reCollections

Caring for Collections Across Australia

DAMAGE AND DECAY

HERITAGE
COLLECTIONS
COUNCIL

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Detail of photograph courtesy of Museum of Western Australia.

Detail of bark painting, *Lightning Snake Story*, Douglas (Nawurapu) Wununmurra. Photograph courtesy of Karen Coote, Australian Museum.

Detail of photograph courtesy of Artlab Australia.

Detail of hand-coloured 19th century children's book. Photograph courtesy of Vicki Humphrey.

There are an estimated 41 million objects held in Australian museums, art galleries and historical collections. Collectively they tell the story of our history and our country and contribute to our sense of identity and national pride. Increasing the conservation skills of people who care for these collections is an important factor in protecting this heritage, and is a key goal of the Heritage Collections Council.

reCollections: Caring for Collections Across Australia has been developed with this goal in mind. This set of practical guidebooks is designed by the Council for use principally by non-conservators who are working with Australia's cultural heritage. The guidebooks are also a teacher-friendly resource which can be used in professional development workshops.

Many of Australia's most experienced conservators have been involved in researching, writing and editing ***reCollections***, through the Conservation Training Australia consortium, led by Artlab Australia, which first developed the package, and through the Collections Management and Conservation Working Party of the Council.

The Heritage Collections Council's mission is to promote excellence in the management, care and provision of access to Australia's heritage collections so that together, they reflect Australia's cultural and natural diversity. The Council is a collaboration between the Commonwealth, State and Territory governments and the museums sector, and comprises people working in a wide range of cultural heritage institutions across the breadth of urban and regional Australia. ***reCollections*** is an important component of the Council's National Conservation and Preservation Strategy for Australia's Heritage Collections.

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A note to readers

reCollections: Caring for Collections Across Australia
has been written by practicing conservators and is intended to provide a sound guide for the preventive care of cultural items. Active conservation treatment of cultural material should only be undertaken by, or on the advice of, a trained conservator. Before relying on any of the material in this guide, users should check its accuracy, currency, completeness and relevance for their purposes and should obtain appropriate professional advice.

If in doubt, consult a conservator

To obtain the names of accredited practicing conservators who are in a position to meet your particular conservation requirements contact the

Australian Institute for the Conservation of Cultural Material (Inc.)

a national organisation for conservators and people interested in the preservation of cultural material.

AICCM
GPO Box 1638
Canberra ACT 2601
National Secretary Phone: (02) 6254 8695
http://home.vicnet.net.au/~conserv/aiccmhc.htm

Introduction to

reCollections

Caring for Collections Across Australia

Our heritage is represented by a vast array of cultural material, from established national icons holding pride of place in major museums and galleries, to everyday items such as household appliances or newspapers which carry meaning for local communities or families. Yet so often the links to our heritage are tenuous because the objects which represent our culture are in danger of decay. However, there is a lot we can do to protect valued objects and collections and so prolong the life of our cultural heritage. ***reCollections: Caring for Collections Across Australia*** provides practical advice and guidance designed to help the reader care for their heritage.

reCollections explains how to apply preventive conservation techniques to cultural objects and collections. Preventive conservation optimises the environmental conditions in which objects and collections are housed. Controlling light and ultraviolet radiation, humidity and temperature, biological pests, and dust and pollutants helps to prevent damage and decay to cultural material. Preventive conservation also means ensuring that good handling, transportation, storage and display techniques are used at all times. Applying preventive methods to the care of cultural artefacts and collections can prolong and protect their life for current and future generations of Australians.

While ***reCollections*** provides conservation information about the care of cultural objects and collections, it is important to recognise that all except the simplest conservation treatments should be undertaken by trained conservators. Active conservation treatment is a response to the damage of cultural artefacts, a highly skilled field which often involves the use of chemicals and complicated technical procedures. Unless performed with a thorough knowledge of appropriate techniques and with the right equipment and materials, conservation treatments can do more harm than good to the objects being worked upon, and can be hazardous to the people performing the work. Conservation treatments should only be conducted by, or on the explicit advice of, a trained conservator.

To complement the preventive conservation advice contained in the volumes *Damage and Decay* and *Handling, Transportation, Storage and Display*, ***reCollections*** supplies detailed information concerning the care of some of the most common cultural materials. These range from the paper and other materials on which so much of Australia's cultural history may be seen, to special considerations in caring for Aboriginal and Torres Strait Islander cultural artefacts. In addition, modern practices concerning the management of collections and of the people who look after those collections are outlined.

Light and Ultraviolet Radiation

Objectives

At the end of this chapter you should:

- understand the adverse effects that visible light and ultraviolet—UV—radiation can have on museum objects;
- be able to identify the items in your collections that are most susceptible to damage caused by exposure to visible light and UV radiation;
- know steps to take to control the lighting and UV radiation levels, and so minimise damage to your collections;
- be aware of the sources of visible light, UV radiation and infrared radiation in a museum, gallery or library; and
- be aware of the need for different lighting levels for the different areas of the museum, gallery or library.

Introduction

Light is necessary in museums, galleries and libraries: for viewing exhibitions, for reading and research, and for curatorial and collection management work.

All common light sources, such as the sun, light bulbs and fluorescent tubes, also give out other forms of radiation, to varying degrees. The most significant of these are UV and infrared radiation.

Light and UV radiation are potentially the most damaging forms of energy present in museums, galleries and libraries, and the damage they cause is cumulative. So when lighting an area where important or valuable works are housed, it is essential to take steps to minimise the potential for damage. We must also provide a safe and comfortable working and viewing environment for people.

Achieving both will nearly always involve some sort of compromise. To determine the type and extent of compromise required, it helps to have a basic understanding of light and UV radiation and how they affect various materials, as well as knowing what types and levels of illumination are required for various activities.

Why worry about light and UV radiation?

Although we could not do without light in museums, galleries and libraries, it is important to remember light is an environmental factor that contributes to the deterioration of our valued collections.

It is vital to be aware that visible light is often accompanied by:

- UV radiation, which can cause more damage faster than visible light; and
- infrared radiation, which heats materials.

When light and UV radiation fall on an object, they deliver bundles of energy to that object. As a result, various chemical reactions can take place, depending on the amount of energy delivered. These reactions are called photochemical reactions. In some cases it is very easy to see the effects of these reactions: try leaving a piece of newsprint in the sun for a few hours and examine the results. The paper becomes discoloured—yellowed. It often feels different as a result. However, most changes caused by photochemical reactions are not as quick as this nor as obvious; so it is difficult to know they are occurring. Nevertheless their effects can be devastating and ongoing.

Light causes extreme and irreversible damage to many materials, most notably organic materials—those that derive from plants and animals. In a museum, gallery or library, these will include furniture, textiles, prints, books, drawings, manuscripts, wallpaper, dyes and inks, feathers and fur.

For example, UV radiation and visible light:

- set off chemical changes in paper and textiles, which weaken and discolour them; and
- cause inks, dyes and pigments to fade, and so seriously affect the aesthetic quality of many items.

Infrared radiation is less energetic than UV radiation and visible light. It:

- heats materials and can cause them to expand, leading to mechanical stresses; and

- can also cause chemical changes to progress more rapidly. As a result, infrared radiation can increase the destructive effects of visible light and ultraviolet radiation.

CAUTION:
Once started, photochemical reactions can continue even after the exposure to light or UV radiation has stopped. This means the deterioration of objects does not stop when the objects are placed in the dark.

What materials are most sensitive to damage?

Some materials are much more susceptible than others to damage through photochemical reactions. Some detailed examples are given below. These illustrate the extent and types of damage which are often found. You will probably recognise some of the problems.

Textiles

Light and UV radiation are the greatest enemies of textiles. Colours will become pale and dull, and the fabric will become fragile and will split readily.

This piece of silk brocade has been folded back on itself to show the degree of light-damage to one side of the item.

Photograph courtesy of Artlab Australia reproduced with permission of the Art Gallery of South Australia

Textiles produced in the 19th century require particular care. The aniline dyes, which were first manufactured and became popular around this time, are particularly susceptible to fading, especially the purples, blues and greens.

Watercolour pigments

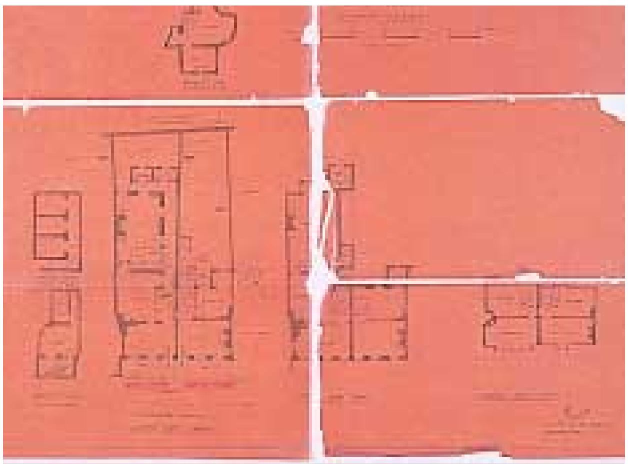
Pigments of plant or animal origin, that is organic pigments, tend to be more sensitive than others.

Photochemical action in pigments has severely altered the appearance of many watercolours. For example, Hooker's Green is a pigment mixture that was widely used for foliage in botanical illustration and landscape watercolours. It is made up of the reasonably durable Prussian Blue mixed with Gamboge, a yellow pigment made from gum from a Cambodian tree. Gamboge is sensitive to photochemical action and fades, leaving the foliage blue.

Many of these sensitive pigments were also used in oil paintings; but because the pigment layer is usually thicker, and the oil medium offers more protection, the effects are less obvious.

Paper

Mass-produced, cheap, modern papers are made from untreated wood pulp. These contain lignin, the substance in trees that gives them their strength. Lignin is very reactive and is susceptible to photochemical deterioration. As lignin breaks down it produces yellow–brown substances, as seen when newspaper is left in the sun, as well as acids.



This paper is severely damaged; it is discoloured and very brittle.

Photograph courtesy of Vicki Humphrey

The acids produced can then attack the paper fibres, making them short, and the paper brittle.

The photochemical deterioration of paper is an example of a reaction that continues even when the paper is no longer exposed to light or UV radiation.

Moderately sensitive materials

Although not all materials are as sensitive to photochemical reactions as those listed above, most are affected by light and UV radiation to some extent.

Materials that are moderately sensitive to light and UV radiation include:

- oil paintings;
- bone and horn; and
- furniture.

Therefore, it is important to consider the lighting conditions under which you store, display and use valuable items, as well as the length of exposure they get.

Can the damage be prevented?

Damage to objects and collections cannot always be totally prevented, but the rate of deterioration can be limited and slowed:

- by exposing objects to light only when necessary;
- by making sure the light is not too bright; and
- by eliminating UV radiation.

It is important to realise that protecting your collections from the damage caused by light and UV radiation may involve reassessing collection and management policies, and taking a different approach to the display of collections.

Select and control the light

Avoid displaying, using and storing items in direct sunlight. Wherever possible, eliminate daylight completely.

If daylight is a major light source for your museum, gallery or library, take steps to diffuse and filter the light. You can:

- use curtains or blinds over windows and skylights; and
- use UV-absorbing plastic films on windows and skylights to eliminate the UV radiation coming into the room from the daylight.

If fluorescent or halogen lights are used, remember:

- some sort of UV-absorbing filter should be used to remove the UV radiation;
- filtering can be used on the lamps or on display cases and frames; and
- UV-absorbing films, acrylic sheets and lacquers are available.

If you have fluorescent light fittings, remember:

- low UV-emitting fluorescent tubes should be used. If you use these, give instructions that the same type of tubes should be purchased when the existing ones burn out; and
- low UV-emitting fluorescent tubes are more expensive than ordinary tubes. It can be tempting to replace these with cheaper and more readily available tubes. If low-UV fluorescent tubes are ever replaced with ordinary tubes, the new ones should be filtered.

If you use incandescent tungsten spotlights or floodlights, remember:

- the intensity of the light is greater the closer the light source is to the object; and
- if the light source is too close to an object, it can cause the temperature to rise, which can lead to damage.

Control light levels by design

Lights should be on only when visitors are viewing a display. You could install switches that turn lights on when people approach particular areas of the display and then turn off after a set period of time.

Covers or curtains can be placed over or in front of a display, for the viewer to move as required. These can be used as part of your exhibition design. Signs explaining why you have curtains will make your audience more aware of the work involved in properly caring for collections.

If your collection includes items that are likely to be damaged by light:

- in an exhibition, try to group them in one area and ensure this area has appropriately low light levels;
- don't keep all items on permanent display; and
- rotate items in the exhibitions, so their annual exposure to light is kept low.

Screens and partitions can be used to create semi-closed areas with lower lighting levels than the general display area. Partitions can provide intimate spaces for exhibits, or create a path through your exhibition.

Arrange display areas so areas with low lighting levels don't appear dark:

- an area with low lighting will appear to be much too dark for viewers who enter from an area that is quite bright—like walking from bright sunlight into a dark room. However, if viewers move through areas in which the lighting levels gradually become lower, their eyes will adjust gradually, and the low lighting level will be quite acceptable for viewing.

Separate areas for separate activities

Wherever possible try to separate different activities into different spaces. For example,

- display, storage and work areas have different lighting requirements, and should be separated;
- items that are not on display should be stored in a separate area, which is lit only when access is required; and
- areas used for reading, for accessioning or for checking the condition of items need higher lighting levels, so people can see well enough and do detailed work. These areas should be separate from storage and display areas.

If it is not possible to separate activities, consider installing dimmer switches, so the lighting levels can be adjusted according to the activity taking place.

CAUTION:

Remember, photocopiers and photographic flashes are sources of intense light—exposure of sensitive items to these should be kept to a minimum.

Light sources in museums, galleries and libraries

Visible light is necessary in museums, galleries and libraries. But, as already noted, it is often accompanied by other forms of radiation that are unnecessary and undesirable.

The major sources of visible light in museums, galleries and libraries—daylight and artificial light produced by incandescent bulbs and fluorescent tubes—are also sources of UV and infrared radiation.

Daylight

Daylight is bright and hot, and contains a high proportion of UV radiation. Ordinary glass, used in windows and skylights, blocks the most damaging, high-frequency, longer wavelength UV radiation. But it does not block the lower frequency range that can still cause damage to sensitive materials.

Daylight is not essential for a display or working environment. You can reduce unwanted UV radiation by careful use of artificial lighting.

Artificial light

There are many types of artificial light sources. Each has advantages and disadvantages:

- incandescent tungsten lamps, in spot or floodlights, have a low UV output, but emit infrared radiation in the form of heat. Therefore, if they are close to items or placed in a closed case, they can cause damage by raising the temperature of the objects;
- fluorescent light tubes are cold, but many emit higher than acceptable levels of UV radiation. However, fluorescent tubes are generally favoured, because they are more cost-effective to run and are longer-lasting than incandescent bulbs; and
- tungsten halide bulbs, which are more efficient than ordinary incandescent bulbs, also give out higher than acceptable levels of UV.

What lighting levels are acceptable?

In order to minimise damage, lighting levels should be kept low. But what is a low level of lighting and what is too high?

In considering appropriate levels of lighting, take into account the following factors:

- how sensitive the materials are to damage by visible light and UV radiation; and
- the activities that take place in the area being considered.

