

BIOLOGICAL PESTS

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Objectives

At the end of this chapter you should:

- be aware of the types of damage that biological pests can cause and have an appreciation of the need to control them;
- be able to protect collections from mould attack;
- know the main insect pests which pose a threat to your collections; and
- know and understand how to set up an integrated pest management system to protect valuable items in your care.

Introduction

In nature, insects and moulds perform the vital task of reducing animal and plant products to reusable chemicals. This is an important part of the cycle of life. There are numerous species of insects and moulds, with an equally huge range of habitats, food sources and behaviours.

Collections in museums, galleries and libraries, as well as possessions in our homes and workplaces provide food and breeding places for insects and moulds. We see them as simple organisms, but in many ways they are more successful than we are in finding food and adapting to the conditions we impose on them.

If they are not controlled, insects and moulds can severely damage many types of organic materials in our collections. Controlling them can be much more complicated than just buying a can of insecticide or calling a pest control company. Chemical warfare on insects and moulds can have very serious effects on humans. Many of the chemicals used are toxic—that's why they kill insects and moulds. These chemicals can also damage objects in collections.

It is important, therefore, to be able to recognise the signs of insect and moulds activity—and these can sometimes be very subtle. It is also important to know which biological pests pose a threat, so that you can take steps to control them, but without placing your collections or yourselves at risk.

What damage do moulds cause?

Damage caused by mould attack can be devastating. Moulds digest and break down the materials they feed on. In the process, paper, textiles and wood become weak and eventually crumble away, and pages of books become mashed together as digestive enzymes attack many layers of paper at once.



The lighter area in this photograph is an area of dry rot in a canoe.

Photograph courtesy of the Museum and Art Gallery of the Northern Territory

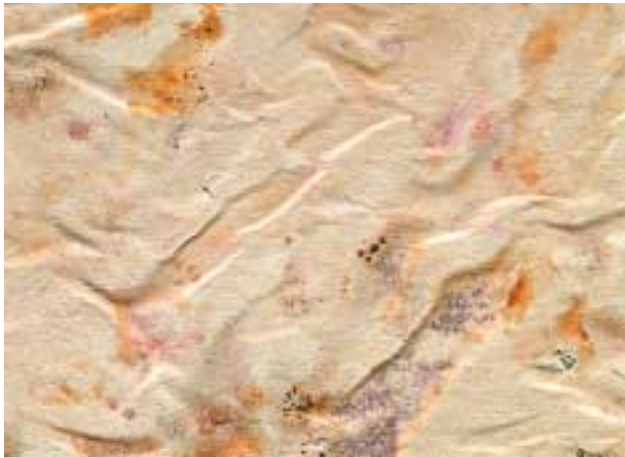


This is from a book which suffered severe mould attack. This page was completely stuck to the ones below it. The paper has no strength left at all, and suffered damage as the pages were separated.

Photograph courtesy of Artlab Australia

These digestive enzymes produce acids that attack materials which are not normally susceptible to mould growth, for example, stone and metals.

What can be done to control moulds?



Mould growth can produce bright stains.

Photograph courtesy of Artlab Australia

They also produce coloured materials which stain wood, paper and textiles.

These stains can be extremely difficult to remove, because they are often insoluble. Even when they are soluble, the stained material is often too weak to treat. If these enzymes attack photographic gelatine, they destroy the photographs.

CAUTION

Don't try cleaning mould off a photograph—you may take the photograph with it.



This document suffered severe mould attack and the paper became very weak and crumbly.

Photograph courtesy of Artlab Australia

Structural elements attacked by mould crumble away, leaving other parts of objects under considerable physical stress.

Mould can produce toxic chemicals which can cause allergies and illness.

It is impossible to stop fungal spores falling on objects. Because of this we must concentrate our efforts on making the environment unfavourable for their development into a mould colony. This can be done by controlling the relative humidity—RH.

If the relative humidity is maintained at a low enough level—that is, below 65%—spores cannot germinate. It is safer to aim quite a bit lower than 65%, because if the relative humidity hovers around this level, fluctuations in temperature could cause the relative humidity to rise above 65%. Certainly between 45% and 55% is considered safe. If the relative humidity is too low—that is, below 45%—some materials can be damaged.

For more information

For information about practical steps you can take to control relative humidity and temperature, please see the chapter on Humidity and Temperature in this volume.

In many situations—such as in buildings without air-conditioning—it can be difficult to control temperature and relative humidity. But there are other steps which can be taken.

Consider the location of materials which are susceptible to mould infestation. If they are against damp walls or in contact with cold surfaces, the local relative humidity may be high enough to permit mould growth. Move any items which are likely to be affected in this way, or wrap them and box them to protect them.

Make sure there is adequate ventilation in storage and display areas. Breezeways are vital in tropical areas.

Try to make sure all materials which could support mould growth are stored in acid-free wrappers or boxes, or are at least covered with dust covers.

