Biosecurity and Australia’s primary industries – the role of biotechnology

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Entry, establishment or spread of exotic pests and diseases pose significant economic, human health and environmental risks. Australia remains relatively free from many of the pests and diseases that affect primary industries in other countries.

As a consequence of globalisation, migration and climate change, Australia’s borders are increasingly vulnerable to pest and disease threats. To maintain Australia’s competitive advantage as an agricultural producer and exporter, effective biosecurity systems are required.

Biotechnology can support biosecurity objectives. At the border, biotechnology can be applied to the rapid and accurate detection of pests or diseases. Post-border, strategies for pest control and management may also be underpinned by biotechnology.

Gaining and maintaining trade and market access can be assisted by applying biotechnology to demonstrate freedom from pests or diseases or to confirm that control measures are successful. Diagnostics based on biotechnology are used to facilitate rapid responses to biosecurity threats and limit their effect.

Increasing the awareness of biotechnology applications, enhancing diagnostic capability through training, and overcoming barriers to commercialisation of discoveries are among the challenges facing the continued development and adoption of biotechnology for biosecurity in primary industries. Challenges for government include encouraging the integration of biotechnology applications within the broader biosecurity framework, and balancing the biosecurity risk and the cost of the technology.
Biosecurity

An effective biosecurity regime is important for Australia because the economic, human health and environmental consequences of introduced pests and diseases can be severe. Australia’s agriculture, fisheries and forestry industries had an estimated export value of $35.8 billion in 2008–09. The potential cost of incursion and establishment of serious plant or animal pests and diseases in Australia is in the order of billions of dollars.

In the context of this brief, biosecurity refers to the risk management practices to counter introduced biological threats to the agriculture, fisheries and forestry industries. Australia invests heavily in maintaining its biosecurity system across a continuum (pre-border, border and post-border), applying measures to identify hazards and manage risks through preparedness, prevention, response and recovery strategies.

Protecting Australia’s borders: challenges and needs

Australia is free from many of the pests and diseases that affect primary industries in other countries and this gives Australia a competitive advantage as an agricultural exporter. However, globalisation, increased travel and trade, and climate change increase the vulnerability of Australia’s borders to unintentional or deliberate introductions of new pests and diseases. The Australian Government has recognised that Australia’s favourable pest and disease status should be maintained.

Risk analysis is an important part of Australia’s biosecurity system, enabling decision-makers to consider the level of risk associated with the importation of animals, plants or other goods into Australia. An effective biosecurity system also requires robust surveillance and accurate diagnostics at the border, as well as reliable and effective control and management regimes post-border. Pre-border biosecurity activities, such as identifying emerging threats and participating in international standard-setting bodies, are needed to enhance Australia’s preparedness. These challenges and needs are addressed in many ways through research, policies, programs and management strategies. Biotechnology can facilitate effective biosecurity in a number of ways.

Research and development providers and funders

Research, development and extension (RD&E) underpins increasing the productivity of Australia’s primary industries. RD&E across Australia comprises a complex web of providers and funders, including rural research and development corporations, state and territory government agencies, CSIRO, universities, and private providers. Biosecurity is one of Australia’s important research priorities and has been identified as one of the cross-sectoral areas that the National Primary Industries RD&E Framework will address (www.daff.gov.au/agriculture-food/innovation/national-primary-industries).

Biotechnology and its importance to biosecurity

Defining biotechnology

Biotechnology can be broadly defined as the application of science to the use of biological agents to perform specific processes or create specific products. In this brief we discuss biotechnology approaches that can prevent or minimise the effect of pests and diseases on Australia’s primary industries through enhanced diagnostics, surveillance, control and management.