Keep in mind that the amount of damage caused by photochemical reactions depends on the energy of the radiation as well as the amount of radiation that falls on the material for the whole time it is exposed.

Guidelines for lighting levels, UV levels and length of exposure to light for materials of different sensitivities have been developed. An outline of the guidelines follows with further explanation in the next section.

For sensitive materials

Note: Sensitive materials include items such as textiles and watercolours.

- The brightness of the light should be no greater than 50 lux.
- The exposure in one year should be no greater than 200 kilolux hours.
- The UV content of the light on sensitive materials should be no greater than 75 μW/lm—microwatts per lumen—and preferably below 30 μW/lm.

For moderately sensitive materials

Note: Moderately sensitive materials include items such as oil paintings and furniture.

- The brightness of the light should be no greater than 250 lux.
- The exposure in one year should be no greater than 650 kilolux hours.
- The UV content of the light should be no greater than 75 μW/lm—microwatts per lumen—and preferably below 30 μW/lm.

Non-sensitive materials

Note: Non-sensitive materials include items such as stone and metal.

- Objects that are not particularly sensitive to light should still be protected.
- Do not unnecessarily expose them to very high lighting or UV levels.

Remember also that many objects are made from composite materials and may contain small amounts of sensitive materials.

What do these levels mean?

To get an idea of what the guideline levels for the brightness mean, it is useful to compare them to recommended lighting levels for more familiar areas where other activities take place. Lighting designers recommend:

- desktops in reference library reading rooms should be lit to 500 lux;
- drawing boards in drawing offices should be lit to 750 lux;
- car showrooms should be lit to 500 lux;
- domestic kitchen work surfaces should be lit to 300 lux;
- cinemas, at seat level, should be lit to 50 lux; and
- conservation laboratories in galleries and museums should be lit to 2000 lux.

It is clear that the use of a particular area contributes to what is an acceptable level of illumination for that area.

For example, items in conservation laboratories can be exposed to bright light, because conservators must see clearly what they are doing to carry out delicate treatments, and because they will not be exposed to that intensity of light for extended periods of time.

Lux? Kilolux hours? μW/lm? Help!

Lux, kilolux hours and microwatts per lumen are units for measuring different qualities of light. They can be explained quite simply.

Lux:

- Is the unit which indicates the intensity to which a surface is lit, or the brightness of the light.
- The closer the light source is to the surface being lit, the higher the lux value will be, that is the greater the intensity of light.
- So if we want to lower the intensity of light falling on an object we can simply move it further away from the light source. For example, if the brightness or intensity of light falling on a object is measured at 100 lux when the object is 1 metre away from the light source, we can alter that intensity to 25 lux by moving the object to a distance of 2 metres from the light source.

Kilolux hours:

- Is the unit which indicates the exposure to light over a period of time.
- Take the example of an historic costume on permanent display in a museum. The museum is open 5 days a week for 5 hours a day all year round and while the museum is open, the costume receives light to an intensity of 200 lux. In a year the costume is exposed to:

  5 x 5 x 52 x 200 lux hours = 260000 lux hours or 260 kilolux hours

- This could be brought to within the levels recommended in the guidelines by adjusting the intensity of light falling on the costume and/or reducing the display time. For example, if the intensity of light was lowered to 50 lux and the costume was on display for only 6 months of the year, the total annual exposure would be significantly altered:

  5 x 5 x 26 x 50 lux hours = 32500 lux hours or 32.5 kilolux hours

μW/lm, Microwatts per lumen:

- Are the units which indicate the amount of UV energy in the light coming from a light source.
- Microwatts are a measure of energy; lumens measure the quantity of light from a particular light source.
- This measurement is constant for a light source and does not alter if the readings are taken at a greater distance from the source.
- If we want to lower the UV content of the light, we can use absorbing filters on windows or on fluorescent tube fittings, or we can install lights that give out only small amounts of UV radiation. Above all we must try to exclude sunlight.

Special instruments can be purchased to measure light and UV levels. The intensity of light on an object is measured with a lux meter and the UV content of the light is measured with a UV meter.

Measuring light and UV radiation

Measuring lux

The device used to measure the brightness of light falling on an object is a lux meter.

A lux meter

Photograph courtesy of Artlab Australia

The meter is held close to the object, facing the light source. It measures the number of lumens, that is, the quantity of light of all wavelengths per square metre.

When setting up your exhibitions, it is handy to have a lux meter. By moving it to different distances from the light source, you can determine a suitable position for the object in relation to the light.

Measuring microwatts per lumen

The amount of energy in the ultraviolet band can be measured using a UV meter/monitor.

This device measures the amount of ultraviolet light energy in each lumen of light.

Measuring the UV content of light can be useful in determining whether or not you have a problem. For example, a conservator taking UV readings in an art centre in the far north of South Australia expected very high UV content. The building is not in a sheltered position and the principle light source is sunlight. The readings, however, were low, because the building has Perspex windows instead of glass. Perspex does not allow as much UV radiation to pass through it as glass. Because the Perspex develops static electricity, it attracts the red dust which surrounds the building. This also helps to reduce UV radiation passing through the windows. In this case, a problem was expected, but did not in fact exist.

UV Monitor

Photograph courtesy of Artlab Australia

Measuring infrared energy

Infrared energy can be measured using a simple thermometer. Infrared light causes objects to heat up. So by measuring the rise in temperature with a thermometer placed near the object and directly exposed to the light, we can get an indication of the quantity of infrared energy.

MORE ABOUT LIGHT AND UV RADIATION

Light and UV radiation are types of energy

Light and UV radiation are forms of radiant energy. They are part of what scientists call the electromagnetic spectrum.

Energy can be defined as the capacity for doing work. The greater the amount of energy available, the more work that can be done. If this work is a chemical reaction leading to deterioration of an object, then the more energy available, the greater the damage that will result.

What is light?

Attempts to understand the nature of light and to adequately describe it have involved scientific experiments and debate over many centuries which are still continuing to this day. This work has led to our present knowledge of the nature of radiant energy and the existence of the electromagnetic spectrum.

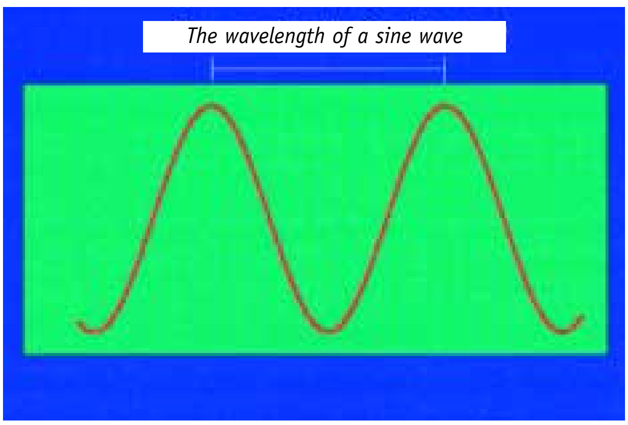
However, to understand light and its effects on objects, we don't need to be physicists! A basic description of radiant energy and the electromagnetic spectrum is adequate for our purpose.

In the mid-19th century it was accepted that light consists of waves. Then, at the turn of the 20th century, light was described as a stream of tiny particles because the wave model did not fully account for some properties of light where it behaves like discrete solid matter—albeit invisible.

To this day, both models are considered correct. Though what light is precisely—wave or particle—let alone what it looks like, is still a mystery.

Nonetheless, light is a form of electromagnetic radiation and travels in waves and as particles, delivering discrete energy in bundles or quanta called photons.

A closer examination of the wave model of light provides information necessary for a more complete understanding of visible light and UV radiation. The sine wave shown below gives us a basic visual aid for the definition of some important terms and will be used to introduce some concepts regarding radiant energy.



The energy in the diagram is travelling horizontally. As it travels, it moves in a wave motion passing through peaks and troughs. The distance between the peaks of the waves is called the 'wavelength' and is measured in nanometres—nm.

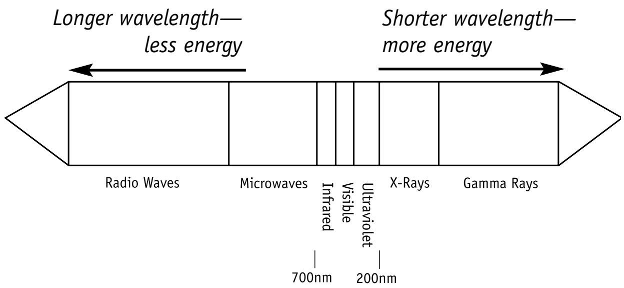
There is a mathematical relationship between the amount of energy transmitted and the wavelength of the radiant energy—namely, they are inversely proportional. In other words, the longer the wavelength the less energy transmitted, and the shorter the wavelength the more energy transmitted.

This is true for the entire electromagnetic spectrum.

The electromagnetic spectrum

The light visible to humans is electromagnetic radiation with wavelengths ranging from approximately 400–700 nm.

But this is only a very small part of the electromagnetic spectrum. The full spectrum has wavelengths ranging in excess of several hundred metres to less than a billionth of a metre. The spectrum is broken into ranges according to the amount of energy transmitted and, therefore, the effect they have on matter.

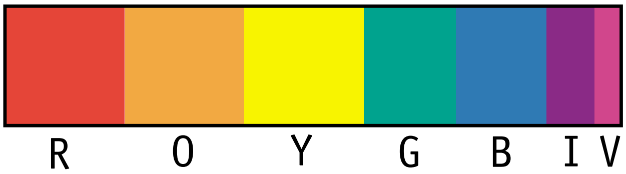


The electromagnetic spectrum with some indicative wavelengths

If you keep in mind that the longer the wavelength, the less energy that is transmitted, we can see:

- radio waves do not transmit as much energy as gamma radiation; and
- infrared radiation is less energetic than UV radiation. The higher energy transmitted by UV radiation is known to be harmful to humans, causing sunburn and skin cancer.

Visible light is further categorised into a spectrum of red, orange, yellow, green, blue, indigo and violet light. We see these distinct colours because the different wavelengths have different energies, and so affect our eyes in different ways.



The visible spectrum

Within the visible light range, the violet/blue end of the visible spectrum is more energetic and so more harmful than the red wavelengths. This has implications for museums, galleries and libraries in the choice, for example, of luminaires—light sources—for exhibitions.

How does the energy cause damage?

When electromagnetic energy encounters matter, such as items in a museum, gallery or library, it is readily converted to mechanical, chemical or electromagnetic energy of a different frequency.

Depending on the amount of energy being carried by the waves electromagnetic energy can:

- cause the object to heat up;
- initiate simple chemical reactions; and
- produce complex chemical reactions called photochemical reactions. If these reactions produce deterioration, it is called photochemical deterioration.

Photochemical deterioration

In the museum environment, photochemical reactions are most likely to be initiated by UV radiation and the higher energies of visible light, that is, 320–500 nm. UV radiation nearly always accompanies visible light, because it is produced by the sun and by some common luminaires, such as fluorescent tubes and tungsten halide bulbs.

Photochemical reactions are rarely isolated or short-lived. For example:

- sometimes a new substance, which forms as a result of the initial photochemical reaction, has sufficient energy to also react with the original substance and produce further chemical change. This is called a ‘chain reaction because the light produces not just one chemical change but a whole series of them; and
- if this happens while the object is still exposed to light, a whole range of chain reactions will occur at a rapid pace.

You should be aware that the amount of damage depends not only on the wavelength of the light, but also on the amount of light that falls on the material for the whole time it is exposed.

And remember that some of these chemical reactions continue after the exposure has stopped. The deterioration reaction does not stop when the material is placed in the dark. Light damage is cumulative.

Examples of typical deterioration of artefacts because of photochemical reactions include:

- dyes fading and changing colour. This is perhaps the most obvious damage caused by light and UV radiation. It can also be seen that the radiation has its greatest impact on the surface of the object, for example, dyes on the exposed side of a carpet will fade, while dyes on the unexposed side appear to retain their original colour;

The areas protected from light, for example, in the armpit of this dress, have not faded.

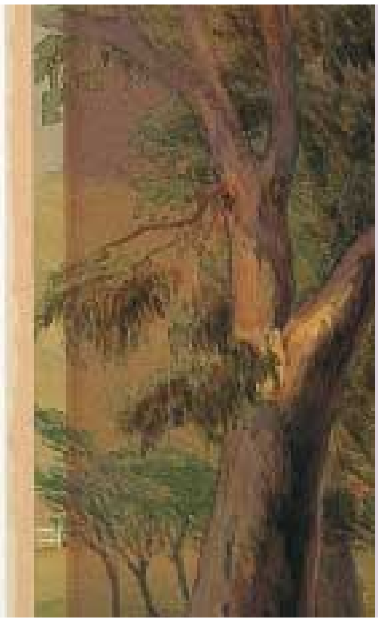
Photograph courtesy of Artlab Australia

- watercolours fade and change colour. This is often noticeable only when the watercolour is removed from its mount. The edges of the work, which have been covered by the mount, often seem to have stronger colour than the part of the work that has been exposed;

The pigments on the very edge of this watercolour have not faded because they have been protected by the mount.

Photograph courtesy of Artlab Australia

- paper yellows. When prints are removed from their mounts, you may see light-coloured paper at the edges that have been protected by the mount, while the exposed paper has become yellowed or even brown;



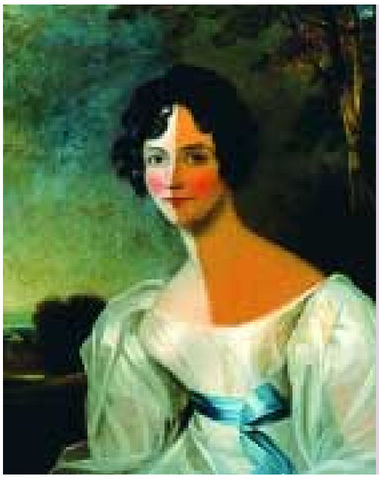
The areas of paper that have been exposed to light have discoloured badly; in contrast to the area at the edge which has been protected by the mount.

Photograph courtesy of Artlab Australia

- paper becomes brittle. The cellulose molecules break down. This can be caused by photochemical reactions in the actual paper fibres or by photochemical reactions involving other materials in the paper or used with the paper. These materials break down because of the production of acids in the reactions. These acids attack the paper fibres and this continues even when the paper is no longer exposed to the radiation;

- textiles deteriorate and discolour. Silk, wool and cotton are all affected by light and UV radiation. But the reactions they undergo are different, because of their differing chemical compositions. Cotton will react in a similar way to paper because both are cellulose-based; it will darken and become brittle. Wool and silk are made up of proteins, and behave differently from cellulose-based materials. Both wool and silk are bleached by visible light, and will yellow when exposed to UV radiation; and

- oil paintings change. This can include the yellowing of varnishes and an increase in the transparency of paints. Changes can also involve complex interactions between the oils, the pigments and the varnishes.



A painting during treatment. You can clearly see the extent to which the varnish had discoloured.

Photograph courtesy of Artlab Australia, reproduced with permission of Skipper Garnthan

Deterioration of museum objects caused by photochemical reactions is inevitable. However, there is much that can be done to minimise this. By being aware of the sources of harmful radiation, museum staff can take positive steps to eliminate it or reduce it significantly.

Sources of light and UV radiation

There are two common ways of making light. One way is to heat something until it glows. This is the principle used for incandescent bulbs. Heating the tungsten element causes it to emit or give out light. The other way to make light is to excite something electrically so that it fluoresces. Fluorescent light tubes and television screens are examples of this method.