Keep objects which are on open display clean.

Make sure the microclimates in display cases are suitable and will not create a favourable environment for mould to grow.

Inspect collections regularly. Don't let the mould grow for months before you find it.

Make sure the building is well maintained. Check for problems such as broken pipes, blocked gutters, rising damp from damaged water mains, broken sewer pipes, inadequate damp coursing and leaky roofs.

If a mould outbreak does occur?

Isolate the affected material immediately. If possible, place it in a plastic bag and seal the bag.

Treat other items which have been in close contact with the affected material in the same way.

Throw away acid-free tissue and other storage materials which have been in contact with the affected object.

Find out what caused the relative humidity to be high enough to allow mould growth. If you are in a tropical area, the climate is the obvious culprit. But you should also check to make sure that there is no other secondary cause, for example, a blocked gutter overflowing.

Take steps to correct the problem. Clear the gutter, buy or borrow a dehumidifier, and change your storage system to allow more ventilation. It is important that you deal with the problem, or it will happen again.

If the outbreak is general and throughout a storage area, you may need to remove all of the items and thoroughly clean the whole area to stop the mould growing again.

Fumigate affected items, if possible. Seek the advice of a conservator before doing this, because some fumigants can cause damage. Regulations about the use of chemicals can vary from State to State, so check the regulations on the use of fumigants for mould, as well.

CAUTION

You should be aware that many chemicals which were used for fumigation treatments in the past are now banned because they are too toxic. If you are following instructions from an old museum manual, you may be breaking the law and putting people, including yourself, at unnecessary risk.

Ideally mould should be killed before it is removed from the object. However, while there is a danger of spreading live spores to other objects, brushing mould off an object is better than leaving it there.

Clean objects using the brush vacuum method. This combines gentle brushing with vacuuming. To reduce the suction of the vacuum cleaner, cover the end with one or more layers of a gauze-like material. Then with a soft brush, push the mould toward the suction pipe of the vacuum cleaner.

CAUTION

Do not attempt to clean mould from an object which has a loose or fragile surface, for example, a pastel or charcoal drawing, a natural history specimen or an ochre painting, because the surface will also be removed. Seek the advice of a conservator before attempting these treatments.

Items may require conservation treatment after mould attack—it is advisable to have them assessed by a conservator.

Once the area and the objects affected have been treated, put the objects back into storage in suitable wrappers and boxes.

Continue to check all of your collection.

CAUTION

If you are going to clean mould from objects, wear a mask so that you don't breathe in the spores. It is advisable to use HEPA filter vacuum cleaners.

What damage do insects cause?

Insects eat organic materials, leaving them damaged and weak. In some cases, the damage is obvious: holes in textiles, for example. In other cases, you have to inspect things carefully to find the damage, for example, some borers in woods.

The following table briefly outlines the insects which are likely to be a problem in museums, galleries and libraries, and the materials they are likely to feed on.

Insect	What they eat in museums, galleries & libraries
Cigarette beetles	A wide variety of plant and animal-based materials.
Drugstore beetles	A wide variety of plant and animal based materials.
Spider beetles	A variety of plant and animal-based materials.
Carpet beetles	Wool, fur, hair, feathers, silk, insect specimens, books and other products of animal origin, for example, horn.
Green timber borers	Freshly-felled trees.
Green to dry timber borers	Live and freshly-felled trees. They will complete their life-cycle in, and continue to feed on, dry or drying timber.
Dry timber borers	Dried wood.
Powderpost beetle	The sapwood of hardwoods.
Furniture beetle	The sapwood of softwoods; will infest some hardwoods.
Common clothes moths	Wool, fur, hair, silk, dead insects, horn and feathers.
Casemaking clothes moths	Wool, fur, hair, silk, dead insects, horn and feathers.
Cockroaches	Cockroaches will eat just about anything, including leather, hair, skins, paper and books. They also cause damage through regurgitation or by gluing their egg-cases onto objects.
Termites	Timber. Termite damage can be extensive if left undisturbed or if not discovered. Dry wood termites will infest small pieces of timber, and are easily transported in artefacts such as wooden carvings.
Psocids—booklice	Booklice feed mostly on mould growing on old books or dead insects, but they can also damage the surface of materials.
Silverfish	Paper, fabrics—starched or stained material especially—cotton, linen, photographs, book bindings and paste or sizes.

Other pests

Mice, rats and birds can also damage collections. The following table outlines the damage they can cause.

Pest	Damage they can cause
Rodents	Rats and mice can cause extensive damage to collections, through feeding—gnawing on materials—and through stains from their droppings. Their nests can also become infested with insects.
Birds	Bird droppings can damage collections; their nests can also lead to insect problems.

Control of common insect pests

The damage caused by insects can range from feeding and regurgitation marks to the total destruction of cultural property. Unfortunately, many of the chemicals used to fumigate or protect this material have the potential to damage the things we are trying to protect, as well as posing significant health hazards to the people using them.