Biotechnology and genetic modification

Understanding how genes and proteins function in an organism (Box 1) is fundamental to the development of some biotechnology applications for biosecurity, particularly post-border control and management of pests and diseases. There are numerous approaches to studying the function of genes. One of the most direct ways is to observe what happens to an organism when a particular gene is missing. Once the expression and function of single or multiple genes are understood, genes can be moved to another organism, transferred between unrelated species or organisms, deleted, silenced or altered, thus ‘genetically modifying’ the organism.
Biosecurity uses

At the border, applications of biotechnology can provide rapid, accurate detection of quarantine pests and diseases. Species may sometimes be indistinguishable based on their appearance, especially when dealing with microorganisms or tissue samples. However, species can be identified based on their unique deoxyribonucleic acid (DNA) sequences, by detecting either the sequence directly or a unique protein that is the product of a specific gene. These techniques are regularly exploited as part of surveillance or diagnostics.

Genetic modification could be used for post-border biosecurity; for example, to develop and deploy crops with resistance to a new pathogen thereby reducing the pathogen’s effects on agricultural systems. However, not all biotechnology applications result in a genetically modified (GM) product. Modern biotechnology techniques such as the use of molecular markers (see Box 2) are routinely used together with traditional breeding methods to develop new (non-GM) varieties of crop plants with desirable characteristics.

Biotechnology applications currently used for biosecurity

Polymerase Chain Reaction (PCR)

What is it?
The Polymerase Chain Reaction (PCR) is a technique enabling the production of a large number of copies of a sequence of DNA. PCR ‘amplifies’ the DNA sequence through many repetitions of a reaction that synthesises the target DNA sequence. Each cycle of the reaction doubles the amount of target DNA present from the previous cycle and millions of copies of a DNA sequence can be made in a few hours.

Why use it?
PCR is useful in the biosecurity context because it can detect and identify very small amounts of pest-specific DNA, making it a very sensitive tool. ‘Real-time PCR’ may be used for both a quantitative and a more rapid analysis but it can be more costly compared with other techniques.

Enzyme-Linked Immunosorbent Assay (ELISA)

What is it?
Enzyme-Linked Immunosorbent Assay (ELISA) is a protein-based technique that can be used to detect specific proteins and thereby identify the presence of pathogens. There are several types of ELISA, including methods that detect the presence of an antibody and methods that detect and quantify antigens.

The 1970s development of ELISA enabled the highly sensitive detection of a range of pathogens, including viruses, bacteria, fungi and nematodes, and also toxins and spores.

Why use it?
ELISA allows relatively cheap, simple, high-throughput assays, which can also be quantitative. However, ELISA-based tests are less sensitive than some DNA-based tests (such as PCR), may produce false positive results, and require good quality samples.

PCR and ELISA used in animal and plant diagnostics

Both PCR and ELISA are now routinely used in animal and plant diagnostics. Despite the emergence of newer techniques they remain fundamental for quick and effective diagnosis of pathogens.

PCR and ELISA are currently used by AQIS to detect avian influenza (AI), a viral disease of birds that causes infections of varying severity depending on the particular AI virus strain. H5N1 is a strain of AI that can cause either low pathogenic avian influenza (LPAI) or highly pathogenic avian influenza (HPAI). Highly pathogenic H5N1 is primarily a pathogen of birds and does not easily cause disease in humans. Since the first isolated case of HPAI was reported in Asia in late 2003, AQIS officers at airports,
seaports and international mail centres have been on high alert for bird and poultry products. In addition, AQIS undertakes surveillance of wild migratory and nomadic birds along Australia’s northern coastline for evidence of HPAI.

Biotechnology plays a vital role in surveillance of wild birds. Blood and faecal swab samples are taken from the birds to test for antibodies and the presence of AI. By detecting antibodies, an ELISA test of the blood provides a ‘history’ of the bird’s infections, including past infections with AI. A PCR test on the faecal swab can detect any AI virus present at the time the sample was taken. The initial PCR test can be used as a general screen for the viral family and, if found positive, more specific PCR testing can determine the actual strain of AI virus. This information can provide an early warning of entry of HPAI to Australia and improve understanding of the ecology of AI viruses circulating in Australia.

PCR has also been used for diagnostics in the forestry industry. For example, *Eucalyptus* rust, also known as guava rust (caused by *Puccinia psidii*), is a fungal disease of plants that is not currently present in Australia. It poses a serious risk to Australia’s eucalypt production forests and biodiversity.