Light from heat

When an object is heated, it gives out light. A hot object emits a broad spectrum of light. However, the frequency and wavelength at which most of the light is emitted depends on the temperature of the object. The hotter the object, the shorter the wavelength of the energy emitted. That is, the hotter the object, the greater the energy emitted.

Observing a piece of metal in a very hot flame will demonstrate this relationship. For example, when the metal starts to heat up, it will initially glow a dull red colour. As it becomes hotter, the colour will become a brighter red, then yellow—the frequency is increasing, the wavelength becoming shorter and more energy is being transmitted. This continues, and the metal glows blue and eventually white.

Incandescent light bulbs

Incandescent light bulbs consist of a filament of tungsten metal suspended between two electrodes inside a sealed glass bulb. The bulb is filled with an inert gas to prevent the tungsten from burning up when it gets hot. When an electric current flows between the electrodes, the tungsten is heated.

The operating temperature of incandescent light bulbs is about 2,500°C. At this temperature tungsten emits most of its light in the infrared range. This is why light bulbs get so hot. But less than 10 per cent of the energy used to power a light bulb is converted into visible light, meaning they are not very efficient. A much smaller amount of power is converted into UV radiation, making incandescent light bulbs a low emitter of UV radiation.

Tungsten halide bulbs

Tungsten halide bulbs operate at a much higher temperature than incandescent light bulbs, usually at about 3,500°C. They emit more light in the visible range, and so are brighter light sources than ordinary incandescent bulbs. They also emit more UV radiation than incandescent light bulbs.

The sun

The sun also emits light because it is a hot object. Its surface temperature is approximately 6,000°C. At this temperature, the sun emits not just heat, but also a tremendous amount of light at higher frequencies and shorter wavelengths than an incandescent light bulb.

Overall, the sun emits about 9 per cent of its light in the UV range, 41 per cent in the visible light range and 50 per cent in the infrared range.

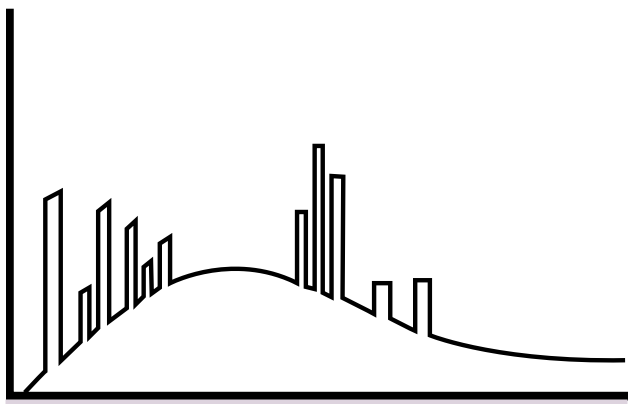
Fluorescence

Fluorescent lights work because some materials fluoresce, that is, they absorb radiation at one frequency and then give it out at another frequency.

The materials used in fluorescent lights are known as phosphors. Different phosphors are selected for use in fluorescent tubes, depending on the specific frequencies of the light they emit.

The inside of the tube is coated with the selected phosphors. A gas inside the tube becomes excited when the electric current is switched on. The excited gas emits light, which is absorbed by the phosphors and re-emitted at a different frequency.

The sharp peaks of a fluorescent spectrum are made up of light emitted by both the phosphors and the gas. The material becomes hot during this process, so that it also emits some light in the same way as hot objects.



The spectrum of light from a fluorescent light tube is composed of a continuous curve caused by thermal—hot object—emission, with sharp peaks corresponding to strong fluorescent light emission at specific wavelengths. The position of the fluorescent peaks depends on the phosphors selected for the fluorescent tube.

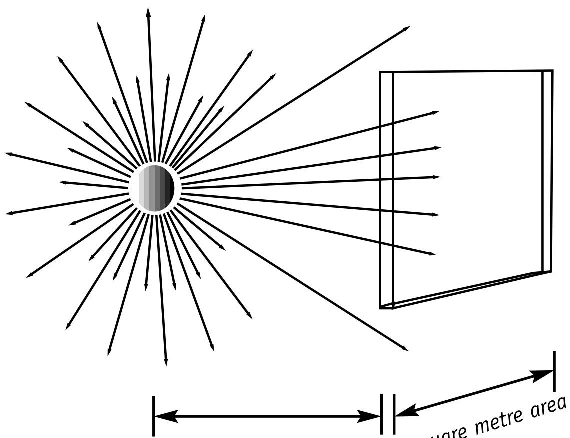
The main advantage of fluorescent lights is that they are very efficient at converting electrical energy into light. This is because most of the power goes into generating light at a few specific frequencies, rather than generating energy over a wider range of frequencies, as incandescent bulbs do. This means that fluorescent lights do not waste energy-producing infrared radiation or heat, as incandescent lights do. Fluorescent lights are therefore cooler and cheaper to run, and last longer.

By selecting particular combinations of phosphors, lighting manufacturers can determine the type of light a fluorescent tube emits. This characteristic is an important consideration when choosing your light source. If fluorescent lighting is to be used in museums, galleries and libraries, care must be taken to select only those types of tubes which emit very little ultraviolet light.

The brightness of light

From experience, we know that the closer we stand to a light bulb the brighter it seems. This is a simple consequence of geometry.

Light spreads out in all directions from its source, rather like a ripple on a pond. The farther away we are from the source, the more spread-out the light is and so it becomes dimmer.



Brightness is expressed as the number of lumens passing through a given area. The brightness of the light an observer sees, therefore, depends on how many lumens catch their eye. For convenience, this area is defined as one square metre and the name given to this unit is lux.

Lux = lumens/sqm

The mathematical law that describes the radiating behaviour of light is the inverse square law. This law states the brightness of the light decreases according to the square of the distance from the source. For example:

- if the observer is 1 metre away from a light and sees a brightness of 100 lux, then at 2 metres distant they will see a brightness of only a quarter — $\frac{1}{2 \times 2}$ — of this, or 25 lux; and
- at 3 metres, they will see a brightness of a ninth — $\frac{1}{3 \times 3}$ — or 11 lux.

The inverse square law is useful to help determine the placement of lighting in a museum, and has important outcomes for the wellbeing and longevity of the art and valuable objects.

Additional information about the units used to measure light

In order to control the effects of light in a museum, gallery or library, it is useful to measure properties such as:

- the brightness or intensity of the light;
- the composition of the light and whether UV radiation is present; and
- how much energy is contained in the light.

Brightness or intensity has already been discussed in some detail; but some of the other units used to measure light may need further explanation.

Watts are the amount of energy that falls on an object per second. This should not be confused with the wattage rating of a light bulb, which is a statement of how much electrical energy goes into the bulb to make it work, not how much light energy comes out.

Lumens are the units that measure luminous flux, that is the amount of light given out by a light source. A 100 watt incandescent bulb, for example, emits about 1200 lumens.

Because light is composed of different wavelengths—or energies—we often need to know the distribution of energy amongst the different wavelengths. This is what we are doing when we measure the UV content of light falling on an object.

So a measurement from the UV meter of 50 microwatts per lumen indicates there are 50 units of energy in the UV wavelength band in every unit of light being monitored.

If you have a lighting problem and don't know how to deal with it, contact a conservator. Conservators can offer advice and practical solutions.

For further reading

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Self-evaluation quiz

Question 1.

Which of the following statements are true?

a) Light is necessary in museums, galleries and libraries.

b) Light does not cause damage.

c) Light levels that are appropriate for people working are fine for objects too.

d) UV radiation can be very damaging.

Question 2.

Which of the following statements are true? Visible light:

a) causes extreme and irreversible damage to organic materials;

b) is often accompanied by UV radiation and infrared radiation;

c) can cause fading of dyes;

d) can lead to the discolouration of paper and cotton fabric;

e) all of the above.

Question 3.

List the following types of light or radiation in this order: from the most energetic to the least energetic, that is, the most damaging to the least damaging.

a) Infrared radiation.

b) Green light.

c) UV radiation.

d) Yellow light.

e) Blue light.

Question 4.

Which of the following materials are considered to be very sensitive to light?

a) Stone.

b) Oil paintings.

c) Textiles.

d) Watercolour pigments.

e) Natural history specimens, such as feathers and fur.

Question 5.

Preferred light sources for museums, galleries and libraries are:

a) fluorescent tubes;

b) sunlight;

c) low-UV emitting fluorescent tubes;

d) tungsten incandescent bulbs.

Question 6.

If you rely a lot on daylight in your museum, gallery or library you should:

a) try and eliminate all direct sunlight;

b) let the sun shine in as it produces a lovely summery atmosphere;

c) use curtains and blinds over windows and skylights to diffuse the light;

d) use filtering films on your windows to eliminate the UV radiation from the light coming into the room.

Question 7.

You can take steps to reduce light damage by:

a) moving objects further away from the light source to reduce the brightness of the light;

b) installing dimmer switches on lights;

c) reducing the length of time that items are on display;

d) grouping light-sensitive items in low-light areas;

e) turning off lights if people are not viewing the display;

f) all of the above.

Question 8.

What is the name of the unit which is used to measure the intensity or brightness of visible light?

a) Lumen.

b) Lux.

c) Microwatts.

d) Kilolux hours.

Question 9.

'Microwatts per lumen' is a measure of:

a) daylight;

b) light from a fluorescent tube;

c) the amount of UV energy in a light source;

d) the distance between an object and the light source.

Question 10.

What is the recommended maximum light level for the display of a watercolour?

a) 75 lux.

b) 250 lux.

c) 650 kilolux hours.

d) 50 lux.

Question 11.

What is the recommended maximum light level for the display of an oil painting?

a) 75 lux.

b) 250 lux.

c) 650 kilolux hours.

d) 50 lux.

Question 12.

What is the exposure, in kilolux hours, of a costume displayed for 11 weeks in a museum which is open for six hours a day, six days a week and where light falling on the costume has been measured as 150 lux?

a) 69,300.

b) 59.4.

c) 59,400.

d) 69.3.

Answers to self-evaluation quiz

Question 1.

Answer: a) and d) are true. b) and c) are false. Light can be very damaging and there is often a need to compromise between accommodating people's needs and the needs of valuable items.

Question 2.

Answer: e).

Question 3.

Answer: c), e), b), d) and a).

Question 4.

Answer: c), d) and e). Oil paintings are considered moderately sensitive and stone is considered non-sensitive.

Question 5.

Answer: c) and d).

Question 6.

Answer: a), c) and d).

Question 7.

Answer: f).

Question 8.

Answer: b).

Question 9.

Answer: c).

Question 10.

Answer: d).

Question 11.

Answer: b).

Question 12.

Answer: b).

Humidity and Temperature

Objectives

At the end of this chapter you should:

- know some of the adverse effects that extremes and fluctuations in relative humidity and temperature have on objects;
- understand the relationship between relative humidity and temperature; and
- be able to take steps to limit damage to collections caused by fluctuations in relative humidity and temperature.

Introduction

Relative humidity and temperature are essential components of a comfortable working environment. However, there can be some conflict between the needs of people and the requirements for the care of collections.

Relative humidity—RH—is the amount of water vapour contained in the air at a particular temperature compared with the total amount of water vapour the air can contain at that temperature. Relative humidity is expressed as a percentage. Various materials respond differently over a range of humidity levels and there is an optimum level of RH suitable for the display and storage of mixed materials.

Extremes of relative humidity and temperature can adversely affect the condition of objects, particularly those made of organic materials. But it is important to remember that many materials will stabilise in a particular climate, even though conditions are extreme. Once stabilised and conditioned to the climate, these materials will not necessarily be adversely affected by the constant, extreme conditions.

If the climate changes or objects are moved to a different climate, problems can arise. Changes in relative humidity and temperature—particularly rapid changes—are potentially far more damaging to most materials than are constant extremes. These changes can occur easily with sudden changes in the local weather, when air-conditioning units break down, and when objects are moved from storage boxes to open display or from one region of the country to another.

Steps can be taken to minimise fluctuations in relative humidity and temperature, and to protect valuable collections from the adverse effects of extremes of relative humidity and temperature. To do this, it is useful to understand how relative humidity and temperature are related, what causes relative humidity to fluctuate, and to know what effects they have on different types of materials.

What is relative humidity?

Heat really needs no explanation. You may have difficulty defining it, but you're certainly familiar with the experience of it. Relative humidity, on the other hand, does need explanation.

Water is an extremely pervasive substance and can be found everywhere on the planet—including in the air, where it's held as vapour.

The capacity of air to hold water-vapour varies according to the temperature of the air.

The warmer the air, the more water-vapour it can hold. As the air cools down, its capacity to hold water will decrease.

Relative humidity is a measure of the amount of the amount of water-vapour contained in air at a particular temperature. It is basically a comparison between:

- the amount of water-vapour held in the air at any one time and at a particular temperature; and
- the total amount of water-vapour which the air **can** hold at the same temperature, that is, the amount of water which will saturate the air at that temperature.

Relative humidity is expressed as a percentage. This can be written as an equation:

$$RH = \frac{\text{water-vapour present in the air}}{\text{water-vapour required to saturate air at that temperature}} \times 100\%$$

As the temperature of air increases, its capacity to contain water-vapour increases. For example:

- At 0°C the air can hold about 6 grams of water for each cubic metre of air, that is, 6g/m^3.

- At 10°C this increases to 10g/m^3
- At 20°C it increases to 17g/m^3
- And at 30°C it increases to 30g/m^3

So, if air at 20°C contains 8.5g/m^3 of water-vapour:

$$RH = \frac{8.5}{17} \times 100\% = 50\%$$

Thus the relative humidity would by 50%.

How does relative humidity change?

Relative humidity is a measure of the amount of water-vapour contained in air at a particular temperature. The capacity of air to hold water-vapour varies according to the air temperature.

However, although raising the temperature increases the capacity of air to hold water, there is not always water available to move into the air to fill that increased capacity. So changes in temperature often lead to quite significant alterations to the relative humidity.

For example, in an empty, sealed box containing a fixed amount of water-vapour, raising the temperature will lower the relative humidity. This is because the capacity of the air to contain water has increased but the actual amount of water has remained the same. Using our previous example of air at 20°C with 8.5g/m^3 of water-vapour, if the temperature is raised to 30°C and no additional water is available:

$$\text{at } 20°C\ RH = \frac{8.5}{17} \times 100\% = 50\% \quad \text{BUT} \quad \text{at } 30°C\ RH = \frac{8.5}{30} \times 100\% = 28.3\%$$

The reverse is also true. If the temperature in a sealed box continuing a fixed amount of water-vapour is lowered, the relative humidity will increase. The capacity of the air to hold water has decreased but the amount of water has remained the same.

This is an important concept, because display cases and sealed storage areas in some ways behave like sealed boxes; and the relative humidity can vary because the temperature varies.

This principle can also be applied to some extent to museums, galleries and libraries. But they are generally far more complex.

They have doors which admit moisture-containing air from the outside, where the temperature and relative humidity is usually different from the inside conditions.

People come into these areas. They raise the temperature, especially when they are in large groups; and they take in and give out moisture as they breathe.

Museums, galleries and libraries contain objects which take up water and give out water, according to the temperature of the surrounding air.

There may also be heating and cooling devices and/or air-conditioning in the building.

Why worry about relative humidity and temperature?

