and lessons learned may be constrained in the private sector.
Engaging private-sector scientists and their businesses in biothreat reduction research is difficult because of the need to make a compelling business case for the companies involved. Developing a new product for an uncertain market is not a wise business decision. Developing a vaccine for a potential biothreat agent, or a disease that affects developing countries primarily, is unlikely to be a high priority of a for-profit business.

Biosecurity garners even less attention in universities than in public- or private-sector institutions. University facilities are constructed first and foremost to support teaching and individual investigators’ research programmes, not the production of sale consumer products. University facilities address minimum legal requirements and investigators make sure that they meet the minimal standards to receive extramural research funding. Beyond these legal requirements, many university faculty staff and students may have only limited training in biosecurity and little awareness of biothreats.

University scientists with an interest in biothreat reduction may be dissuaded from pursuing that interest by the lack of extramural research funding and the prevailing promotion and tenure guidelines of their universities, many of which favour publications and research dollars more than public service. Additionally, research involving live biothreat agents may be restricted or require special laboratory conditions that are prohibitive in cost. Furthermore, concern regarding ‘dual use’ biotechnology research has had a chilling effect on some important biothreat research in universities.

Finally, the bias towards ‘discovery’ research is widespread, having been recognised for more than 25 years in the United States (13). Emphasis on discovery research creates a disincentive for research in areas of integration and the application of science to current challenges, which is needed for much biosecurity research. Researching new disinfection and inactivation techniques and their application to biothreat reduction is one example of an important research area which is undervalued in many academic institutions, because of competitive funding and limited opportunities to publish these findings in peer-reviewed scientific journals. Similarly, risk assessments of biothreat scenarios, serving on national or international advisory groups, or leading training on biosafety procedures or emergency response protocols, such as the use of personal protection equipment, do not generate publications. Faculty members seeking promotion are mentored to steer away from these types of activities and focus on other areas whose value is more easily recognised by their academic colleagues.

Strengthening global biosecurity and resilience and ensuring sustainability require collaboration across disciplines, between sectors and, importantly, with stakeholders, including the general public. However, scientists may be reluctant to join collaborative efforts because of ‘potential professional repercussions’ (14). Lack of incentive, recognition, funding and support, the opportunity cost of participation (since it takes time away from ‘doing science’); limited networks outside the researcher’s own expertise or institution, and lack of communication skills are also barriers to engaging scientists in education and public outreach (15).

**Encouraging the involvement of scientists and veterinarians**

Encouraging the greater engagement of private-sector and university scientists and veterinarians in biosecurity education, training, outreach and research requires changes in their vocational training, professional development, institutional cultures and attitudes. Such changes include better education on biosecurity and more intensive training in the skills necessary to implement biosecurity programmes.

Education builds awareness and understanding. Training focuses on building skills in techniques and approaches. Typically, universities focus on education, while the public and private sectors place emphasis on training related to their specific area of responsibility or interest. Neither education nor training alone is sufficient. Scientists typically have extensive education with variable degrees of training, while their laboratory staff may have the requisite training without a full understanding of the biothreats that they are charged with preventing.

Effective engagement requires an understanding of biological threats and a broad awareness of their dangers (16). It also requires training that emphasises both prevention and response, and capacity-building that includes access to the proper equipment and materials, as well as trained personnel who can be rapidly mobilised. In addition, sustainable biosecurity systems require leadership, communication and facilitation skills to enable collaboration, and a team approach in which all contributions are recognised and rewarded by the institution involved, as well as the line managers.

Changing curricula and incorporating new information and skill-building into a university education means educating lecturers, as well as providing teaching materials that can be adapted for different audiences to overcome any pedagogical barriers. Relevant case studies and ‘train-the-trainer’ programmes have been used to enhance an understanding of biosecurity among educators and equip them with the skills and confidence to take these materials back to the classroom (16).
Adult education approaches using experiential learning appear to be more effective in skill-building than the traditional lecture format in the continuing professional education of scientists and veterinarians working in fields related to biosecurity. The use of high-fidelity simulations has proven effective in emergency-preparedness training (17).

If veterinarians and scientists gain professional recognition and career promotion and rewards for participating in biosecurity programmes, their engagement will be greatly encouraged. At present, professional development for veterinarians tends to mirror what is taught in the original curriculum, with added emphasis on topics promoted by the private sector serving the veterinary profession. Consequently, biothreat reduction attracts relatively little attention unless promoted by public-sector veterinarians or government funding. Preparedness training for natural and human-made disasters is a notable exception to this trend, since the importance of including companion animals in disaster response has gained attention. While not addressing biothreats per se, emergency-management training has some potential spillover benefits for biothreat preparedness.