*P. psidii* is native to South and Central America and infects plants of the family Myrtaceae, producing lesions on young actively growing leaves and shoots as well as on fruits and sepals. Severe rust disease in young trees and seedlings may kill shoot tips, causing loss of leaders and a bushy growth habit.

Australian actions to prevent *Eucalyptus* rust from entering and establishing in the country include analysing the pathways through which the rust could enter Australia. This is particularly important because the United States is using *P. psidii* as a biocontrol agent for the Australian native species *Melaleuca quinquenervia* which

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**Box 1**

**From DNA to proteins**

All living organisms are made up of one or more cells. Living cells contain the organism’s DNA, made up of chemical units known as nucleotide bases. Four different types of nucleotide bases occur within two complementary chains bound together and wound around each other to form the DNA double helix. The precise sequence of bases along the DNA double helix spells out the genetic code. Only some viruses, which cannot grow or reproduce outside a host cell, lack DNA; their nucleic acid is ribonucleic acid (RNA).

Genes are sequences of DNA that encode instructions for the synthesis of specific proteins that are produced by a cell. An organism’s genes control a wide range of hereditary characteristics such as physical, biochemical and physiological traits and their developmental processes.

To make a protein, the DNA sequence for a particular gene is first transcribed into RNA. The RNA is then transported to a different part of the cell where it is used as a template (‘translated’) to produce proteins. The proteins may be used by the cell or exported from the cell.
has become a weed species in some parts of the United States, particularly in Florida.

A highly sensitive species-specific PCR-based assay has been developed that is capable of detecting a single spore of *P. psidii* on small pieces of plant tissue. The assay has been internationally verified and detects the fungus reliably in naturally infected leaves, flowers, fruits, pollen, seeds, stems and wood, including asymptomatic plants.

This assay was used in Australia in 2004 to confirm the presence of *P. psidii* on dried sawn Eucalyptus timber and cargo containers imported from Brazil. The evidence supported AQIS’s imposition of controls, including, in October 2004, the suspension of trade in timber from countries with *Eucalyptus* rust. This diagnostic support highlights the usefulness of biotechnology in managing biosecurity risks. PCR will continue to play a significant role in pest monitoring and risk management at the border by facilitating rapid responses to threats and timely implementation of risk management strategies.

### Recombinant live vectored vaccine

**What is it?**

The general term ‘recombinant DNA technology’ refers to the re-joining or recombining of fragments of genetic material cut from different sources. Organisms can be genetically modified using recombinant DNA technology—for example moving single or multiple genes, whose functions are known, from one organism to another—or by duplicating, deleting or silencing genes.

Recombinant live vectored vaccines are live vectors—viruses and bacteria—with one or more sequences of genetic material from disease-causing agents inserted into them. The genetically modified vectors are carefully chosen so they have little effect on the host species.

Recombinant live vectored vaccines work by infecting the host with the recombinant vector. Antigens from the recombinant vector trigger a small immune response, stimulating the host’s immune cells against the target disease-causing agent. Ideally, the immune cells continue to circulate in the vaccinated host, conferring the ability to mount a protective immune response should an infection with the target pathogen occur.

**Why use it?**

The primary advantage of recombinant live vectored vaccines is their prolonged protection against disease, because the immune response involves both production of antibodies and cell-mediated immunity (an immune response that does not involve antibodies).

### Recombinant live vectored vaccines used for control and eradication of horse disease

Vaccination can assist the control and eradication of emergency animal diseases should they occur in livestock industries. For example, the 2007 outbreak of equine influenza in Australia was rapidly and effectively contained and eradicated by using a recombinant live vectored vaccine, together with movement controls, quarantine, zoning, and surveillance. The recombinant live vectored vaccine used for
equine influenza was created by inserting genes from two strains of equine influenza virus into a canarypox viral vector, which is not virulent in horses.

