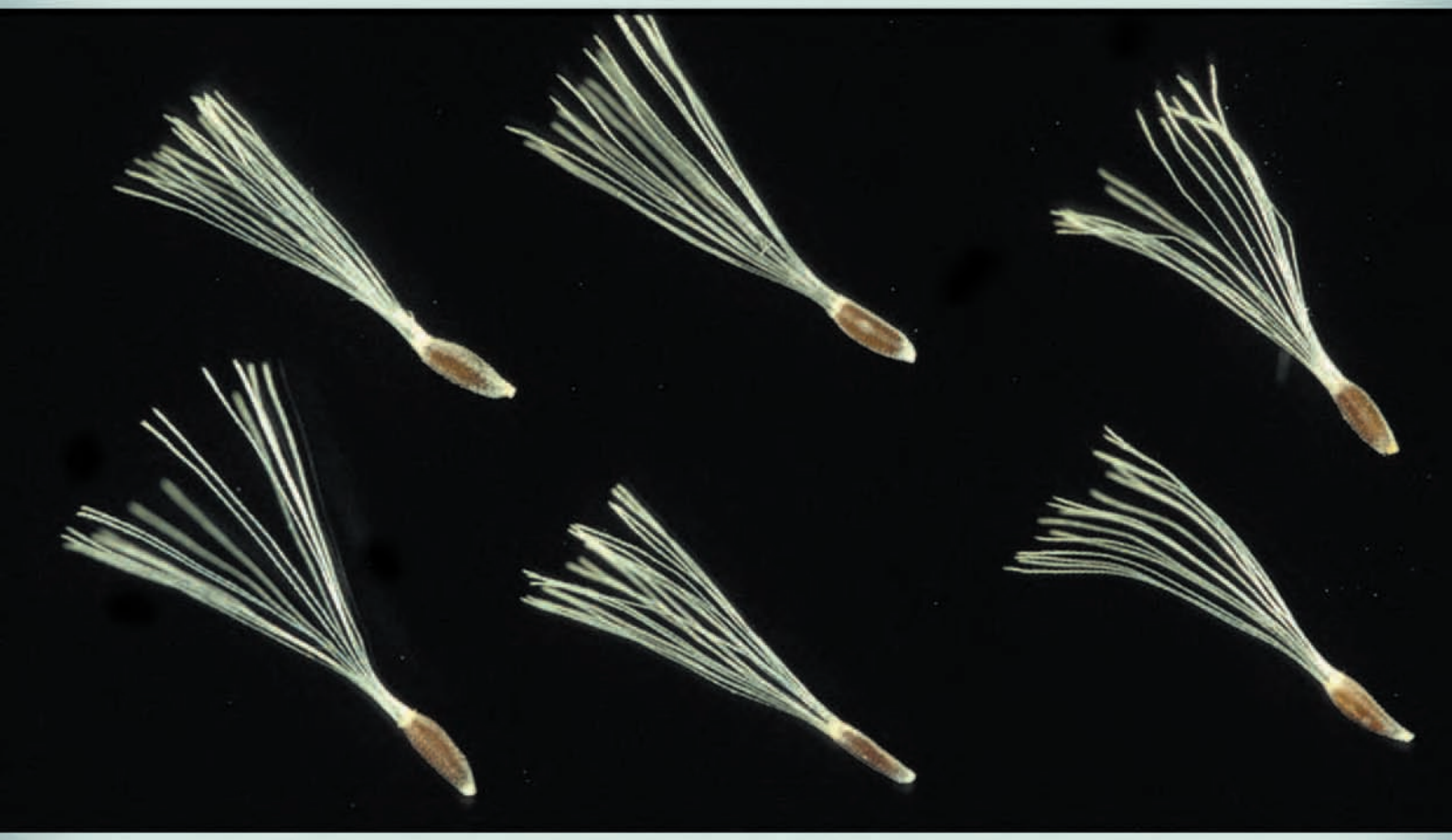
AUSTRALIAN SEEDS

A Guide to their Collection, Identification and Biology



Editors: Luke Sweedman and David Merritt

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A GUIDE TO THEIR COLLECTION, IDENTIFICATION AND BIOLOGY

This book is dedicated to my favourite person in the world, my beautiful daughter Koromiko who has been with me throughout this entire project and who will be relieved not to hear about it again.