Government scientists and veterinarians are the easiest to engage in biosecurity education, research, outreach and implementation, as long as their government makes it a priority and ensures that funding is available. The participation of government scientists and veterinarians in scientific committees and international organisations interested in biosecurity may, in addition, be considered part of their overall paid responsibilities. It is the most developed countries that have the greatest flexibility to commit their scientists to assist with global biosecurity and biothreat reduction work. Some countries make it a priority for their scientists to engage in international activities as a means of increasing their influence in global activities and priorities.

Government scientists and veterinarians represent a significant resource for enhancing university education. Government scientists with the requisite knowledge, skills and biosecurity experience can work with university faculties to develop and deliver real-life case studies and simulations. Temporary government appointments for scientists and veterinarians, and sabbaticals for university faculty staff may also serve to increase awareness and appreciation of biosecurity’s importance.

In conclusion, opportunities exist for creative public–private–academic partnerships to be built around shared interests in biosecurity education, research, outreach and implementation. Creating ‘win-win’ collaborations that benefit all those who contribute offers great promise as a way of engaging scientists and veterinarians in strengthening biosecurity and creating resilient and sustainable biosecurity systems (18). Agreement among the nations of the world on the global priority of biosecurity education, research, outreach and implementation and the creation of a global fund to support public–private–academic partnerships to strengthen biosecurity resilience and sustainability are two approaches that hold considerable promise for the future.

Participation des chercheurs et des vétérinaires au renforcement des systèmes de biosûreté

W. Hueston

Résumé
La participation des chercheurs et des vétérinaires au renforcement des systèmes de biosûreté est d’une importance capitale pour garantir la résilience et la durabilité de ces systèmes. Les chercheurs et les vétérinaires qui s’engagent dans ce domaine le font dès leur formation universitaire, grâce à l’émulation de leurs mentors, et cet engagement se poursuit tout au long de leur carrière grâce au perfectionnement professionnel et à la sagesse acquise avec l’expérience. La durabilité et la résilience des systèmes de biosûreté nécessitent également une culture organisationnelle qui encourage, reconnaît et récompense les chercheurs et les vétérinaires qui s’engagent dans des activités d’enseignement, de recherche, de vulgarisation et de préparation dans le domaine de la biosûreté.
À l’heure actuelle, cette participation est rendue plus complexe par les nombreuses définitions données à la biosûreté dans les sciences du vivant.
Participación de científicos y veterinarios en el refuerzo de los sistemas de seguridad biológica

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Resumen
La participación de científicos y veterinarios en el refuerzo de los sistemas de seguridad biológica reviste cardinal importancia para asegurar la resiliencia y la sostenibilidad. Esta participación, que empieza en el momento de la formación universitaria, se ve impulsada por los ejemplos que ofrece el profesorado y continúa a lo largo de toda la carrera gracias al perfeccionamiento profesional y a las enseñanzas que depara la experiencia. Para que los sistemas de seguridad biológica sean duraderos y resilientes se precisa también una cultura organizativa que aliente, reconozca y recompense a los científicos y veterinarios que intervienen en labores de pedagogía, investigación, difusión y preparación en relación con la seguridad biológica. A día de hoy, esta participación se ve complicada por las disparejas definiciones que se dan de «seguridad biológica» en las ciencias de la vida y la medicina veterinaria y por la existencia de varias organizaciones internacionales con responsabilidades en la materia. La seguridad biológica representa un bien de interés a la vez público y privado. No obstante, los sectores público, privado y universitario no coinciden ni de lejos en el grado de prioridad que otorgan a la enseñanza, la investigación, la difusión y la aplicación de la seguridad biológica. El sector público exhibe la participación y el mandato más amplios en la materia. Los planteamientos del sector privado al respecto responden a decisiones empresariales y a su utilidad, o no, para...
traducirse en bienes de consumo. En los medios universitarios, si bien se presta cada vez más atención a la enseñanza de la seguridad biológica, hay factores que desincentivan la investigación en la materia.

Las estrategias para alentar una mayor participación de científicos y veterinarios pasan especialmente por consensuar una definición integradora de «seguridad biológica», elaborar material pedagógico y métodos de aprendizaje experimental e introducirlos en los programas de estudios universitarios y de perfeccionamiento profesional de posgrado, instituir programas de formación del profesorado, impulsar una mayor intervención de científicos y veterinarios del sector público en la enseñanza universitaria y de perfeccionamiento profesional y potenciar la colaboración público-privada en la universidad en torno a temas de interés común relacionados con la enseñanza, la investigación, la difusión y la aplicación de la seguridad biológica.

**Palabras clave**
Enseñanza de la veterinaria – Formación científica – Refuerzo de capacidades – Seguridad biológica.

**References**