Although other vaccines were available, the recombinant live vectored vaccine was chosen because it had been effective against this strain of the virus overseas and there was evidence that it resulted in rapid development of immunity. Also, because the vaccine stimulated immunity to just one antigen from equine influenza virus, vaccinated animals could be differentiated from those infected with equine influenza by the detection of antibodies to viral antigens not included in the vaccine. Thus, it was possible to detect whether equine influenza virus was circulating between vaccinated horses.

Potential future applications of biotechnology for biosecurity

Microarrays

What are they?

DNA microarrays are also known as DNA chips. They are made up of unique short sequences of DNA (functioning as ‘probes’) that are arranged in a microscopic array fixed on a solid surface such as a membrane or glass slide. DNA microarrays can be used to identify unknown DNA samples by simultaneously testing for the expression of multiple genes, and have been used to identify the presence of animal or plant pathogens.

Sequences prepared from the sample being tested (the target sequences) bind to complementary sequences on the DNA microarray. Fluorescent markers are attached to the target sequences, and allow bound sequences to be detected by fluorescence under light of the appropriate wavelength. The position of fluorescent spots on the DNA microarray corresponds to the short sequences unique to certain genes, enabling identification of the genes in the sample. Microarrays are a high-throughput technology with the ability to ‘spot’ 10 000 to 30 000 unique DNA sequences on a single chip, and hence can detect many different pathogen species simultaneously in one sample.

A range of microarray technologies is based on the same concept. In protein microarrays, the solid surface (the ‘chip’) is a slide, spotted with protein molecules, which identifies protein-protein interactions, for example antibody-antigen interactions to identify proteins unique to a target sample. Proteins are less stable than DNA and the development of protein microarrays is more difficult than for DNA microarrays.

Possible application to diagnostics in all industries

DNA microarrays are a standard tool in molecular biology research and in certain diagnostic practices in medicine. This technology could potentially be widely applied as a routine diagnostic tool in the agricultural sector, particularly for identification of viruses.

Viruses can be significant pathogens of plants and animals but often go undetected because of their low concentrations in samples being tested and their small particle size. Virally-infected hosts can also be symptomless, and different viruses can cause similar symptoms. Successful identification of viruses may therefore need molecular tests in addition to visual examination of disease symptoms.

Testing methods that enable parallel detection of multiple viruses are highly desirable in biosecurity situations. Microarrays can provide this function—for example, a DNA microchip

Example of a DNA microarray chip
that is able to detect a range of crop potato viruses in single or mixed infection samples has been developed. Microarrays also have potential for detecting novel pathogens such as livestock viruses in surveillance programs in animal industries. Microarrays are generally expensive to design and construct—although costs could reduce over time—and DNA sequence data are needed to make the probes for the chip.

The potential of DNA microarrays may be greatest for screening purposes and for detecting novel pathogens, because they can

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**Box 2**

‘Genetic preparedness’ for disease prevention and control

‘Genetic preparedness’ for plant biosecurity involves:
- understanding a pathogen’s genetic structure
- understanding a pathogen’s threat, including its evolution and genetic variation
- developing tools that allow these aspects to be understood and detected
- identifying resistance genes in the host and novel resistance
- planning how to use this understanding to improve crops.

‘Genetic preparedness’ can facilitate preemptive breeding or rapid-response breeding of resistant varieties, which are both important risk management strategies if a disease outbreak were to occur.

The identification of molecular markers—short sections of a species’ DNA associated with a particular gene or trait—is key to ‘genetic preparedness’ research, and helps reveal the genetics behind a pathogen threat and host resistance. There are many types of molecular marker techniques and most are based on PCR.

Sugarcane smut was reported in Western Australia in 1998 and arrived in eastern Australia in 2006. Genetic preparedness activities, including cultivar exchange programs, began before 2006. In 2006, most lines were smut-sensitive, but by 2007 virtually no susceptible lines were being used for breeding Australian sugarcane.

Understanding variations in pathogen populations is crucial for successful disease management. The extent of genetic variation among isolates of sugarcane smut from 13 countries was assessed using molecular markers. A low level of genetic variation was revealed. Therefore, breeding resistant sugarcane lines is an achievable goal.