In recent years, many new, low-toxic and non-toxic methods of insect control, which are suitable for use with heritage collections, have been developed. Some of these methods are:

- use of low temperatures;
- fumigation using controlled atmospheres;
- use of sticky traps;
- biological control—the use of parasites and predators; and
- use of some of the new-age pesticides, for example, insect-growth regulators and pheromones, to control insect pests.

Integrated pest management

Although the methods mentioned above will help to overcome an existing pest problem, it is

preferable to avoid problems. Because of this, there is greater reliance on Integrated Pest Management—IPM—within cultural institutions.

An IPM program aims to reduce the occurrence of pests and the damage they cause within collections. An IPM program relies on a knowledge of pests and their habits, to make the environment undesirable or hostile for them. The success of an IPM program comes from a thorough understanding of pests' ecologies, and the ability to modify the conditions which will enhance pest numbers. That is, the ability to control temperature, food and shelter.

Probably the most important first step in an IPM program is to find and identify any insects infesting the collection. By correctly identifying the insect, you can find out:

- whether or not the insect is a pest normally found in museums, galleries and libraries;
- what types of material are likely to be infested; and
- where to look and what to look for, for example, frass from borers.

If you have no success identifying the insects from the notes in this section, try insect identification books or the entomology department of a museum. You can also contact your local pest control operator for assistance.

One of the major benefits of IPM is that pest problems are controlled without relying solely on the use of chemicals. It involves the implementation of a number of measures. These include physical, cultural and chemical control.

Physical control alters the environment by making it hostile or inaccessible to pests. Some examples of physical control are:

- physical exclusion, that is, packaging to exclude insects, seals around doors and insect screens;
- sealing cracks and other crevices in which insects can hide, using a caulking gun or sealer; and
- draught strips and seals around and under doors, and screens for windows and vents.

Cultural control manipulates the pest's environment to make it less favourable. Some examples of cultural control are:

- controlling relative humidity and temperature;
- good housekeeping. A clean environment helps to deter or reduce most pest problems because there will be no food for them. A vacuum cleaner is useful for several reasons: it instantly reduces insect numbers by removing them, their eggs, and any materials they have left behind. It removes a variety of insects in one hit; and
- improving ventilation and air movement.

For more information

For more information about the control of relative humidity, please see the chapter on Humidity and Temperature in this volume.

Chemical control means carefully selecting and applying pesticides on the advice of your local pest control operator or museum conservation officer. There are two main categories of pesticides:

- biological: insect growth regulators and pheromone attractants; and
- general pesticides: insecticides, rodenticides and herbicides.

Summary of integrated pest management

Make the environment undesirable to pests by:

- physical exclusion;
- physical removal—vacuuming;
- good housekeeping;
- maintaining good environmental conditions; and
- applying chemicals as required.

Monitor the area by:

- inspecting the area regularly; and
- placing and inspecting insect traps.

If a pest infestation is found, implement non-chemical eradication methods first:

- inspect and remove all infested or suspect material;

- thoroughly inspect neighbouring material;
- thoroughly clean the area by vacuum cleaning;
- apply pesticides, if and where necessary;
- use blunder or pheromone traps; and
- carry out subsequent inspections.

To treat infested material:

- Bag and seal material to contain infestations until the situation is controlled; and
- Freeze infested material, or treat it using one of the alternative methods, such as low-oxygen fumigation.

Check the IPM program you have developed with a conservator.

Common insect pests: a guide to identification and non-toxic control

Beetles

Beetles make up the largest insect order. All have a complete life cycle. That is, they develop right through from larval stage to adults. They can be distinguished from other insects by their hardened wing-covers, which are called elytra.

Cigarette beetles

Description: Adults are 2–3mm in length, oval-shaped and brown to red in colour. Their hardened wing-covers are covered in fine hairs and their antennae are serrated. Larvae are cream to white-coloured and hairy.

Attack: They attack a wide variety of plant and animal-based materials. The destructive stage is the larval stage. But the adults often cause damage when they eat their way out of a food source: chewing their way out of a cereal box, for example. Affected materials will have a shot-hole appearance.



Cigarette beetle—*Lasioderma Serricorne*.

Photograph courtesy of the Museum and Art Gallery of the Northern Territory

Control: Thoroughly inspect and treat new acquisitions as necessary to prevent their introduction. Locate, then have treated, the source of the infestation. Arrange for the treatment of any infested artefacts using one of the low-toxic methods available: freezing, low-oxygen and controlled atmospheres. Pheromone traps are available for cigarette beetles, and are useful in locating infested material.

Drugstore beetles

Description: Drugstore beetles are almost identical to Cigarette beetles in their size and feeding habits. The main difference is that Drugstore beetles have lines of pits on their hardened wing covers and their antennae end in a three-segmented club.

Attack: They attack a wide variety of plant and animal-based materials.