Relative humidity and temperature are two of the environmental factors which can contribute to the deterioration of our valued collections.

A bark painting—split after drying out in a low relative humidity environment.

Photograph courtesy of Artlab Australia, reproduced with permission of the Museum of Victoria

Extremes of temperature and relative humidity—and rapid fluctuations in these—can lead to a range of problems. The risks of physical damage, such as warping, cracking and splitting, chemical deterioration, and insect or mould attack are all increased when temperature and relative humidity are too high or too low.

The discolouration of the cotton proceeded much more rapidly in a damp environment.

Photograph courtesy of Artlab Australia

Insects generally like a warm damp environment.

Photograph courtesy of Artlab Australia

For more information

For more information about insects and mould, please see the chapter on Biological Pests in this volume.

The effects of extremes and fluctuations in temperature

Extremes and fluctuations in temperature are potentially less harmful than extremes or fluctuations in relative humidity; but it is difficult to separate the two because they are closely interrelated. Some independent effects of high temperature include:

- increased biological activity. Most insects and moulds thrive and reproduce readily in warmer conditions; and
- acceleration of chemical deterioration processes. Temperature affects the rate at which chemical reactions take place. For example, a temperature rise from 20–30°C may double the rate of some degradation reactions. And this worsens if light, water or pollution also contribute to these chemical reactions.

For more information

For more information about how light and pollutants can affect chemical deterioration, please see the chapters on Light & UV Radiation and on Dust and Pollutants in this volume.

Fluctuations in temperature cause:

- expansion and contraction. If this is uneven and/or rapid, it can cause physical damage and distortion. This can be hazardous for objects made of composite materials; and
- some types of plastic, for example, vinyl records, shrink and warp in high temperatures.

The most important effect of temperature is the effect it has on altering relative humidity levels.

The effects of extremes and fluctuations in relative humidity

In high relative humidity conditions insects and moulds thrive and reproduce readily, metals corrode, dyes and textiles fade and deteriorate more quickly, organic materials such as wood and leather swell or change shape, and gelatine emulsions and adhesives become sticky.

High relative humidity conditions promote the corrosion of metals.

Photograph courtesy of Sarah Jane Rennie

The bolts are corroding in high relative humidity conditions. The corrosion products are staining the wood, and will eventually cause splitting.

Photograph courtesy of Sarah Jane Rennie

Organic materials absorb water. This is particularly noticeable in thinner materials, such as paper, vellum and parchment, textiles, leather and bark paintings. As materials absorb water, they swell and change shape, for example, stretched vellums and mounted textiles sag.

The effects of humidity on organic materials are not always immediately noticeable. But after a while, extensive damage eventually occurs.

For example, a large block of wood may take weeks or even months to transfer water from its surface into its bulk, leading to different parts of the wood having different water-contents. The consequence this has on the wood is to make it swell by different amounts, which will have the effect of splitting and warping the material.

Wood also swells more across the grain than along the grain; and by an amount which varies according to the type of wood. This makes life complicated when caring for furniture.

Textiles can display what seems to be the opposite response to changes in relative humidity. A multi-strand thread shortens in length when the relative humidity goes up. This is because the individual threads expand in diameter more than they expand in length. The result is that the strands wrap around each other more tightly, which causes the overall length to decrease. Often this process does not reverse when the relative humidity drops again.

A canvas responds in the same way as textiles; however, the paint layer on the canvas does not contract. Rather, it will compress, leading to cracking or separation between canvas and paint layer.

Different components of single objects absorb moisture at different rates and swell by different amounts. This can cause problems, such as paint layers splitting and separating from timber panels.

Composites of metal and wood are affected also. As the metal corrodes, the wood starts to split in order to accommodate the corrosion products.

Adhesives that absorb water become sticky and are an attractive food source for moulds and insects.

Gelatine emulsions on photographs also swell in humid conditions and can readily stick to the glass in their frames or, if they are stacked, they can stick together.

As for papers which are stuck down at the edges, they will increase in size in humid conditions and thus expand in the middle as their edges are restricted. This can lead to creasing.

In very low relative humidity conditions, such as in arid areas:

- insects can still survive;
- organic materials give out the moisture they contain. This can cause materials to dry out and become brittle or to distort and split;
- thicker materials lose moisture much more rapidly from their surface. This can cause warping;
- different components of single objects release moisture at different rates, which can cause the bonds between them to loosen; and
- adhesives dry out and crack, and can fail as a result.

If fluctuations are occurring constantly, the materials are being subjected to constant movement which is usually not uniform and often results in cracking, splitting and warping. Some examples of extreme damage caused by fluctuations are:

- bark paintings expand and contract as they absorb water and release it. This leads to the bark warping and splitting, and they can lose paint;
- bone and ivory are very susceptible to damage caused by fluctuations; and they warp

and split. This is especially a problem for very thin ivory sheets, such as those used for miniature painting;

- furniture with veneers can be damaged severely, because the thin, veneer layer is likely to curl and pop off the surface of the furniture if it repeatedly expands and contracts; and
- fluctuations in relative humidity can also alter the chemical composition of some minerals, so that they become another mineral.

What happens in extreme, but stable environments?

When conditions are extreme but constant, damage can still occur. Experience shows, however, that many materials become conditioned to an extreme environment.

An object in constantly high or low relative humidity does not absorb and lose water repeatedly; and it is not subject to the enormous stresses of the cycles which affect objects in fluctuating environments. Such an object is likely to be preserved longer and in better condition than a similar object in a fluctuating environment.

Remember, the emphasis should be on stability.

Can the damage be prevented?

Damage to objects and collections cannot always be prevented totally; but it can certainly be limited and slowed by controlling the relative humidity and temperature.

The most significant effect temperature can have in a museum, gallery or library environment is the way it can alter relative humidity levels.

Relative humidity and temperature are closely linked; and it is helpful to understand this link when setting out to control the environment where collections and items of value are stored.

Remember that for a fixed quantity of moisture in a given air space, as temperature rises, the relative humidity drops and, as the temperature drops, the relative humidity rises.

Identifying the source of the problem

Extremes and fluctuations in relative humidity and temperature which damage collections are experienced in many museums, galleries and libraries. These changes can be caused by:

- the regional climate;
- the climate within buildings;
- localised climates with buildings;
- microclimates; and
- visitors.

Australia is a large country with three very different climates—tropical, arid and temperate. Regional climates are particularly significant for objects which are displayed outside.

Because buildings are not fully sealed, outside conditions have a significant influence on the climate inside the building. The building's style, the materials used, the state of repair of the building and whether the building is insulated, air-conditioned or without either, all influence the impact outside conditions have on the climate inside the building.

Although buildings are not fully sealed from the outside weather, they act as barriers to the free flow of heat and moisture. This is why air-conditioning and heating are effective in providing a comfortable climate.

Within buildings there are localised climates and microclimates where conditions vary greatly from conditions in other parts of the building. For example, there would be greater variations in temperature and humidity in a small tea room with a toaster and a kettle than there would be in a closed-off storage area.

Cupboards, display cases, boxes and frames act as barriers to air and moisture circulation and can develop their own microclimate. The materials used to make the display cases, boxes and frames, combined with what's stored in them, also influence the microclimate.

People are important to the museums, galleries and libraries. The effect they have on the local climate depends on:

- how many visitors there are and whether they arrive individually or in groups;
- whether they have wet or damp umbrellas and coats;
- how long they stay; and
- their ages—school groups are potentially more disruptive to a controlled environment than adult tour groups or individuals.

All of these factors can contribute to fluctuations in, and problems with, relative humidity. Careful manipulation of these factors helps create a stable environment where the risk of damage is minimised.

What can be done to minimise damage?

The potential for damage to collections from the effects of relative humidity and heat is greatest when relative humidity and temperature fluctuate rapidly, or are extremely low or extremely high.

The damage can be minimised by modifying the conditions, if possible, and creating buffer zones between your objects and the extreme or fluctuating conditions.

There are many ways of controlling temperature and relative humidity. Some methods are better than others and their advantages and disadvantages will be discussed.

The measures you use to improve your building's environment should be selected so that you can monitor their effects and, if necessary, modify them.

Modifying the conditions in buildings

Airconditioning

Airconditioning is the most obvious, but not necessarily the best, method of controlling temperature and relative humidity. The method involves taking air—either fresh air from the outside or recycled air from the inside—and changing its temperature and moisture content.

There are two basic types of cooling airconditioners available.

An evaporative airconditioner works by passing air over a moist surface and increasing the moisture content of the air, raising the relative humidity. This type of airconditioner should not be used unless there is a dehumidifier to remove the moisture from the cool air.

Cooling coil airconditioners work on the refrigerator principle of keeping the air cool and dry. This type of airconditioner should be used with caution, and preferably with a humidifier to add moisture to the air. Monitoring the effectiveness of such equipment is crucial.

If you have airconditioning or you are considering installing it, you should be aware of the following important points:

- the cost of purchasing, operating and maintaining an airconditioning plant is high. If such a financial commitment is possible, seriously consider getting a system which not only regulates temperature but is capable of controlling the relative humidity as well;
- if airconditioning is used to control the environment, it should operate continuously. For example, it is tempting to turn off the airconditioner because of the high operating costs. But the cyclic process of turning it on and off is likely to be more damaging to collections than no air-conditioning at all;
- airconditioning systems have a limited life. They will operate at greatest efficiency for 10 to 15 years; and
- airconditioning systems should be well maintained, otherwise you could experience fluctuations in the environment.

Heating

It is sometimes necessary to heat whole buildings or individual rooms. Generally, heating is used to make people comfortable. This is an important consideration; but you should be aware also that raising the temperature affects the objects in the building.

Heating affects relative humidity. Remember:

- heating a building in an already dry environment could be disastrous, because it will lower the relative humidity;

- heating a building when there is an additional source of water will evaporate more of the water. The relative humidity may remain unchanged or it may alter, depending on the amount of water available and the amount of heat applied. This may not be the effect you're hoping to achieve; and

- if you want to raise the temperature without lowering the relative humidity, you need additional water. Additional water sources could include mechanical devices such as humidifiers or, more simply, dishes or trays of water left to evaporate.

Altering the relative humidity

It is possible to vary the humidity without markedly changing the temperature. Relative humidity can be reduced using a dehumidifier. This is a remedial measure which adjusts a dangerously wet environment.

Dehumidifiers.

Photograph courtesy of Artlab Australia

Moisture can be introduced to the air using either a steam generator or an ultrasonic humidifier. These are remedial measures which adjust a dangerously dry environment.

These machines should not be seen as permanent solutions to your environmental problems. They can be costly to run, they need fairly constant attention and can be bulky and noisy.

The building as a buffer zone

Don't despair if your building is not air-conditioned and you can't afford airconditioning. A well-maintained building of solid construction provides a very reasonable environment for collections.

A building made of thick stone walls or cavity-brick construction with high ceilings provides good insulation against climatic changes. In hot weather, these buildings take a few days to heat up; and then, as the outside temperature drops, they lose heat slowly. Fluctuations occur, but they occur gradually.

Make sure your building is well-maintained, so that it provides the maximum possible seal against fluctuations in the outside environment. This is particularly important if the building is made of light building materials and is in a fairly extreme environment.

Clean out gutters, repair cracks in walls and ceilings, and have leaky roofs checked. This improves the stability of the temperature and humidity inside.

If you are considering upgrading the buildings, remember to insulate walls and ceilings—especially if the building is constructed from light-weight or heat-conductive materials such as fibro and corrugated iron. By so doing, it can not only help to modify the internal environment, but also ensure better preservation of the collection as well as making people feel more comfortable inside.

Use the features of the building

Improved conditions for the storage and display of collections can be achieved by choosing good storage and display sites within the building, and using the features of the building to modify conditions.

The most stable area of a non-airconditioned building is an internal room on the ground floor—because it is buffered against climatic changes.

There are other areas one could choose. Basements are acceptable as they provide a cool temperature. However, they are likely to be damp. On the other hand, an attic would often not be insulated, but would be dry.

If there is an optimum choice, the most sensitive objects should be displayed in an internal room, or at least against an internal wall in preference to an external one.

In warm, humid conditions, such as in tropical areas:

- air flow and good ventilation are important if you want to minimise damage to collections;
- use oscillating fans, with doors open to improve air movement; and
- consider other ways of cooling the inside of the building. For example, install interior blinds on windows to limit the amount of heat coming into the building, install exterior shutters or awnings, or put up shade-cloth. If possible, plant trees around the building, but not too close because this gives insects easy access to the building.

If you are building a museum or modifying an existing building in the tropics, remember that non-airconditioned buildings should have breezeways, if possible.

In arid or temperate zones, when the temperature is extreme outside the building, you can limit temperature fluctuations inside your building by:

- keeping doors and windows closed;
- keeping self-closing doors well oiled, so that they shut quickly and fully;
- installing interior blinds on windows, to buffer against outside conditions;
- installing exterior shutters or awnings, or putting up shade-cloth; and
- planting trees around the building—but not too close because this gives insects easy access to the building.

Encourage people to leave wet umbrellas and coats at the front door—by providing umbrella basins and coat hooks. This will prevent the introduction of excess moisture.

Local climates and microclimates

In the same way that you use the features of a building to modify the conditions within the building, you can use doors, windows, blinds and awnings—to modify conditions within individual rooms.

There are a number of other steps which can be taken to create and modify microclimates within the building.

Layers of storage

When storing important objects, give them their own microclimate by providing layers of storage as this provides some protection against climatic extremes and fluctuations, even when conditions in the room or building are difficult to control.

Microclimates also exists within glazed frames, display cases and boxes.

For more information
There is information about conservation framing in the chapters on Textiles, Photographs and Paper in *Caring for Cultural Material 1* and *2*.

A display case is a box with transparent sides into which an object is placed. The walls of the box isolate the object to some extent. Passive control systems can also be set up within the box.

Silica gel is the most common material used to control relative humidity in display cases. It can be pre-conditioned to achieve a desired humidity level; the quantity placed in the case depends on the volume of the case.

For more information
Silica gel is not particularly easy to use. For more information about its use refer to the section on the use of silica gel later in this chapter.

Other materials, such as Nikka pellets and Artsorb, operate on the same principles as silica gel.

Cheaper alternatives which can be used include clean, cotton scraps and shredded, acid-free paper. These absorb excess moisture, but do little to correct a dry environment.

These documents are well protected from environmental fluctuations by layers of storage—individual sleeves plus a storage box.

Photograph courtesy of Artlab Australia

Acid-free wrappers, interleaving, mounting and framing when used individually or in combinations, create layers of protection from extremes of, and fluctuations in, relative humidity. They create small, isolated microclimates in which the relative humidity fluctuates slowly.

CAUTION

Avoid sealing objects in plastic in tropical conditions—it will not allow them to breathe, creating a risk of mould growth.

The layers of mounting and framing materials buffer these items against environmental extremes and fluctuations.

Photograph courtesy of Artlab Australia

A word of caution about travelling exhibitions and loans

Remember that your collections may be subject to a changing environment within and outside a museum. Of particular concern is if items are lent to other organisations, or are transported for other reasons. They should be well packed and sealed, to ensure that they are not subjected to unacceptable fluctuations in transit.

On arrival at the destination of transported items, the local climate within the crate should be allowed to gradually adjust to the conditions of the new environment. The crates should remain unopened at the destination for a full 24 hours. This should also be done on the return journey.