Luke Sweedman

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Seeds of *Podolepsis gracilis*, Slender Podolepsis, by Luke Sweedman.

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Foreword

At a time when the world's plant biodiversity and ecosystems are being destroyed at alarming rates, it is most appropriate – and highly desirable – that plant biologists in Australia are devoting time and resources to preserving through seedbanking the species richness of that part of Gondwana. While seedbanking will not conserve ecosystems, it will at least conserve biodiversity, and thus genetic diversity, *ex situ*.

This book is about the biology, collection, storage and use in conservation and restoration of seeds of native Australian species, with emphasis on those that occur in Western Australia. The authors represent a wide range of expertise on the various basic and applied aspects of seed biology it covers.

The core of *Australian Seeds* contains much useful advice about seed collecting tools, equipment and procedures; how to determine the right time to collect seeds; sampling strategies; collecting seeds of rare species; and how to keep good records about seed collections. It also contains much well thought-out, and thus very good, advice on handling of seeds in the field prior to return to the storage facility and on drying and cleaning seeds after returning from the field, including an overview of equipment needed in processing of seeds; seed-cleaning tips for the 'unusual' genera *Banksia* and *Dryandra* (Proteaceae); and how to assess and prevent or minimise damage to seeds by pests and diseases. There is also a lucid presentation about laboratory storage of seeds and of testing them for purity, moisture content, viability and germination.

There are many photographs that complement nicely the subject matter discussed in the text. Guidelines for collecting seeds of species of the common Australian families Amaranthaceae, Asteraceae, Fabaceae, Mimosaceae and Myrtaceae, and of more than 260 selected genera in these and other families are covered in a separate chapter.

In chapter 9, the excellent photographs of seeds of more than 1200 native Australian species illustrate the diversity and beauty of Australian seeds. These photographs also can be used as a 'visual guide' for identifying the species that produced the seeds. This chapter in itself is a major photographic contribution to the diversity and beauty of seeds.

In contrast to the detailed advice on how to collect, process and store seeds of Australian plants, *Australian Seeds* contains very little information on how to germinate them. Although studies have been done on dormancy and germination of seeds of many Australian species, no attempt has yet been made to organise the data and fit them into a dormancy classification scheme to infer, either from taxonomic relationships or from results of studies on dormancy and germination of a taxonomic group, what kind of dormancy may be present in seeds of species for which information is not available. Thus, we suggest that the next step in enhancing knowledge about the biology and technology of seeds of Australian plants should be an attempt to classify them with respect to kind of dormancy. This may not be as difficult as it at first might seem to be. For example, seeds of most species of Asteraceae, Myrtaceae and Poaceae are likely to have (non-deep) physiological dormancy (and some perhaps no dormancy at all) and those of Fabaceae and Mimosaceae physical dormancy (i.e. water-impermeable seed or fruit coat).

Australian Seeds is an excellent contribution to plant conservation and restoration in Australia, and the editors and all the contributors are to be congratulated for making the information available in a single volume. Although the book is about seeds of Australian species, it will be of considerable interest and use to people involved in seedbanking and/or plant conservation and restoration worldwide. Also, it will be greatly appreciated and enjoyed by people who are fascinated by the beauty and diversity of seeds.

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Commendation

Seeds are vital elements for a sustainable global future. Knowing how to identify, collect, store and germinate seeds is essential to make optimum use of this important resource, especially the poorly known seeds of a large range of dryland species. We are delighted to see this book, focused on seeds of the unique Australian flora, published in such an accessible and beautiful format. The book represents the outcome of years of hard work and collaboration by many individuals and organisations. All are to be congratulated for setting such a high international standard – a model for other countries to emulate.