Control: Thoroughly inspect and treat new acquisitions as necessary to prevent their introduction. Locate the source of the infestation. Arrange for the treatment of any infested artefacts with one of the low-toxic methods available: freezing, low oxygen and controlled atmospheres.

Spider beetles

Description: Adults are 1.5–4.5mm in length, are red or brown-black in colour, with a bulbous body and long legs, and resemble small spiders. Their larvae are white and up to 4mm long, and often spin a silken case in which to feed.

Attack: Spider beetles attack a variety of plant and animal-based materials.

Control: Thoroughly inspect and treat new acquisitions as necessary to prevent their introduction. Locate the source of the infestation. Arrange for the treatment of any infested artefacts by one of the low-toxic methods available: freezing, low oxygen and controlled atmospheres.

Carpet beetles

Description: There are several species which will attack museum and library collections. The adults are up to 5mm in length and are oval or elongated oval in shape. They vary in colour, depending upon the species, and can be black, white, brown, mottled or variable. The larvae vary in size, depending on the species; they are very active, and usually brown in colour. All are covered with bristles. The only evidence usually found of this beetle's presence is cast-off skins of the larvae and pupae.



Carpet beetle - *Attagenus Fasciculatus*.

Photograph courtesy of the Museum and Art Gallery of the Northern Territory



Carpet beetle larvae.

Photograph courtesy of the Western Australian Museum

Attack: All damage is caused at the larval stage. The adults are mostly pollen or nectar feeders, which means that this pest could come in on cut flowers.

The materials likely to be attacked include wool, fur, hair, feathers, silk, insect specimens and other products of animal origin, for example, horn. They will also attack books, making irregular holes and cavities for pupation.

Control: Thorough vacuuming, with particular attention to areas which are rarely disturbed as these are often used for pupation. Avoid bringing cut flowers into storage areas. Thoroughly inspect and treat new acquisitions, to prevent their introduction. Locate the source of infestation. Arrange for the treatment of any infested artefacts by one of the low-toxic methods available: freezing, low-oxygen and controlled atmospheres.

Borers

Borers are insects which as larvae bore their way through timber. Most borer larvae feed on the sugars and starch found in the sapwood of trees. When the larval stage of their life cycle is complete, the adults emerge through holes which they make in the surface of the wood. The length of time taken for the life cycle depends on many things, including the temperature and moisture content of the wood. There are many different types of borers, but they can be broken down into three main groups.

Green timber borers

Description: These borers need a moist environment to survive, and will not re-infest dry timber. They include Pin-hole borers and the Cypress Bark weevil.

Attack: They attack live and freshly-felled trees.

Green to dry timber borers

Description: Most of the borers in this group will not re-infest the wood once it has dried out. One exception is the Auger beetle, which can continue to re-infest the wood as long as the moisture content is above 20 per cent. This group also includes such borers as the wood wasps, Longicorn and Jewel beetles.



Large Auger beetle—*Bostrychopsis Jusuita*.

Photograph courtesy of the Museum and Art Gallery of the Northern Territory

Attack: These attack live and freshly-felled trees, but complete their life cycle in dry, or drying timber. For example, if a piece of untreated green timber is used for a carved wooden figure, any larvae present continue to feed and complete their life cycle in the carving, although the time taken to complete the life cycle may be extended.

Dry timber borers

The two most common borers found damaging artefacts are the Powderpost and Furniture beetles. These borers attack dried wood. They continue to re-infest the timber until there is no sapwood left. Most attack only the sapwood because of its high starch and sugar content; but some also attack the heartwood.

Powderpost beetle. **Description:** Adults are 4–5mm long, cylinder-shaped and red to brown in colour. Their larval stages are not usually encountered because these remain inside the wood. After feeding, the larvae tunnel close to the surface of the wood and pupate. The adults emerge two to four weeks later through round holes which are 1–1.5mm in diameter. The dust or frass produced is like fine talcum powder when rubbed between fingers.

Attack: Powderpost beetles eat the sapwood of hardwoods.

Control: Thoroughly inspect and treat new acquisitions as necessary to prevent their introduction. Locate the source of the infestation.

Arrange for the treatment of any infested artefacts by one of the low-toxic methods available: freezing, low-oxygen, controlled atmospheres. Record any damage; for example, put chalk marks on existing holes. Try to use borer-resistant timber when building.

Furniture beetle. Description: Furniture beetles are 4–6mm in length, cylinder-shaped and red/brown in colour.

Attack: Unlike the Powderpost beetle, the Furniture beetle attacks aged wood. The adults emerge through round holes about 1.5–2mm in diameter, leaving frass—like fine sand. Furniture beetles attack the sapwood of softwoods, but will infest some hardwoods.

From Northern NSW to Queensland, the Queensland Pine beetle does the same damage as the Furniture beetle.