Research into resistance continues with the goal of combining multiple types of resistance. This involves identifying all the genes associated with smut resistance and combining them in one cultivar—a challenge because sugarcane is one of the most genetically complex of all crop species. Molecular markers are needed to identify, or ‘tag’, disease resistance in individual plants. New biotechnology tools, like a sugarcane microarray (chip), which has 7000 sugarcane molecular markers on it, contribute significantly to identifying suitable resistance markers.

Sugarcane smut is a good case study of the role of biotechnology in genetic preparedness. Sugarcane smut is caused by the fungus *Ustilago scitaminea* and is a serious threat to the sugarcane industry. The disease is spread by wind-blown spores. Once an incursion has occurred and has spread, breeding disease-resistant hosts is the only realistic control option.

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detect a large number and combination of viruses simultaneously. A better understanding of viruses and other pathogens, gained for example in surveillance programs, is likely to provide valuable information for risk assessments and disease management.

Biosensors

What are they?

Biosensors are analytical devices composed of biological material (such as DNA, an enzyme or antibody) linked to a transducer. When the biological material binds to a target substance of interest (the substance to be ‘sensed’) a signal is produced. The transducer converts this signal into a digital electronic signal that can be quantified. The signal strength is proportional to the concentration of the specific substance or substances being analysed. Biosensors can be laboratory-based or hand-held devices. Some can even be implanted under skin.

Possible application to diagnostics of animal and plant pathogens

Fast detection of pathogens can increase the success of control or eradication strategies. The collection of samples and surveillance data, particularly from free-living populations of animals, can be difficult if samples have to be obtained over large areas. Time delays between sample collections and transportation to laboratories can be considerable. Analytical measurements need to be highly sensitive, fast and accurate, and preferably be made in the field. Consequently, there is considerable interest in developing biosensors as diagnostic tools.

Laboratory-based diagnostics that incorporate biosensor technology are already available and more will be developed. Hand-held biosensors have been commercialised. A well known example from the health sector is the blood glucose biosensor used by patients with diabetes. International diagnostics companies and research institutions are researching and developing hand-held, remote or implantable biosensor technologies for the agricultural diagnostic sector—for example, to detect if an animal is infected by a pathogen. Biosensors could be implanted into sentinel livestock to detect disease, and data about the infection would be sent to a computer server for analysis. Biosensors’ portability could allow more people to participate in surveillance and diagnosis, benefiting detection and management of biosecurity threats.

Biosensors can provide: real-time monitoring; diagnosis in-field; portability; and the potential to detect proteins, DNA or whole microorganisms in a hand-held device. In biosecurity contexts, they could be valuable in detecting the outbreak of emerging infectious diseases, such as avian influenza or Hendra virus. However, there are currently very few commercial biosensors available for such detection. Biosensors for diagnostic purposes in plant biosecurity are at an even earlier stage of development than microarrays.

The development of biosensors is limited by the high cost of instrumentation and tests, sensitivity, and speed. This restricts their ability to compete with established chemical, DNA and immunoassay techniques. Despite these challenges, there is great interest in hand-held biosensors and, to a lesser extent, implantable biosensors. Improvements to these biotechnology-based products are likely to facilitate their broader application to biosecurity in primary industries.

RNA interference (RNAi)

What is it?

RNA interference (RNAi) is a process by which foreign double-stranded RNA (dsRNA) is recognised and degraded by specialised protein complexes, thereby preventing the RNA from being translated into a protein. When a cell detects the dsRNA, a special enzyme cuts the dsRNA into small fragments, inactivating the RNA. RNAi also prevents expression of any messenger RNA (mRNA) containing the same
nucleotide sequences as the virus. RNAi is found in a diverse range of organisms, including plants, nematodes, fruit fly, fungi and mice.

In nature, RNAi protects cells against infection by dsRNA viruses and certain other viruses and threats. RNAi has been widely exploited by scientists to reduce, or ‘silence’, the expression of selected genes. Genes are silenced by introducing dsRNA that has nucleotide sequences matching the sequences of the mRNA of the gene targeted and interfering with translation of that mRNA.