Our organisations take special pride in playing significant roles in seeing *Australian Seeds* through to publication over a 10-year gestation period. We know the book will prove immensely useful, and wish it the long shelf life it so richly deserves.

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Contents

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We gratefully acknowledge the contribution of Willie Kullmann for compiling the initial set of seed germination data in Appendix 1, and the nursery staff of Kings Park and Botanic Garden who collected the data over 40 years.

The authors of Chapter 4 thank Annemarie Menadue for kindly providing the illustrations; the authors of Chapter 8 thank the staff and volunteers of the Department of Conservation and Land Management, particularly Sarah Barrett and Gina Broun, for assistance with seed collection and translocation planting and monitoring.

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Preface

This book began more than 10 years ago with an idea by Dr Stephen Hopper, then Chief Executive of the Western Australian Botanic Gardens and Parks Authority. He suggested we compile the years of accumulated knowledge and experience of the Botanic Gardens staff working with seeds and publish it in a form suitable for the general reader. Over the years, the work evolved and progressed with the help of many people and the book now contains input from several organisations across Australia and overseas. The completion of this book is due mostly to the staff at the Botanic Gardens and Parks Authority, many of whom helped directly, and all of whom share a great vision and passion for the Australian flora and for Kings Park itself, which is such a special place in Western Australia.

Australian Seeds covers important aspects of the biology, collection, storage and use of seeds in conservation and restoration. It encapsulates much of what is currently known about collecting and storing seeds, with information collated over the last 10 years in which time the science of seeds has been moving at a rapid rate. The book can be used to identify seeds of more than 1200 Australian species and many genera, with photographs showing their diversity, beauty and significant variations. The practical and scientific information relates to seeds across Australia – in fact, seeds anywhere. Many of the major genera, such as *Eucalyptus*, *Acacia* and *Grevillea,* are common throughout Australia. However, since half of Australia's species occur in Western Australia, it is appropriate that many of the species examples in this guidebook are from this part of the continent. The book fully exploits the authors' deep knowledge and experience of this vast region, stretching some 3000 km south to north, from a granite coast buffeted by the raw weather patterns of the Southern Ocean, to the tropical, tidal mangroves of the Kimberley, and the deserts between.

Chapter 2 explores the evolution of seeds of Australian plants through time, tracing the fossil and geomorphologic records of the Australian continent since the Devonian, when land plants evolved. An appreciation of the role that seeds play in ensuring the continuation of a species in the face of changing environments (periods of glaciation, global warming, global aridity) provides an insight into the reason behind the remarkable diversity of seed sizes, shapes and germination-timing cues we see today.

The reader is introduced to the morphology of Australian seeds and their fruits in Chapter 3. It shows the array of shapes and sizes of seeds and fruits and explains and illustrates many of the botanical terms relating to the description of seed and fruit morphology.

Chapter 4 discusses aspects of seed ecology, describing some of the adaptations Australian species have developed in order to time seed release and germination to the time of year which will maximise seedling establishment in habitats which are often subjected to a high degree of environmental stress, including periodic drought, temperature extremes and fire.

Chapters 5 to 7 form the core of the practical guide. Chapter 5 covers in detail the planning required prior to a field trip, the equipment and tools necessary, the sampling strategies for collecting seeds and the documentation essential for a successful collecting trip. This is followed by Chapter 6 which covers the actions required after seed collection, both in the field and upon return to the seedbank. It discusses in detail techniques of seed handling, cleaning and processing, as well as the procedures for drying large quantities of seeds. It also reviews the tools and equipment available for seed processing.

Chapter 7 provides an introduction to the steps undertaken in the laboratory to correctly dry, store and test seeds. It outlines drying and storage techniques that will maximise seed longevity and describes current international, best-practice standards. It also outlines the methods employed for seed moisture, viability and germination testing, and includes tips for assessing data and determining the success of a particular storage regime.

The role that seedbanks play in conservation, restoration, horticulture and education, is illustrated in Chapter 8, which highlights the range of uses of native seeds. Several case studies illustrate how seedbanks can contribute to the protection and recovery of species that are perilously close to extinction, unfortunately an increasingly common scenario in the modern world.