Control: Thoroughly inspect and treat new acquisitions as necessary to prevent their introduction. Locate the source of the infestation. Arrange for the treatment of any infested artefacts using one of the low-toxic methods available: freezing, low-oxygen, controlled atmospheres. Record any existing damage: make chalk marks on existing holes; take photos. Try to use borer-resistant timber when building.

For more information

For more information on sapwood, softwoods and hardwoods, please see the chapter on Wood in *Caring for Cultural Material 2*.

Moths

Most moths will not attack artefacts, so it is important to identify them correctly. The two most damaging moths encountered in collections are the Common clothes moth and the Casemaking clothes moth. Neither of these moths are attracted to light.

Common clothes moths

Description: Common clothes moths are 8–10mm long and are white to silver-buff in colour. The larvae are up to 12mm long and can be found amongst a network of silken tubing.



Common Clothes moth—*Tineola bisselliella*—larvae (left) and adults with laval case (right).

Photograph courtesy of the Museum and Art Gallery of the Northern Territory

Attack: They feed on wool, fur, hair, silk, dead insects, horn and feathers.

Control: Keep rooms light and airy. Dry-clean material where necessary before storing it in sealed plastic bags. Thorough, regular vacuuming helps to reduce the moth's food sources. Thoroughly inspect and treat new acquisitions as necessary to prevent their introduction. Locate the source of the infestation. Arrange for the treatment of any infested artefacts by one of the low-toxic methods available: freezing, low-oxygen and controlled atmospheres.

Casemaking clothes moths

Description: Casemaking clothes moths are 7–10mm long, are darker than Common clothes moths and have three dark spots on their wings. The larvae are up to 10mm long and are usually found in a case made from the material that they are feeding on. The colour of this case usually indicates what is being attacked.

Attack: They feed on wool, fur, hair, silk, dead insects, horn and feathers.

Control: Keep rooms light and airy. Dry-clean material where necessary before storing in sealed plastic bags. Thorough, regular vacuuming helps to reduce its food sources. Thoroughly inspect and treat new acquisitions as necessary to prevent their introduction. Locate the source of the infestation. Arrange for the treatment of any infested artefacts by one of the low-toxic methods available: freezing, low oxygen and controlled atmospheres.

See image overleaf.



Cases of a Casemaking clothes moth—*Tinea Pellionella*—found in an Aboriginal feathered bag.

Photograph courtesy of the Museum and Art Gallery of the Northern Territory

Cockroaches

There are several species of cockroaches which can damage collections. Most of the damage is caused while feeding, which makes irregular surface erosion on the object. But cockroaches can also cause damage through regurgitation, leaving marks on the object they have been feeding on, or by gluing their egg cases onto objects. Cockroaches are social insects, living in groups or colonies, so it is not unusual to find hundreds in the same location.

Attack: Cockroaches eat just about anything, including leather, hair, skins, paper and books.



German cockroach (left) and Brown Banded cockroach (right).

Photograph courtesy of the Museum and Art Gallery of the Northern Territory

Control: Clean regularly and thoroughly. Fill all cracks and crevices with a suitable sealant. Thorough, regular vacuuming helps to reduce its food sources. Lay cockroach baits and sticky traps where necessary. Thoroughly inspect and treat new acquisitions to prevent their introduction. Locate the source of the infestation. Arrange for the

treatment of any infested artefacts by one of the low-toxic methods available: freezing, low oxygen and controlled atmospheres.

Termites

Termite damage can be extensive if left undisturbed or if not discovered. Termites are social insects, living in groups or colonies. There are many different species; the three main varieties are:

- subterranean termites. These termites travel underground from the nest to a food source. They form mud tunnels across surfaces which are exposed to air;
- dampwood termites. These are found in dead and dying trees, or wood which is in contact with damp soil. They can also be found infesting wood in poorly ventilated sub-floors. Dampwood termites rarely infest timber in well-ventilated areas; and
- drywood termites. These termites do not need ground contact because they obtain their moisture from the atmosphere or the wood that they infest. They are common in tropical and sub-tropical areas where the high humidity increases the moisture content of wood. They infest small pieces of timber, and are easily transported in artefacts such as wooden carvings.

It is recommended that you obtain information through the Forestry Commission, or from one of the many books available, about the different types of termites and how to control them.

Prevention: Many buildings are given a preventive termite treatment during construction or in subsequent years. As the pesticides used in these treatments are extremely stable, it is unlikely that further treatment will be necessary for some years after the initial treatment. This is assuming that the initial treatment was effective, and that the chemical barrier around the building has not been breached. Gardens planted near a building sometimes break the barrier, as do excavations for plumbing and extensions. Measures which reduce the risk of attack from termites include:

- not storing anything, especially wood, under buildings;
- maintaining good ventilation in sub-floor areas. This helps to prevent mould, which in turn can lead to termite attack;

- repairing any leaks; and
- using resistant and treated timbers for any structural work.