### Potential application of RNAi for vaccination of prawns and shrimps

White Spot Syndrome Virus (WSSV), a highly virulent pathogen of crustaceans, causes losses of production in the prawn and shrimp industries worth billions of dollars worldwide. WSSV has had a major effect on prawn farming in South-East Asia because the disease causes mortality of up to 100 per cent within several days of infection. WSSV is listed as ‘notifiable’ to the World Organisation for Animal Health. It is not present in Australia and its introduction could have devastating effects on the Australian aquaculture industry and marine biodiversity.

### Using biotechnology to differentiate look-a-like species

Similarities in the physical appearance of closely-related species can present significant challenges for quarantine diagnostics, particularly when one or more but not all of the species are a serious threat.

The fungal pathogen *Tilletia indica* causes Karnal bunt disease of wheat and is an extreme risk to the wheat industry. An incursion of Karnal bunt could seriously threaten the ‘disease free’ status of Australia’s high quality wheat industry and reduce trade and income.

Spores of *Tilletia ehrhartae*—a smut fungus known to infect only perennial veldt grass—and *Tilletia walkeri*—which only causes bunt of ryegrass—closely resemble spores of *T. indica*. Spores can be identified by colour, size and ornamentation but at least 50 spores are needed in a sample to allow reliable identification. Misidentification can occur when there are only a few spores. This is a considerable issue for Australian exports because *T. ehrhartae* and *T. walkeri* are present in Australia and may be misidentified as *T. indica* in Australian exports of wheat grain.

Multiple surveys have confirmed that *T. indica* is not present in Australia. To ensure adequate preparedness for a potential incursion of the pathogen, a national diagnostic protocol was developed in 2003. Plant pathologists from around Australia were trained to apply the protocol, which involves both microscopy and molecular techniques (PCR).

However, this existing diagnostic protocol requires spores to be germinated before molecular analysis can be performed. This could incur a delay of weeks, which is not ideal in a quarantine situation. To address this, a new cost-effective two-step PCR protocol for *T. indica* has been developed and is currently being validated. It does not require spore germination or microscopy and can detect and identify the pathogen in a small sample of spores (≤10 spores).

Workshops on the new protocol have been conducted in Australia and overseas and it is hoped the new protocol for Karnal bunt will supersede the existing national diagnostic protocol. This will have significant implications for biosecurity because fast and unequivocal identification of *T. indica* in samples containing a mixture of *Tilletia* species is vital for recognition of Australia’s Karnal bunt-free status.
As the immune system of invertebrates is becoming better understood, researchers in Australia and overseas are developing immunisation strategies to protect prawns and shrimps from WSSV. For example, RNAi constructs could be used to stimulate the immunity of prawns and shrimps against viruses. However, many complexities relating to specific and non-specific virus inhibition are not yet understood. For RNAi constructs to be used as an effective control option for biosecurity in the shrimp and prawn industries their effective delivery to trigger immunity is key.

Daughterless gene technology

What is it?

Daughterless gene technology is a potential type of biocontrol for pest animals. It involves manipulating genes in a specific pest species to create individuals that are ‘daughterless’ and can produce only male offspring. The ‘daughterless’ genetic modification is heritable and passed from generation to generation. Releasing genetically modified ‘daughterless’ individuals into a wild population is predicted to result in successive populations with increasingly more males than females. Models predict that with fewer females in the population the population size would decrease over decades to near zero.

Potential application of ‘daughterless’ technology for control of carp

Carp (Cyprinus carpio) is a freshwater fish, introduced to Australia. Carp degrade waterways by uprooting aquatic plants and sifting through sediment when feeding, increasing the turbidity of water and damaging aquatic plants. There is also some evidence that carp increase water nutrient levels. These effects can alter ecological functions and affect tourism and recreational values in otherwise scenic wetlands.