If the objects are travelling from one extreme to another, for example, from a tropical to an arid climate, it may be advisable to allow more than 24 hours for conditioning at each end.

The hand on this polychrome sculpture split after getting very damp and then drying out quickly. Mould has grown on the sculpture as well. The sculpture became very damp when it was shipped from Europe to Australia.

Photograph courtesy of Artlab Australia

In an ideal world...

The levels of relative humidity—RH—recommended for the safe-keeping of collections in museums, galleries and libraries are:

- 50% ± 5%;
- this is a compromise which has been arrived at by assessing the average requirement of an average collection in an average climate;
- it is almost impossible to achieve a constant relative humidity of 50%; so a margin of 5 per cent either side of this has been permitted, that is, between 45% and 55%;
- the danger zones for relative humidity are over 65%, when mould grows and metal corrosion is common; and below 35%, when some materials dry out and become brittle;
- in tropical areas, 60% ± 5% is more realistic.

For the safe-keeping of collections in museums, galleries and libraries, the temperature should be kept constant—in the range 18–22°C.

These recommended levels are ideal. However, in some areas of Australia it is extremely difficult to come close to achieving these recommended levels. It is not always practical to put all our efforts into achieving these levels within a building, when there are many others ways of providing protection.

CAUTION

We're not in an ideal world, so it is important to remember that many objects become conditioned to their environments—even though these may be extreme.
A lot of damage can be done by attempting to place an object, which is stable in an extreme climate, into an environment that conforms to the recommended levels.

Australia's climatic zones

ARID

An arid climate is generally very dry.

For example:

	Av. Min RH	Av. Max RH	Av. Min Temp	Av. Max Temp
Broken Hill	25%	75%	12.1°C	23.7°C
Kalgoorlie	23%	74%	11.5°C	25.1°C
Alice Springs	17%	65%	16.3°C	33°C

In arid areas, it is often very hot during the day and very cold at night. This wide fluctuation is matched by wide fluctuations in relative humidity. Take Alice Springs for example:

- temperatures have been known to range from 42°C to 20°C in summer;
- and in winter from 18°C to -5°C; and
- relative humidity can range from 75%–20%.

TEMPERATE

A temperate climate is considered a moderate climate.

For example:

	Av. Min RH	Av. Max RH	Av. Min Temp	Av. Max Temp
Launceston	44%	90%	6.2°C	16.8°C
Adelaide	34%	79%	12°C	22.1°C
Ballarat	40%	91%	7.3°C	17.4°C

However extreme and fluctuations can be experienced in temperate areas. Take Adelaide for example:

- temperatures have been known to range from 40°C to 15°C in a day;
- relative humidity can range from 100%–30%; and
- when it is hot in Adelaide it is often quite dry.

Temperate climates tend to have a greater range of temperatures than tropical climates and may include extreme climatic variations.

TROPICAL

Tropical climates occur north of the Tropic of Capricorn. They are characterised by heavy rainfall, high humidity and high temperatures.

For example:

	Av. Min RH	Av. Max RH	Av. Min Temp	Av. Max Temp
Darwin	43%	85%	23.8°C	31.6°C
Townsville	51%	75%	19.5°C	28.6°C

Average readings do not give a very good indication of the extremes that can be experienced. In Darwin, for example:

- temperatures can range from 35°C to 20°C in a day;
- relative humidity can range from 100%–50%; and
- high temperature and relative humidity tend to coincide.

Note: Townsville may not be considered tropical—it may be more accurately classified as sub-tropical. It must be remembered that these categories are only a guide. Climates change gradually and there are many areas in Australia that would be difficult to place in these very broad categories.

MORE ABOUT RELATIVE HUMIDITY AND TEMPERATURE

Measuring relative humidity

Being able to measure relative humidity is not absolutely necessary when controlling fluctuations or extremes; but it is helpful in identifying problems.

If the environment is very dry or very damp, you can generally feel it—your skin responds to these conditions. We feel dry and sometimes a bit itchy in very dry conditions, and clammy in humid conditions. But feeling the extremes doesn't tell us how extreme the conditions are; and it gives us no indication of how rapidly the conditions are fluctuating.

To gather information about the levels, you need to measure the relative humidity and temperature; and to get information about the rate of fluctuation, you need to monitor the environment.

Measuring the conditions involves taking readings at a specific time—a snapshot of the conditions.

Monitoring conditions involves continuous or repeated measurement, so that you get a changing picture or series of snapshots over a period of time.

There are a number of devices which can be used to measure relative humidity.

Whirling hygrometer

A whirling hygrometer—also called a sling psychrometer—measures relative humidity and temperature directly.

It has two matched thermometers. One thermometer is called the dry bulb and the other the wet bulb. The wet bulb thermometer has a cotton sleeve wrapped around its base. Distilled water from a small reservoir is used to keep the sleeve wet.

The hygrometer is whirled around in the air. While this happens, water from the sleeve of the wet bulb thermometer evaporates, and the wet-bulb temperature shown by the thermometer goes down.

A whirling hygrometer or sling psychrometer.
Photograph courtesy of Artlab Australia

The amount of water which evaporates depends on the capacity of the air to contain water. The decrease in temperature shows how much water has gone into the air; this shows the capacity of the air to contain water.

The dry bulb gives the temperature of the air.

By comparing the two temperatures after the instrument has been whirled, the relative humidity can be calculated. This is made easier by using published tables listing the relative humidity against the dry and wet-bulb temperatures. These tables should be provided with the hygrometer.

The advantages of using a whirling hygrometer are:

- they are relatively cheap;
- they don't require ongoing maintenance; and
- if you purchase another measuring device, you will still need a whirling hygrometer, as a reference device to calibrate the other device.

The disadvantages of using a whirling hygrometer are:

- they provide a snapshot only. They do not continuously monitor the environment;
- to monitor the environment with a whirling hygrometer, you need to take readings in the same places at regular intervals, and record when and where you took the readings; and
- whirling a manually-operated hygrometer can make your arm tired. Battery-operated whirling hygrometers are available.

Thermohygrograph

A thermohygrograph allows for continuous measurement of relative humidity and temperature over a period of time. It monitors the environmental changes.

Thermohygrographs work on the principle that organic materials expand and contract as the relative humidity changes. In this case, the organic material is human hair.

The hairs are bundled together and stretched between a fixed pin and a moveable pin. The moveable pin is attached to a series of levers, which amplify the movement of the hairs.

A pen is attached to the end lever; and this pen plots the movement of the lever on a chart, which is mounted on a rotating cylinder. The rate of rotation can be altered, so that the relative humidity is plotted over a day, a week or a month.

A thermohygrograph also has a temperature sensor—which records the temperature on the same chart.

The chart should be changed at the end of each recording period. When you change the chart, set the pen on the correct time, and you will have a record of the times when changes occur.

The advantages of using a thermohygrograph are:

- the thermohygrograph chart contains information about temperature and humidity, as well as the relationship between the two; and

A thermohygrograph.

Photograph courtesy of Artlab Australia

- the chart also shows when fluctuations occurred, so you can relate fluctuations to events in the area being monitored, for example, the arrival of a bus-load of tourists on a wet day!

The disadvantages of using a thermohygrograph are:

- they require ongoing maintenance, to ensure they are recording accurately and to ensure that the cylinder is rotating at the right rate;
- they need to be calibrated periodically, and the hairs need to be re-conditioned; and
- thermohygrographs give you information only if you look at the charts. Most people look at the charts only at the end of the recording period, so they don't respond immediately to problems as they arise.

Dial hygrometers

Dial hygrometers work on the same principle as the thermohygrograph—using human hair to operate a lever which moves a dial.

A dial hygrometer.

Photograph courtesy of Artlab Australia

The advantages of using a dial hygrometer are that it is small and can be placed in display cases and on shelves.

The disadvantages of using a dial hygrometer are:

- they measure relative humidity, but not the temperature; and
- they measure continuously, but don't record the information—you have to look at them continuously if you want to use them to monitor changes.

Electronic hygrometers

Electronic hygrometers are generally used to provide a snapshot of conditions. They measure relative humidity and temperature, and need to be calibrated periodically. Before they are used, they need to be allowed to acclimatise to the area they will be monitoring.

Data loggers

Systems which monitor relative humidity and temperature, and download data to computers are now available—they are called data loggers.

The advantages of using data loggers are:

- they can be linked to alarms so that when conditions move outside the recommended levels, action can be taken; and
- the remote sensors can be placed in display cases, storage boxes and crates.

The disadvantages of using data loggers are:

- you need a computer to access the information; and
- they are expensive—although they are likely to become cheaper as time goes by.

Humidity indicator cards

Humidity indicator cards are also available. These use moisture-sensitive salts which change colour as the relative humidity alters. They can be very useful for low-cost monitoring—especially within display cases and storage boxes—provided you check them regularly.

Separate temperature cards are needed if you want to check temperature variations.

Calibration

Thermohygrographs and dial and electronic hygrometers do not remain accurate. Ideally, they should be calibrated against an instrument such as a whirling hygrometer once a month and if they have slipped out of calibration, they should be recalibrated. The hairs in thermohygrographs and dial hygrometers must also be reconditioned regularly.

We will not give detailed instructions for the calibration of individual instruments because there will be slight variations, depending on the type of instrument you have—whether a thermohygrograph or a dial hygrometer. The instrument will come with instructions. If it does not, ask the supplier for clear instructions. If you don’t follow the instructions, your readings won’t be accurate and can’t be relied on.

If you buy a thermohygrograph, you will need to buy a whirling hygrometer as well. If funds are limited, the whirling hygrometer would be a wiser investment.

Dehumidifiers

A dehumidifier is basically a cooling coil airconditioner. Instead of conducting the compressor heat out of the building, the heat is retained inside the building—and so the temperature does not change, except when the dehumidifier is in a small room. In this case, the temperature in the room can be raised by the operation of the dehumidifier.

Moisture from the air, however, is still condensed on the cooling coils, and taken away by a hose or collected in a bucket. Dehumidifiers are a remedial measure to adjust a dangerously wet environment.

If using a dehumidifier to dry an area of your building, remember to empty the catchment bucket—the buckets are not very big.

Humidifiers and steam generators

Moisture can be introduced into the air by using either a steam generator or an ultrasonic humidifier.

A steam generator uses heat to create steam. The steam is then cooled to form a water-vapour, which can be introduced into the museum.

An ultrasonic humidifier uses a small crystal—vibrating at very high frequency—to smash liquid-water into tiny droplets. The droplets are small enough to be suspended in air as a cold vapour.

Both devices are remedial measures to adjust a dangerously dry environment.

NB. The water in humidifiers and steam generators needs to be topped up regularly. If this is not done, the steam generator or ultrasonic humidifier could be severely damaged.

The use of silica gel

Individual display cases can act as buffer zones, and maintain humidity at reasonably constant levels—provided the temperature does not vary greatly. However, fluctuations can occur and it is sometimes necessary to use buffering materials: silica gel, for example.

Silica gel is often seen as a simple solution to environmental problems. In some museums and galleries, small bags of silica gel are placed in display cases and left there permanently. Unfortunately, this has almost no effect.

Using silica gel is not simple. The calculation used to determine the amount of silica gel required is complex. It involves a knowledge of the daily rate of air-changes in the case, the local humidity conditions and the volume of the case.

The amount of silica gel required is far more than most people imagine. The amount required can range from approximately 7kg/m^3 to about 20kg/m^3, depending on conditions. This is a lot of silica gel.

The dish of blue silica gel is ready for use. It will absorb moisture and so remove water from the atmosphere. When silica gel has absorbed all the water it can, it turns pink. When the silica gel is pink, it needs to be reconditioned.

Photograph courtesy of Artlab Australia

Silica gel also needs to be reconditioned, because it absorbs water and retains it. The silica gel has to be removed from the case and reconditioned—usually by heating in an oven—and then put back in the case. You may need two batches of silica gel, so that when you are reconditioning one, the other is in the case.

Display cases that are to contain silica gel should ideally have separate compartments: one for the object and one for the silica gel; and there should be air flow between these compartments.

CAUTION

If you use silica gel in its granulated form, it is advisable to wear a dust mask.

If you have a problem relating to temperature and humidity and how to manage it correctly for the preservation of your important objects, contact a conservator. Conservators can offer advice and practical solutions.

For further reading

Stolow, Nathan, 1987, *Conservation and Exhibitions: Packing, Transport, Storage and Environmental Considerations*, Butterworth and Co., London.

Thomson, Garry, 1994, *The Museum Environment*, 3rd edn, Butterworth-Heinemann, Oxford.

Self-evaluation quiz

Question 1.

Which of the following statements are false?

a) Extremes of temperature and relative humidity can cause damage to objects in museums, galleries and libraries.

b) Most insects and mould thrive in warmer conditions.

c) Relative humidity and temperature are closely related.

d) Relative humidity can affect the comfort of people in museums, galleries and libraries, but won't affect the collections.

Question 2.

In high relative humidity conditions:

a) bark paintings dry out and crack;

b) dyes and textiles fade and deteriorate quickly;

c) moulds become too wet to grow;

d) mounted vellums become taut.

Question 3.

Rapid fluctuations of relative humidity:

a) subject materials to constant movement as they absorb moisture and give it out again;

b) can cause extreme damage;

c) can alter the chemical composition of some minerals;

d) should be avoided;

e) all of the above.

Question 4.

If a collection has become conditioned to an extreme environment, you should:

a) alter the environment to meet the recommended ideal conditions because this will be better for the collection;

b) concentrate your efforts on maintaining a stable environment;

c) send the collection to a more moderate climate;

d) none of the above.

Question 5.

Relative humidity is a comparison between:

a) water in the air and temperature;

b) the amount of water-vapour in the air at different temperatures;

c) the amount of water-vapour in the air and the total amount of water-vapour that the air can hold at a particular temperature;

d) the humidity inside relative to the humidity outside.

Question 6.

Which of the following statements are true?

a) Changes in temperature can often lead to significant alterations in relative humidity.

b) People have no effect on relative humidity and temperature levels in museums, galleries and libraries.

c) If the temperature inside a sealed box drops, the relative humidity inside the box will be raised.

d) Display cases have 0% relative humidity.

Question 7.

The climates which are relevant to objects in museums, galleries and libraries are:

a) microclimates;

b) the climates within their storage and display areas;

c) the regional climate;

d) the climate in the building in which they are stored;

e) all of the above.

Question 8.

In warm, humid conditions:

a) good ventilation and air flow help to prevent mould outbreaks;

b) you should shut all doors and windows to prevent mould spores entering the building;

c) dehumidifiers should be used to dry the air;

d) seal your objects in plastic.

Question 9.

To protect important objects from fluctuations in relative humidity and temperature, you should:

a) provide them with layers of storage;

b) ensure the building is well maintained;

c) get air-conditioning installed;

d) buy a steam generator.

Question 10.

Layers of storage to protect against fluctuations and extremes of relative humidity can be created by:

a) placing items in storage boxes;

b) interleaving or wrapping objects;

c) placing items in display cases for exhibition;

d) mounting and framing;

e) all of the above;

f) combinations of the above.

Answers to self-evaluation quiz

Question 1.

Answer: d) is false.

Question 2.

Answer: b) is correct. a), c) and d) are incorrect. Bark paintings and vellums absorb moisture. This can cause changes in shape and distortion. Mounted vellums sag. Moulds thrive.

Question 3.