Control: Only a qualified pest controller should treat termite infestation. If the area is high-risk, a qualified person should do a regular inspection. As most termites require ground contact, removing affected material from an infested area should be sufficient to control an infestation of individual pieces. Artefacts infested with Drywood termites can be treated by one of the low-toxic methods available: freezing, low-oxygen, controlled atmospheres.

Psocids—booklice

Booklice are 1–2mm long and greyish-white in colour.

Attack: They feed mostly on mould growing on old books, or dead insects; but they can also damage the surface of materials.

Control: As booklice feed on mould, their presence usually indicates other problems: poor ventilation, for example. Look at the environment in which the material is stored and improve ventilation if necessary. Thoroughly inspect and treat new acquisitions to prevent their introduction. Locate the source of the infestation. Arrange for the treatment of any infested artefacts by one of the low-toxic methods available: freezing, low oxygen and controlled atmospheres.

Silverfish

Silverfish are 5–15mm long and silver-grey in colour. They have three distinct tails. Young silverfish resemble adults.

Attack: Silverfish feed on paper, fabrics, especially starched or stained material, cotton, linen, photos, book bindings and paste or sizing. Their damage includes holes and surface erosion.

Control: Increased ventilation and regular vacuuming will help to make the environment less desirable to this pest. Wrap material in acid-free tissue and seal in plastic bags. Thoroughly inspect and treat new acquisitions to prevent their introduction. Locate and treat the source or sources of infestation. Treat any infested artefacts by one of the low-toxic methods available: freezing, low-oxygen, controlled atmospheres.

Rodents

Rats and mice can cause extensive damage to collections through feeding—gnawing on materials—and through staining from their droppings. Their nests can also be a source for insect infestations.

Control: Seal possible entry points. Removing food sources and repairing any leaking pipes helps to deter rodents. Avoid baiting because the rodent may die somewhere where you are unable to find the body, causing unpleasant odours as well as insect problems. Use traps if necessary.

Birds

Bird droppings can damage collections; their nests can also cause insect problems.

Control: Many different methods of deterring birds are available. These methods include:

- using chicken wire to keep them out of roof and wall cavities;
- placing deterrents such as plastic or wire strips on landing surfaces; and
- increasing the angle of the ledge to remove roosting sites.

Tropical insects

Most of the pests found in museums, libraries and art galleries are cosmopolitan in nature, that is, they can be found infesting artefacts throughout the world, irrespective of the climatic zones in which they are located. These pests vary in species, but by and large the pest and its damage will remain the same.

The most common insect pests of museums in the tropics are borers, termites, clothes moths, carpet beetles, silverfish and, to a lesser extent, cockroaches.

The high temperatures and humidity found in the tropics are conducive to a higher incidence of insect attack. Some pests, notably the termite *Mastotermes Darwiniensis*, are found exclusively in the tropical north of Australia.

MORE ABOUT BIOLOGICAL PESTS

Moulds

What are they and what do they need to live?

Moulds are simple plants which do not require sunlight for their existence. But they require organic material as a food source, and water if they are to grow and reproduce.

We are familiar with fungi as harmful organisms: in the form of moulds, diseases of crops and fungal infections. But humans have also used mould very productively in the fermentation of beer, production of cheeses and antibiotics, and as a food source—mushrooms.

Fungi feed on organic material; and museums, galleries and libraries are full of organic materials. Provided there is sufficient moisture available in the material or in the atmosphere, they will feed on:

- leather
- wool
- wood
- fur
- photographic emulsions and glazes
- adhesives
- cotton
- paper
- bark
- rawhide
- some varnishes
- some pigments

Under suitable conditions they will also grow on metal and stone surfaces, particularly those with a coating of dust or organic debris. Some species will grow on creosote-treated wood, or will even incorporate poisonous, chlorine-containing compounds into their diets.

Fungi can tolerate extreme temperatures—some species are known to survive in temperatures as low as -10°C and as high as 110°C .

Fungi and moulds are more affected by relative humidity than by temperature. A few species survive at relative humidities below 60%, but the majority require a relative humidity of at least 65% to survive and reproduce. If relative humidity

drops below 60%, the fungal body normally dies; but the spores usually released at the time of such adversity lie dormant until the conditions are suitable for growth again.

Fungi and moulds survive best in environments where there is little disturbance and where air-flow is low. Such environments are found underneath suspended floors and in cellars, and can be present in store rooms and cupboards, or where objects are stacked very closely together.

Where do they come from?

Most people at one time or another have seen mould growing on old bread, cheese, jam, damp wood or leather. This growth, usually appearing as a fine, fluffy mass on the surface of such materials, is called the mould colony.



This mould colony appeared as thick multicoloured lumps.

Photograph courtesy of Artlab Australia

If you look at a thriving colony under a microscope it is possible to see fruiting bodies. These structures contain the individual reproductive bodies called spores. The fruiting bodies stand up above the mass of the colony—so that the spores can be discharged unhindered into the atmosphere and be carried away by air currents.