When carp develop naturally, all embryos begin life as males. A gene that codes for a specific enzyme (aromatase) needs to be expressed in a developing carp embryo for it to develop into a normal female fish. By blocking the expression of the aromatase gene, females cannot develop. The ‘gene silencing’ construct developed to produce daughterless carp would need to be customised to the specific gene sequence coding for aromatase in carp, so that the construct was species-specific and could not function in any other species.

In addition to the technical hurdles to developing this approach, the ecological, economic, human safety and social concerns related to this technology must also be considered, including its potential to affect target species in their countries of origin. In Australia, dealings with genetically modified organisms are regulated by the Gene Technology Regulator under the Gene Technology Act 2000 (Cwlth). The role of the Regulator is to protect human health and safety and the environment by identifying and managing potential risks posed by the use of this technology.

Implications of biotechnology for biosecurity policy and management

The use of biotechnology techniques and products has many implications for biosecurity policy and management. Policy implications centre on issues relating to trade and market access—disease and containment issues are increasingly sensitive in agricultural trade and can create barriers to trade.

Biotechnology can demonstrate freedom from pests and disease (Box 3) and the success of control measures, thereby assisting in gaining and maintaining trade and market access and providing Australia with a competitive advantage. The rapid deployment of biotechnology applications such as PCR tests can be critical to resolving disputes, particularly in situations where large consignments are detained overseas pending clarification of
pest and disease status. Biotechnology can also make export certification more robust by the provision of more detailed and specific information.

Biotechnology can assist biosecurity management along the biosecurity continuum. Australia’s preparedness is improved by biotechnology research that provides potential risk management strategies should an incursion occur (for example, cropping using smut-resistant sugarcane lines). At the border, diagnostics and surveillance techniques based on biotechnology provide rapid and accurate detection of pathogens (like *Eucalyptus* rust) and allow timely and targeted risk management strategies to be put in place, limiting the effect of an incursion threat. In post-entry plant quarantine, PCR and ELISA are used widely. In an emergency outbreak situation, biotechnology products provide policy-makers with additional effective control options to consider, for example the use of the equine influenza vaccine.

Advances in portable and field diagnostic tests are likely to increase efficiencies. New diagnostic techniques will minimise and potentially replace the need to maintain or import microorganisms that are currently used in higher risk ‘culture’ techniques for diagnostic screening. Some applications, such as microarrays, offer the potential to increase screening efficiency and accuracy, and simultaneously detect a large number of pathogens, providing valuable information for risk assessments. In addition, some emerging biotechnology applications may allow participation of people not usually involved in biosecurity operations (for example, primary producers using hand-held biosensors for disease surveillance). This sharing of responsibility for biosecurity by the wider primary industry community could increase the community’s ownership of biosecurity systems and reduce reliance on experts, particularly for diagnostics.
Challenges

There are many challenges to the continued development and adoption of biotechnology in biosecurity for the primary industries. Research output could be enhanced by increased collaboration and interaction among researchers and sharing of limited resources. Continuity of investment in research and development is a challenge, particularly the financing of the field application of some techniques and products after their development and proof-of-concept. Marketing and commercialisation of biotechnology discoveries also present a barrier, with issues ranging from technical difficulties to public acceptance and concerns about intellectual property.

On the ground, more people need to be trained in recognising and diagnosing pests and diseases, and diagnostic experts need to refresh their skills as technologies change. There needs to be greater awareness among veterinarians, farmers, extension officers and the general public of biosecurity issues and how biotechnology applications can benefit biosecurity. While university courses address biosecurity issues, they could place more emphasis on the role and value of biotechnology applications in biosecurity for primary industries.

Challenges for government include encouraging the integration or alignment of biotechnology applications within the broader biosecurity framework and objectives, as well as balancing the biosecurity risk with the cost of the technology. Policy-makers need to be aware of the current and potential capacity of biotechnology and appreciate the effective contribution existing applications have already made to biosecurity. This will help policy-makers identify how biotechnology can be effectively accessed and integrated into program development and also demonstrate the value of research into new and improved biotechnology tools for biosecurity.

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