Answer: e).

Question 4.

Answer: b). The emphasis should be on stability.

Question 5.

Answer: c).

Question 6.

Answer: a) and c) are true.

Question 7.

Answer: e).

Question 8.

Answer: a) is correct. b), c) and d) are not correct. It is no use shutting doors and windows to keep mould spores out because they are everywhere anyway. Dehumidifiers should be used only as a remedial measure to adjust a dangerously wet environment. In warm, humid conditions, you should avoid sealing objects in plastic, because it will not allow them to breathe, creating a risk of mould growth.

Question 9.

Answer: a) and b). You could install airconditioning; but it's not completely necessary if you are able to create suitable microclimates. Steam generators should only ever be used to adjust a dangerously dry environment.

Question 10.

Answer: e) and f). The methods used will depend on the object type.

Biological Pests

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.

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.

What can be done to control moulds?

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 pheremone 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

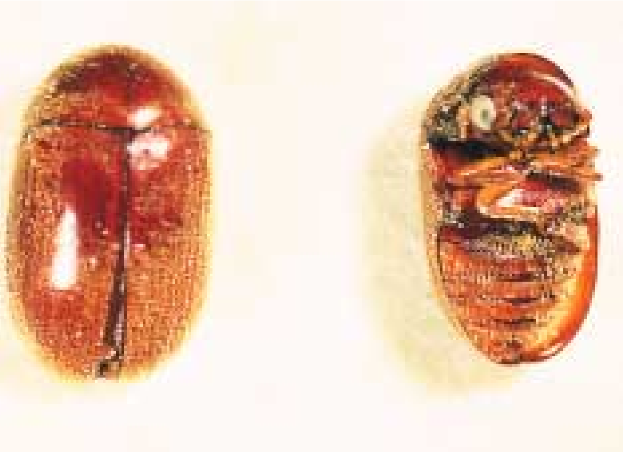
Beetles

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 Fascisculatus.

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—Bostrychopis 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—lavae (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.

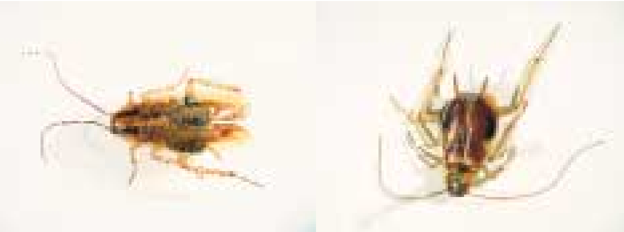
Cases of a Casemaking clothes moth—Tinea Pellionella—found in an Aboriginal feathered bag.

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 -10ºC and as high as 110ºC.

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 disinfesting 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.

Dust and Pollutants

Objectives

At the end of this chapter you should:

- be familiar with the types of dust and pollutants which can affect cultural heritage material;
- be familiar with the sources of these pollutants;
- have a basic understanding of how to minimise pollution in your collection's environment;
- have a basic understanding of how to deal with the problems caused by dust and pollution; and
- be familiar with the types of materials which are safe to use with cultural material.

Introduction

There are three main sources of damaging pollutants that can affect cultural material:

- the external environment, that can produce dust and atmospheric pollutants;
- the environment inside the museum or storage space that can produce dust and pollution through workshop, tearoom or conservation activities; and
- materials that are used to store or display objects which can contain harmful chemicals.

Sulphur dioxide, salt-laden winds, and carbonaceous material are good examples of pollutants produced in the external environment. Acetic acid or formaldehyde offgassing from display cases, cement dust from a new building, and dust generated from workshops are all good examples of pollutant material that may be produced in close proximity to the collections area.

Damaging pollutants are usually referred to as being either particulate or gaseous.

Particulate matter

Solid particles that are suspended in air are usually referred to as particulate matter or aerosols.

Materials that settle on surfaces in still air are usually referred to as dust or grit.

The size of the particles is measured in microns—µm. One micron is one-thousandth of a millimetre. Smaller particles remain suspended in the air until they are trapped on a surface. Materials which are porous or have heavily textured or sticky surfaces are particularly likely to attract these very fine particles. Larger particles tend to settle near their source.

Where does particulate matter come from?

Particulate matter from the outside environment comes from a variety of sources: burning fuel, motor vehicle exhaust, furnaces, metal from tram tracks, dust from building sites, chlorides from salt spray or dust and dirt from the natural environment.

Particulate matter can also be generated within a building. In new buildings, concrete and cement can give off very fine dust particles for up to two years after initial pouring. These particles are extremely alkaline and will damage objects they settle on, for example, they will discolour linseed oil, some dyes and pigments and attack alkaline-sensitive material such as silks and photographs.

In existing buildings, air-conditioning systems which are not cleaned regularly or do not have appropriate filters, as well as gas and oil heaters, kitchens and workrooms, have the potential to produce particulate pollution which can affect objects.

A lot of dust is made up of human skin and hair. These materials are very attractive to insects.

Chemically active particulate material can also be introduced as part of some pest control treatments. For example, certain large chemical dust particles placed on surfaces such as shelves can poison pests as they crawl over these areas. However, this type of pest control treatment is not advised where cultural materials may be present.

Particulate matter may also contain other adsorbed or absorbed material such as acids from atmospheric sulphur dioxide, or traces of metal from industrial processes.

Problems with particulate matter

Dust can build up to quite a large mass in areas that are not easily accessible, or which may easily trap airborne dust particles. Dust absorbs moisture readily, so that areas with a large build-up of dust can have quite high local humidity even when the environment surrounding the object is completely stable at 50%RH.

In recessed areas, such as between the lower stretcher bar and the canvas of a painting or in the interstices of basketwork, the build-up of dust creates problems for paint layers. This can lead to cracking and other physical damage as the dust creates physical distortion of the structural components of the object.

Dust on objects will absorb and adsorb pollutants. In conjunction with moisture, absorption of pollutants can lead to severe damage. For example, dust particles which contain chlorides can cause bronze disease on bronze objects.

Dust also attracts and harbours pests—enabling insects to hide and nest in secure environments.

Gritty dust causes physical damage, particularly if you clean the dust away by rubbing. It could lead to abrasion and scratching.

Sticky dust, for example, soot, will stain most surfaces. Dirt can be absorbed into extremely porous or intricate surfaces such as paper, basketwork and plaster casts which, once dirty, may be impossible to clean.

Carbonaceous material

Carbonaceous particulate matter is produced from several sources including cigarette smoke, car fumes, furnaces and industrial workplaces which burn material. It is often extremely sticky and tarry.

If a surface is not porous, carbonaceous particles are quite easy to remove when they first settle. However, if left on an object, their acidity will cause them to etch into the surface. Airborne carbonaceous material is also likely to contain sulphur compounds.

Chlorides

Salt air is a particular problem. While marine environments are the most likely source of salt, there are other sources of chloride contamination of cultural material. These include chlorinated water and areas with high saline concentrations—such as occur in some inland areas of Australia—and sweaty fingers.

Chlorides are gritty and will abrade surfaces, but they can also produce chemical reactions. An example of this is the reaction in copper which produces copper chlorides—a highly corrosive substance capable of causing considerable damage to cultural material. This type of damage to copper and bronze objects is commonly known as bronze disease.

For more information

For more information on chlorides and bronze disease, please see the chapter on Metals in *Caring for Cultural Material 2*.

Protection from dust

Protecting your collection from the harmful effects of dust is a combination of common sense and expertise. Good building design to keep dust out—together with good housekeeping practices to stop its distribution through to display and storage areas—will radically reduce damage from particulate matter.

It is worth developing a strategic plan to identify and deal with problems. The best place to start is to look at the building and its ability to keep out dust. In salty, dusty or dirty environments:

- use air-sealing strips around doors, windows and filter air vents;
- provide doormats for visitors;
- double doors will provide some protection against dust entering the building;
- keep windows closed if possible. This is not always advisable in a tropical climate, because good ventilation is vital to reduce the risk of mould growth; and
- place any objects which are particularly susceptible to abrasion—or are hard to clean—in dust jackets or boxes during storage, and in display cases for exhibition.

Even well-protected buildings can have large amounts of particulates in the atmosphere. New concrete should be sealed. But remember to check that the sealant is safe for use in areas which contain cultural objects, and make sure that there are no objects nearby when it is applied. It is important also to allow enough time for the sealant to dry and offgas before housing the objects in the area. Don't underestimate the time it takes a material to offgas. Plastic paints need to be aired for three to six weeks to allow for the acetic acid to dissipate fully.

Workshop areas and kitchens are known producers of particulate matter. If possible, these areas should be sealed well and sited away from storage and exhibition areas. Use good housekeeping practices in these areas—try to vacuum regularly.

Remember that air-conditioning systems will circulate harmful material from one outlet to another, so check that your ducting system is not pumping workroom dust or tearoom grease onto your objects. If possible, design your air-conditioning ducting so that dust-producing areas are at the end of the system.

Protect particularly susceptible surfaces. Plaster casts and natural history specimens should be housed in cases or provided with dust jackets. Works of art on paper should be stored in Solander boxes or sealed in frames. Objects with intricate surfaces, such as basketry or textiles, should be boxed for storage or displayed in display cases. And avoid spraying aerosols near objects. These usually contain hydrocarbons and other harmful pollutants. Hydrocarbons react in the presence of air, and become brown and sticky over time, causing irreversible staining.

Many materials are either electrostatic or sticky enough to attract dust. Perspex, Mylar and plastics are good examples of this. Some coatings which are recommended in conservation literature may also be sticky, for example waxes and dressings, or will build up an electrostatic charge, for example, synthetic resins. Seek the advice of a trained conservator before using coatings and resins on cultural objects.

Cases, boxes, slip covers and folders can all be used to protect objects from particulate matter. Cases can be fitted with dust filters; and silicon sealant can be used in loose-fitting cases. Slip covers can be made out of undyed, natural fabrics such as calico.

If you have an air-conditioning system, it needs to be kept in good condition, and filters checked and changed as necessary. An air-conditioning system which is not maintained properly can cause more damage to a collection than no air-conditioning at all.

Pollutant gases

Damage from pollutant gases may result from:

- the offgassing of chemically active materials in the museum, gallery or library; or
- from pollutants in the external environment.

Industrial pollution occurs in most major cities in the world. In Australia, Melbourne and Sydney are well known for their polluted environments; but even in small country towns air pollution can be a problem.

Sulphur dioxide, nitrogen oxides, carbon dioxide and ozone are all pollutant gases. Of these, sulphur dioxide, nitrogen dioxide and ozone cause the most damage. Sulphur dioxide and nitrous oxide are called acidic gases because they react with water to produce acids.

Sulphur dioxide and sulphuric acid

Sulphuric acid and sulphur dioxide are harmful substances produced from pollutants in the air. These substances are formed when sulphur reacts with oxygen in the atmosphere to produce sulphur dioxide, and ultimately sulphuric acid while in the presence of water.

Polluting sulphur in the environment reacts with oxygen to produce sulfur dioxide:

$$\mathbf{S + O_2 = SO_2}$$

The sulphur dioxide further reacts with oxygen:

$$\mathbf{2SO_2 + O_2 = 2SO_3}$$

and in the presence of water sulphuric acid is formed:

$$\mathbf{SO_3 + H_2O = H_2SO_4}$$

Sulphuric acid is highly corrosive. It attacks outdoor sculpture and damages buildings as these contain calcium carbonate—a material present in limestone, marble and sandstone.

All three sulphur compounds—sulphur, sulphur dioxide and sulphuric acid—also have an affect on certain metals. For example, sulphur dioxide rusts iron. Whereas sulphur on its own can cause silver to tarnish. As for lead, this metal deteriorates rapidly in the presence of sulphur dioxide.

But not all metals are affected by the sulphur compounds. For example, bronzes which have a patina are generally not affected by sulphur dioxide.

Materials containing cellulose—as used in the production of paper—are susceptible to damage from sulphuric acid. The widespread phenomenon of brittle books is a direct consequence of this problem.

Sulphuric acid also affects protein-based materials. One example of this is red rot—a well-documented problem in libraries—caused by sulphuric acid attacking bookbinding leathers.

Silk and photographs are affected by sulphuric acid—whether in the gaseous or liquid state. Synthetic textiles are also affected by acid gases.

For more information
For information about red rot, please see the chapter on Books in *Caring for Cultural Material 1*.

Nitrogen oxides

Like sulphur dioxide, nitrogen dioxide is also a harmful substance in itself, which, when combined with water, forms nitric and nitrous acid.

$$2NO_2 + H_2O = \underset{\text{nitrous acid}}{HNO_2} + \underset{\text{nitric acid}}{HNO_3}$$

Nitrogen dioxide attacks cellulose and polyesters as well as some dyestuffs.

Nitrogen oxides also produce oxidising agents. These are very reactive and cause severe damage to most materials with which they come in contact.

Ozone

Ozone is an extremely reactive oxidising gas. It attacks organic materials at a molecular level. Because many objects in museums, galleries and libraries are organic, ozone in your environment could be disastrous.

Photographs, which are usually made up of a paper support with a gelatine emulsion, are extremely susceptible to damage from ozone.

Metal corrosion is also very common in the presence of ozone.

Fortunately, ozone has a short life. Even in a polluted environment, it is likely to have reacted with the external environment before it reaches the collection storage and display areas. Unfortunately, ozone can still be produced within a museum environment—for example, by photocopiers.

Factors which increase the effect of acidic gases

Strong visible light, continuous exposure to UV radiation, and high levels of humidity and temperature in the museum environment, all increase the effects of acidic gases on materials used in cultural objects.

For example, strong light levels can accelerate the chemical production of harmful acids in the environment as well as increase the rate of deterioration of various materials with these acids.

Some reactions are initiated by more energetic wavelengths of light and by UV radiation.

Furthermore, chemical reactions are more likely to take place and proceed faster in humid conditions and at higher temperatures. As a rough guide, a 10°C increase in temperature doubles the rate of chemical reactions.

For more information
For more information about adverse environmental effects, please see the chapters on Light and Ultraviolet Radiation and on Humidity and Temperature in this volume.

Display and packing materials

There are many reasons to place items in their own sealed environment when they are on display, in storage or being transported. A sealed and protected environment will:

- limit damage from dust and air pollution;
- impede insects;
- reduce accidental and physical damage such as scratches, knocks and breakages; and
- reduce the risk of theft.

But remember, objects that are placed within a sealed, secure environment are at risk if that environment contains active chemicals which can affect the object. Paper is affected by acidic materials such as wood-pulp, cardboard or wood, whereas ceramics will be unaffected by these materials. The following information is provided as a guide—so that you can avoid damage caused by display and packing materials.

Wood

Different woods produce different volatile substances. For example, plantation pine gives off phenolic acid; other woods produce acetic acid.

Paper, textiles and other items which are adversely affected by acids should not be in direct contact with wood.

Lead is extremely susceptible to acids from wood, particularly from oak. Solid, metallic lead will react with acids from the oak, to form a white powdery substance.

Woods are generally considered safe for packing, storing and displaying cultural material include Hoop, Kauri Pine and Ash.

Metals

Metals are generally considered to be safe, but if they are likely to corrode they should not be used.

Some problems have been noted with enamelled coatings on steel cabinets, where underfiring of the coating has resulted in the subsequent offgassing of formaldehyde (Applebaum, 1991).

Stainless steel and aluminium are generally considered safe.