Mould spores are microscopic in size, but are produced in very large numbers. They are everywhere—in the air we breath, on every surface around us, on our skin and on every object we value.

Under favourable environmental conditions the spores absorb water and grow. They grow rapidly and branch repeatedly—forming a new mould

colony. When the colony is established and large enough, the fruiting structures appear, spores are produced and the cycle is repeated.

Insects

Insect life cycles

Most insect pests have similar life cycles: going from egg, to larval and adult stages. In all pests except silverfish, larvae do most of the damage to artefacts. The adults are generally most active in selecting the site for egg-laying.

The silverfish has no larval stage and develops straight from the egg to a miniature adult form, termed the nymph stage. The insect develops to the adult stage by a series of intermediate nymph stages. At the end of each of these stages, it sheds its skin—moults—and continues, slightly bigger, towards its next skin-shedding.

The other museum pests go through the usual egg-larval-adult process of most common insects. This process occurs generally as follows. The adult lays an egg or batch of eggs on a suitable material in a suitable site. Miniature larvae hatch from the eggs, which then either burrow into—or browse across—the material on which they have been laid. As the larvae feed they grow, usually to several times the size of the adults before pupating, during which time the larvae change to the adult form. When they are fully developed, they fly off to mate.

Insect control without damage to collections

In recent years, many new, low and non-toxic methods suitable for use on heritage collections have been developed. These methods are described below.

Use of low temperatures: fumigation by freezing

Exposure to low temperatures is lethal to insects. The technique has been used at the Australian Museum and other institutions for many years. It provides an efficient and inexpensive alternative to other fumigation methods.

A large variety of materials can be disinfested by exposure to low temperatures for varying periods of time. The mortality rate depends upon the temperature used, the type of insect and the thermal conductivity of the material being treated.

The possibility of damage to some artefacts caused by exposure to sub-zero temperatures is a common concern. Any material which may become brittle and crack when frozen should be treated by one of the many alternative methods now available. Seek advice from a conservator to be sure freezing is appropriate.

The object to be treated is placed inside a plastic bag. The bag is necessary to prevent condensation forming on the object after freezing.

As much air as possible is evacuated. This reduces the amount of moisture which would otherwise be absorbed by, or condense on, the artefact. A buffer, such as silica gel or cotton wool, can be added to absorb excess moisture. This should not be necessary with organic materials which do not contain excessive amounts of moisture.

The bag is sealed using a heat-sealer or waterproof tape.

The bagged and sealed object is then placed in the freezer for 48 hours at -20°C . Times can vary, so please refer to the notes below for further information.

After the appropriate length of time, the object is removed from the freezer. Allow it to thaw before taking it out of the bag.

Freezing times will need to be extended if:

- the freezer being used cannot hold temperatures of -20°C or lower. If the temperature of the freezer is around -15°C , the time required for 100 per cent mortality may be up to 14 days. The time needed varies according to the material and insect being treated; and
- fumigating large artefacts, for example, carved trees, or objects where the diameter exceeds 35 centimetres.

Wood, leather, feathers, fibre, books and textiles can all be treated this way. Freezing kills insects at all stages of their life cycles.

Low-oxygen atmospheres

Another method of disinfesting material is by exposing it for varying lengths of time to an atmosphere which lacks oxygen. Low-oxygen atmospheres can be achieved using an oxygen scavenger.

AGELESS™ is a scavenger which is used extensively in the food industry to remove any oxygen present within a sealed bag or container, thus preserving the product and preventing deterioration from mould and insect attack. The chemical oxygen absorber present in AGELESS™ is prepared from powdered iron oxide, which rapidly absorbs atmospheric oxygen.

At some major museums, AGELESS™ is used routinely as part of the fumigation program. Artefacts requiring treatment are placed in a bag manufactured from a material which has a low-oxygen permeability. The amount of AGELESS™ needed to absorb the oxygen present is calculated and then added, along with the indicator tablet AGELESS Eye.

The time needed for disinfestation depends on the temperature at which the bag is then stored. For example, at a constant temperature of 30°C it takes, three weeks to achieve 100 per cent mortality—based on the more tolerant insects tested. But if the bag is stored at 15°C the time taken to achieve 100 per cent mortality could be as high as 24 weeks.

Fragile artefacts or those which are of an odd shape or size may require large amounts of AGELESS™.

Insect traps

Blunder traps are non-specific traps which assist in identifying any insects present within the collection.

Although food is the attractant in most traps, the insect's capture is due largely to the location and placement of traps where insects are common.

Most traps incorporate a piece of cardboard, one or both sides of which are sticky; but many other types are available.

Many traps now incorporate a pheromone. Pheromones are chemical messengers similar to the hormones within our bodies. Insects produce them to communicate messages. These chemicals, when passed from one insect of the same species to

another, cause a certain response, either behavioural or physiological. Some examples of these are:

- aggregation pheromones, which may attract both males and females, for example, to a food source;
- trail-marking pheromones, such as those used by termites and ants; and
- sex pheromones, which cue for mating.