The beauty of Australian seeds is showcased in Chapter 9, which contains photographs of 1260 Australian seeds. This chapter can be used as a visual guide for identifying species and to appreciate the incredible diversity of Australian flora, reflected in the diversity of the seeds.

Chapter 10 describes specific collecting techniques for some of the main plant families, giving details for more than 260 genera of Australian plants.

The genus *Corymbia* is recognised in this book as a separate genus to *Eucalyptus*. The book largely follows the family classification of the Angiosperm Phylogeny Group.* Notable changes in this system compared to recent books such as the *Flora of Australia* series include a significant reclassification of the lilioid monocotyledons (Liliaceae and Anthericaceae), and a broad definition of the legume family (Fabaceae). The cotton family (Malvaceae) and relatives Sterculiaceae are included in the broad concept of Malvaceae.

At the end of the book is a list of germination times for Western Australian species. These provide useful information for seed propagation planning. This is followed by a reference guide to the seed photographs, linking them to the herbarium records at the Botanic Gardens Park Authority Herbarium, Perth, Western Australia. There is also a full glossary of terms.

All photographs are by chapter authors unless otherwise noted.

* Angiosperm Phylogeny Group (2003). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II. *Botanical Journal of the Linnean Society* **141**, 399–436.

Contributors

EDITORS

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Luke joined the Botanic Gardens and Parks Authority in 1990, initially working as the seed collector. He now holds the position of Curator for the Western Australian Seed Technology Centre at Kings Park. His role has continued to evolve with an increasing focus on the storage of species for both local and international threatened flora programs as well as providing material for display for the Botanic Gardens at Kings Park.

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OTHER CONTRIBUTORS

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Grady is the Curator of the Western Australian Botanic Gardens. Over the last 27 years, while employed by the Botanic Gardens and Parks Authority, Grady has played an active role in assisting and overseeing the collection, propagation, cultivation and display of the Western Australian flora, including four floral displays held at International Horticultural Exhibitions (UK and Japan).

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Clare is the International Programme Officer for the Millennium Seed Bank Project. She oversees and coordinates the activities of the MSBP International Programme, including monitoring and reporting on progress towards the Project goals and developing links to other appropriate biodiversity initiatives.

Margaret Wilson
For three decades Margaret has produced thousands of illustrated botanical descriptions for research publications in which Australian native fruits and seeds feature as key elements for plant identification. A dedicated conservationist, Margaret propagates native seeds for use in nature reserves and believes a greater cultural appreciation of the vital role of seeds in conservation is essential.

Paul Wilson
For more than 50 years Paul has been involved with plant taxonomy. Initially at the Kew Herbarium, England, he worked on the plants of Mexico. After moving to Australia in 1958 he focused his research on the families Asteraceae, Chenopodiaceae and Rutaceae, seeds and fruits being particularly significant in their classification.

CHAPTER 1

Introduction

Clare Tenner, Stephen Hopper, David Merritt, Anne Cochrane and Luke Sweedman

Some 25 000 species of vascular plants – 10% of the world's total – are found in Australia. At least 85% of these species are endemic, an outcome of 42 million years of isolation. Two-thirds of the Australian continent is arid, with less than 300 mm of rain a year. This area stretches from the Pilbara region of the north-west to the southern Nullarbor, where the desert meets the coast. Surrounding the arid zone on three sides are broad semi-arid belts in which woodlands, mallee, and sclerophyll shrublands are prevalent. Salt lakes with uncoordinated drainage are common in broad valley floors, particularly in the west and south of the semi-arid zone, but the east is occupied by the bulk of Australia's largest river system, the Murray-Darling. The wetter parts of Australia occupy less than a fifth of the continent, south and eastwards of the eastern highlands, across the tropical north and in a small isolated region of the south-west. Vegetation is complex, matching the topography and geology of these areas. The wettest places, often with deep fertile soils in eastern and northern Australia, are occupied by rainforests, while shallow soils in the highest rainfall areas have stunted woodlands and heaths. Wet sclerophyll forests occupy fire-prone sites and contain immense hardwoods such as mountain ash (*Eucalyptus regnans*) in the southeast and karri (*Eucalyptus diversicolor*) in the south-west. The highest mountains support alpine vegetation and stunted sclerophyll communities. Less fertile soils on rock outcrops throughout the wetter parts of Australia also have sclerophyll shrublands and stunted woodlands. Freshwater lakes and streams are strongly seasonal, as are coastal estuaries and bays into which the latter discharge. Coastal floras include mangroves and the usual cosmopolitan plants of dunes and strand, while adjacent Australian marine environments are noteworthy in the north for their coral communities of the Great Barrier Reef on the east coast and such places as Ningaloo Reef on the west coast.