Acrylics

Acrylics are generally considered safe. They include Perspex and resins which can be mixed to form emulsions and solutions.

Acrylics in emulsion and solution form can be used as varnishes or surface coatings. If you are using a commercially prepared emulsion or solution, make sure that it does not contain harmful additives such as excess catalysts, or materials like toxic plasticers.

Polyvinyl chlorides—PVC

Polyvinyl chlorides breakdown over time—with moisture from the air— to produce hydrochloric acid. Avoid using PVC and other chlorinated hydrocarbons.

Polyester, polyethylene and polypropylene

Polyester, polyethylene and polypropylene come in a variety of forms and grades. Whatever the type, these substances are safe to use.

Polyvinyl acetate and polyvinyl alcohol—PVA & PVOH

Polyvinyl alcohol is a derivative of polyvinyl acetate. Both of these materials are used as a base for paints, coating and adhesives. They are safe to use in some circumstances, but must be allowed to fully dry and cure. For advice on their use in specific applications, consult a conservator.

Fabrics

In general, pure cotton and linen which are unsized and undyed are safe to use near objects. Wool—sized or dyed fabrics—should not be used because they may contain reactive substances and may hold water, increasing the local relative humidity. Wool should not be used with metals and other sulphur-susceptible materials, because it usually contains sulphur.

Polyurethanes

Polyurethanes react with light and heat, and break down. As they always contain additives, a range of potentially harmful chemical compounds can be released into the environment. They should not be used as coatings.

Chipboard, compressed board and plywood

Chipboard, compressed board and plywood should be avoided. They are usually prepared with formaldehyde, which produces formic acid. It is possible to buy processed wood products which do not contain formaldehyde, but it is important to check that they do not contain other corrosive volatile organics.

Sealants

It is often suggested that sealing cases with varnish or an acrylic sealer will stop offgassing. This is not true. No sealant is truly impermeable and their use will slow down, but not reduce, the total amount of offgassing.

Nitrate film

CAUTION

Nitrate film is extremely dangerous. It is made from cellulose nitrate which is a very unstable material. As it degrades, it produces nitrogen oxide. Further degradation will result in spontaneous combustion of the film. And as nitrogen oxide reactions produce oxidising agents, this reaction can occur without the presence of oxygen in the air. This means that degraded cellulose nitrate can burn even under water or when smothered. Degraded cellulose nitrate becomes dark, sticky and smelly.

The National Film and Sound Archive has conducted a search for nitrate film in Australian collections. If you suspect you have cellulose nitrate in your collection, contact the National Film and Sound Archive, or a relevant State institution.

Cellulose nitrate was used as a coating, as a film emulsion and to make objects. It seems to be at its most unstable as film stock; however, if you suspect you have cellulose nitrate in any form seek the advice of a conservator.

Methods for detecting pollutant gases

Detecting the presence of pollutant gases is generally best left to the experts. But there are some simple methods that will detect pollutant gases which might affect your collection.

Oddy tests

Oddy tests are named after the person who devised them. They involve placing different types of metal strips in the areas where you think pollutant gases may be a problem. The effect of the gas is measured by the condition of the metal.

These tests are described in the literature (Oddy, 1975) and are a quick and easy way of checking for problems.

Draeger detector tubes

These tubes are available commercially and there are a wide variety of tubes—each specific for a certain gas.

You will need to contact a supplier to buy these tubes. Try chemical supply companies in your area, or ring your State or Territory Environmental Pollution Authority.

Various monitors

There are a wide range of specialist monitors and detectors on the market. Osborn (1989) provides a list of many of these. In most cases, you will need to commission an expert who is familiar with the use of the equipment to undertake an assessment and provide a report.

pH indicator strips

pH indicator strips are used to determine whether acidic gas is being produced in an area. When moistened with neutral pH distilled water, the strips absorb gases from the air and indicate whether acids are formed.

You will need distilled water and one or two pH indicator strips for each test you make. Test the pH of the distilled water with a pH strip. Compare the colour change on the strip with the reference chart on the case, and record the pH of the water. The water should be at pH 7: neutral. A small variation in pH—down to 6—is acceptable, because contact with carbon dioxide in air makes distilled water slightly acidic.

Leave the moist pH strip in the air for 15-30 minutes, and monitor any colour changes against the reference chart on the indicator strip case.

pH indicator strips are a guide only, so further testing should be done.

Check with experts

Your local municipal offices have information about environmental pollution in your area, and may be able to help you contact local experts.

The Environment Protection Authority or similar authority in your state should be able to give you the names of professionals who can help.

Outdoor objects

The protection of exposed objects from pollutant gases requires commonsense and expert knowledge.

Remember that reactions from pollutant chemicals are increased with high light levels, and changes in relative humidity and temperature. The possible impact of these factors can be reduced fairly easily. The following steps will help.

- Provide drainage channels around the base of statues and clean away accumulated organic debris.
- Reduce moisture levels in and around cultural objects. Moisture in tropical climates can be more difficult to control, but you may be able to provide shelter from rain, and shade to help keep the temperature down.
- Relocate an object to the least-exposed area of a building. For example, moving an object from the seaward side of a building to a more protected location will reduce, although not completely stop, the effect of salt-laden wind.
- Commonsense often dictates the use of protective coatings on objects. But commonsense can be wrong. If you want to provide a protective coating on an outdoor object, then you need to consult an expert. Surface coatings applied inappropriately can do more harm than good. If the coating is to be applied to a work of art and is likely to change the finish of the work, then you should consult the artist as well.
- Some metals provide their own protective layers against corrosion. These could be disturbed by cleaning.

Protecting from atmospheric pollution

To develop proper strategies for the care of your objects, you will need to do much more reading and familiarise yourself with a wider body of information than it is possible to provide in this manual. Talk to as many experts as possible, and get to know the problems which are particular to your area.

Air-conditioning

If you are thinking of installing an air-conditioning system, it is advisable to talk to small museums or institutions similar to your own. Cultural material has special requirements, and if you deal with experienced people you are likely to have fewer problems.

Pollutant gases are removed usually by water sprays or activated carbon filters. Air-conditioning systems which incorporate water sprays pass air through a sheet of water to trap pollutant gases. It is important that a system like this incorporates a dehumidifier, to maintain a stable humidity. It is important also to keep the water source clean because it could become acidic from a build-up of pollutants, and circulate humidified, acidic air onto objects.

Air-conditioning systems should be designed to correct specific temperature, relative humidity and pollution problems. They are expensive to build, install and maintain, and it’s best to consult an expert who has experience with buildings of a similar scale to yours; rather than, for example, a firm with experience in domestic air-conditioning only.

Many new buildings are designed to incorporate passive environmental control techniques within the building. Air-conditioning may not be required if your building has been designed this way and is working effectively.

If you have an existing system in the building, have it checked regularly and keep a report on its condition which can be reviewed at each subsequent examination.

Activated carbon filters

Activated carbon filters control pollution emissions by adsorbing pollutants onto their surfaces. They need to be checked regularly. Once they are saturated, they will give out pollutants—and the problem will worsen rather than improve.

Potassium permanganate

Potassium permanganate is a good filtration system for museums (Appelbaum 1991). The system is similar to silica gel systems used for humidity control. You should seek advice from a conservator before considering this option.

Commonsense approaches

While some options for controlling pollution require expert advice and financial outlay, there are a number of options which offer protection with little cost and effort. For example:

- use display cases and layers of storage to provide a protective local environment for the object;
- frame and glaze artworks which are on display;
- provide dust jackets for books;
- place flat paper-based objects in Solander boxes;
- provide archival-quality boxes for fragile or susceptible objects; and
- cover large objects which will not fit in storage cases or boxes with appropriate sheeting, for example, unbleached and undyed cotton or linen, or Tyvek, when they are not on display.

For more information
For more information about Tyvek, please see the chapter on Textiles in *Caring for Cultural Material 2*.

These are some options only. As you familiarise yourself with more information in other sections of *reCollections*, you will find that other simple options are available. Even if you can't control the environment completely, you can make some difference with even small changes.

MORE ABOUT DUST AND POLLUTANTS

Particulate matter

Aerosols

The term aerosol is used in a number of different ways in the literature. Osborn (1989) provides a good definition. He defines aerosols as 'very small particles which are less than 1 micron and which act as a nucleus for the condensation of liquid'.

Smaller particles which tend to be trapped

Generally, smaller particles—from .01 microns to 15-20 microns—remain suspended in the air until they are trapped. They can be trapped by adhesion to sticky surfaces such as waxes; porous surfaces such as paper; textured surfaces such as feathers; or by a physical barrier. Being small, they are usually light and are extremely mobile.

Larger particles which tend to settle

Larger particles—particles greater than 15-20 microns—tend to settle near their source. This means that near the source there is likely to be a heavy deposit of these large particles. This kind of particulate matter is easier to collect than the smaller particles, but it will cause more damage because of its mass.

Concrete buildings

Studies have indicated that concrete dust can be given off for up to two years after the completion of the building. The only studies on this have been done by Toishi (Thompson, 1986). However, this phenomenon has been seen in buildings in Australia, and is easily checked in buildings—by placing a clean blotter on a shelf in a suspect area. If concrete dust is a problem, you will see dust settling on the paper.

Developing a strategic plan for examining the problems in your building

If you are concerned about your building, try to work systematically through a checklist of perceived problems, and determine strategies for dealing with these problems. In some cases you'll be able to deal with the problems simply and without expert help; in other cases you'll need expert help.

If you have a plan, you can budget in advance for times when specialist advice or expensive modifications to the building are needed. First determine your problem.

The external environment

The first step is to look at the external environment and determine any problems.

If one side of the building is near a busy freeway, you may need to completely seal this side of the building.

You may be surrounded by dusty parkland, and so may need to put good seals around doors and windows.

You may be in a very polluted environment and so need to have sealed cases with pollutant scavengers to protect your objects.

The internal environment

Look at areas which produce dust or pollutants, and work out how these move through your building.

Simple solutions—like providing doormats and keeping doors shut; or more complex solutions like adding a double entry door into a collection area—may reduce significantly the movement of dust or pollutants.

If the dust is being produced in a workshop, consider installing a localised extraction system.

If the air-conditioning system is pulling dust into collection areas, you may need to have the duct system redesigned.

Products used with cultural material

While you will probably be more concerned with offgassing, some materials with your cultural materials will cause dust problems.

For example, polystyrene packing material breaks down into small particles which are extremely electrostatic.

Call in experts

Think about whether you need to call in experts.

Do you understand the problems you are facing?

If you're not sure of the type of pollutants in the air, you may want to have an analysis undertaken.

Then take action

Once you have determined the problems you're facing, draw up an action plan.

Deal with the simple problems, and get expert advice and written reports if you need them. Plan for the long term.

It may be advisable to allocate a budget line—to ensure that you can afford to fund changes.

If necessary, locate larger grant programs which will enable you to undertake major works when required.

If you have a problem related to dust or pollutants and don't know how to deal with it, contact a conservator. Conservators can offer advice and practical solutions.

For further reading

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Self-evaluation quiz

Question 1.

Which of the following are sources of pollutants that may affect cultural material?

a) The external environment, a source of dust and atmospheric pollution.

b) The internal environment which produces dust and pollution from activities undertaken in the building.

c) Inappropriate materials which will offgas or contain chemicals which may damage cultural material.

d) All of the above.

Question 2.

Particulate matter includes:

a) sulphur dioxide;

b) aerosols;

c) dust and grit;

d) carbonaceous material.

Question 3.

Give examples of sources of particulate matter.

Question 4.

Which of the following statements are true?

a) Dust attracts and harbours pests.

b) Dust can cause mechanical damage.

c) Dust adsorbs and absorbs pollutants.

d) Dust deposits can create localised areas of high humidity.

e) Dust can impregnate porous surfaces, making them impossible to clean.

f) All of the above.

Question 5.

Chloride contamination can come from

a) sweaty fingers;

b) chlorinated waters;

c) cigarette smoke;

d) sea air;

e) car exhausts.

Question 6.

Collections can be protected from the effects of particulate matter by:

a) providing seals and filters on windows, doors and air vents;

b) locating workshops and kitchens away from collection display and storage areas ;

c) spraying regularly with aerosol polishes;

d) boxing, framing or providing covers for cultural objects.

Question 7.

Which of the following statements are false?

a) Sulphur dioxide, nitrogen dioxide and ozone are pollutant gases.

b) Photocopiers present no risk to valuable items.

c) Sulphur dioxide can convert to sulphuric acid in the presence of moisture.

d) Nitrogen dioxide is not a problem for collections.

Question 8.

Match the following materials with the damaging materials they can produce.

a)	wood	1.	sulphur
b)	metals	2.	acetic acid
c)	acrylics	3.	phenolic and acetic acids
d)	PVC	4.	formaldehyde
e)	PVA	5.	hydrochloric acid
f)	compressed wood pulp	6.	corrosion and some coatings are damaging
g)	wool	7.	some additives can be harmful

Question 9.

Which of the following methods can you use to detect pollutant gases?

a) Oddy tests using metal strips.

b) Activated carbon filters.

c) pH indicator strips for acidic offgassing.

d) Air-conditioning.

Question 10.

Activated carbon filters:

a) adsorb pollutant gases;

b) need to be checked regularly;

c) need to be used with caution because if saturated they will give out pollutants;

d) all of the above.

Question 11.

Give four examples of how you can protect items from the effects of pollutant gases.

Answers to self-evaluation quiz

Question 1.

Answer: d).

Question 2.

Answer: b), c) and d). a) is a pollutant gas.

Question 3.

Answers could include:

- burning fuel;
- exhaust fumes from cars;
- industrial furnaces;
- burning off;
- metal from train and tram tracks;
- dust from building sites or paddocks;
- salt spray;
- pesticide dust;
- old or poorly maintained air-conditioning systems;
- dust from new concrete.

Question 4.

Answer: f).

Question 5.

Answer: a), b) and d). c) and e) are sources of carbonaceous materials.

Question 6.

Answer: a), b) and d). You should not spray aerosols near valuable items.

Question 7.

Answer: b) and d) are false. Photocopiers produce ozone which is extremely reactive with carbon-based material, and it increases the corrosion of metals. Nitrogen dioxide can convert to nitric acid in the presence of moisture, and is very corrosive. It produces oxidising agents which are very reactive and easily break chemical bonds.

Question 8.

Answer:

a) 3

b) 6

c) 7

d) 5

e) 2

f) 4

g) 1

Question 9.

Answer: a) and c). b) and d) are methods to help protect against pollutant gases.

Question 10.

Answer: d).

Question 11.

Answer: Answers could include:

- frame and glaze artwork;
- provide dust covers for large objects;
- use display cases for smaller objects;
- ensure stable temperature and humidity—avoid high temperatures and high humidity;
- provide layers of storage;
- place items in boxes.

Common Deterioration Processes

Objectives

At the end of this chapter you should:

- have a basic understanding of some deterioration processes;
- have a visual reference for some of the issues discussed in other sections; and
- have a basic understanding of some of the problems you may encounter in your collection.

Introduction

Deterioration is caused by physical damage and chemical activity—usually in combination. For many materials, physical damage can create conditions that are favourable for chemical activity.

For example, as aluminium corrodes, an aluminium oxide layer forms on the surface which protects the rest of the metal from corrosion. If this layer is scratched or broken in any way, un-oxidised aluminium will be exposed and it will corrode. Fortunately the corrosion produces a new oxide layer which protects the rest of the metal.