Many traps use pheromones as an attractant to lure insects. Any insects within a certain distance of the trap, home in on the odour and become trapped.

By checking these traps on a regular basis, it is possible to get an indication of the presence of a specific insect within the monitored area.

Pheromone traps are insect-specific, that is, a clothes moth trap will attract only clothes moths.



An example of a commercially available insect trap.

Photograph courtesy of Artlab Australia

Making blunder traps

You will need corrugated cardboard, another non-corrugated piece for use as a backing board, and a roll of double-sided sticky tape, the stickier the better.

Cut the backing board and the corrugated cardboard pieces into rectangles about 15cm x 7cm.

Cut the corrugated board so that the holes formed by the corrugations are along the edge.

Cut a second, smaller rectangle out of the centre of the corrugated cardboard.

Cover one side of the backing board with the sticky tape, and then stick the corrugated cardboard to the backing board.

Another piece of backing board can be placed on top to prevent dust entering if required.

Traps can be baited with wheatgerm oil, or something else which will attract insects.

Check the traps regularly and identify any insects found in the traps. Change traps when they are no longer sticky or when they are full.

Common pesticide application methods

The methods chosen to control pests will depend largely on the area being protected and the type of pests present. Infested material should be treated before being introduced to a clean collection. As long as storage conditions are good, this greatly reduces the risk of infestation.

Misting, or gassing, using pesticides

An insecticide, for example, Pestigas or pyrethrum, is applied to an area as a mist or aerosol.

Residual sprays

A residual spray is one which is applied and remains active for a long period of time. Most household pesticides are not residual sprays: they usually become inactive and lose their toxicity within a matter of hours. Other pesticides, organochlorides and organophosphates can remain active for many years.

Residual sprays are applied to skirting boards, cracks and crevices within the area being treated. When the water dries away, the pesticide remains on the surface, where it is picked up by insects or ingested by insects during grooming.

Baiting

Cockroach, ants or rodent baits.

Fumigation using toxic chemicals

Fumigation is one of the oldest methods of pest control. It allows the pesticide to penetrate areas which would not be affected by other applications. The fumigant, one of many toxic chemicals, is released inside a specially-built chamber, or under a gas-tight tarpaulin. Fumigants are generally broad spectrum pesticides, that is, they kill a wide variety of insects and animals.

Non-toxic fumigation

There are now many methods of disinfecting material without the use of toxic chemicals. Some of these methods are freezing, controlled atmospheres, and oxygen deprivation using a scavenger.

If you have a problem related to attack or damage caused by insects, contact a conservator. Conservators can offer advice and practical solutions.

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Suppliers of pheromone and blunder traps

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Self-evaluation quiz

Question 1.

Which of the following statements are true?

- a) Mould can digest paper, textiles and wood.
- b) Mould never grows on metal.
- c) All fungi are safe—after all we eat mushrooms.
- d) Mould can stain objects.
- e) Fungal spores are everywhere.

Question 2.

To control moulds, you can

- a) control the environment—keeping relative humidity between 45%–55%;
- b) make sure storage spaces are clear and well ventilated;
- c) separate infected items from non-infected items;
- d) set up a program of building maintenance and housekeeping;
- e) All of the above contribute to the controlling moulds.

Question 3.

Which of the following are low or non-toxic methods of controlling insects?

- a) Fumigation with ethylene oxide.
- b) Freezing.
- c) Sticky traps.
- d) Controlled atmospheres.

Question 4.

What are the main elements of Integrated Pest Management?

- a) Find the insects and fumigate the area.
- b) Prevent insects entering the building and fumigate on a regular basis in case some get through.
- c) Make the environment undesirable to pests, monitor the area and fumigate regularly.
- d) Make the environment undesirable to pests, monitor the area and if pests are found implement non-chemical methods of prevention and treat infested material.

Question 5.

Which of the following statements are false?

- a) All moths attack artefacts.
- b) Carpet beetles attack wool, fur, hair, feathers, silk, insect specimens and other animal products.
- c) Rats and mice should be kept in museums to control insects.
- d) Silverfish prefer dark, unventilated areas.

Answers to self-evaluation quiz

Question 1.

Answer: a), d) and e). b) and c) are not true. Mould can grow on layers of dust on metal objects. Many moulds are toxic and you should take precautions when handling mouldy objects.

Question 2.

Answer: e).

Question 3.

Answer: b), c) and d) are true. a) is untrue—ethylene oxide is toxic.

Question 4.

Answer: d).

Question 5.

Answer: a) and c) are false. Not all moths attack artefacts—the most damaging to objects in collections are the Common clothes moth and the Casemaking moth. Rats and mice can damage collections by eating objects, by staining them with their droppings and by encouraging insect infestation.