Across Australia, there are three key floristic elements: woody evergreens, rainforests and the cosmopolitan plants. The bulk of the 25 000 species are endemic evergreen sclerophyllous plants of forests, woodlands, mallee, shrublands, sedgelands and grasslands. Particularly noteworthy is the dominance of three woody, evergreen genera: *Eucalyptus/Corymbia* (more than 900 species) and *Acacia* (more than 1100 species). Spinifex hummock grasses of the genus *Triodia* are prominent over vast desert areas. Species-rich families in Australia include the Proteaceae (banksias, grevilleas, etc.), Myrtaceae (eucalypts, melaleucas, etc.), Ericaceae (Epacridaceae – southern heaths), and Restionaceae (southern rushes). Occupying about 5% of the continent, the south-west of Western Australia is especially rich in the Gondwanan element of the Australian flora, with an estimated 8000 species, 50% of which are endemic to the region.

Tasmanian rainforest, a living Gondwanan museum.

In contrast, the extensive central Australian desert region, occupying one-third of the continent, has only 2000 species.

The ancient rainforest element covered only 1% of the Australian landmass at European colonisation. Rainforests occur in scattered sites from Tasmania to north Queensland and westwards across the tropical Northern Territory to the Kimberley region of Western Australia, and contain upwards of 2000 species, many endemic to Australia. The rainforests are living Gondwanan museums – fragmented and depleted relicts of vegetation that covered parts of the continent before the onset of Tertiary aridity after Australia drifted north from Antarctica, beginning 42 million years ago. These rainforest patches differ significantly in composition, with three major floristic groups recognised. There are cool-wet temperate rainforests of Tasmania, Victoria and New South Wales, hot-wet subtropical-tropical rainforests from near Sydney north to Queensland and the wettest parts of the Northern Territory, and hot-dry semi-deciduous or deciduous rainforests and vine thickets extending from the Kimberley across to north Queensland and south into semi-arid New South Wales.

The cosmopolitan element of up to 3000 species occupies coastal habitats, saltlands, wetlands and alpine or mountainous areas. Typically, endemism is lower in this component of the flora.

The Australian flora is, indeed, extraordinary. And never has an appreciation of its seeds, and the need to conserve them, been greater.

SEEDBANKING IN CONSERVATION: THE INTERNATIONAL CONTEXT

An understanding of the role of seeds in conservation of the world's biological diversity is necessary to appreciate the resources now dedicated to working with seeds. It is well recognised by the global community that biodiversity is being destroyed irreversibly by human activities and that a major effort is needed to better understand and conserve biodiversity. In January 2005, the Paris Declaration on Biodiversity noted that humans were altering the environment at unprecedented speed, with species being lost at a rate about 100 times faster than the average natural rate. The large-scale loss is irreversible, but the declaration calls for a major effort to discover, understand, conserve and use biodiversity sustainably.