Iron objects are often coated to protect them from contact with moisture and oxygen. If they are not protected they rust. Rust is iron oxide; but unlike aluminium oxide it does not protect the underlying metal from further corrosion. If a coating applied to an iron object is scratched or broken in any way, the object rusts. At first, the rust is localised, but it spreads gradually over the whole object, destroying it totally.

Chemical activity often accelerates physical damage, or leaves objects more susceptible to physical damage. For example, pressure-sensitive adhesives—as used to make sticky tapes—age and become less sticky. The adhesives harden and no longer hold things together. This also happens to adhesives such as rubber cement. Collages and other items which include a lot of adhesives can fall apart once the adhesives have aged.

Paper that was once flexible and easy to use can become brittle, to the point where it crumbles away to fragments when handled roughly. This extreme vulnerability to physical damage is a result of chemical deterioration. Acids within the paper attack the paper's fibres, making them shorter and much less flexible.

Examples of deterioration

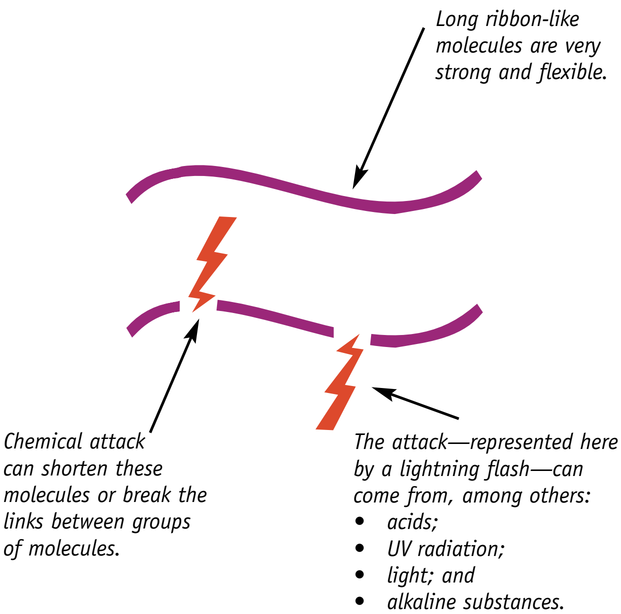
The following examples illustrate the common changes that occur in materials as they deteriorate chemically:

- flexible organic materials, for example, paper, fabrics and some plastics, often become brittle;
- the change in solubility characteristics and loss of flexibility of some adhesives, paint layers, varnishes and coatings;
- colour change, for example, dyes fading and becoming discoloured; and
- corrosion of metals.

Flexible organic materials becoming brittle

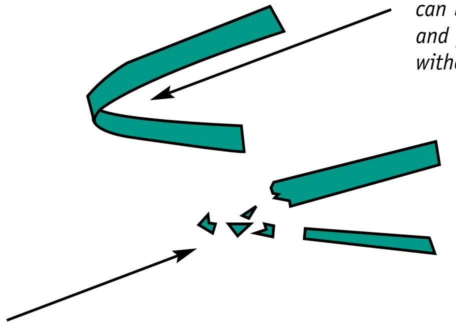
Paper is made up of cellulose fibres. Fabrics are made up of cellulose, protein or man-made fibres.

All of these fibres are made up of long ribbon-like molecules. Flexible plastic films are also made up of long molecules.



The shortening of the molecules has a major impact on the physical characteristics of the materials.

Long molecules and fibres are flexible and can be moved around and partially folded without damage.



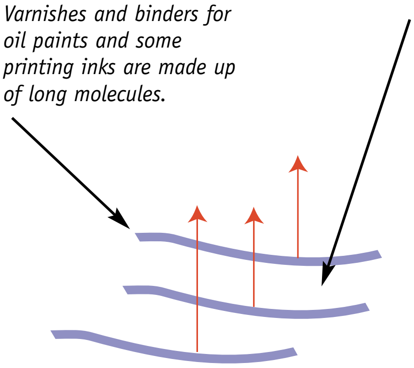
If the molecules have been attacked and have been broken into shorter units, they and the fibres they make will be much less flexible and cannot be moved and folded without braking. For this reason, textiles should not be stored folded, paper should not be folded and any aged and degraded materials should be supported and handled with care.

Change in solubility characteristics and loss of flexibility

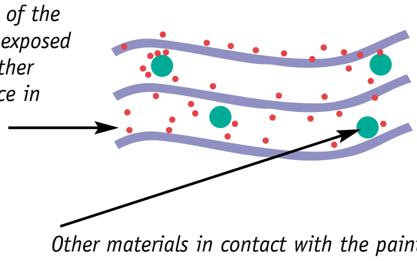
Many paints, inks, varnishes and coatings dry by a combination of evaporation and chemical change. The chemical change that takes place is called crosslinking. The relative importance of evaporation and chemical change in the drying stage depends on the original formulation of the paint, ink or varnish.

Varnishes and binders for oil paints and some printing inks are made up of long molecules.

Once applied to a surface, some evaporation occurs, bringing the molecules closer together allowing them to interact with each other more readily.



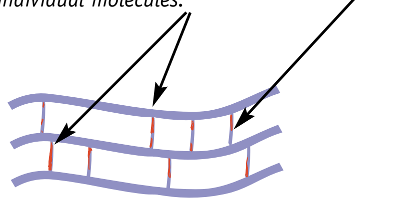
The surface area of the material is fully exposed to oxygen and other reactive substance in the atmosphere.



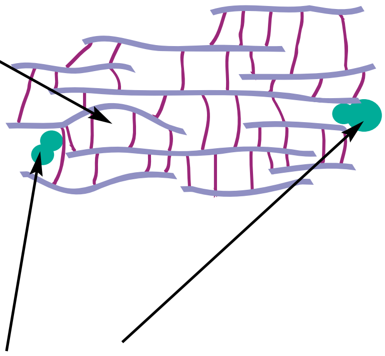
Other materials in contact with the paint, varnish or ink can also react with it or speed up its reaction with oxygen. Some pigments in paints have this effect.

As chemical changes occur, crosslinks form between the individual molecules.

The formation of these crosslinks gives the drying effect. The varnish or paint becomes less sticky to the touch and it 'sets' or hardens, but it remains flexible.



If crosslinking continues the material becomes more rigid. As it loses flexibility, it is more likely to fracture and break up.



With a great number of crosslinks, it is harder for solvents to get into the material to dissolve it.

Solvents that were effective before crosslinking took place are sometimes able to act on the material to soften it even if they cannot fully dissolve it.

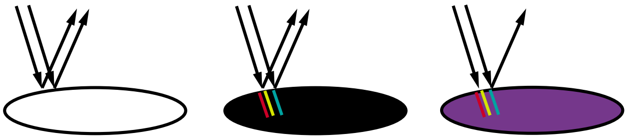
When it is part of the drying process, crosslinking is seen as a useful and desirable chemical reaction. But it is not desirable when it is seen as an ageing process which causes:

- sticky tape adhesives to set and become insoluble;
- varnishes to become less soluble and to discolour; and
- paint and ink films to become very hard and brittle.

It is important to note that crosslinking can occur at the same time as other parts of the same molecules are being broken into smaller units.

Colour change

We see materials as coloured because they selectively absorb some wavelengths of visible light and reflect others.



White objects appear white because they reflect all wavelengths of visible light.	Black objects appear black because they absorb all wavelengths of visible light.	Coloured objects selectively absorb some wavelengths and reflect others. A blue object, for example, absorbs all wavelengths apart from blue, which it reflects.

At a molecular level there are certain chemical groups which determine the absorption of particular wavelengths of light—these groups are called chromophores and are responsible for the colour of materials.

In organic materials, colour is associated with particular molecular structures that absorb and emit visible light of specific frequencies; that is, chromophores are groupings of atoms within a molecule.

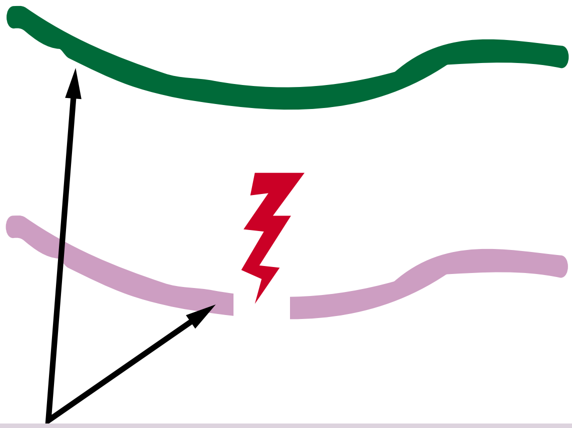
For example:

-C=C-	**-C=O**	**-N=N-**
C=C represents two carbon atoms joined by a double bond. Each carbon is then bonded with a single bond to adjoining atoms. The single bonds are represented by -.	C=O represents a carbon atom joined to an oxygen atom by a double bond. The carbon is then bonded with a single bond to adjoining atoms. The single bonds are represented by -.	N=N represents two nitrogen atoms joined by a double bond. Each nitrogen is then bonded with a single bond to adjoining atoms. The single bonds are represented by -.

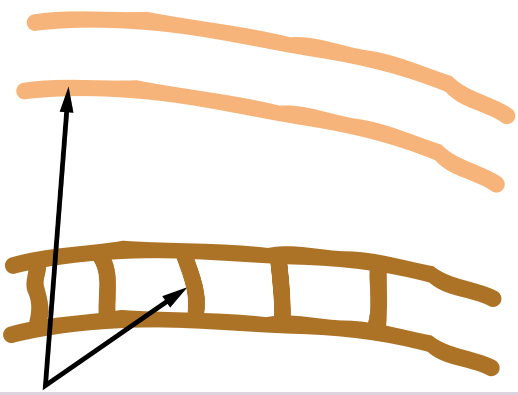
Double bonds are strong, but they are far more reactive than single bonds, so they are broken readily during chemical reactions.

When talking about flexible materials becoming brittle, and the change in solubility characteristics and loss of flexibility of materials, we examined the breaking and crosslinking of large organic molecules. The chromophores described above occur in these molecules.

This long molecule is made up a chain of atoms jointed together, for example, it may be:
-C=C-C=C-C=C-C=C-C=C-C=C-C=C-C=C-C=O



Breaking these molecules may involve breaking double bonds—this would lead to loss of colour.

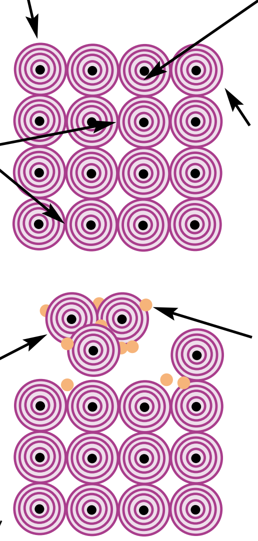


Chemical crosslinking involves creating new bonds between molecules and atoms. These new bonds may be double bonds that produce chromophore groups. This could lead to darkening of colour or colour where there was no colour before ie. staining or discolouration.

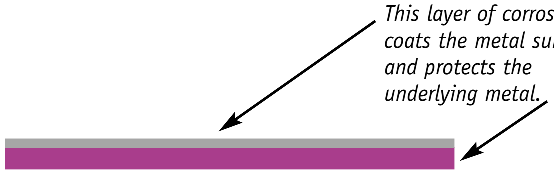
If molecules are being broken down and crosslinked at the same time, a whole range of colour changes are possible. Just what the colour changes will be is difficult to predict.

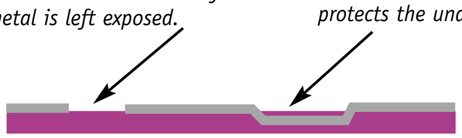
Corrosion of metals

The chemical deterioration of metals is known as corrosion.

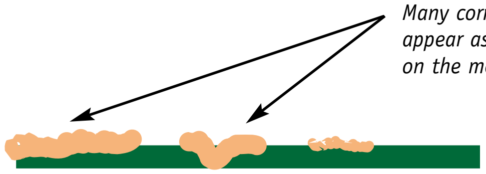


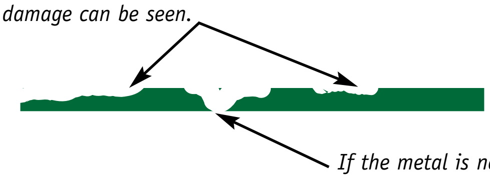
Some metals are protected by a layer of corrosion. For example, when aluminium is exposed to air, it corrodes to form aluminium oxide which covers the surface of the metal item.



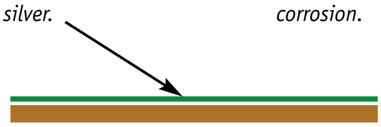


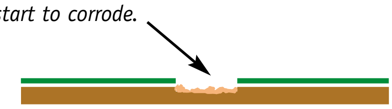
Other metals like iron are not protected by their corrosion products.



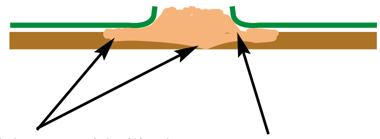


Some metal objects are electroplated. Electroplating is used to make cheaper metals look like silver. The physical properties of the materials are dominated by the underlying metal.





Wherever the underlying metal is in contact with air, moisture or any other agents of corrosion, it will deteriorate.



As stated earlier, this section provides a simplified overview of some of the processes of deterioration. For further information about the effects of these processes and on minimising these effects, please refer to the chapters relating to specific types of materials.

For more information

For more information about deterioration of paper and fabrics, please see *Caring for Cultural Material 1*. For more information about corrosion in metals, please see *Caring for Cultural Material 2*.

If you would like further information about the deterioration of items in your collection, consult a conservator.

For further reading

Crafts Council Conservation Science Teaching Series 1982, *Science for Conservators Book 1— An Introduction to Materials*, Crafts Council, London.

Crafts Council Conservation Science Teaching Series 1983, *Science for Conservators Book 2— Cleaning*, Book 2, Crafts Council, London.

Mills John S. and White Raymond, 1987, *The Organic Chemistry of Museum Objects*, Butterworths, London.

Self-evaluation quiz

Question 1.

Which of the following statements are true?

a) For many materials, physical damage can create conditions which are favourable for chemical activity.

b) Physical damage and chemical deterioration are in no way linked.

c) Chemical deterioration can accelerate physical damage.

d) None of the above.

Question 2.

Crosslinking:

a) is part of the drying process of oil paints, some printing inks, and varnishes;

b) is part of the ageing process that makes some adhesives and varnishes less soluble over time;

c) can lead to discolouration of some adhesives;

d) is all of the above.

Question 3.

Which of the following statements are false?

a) Crosslinking and breaking of molecules can occur simultaneously.

b) The change in the length of organic molecules can have a major impact on the physical characteristics of materials.

c) All metals are protected from further corrosion by their corrosion products.

d) Chemical deterioration has no effect on the colour of materials.

Answers to self-evaluation quiz

Question 1.

Answer: a) and c) are true.

Question 2

Answer: d).

Question 3

Answer: c) and d) are false. Aluminium is an example of a metal that is protected by its corrosion products but many other metals are not. Aluminium will not be protected if the corrosion layer is broken. The breaking and re-forming of bonds in molecules, processes which are part of chemical deterioration, can have significant effects on colour changes, both fading and staining. Chemical deterioration causes these changes.

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