In 2002 the Parties to the Convention on Biological Diversity (CBD) adopted a strategic plan with a mission to achieve by 2010 a significant reduction of the current rate of biodiversity loss. This was later endorsed by the World Summit on Sustainable Development. The CBD recognises that *ex situ* (off-site) measures – collecting seeds and then keeping them in seedbanks, for example – have an important role to play in the conservation of biodiversity. The CBD definition of biodiversity recognises diversity within species, between species and at the ecosystem level. Many studies have shown the threats that face biodiversity occur at all three levels. For example, at the ecosystem level, models suggest that by the year 2032 up to 48% of ecosystems could be converted to agricultural land, plantations or urban areas, compared to 22% today. At the species level it is thought that as many as two-thirds of the world's plant species are in danger of extinction in nature during the course of the twenty-first century.

With regards to genetic diversity, it is estimated that 16 million populations are lost annually. In Australia alone, 2891 individual ecosystems have been identified as at risk, and 1595 native animal and plant species. The biggest direct cause of species loss is habitat loss and degradation – this affects 91% of all threatened plant species described in the 2000 IUCN red list. Habitat can

be lost through conversion for, or intensification of, agriculture, urbanisation and infrastructure development, amongst other things. Protected areas can help safeguard habitat, but there are limits to the area of land that can be covered. It takes time to establish protected areas and it can be difficult to situate them for the optimal protection of plant species. Even in well-protected areas plants are subject to further threats including climate change, invasive alien species, over-exploitation by humans and man-made and natural disasters.

The Intergovernmental Panel on Climate Change predicts that the synergy between the stresses of climate change, habitat loss and fragmentation, and alien species will lead to extinctions. In Australia additional threats to biodiversity include dieback/disease, salinity, overgrazing, feral pests, and inappropriate fire regimes.

The root causes of biodiversity loss are, of course, more complicated to unravel, but include elements such as demographic changes, poverty and inequality, macroeconomic policies and trade practices and patterns of consumption. These will take time and political will to tackle. In the meantime seedbanks can play a significant role by conserving inter-species and intra-species diversity.

The collection and storage of seeds is not new. Many peoples have done this for millennia. Certainly, since the beginning of agriculture, most of the world's food supply has relied on seeds that can be harvested and stored for a period of time. However, the establishment of native seedbanks for biodiversity conservation is a relatively recent occurrence, as is the use of stored seed in flora recovery projects. In some cases, *ex situ* conservation represents the only option available if the remaining natural populations are to be conserved in the face of destruction of their habitat. Actions to conserve individual species contribute in a fundamental way to broader conservation objectives, even if the species themselves are not highly threatened. Seedbanking cannot directly protect biological diversity of ecosystems, but it can ensure the protection of genetic diversity. Material can be provided for species and ecosystem recovery, and it has proved a cost-effective source of material for research. Investigations into seed germination and storage behaviour maximise the value of the material, and seedbanks have made an important contribution to education and public awareness.

Ex situ conservation is a critical component of an integrated global conservation programme, and seedbanking is one of the most valid and widespread methods used at present owing to its simplicity and economy in terms of technology, infrastructure, manpower and operating costs. It is possible to maintain large samples with wide genetic representation at an economically viable cost. Of the 9000 plant species whose storage characteristics are known, 92% have desiccation-tolerant seeds and are expected to remain viable in storage for at least 200 years.

Today there are around 150 seedbanks found within the world's botanic gardens. In addition, many national crop and tree seedbanks are increasingly moving into conservation of wild plant species. In any case, seed collections are a readily accessible and cost-effective source of material for research. Material is quickly and easily accessible to researchers, without the need to carry out expeditions or to over-exploit wild populations. Terms and conditions can be attached to the supply of this material which ensure the fair and equitable sharing of any subsequent benefits.

The CBD provides the international framework for activities on biodiversity. The overall objectives of the CBD are conservation of biological diversity, sustainable use of components of biological diversity, and fair and equitable sharing of the benefits arising from the use of genetic resources. As has been discussed above, seedbanks have a role to play in meeting all three of these objectives. The CBD emphasises that the fundamental requirement for the conservation of biodiversity is *in situ* (on-site) conservation, but that *ex situ* measures have an important role to play.

The Millennium Seed Bank, Wakehurst Place, UK, is an example of a modern, well-equipped seedbank.