International Institute for Conservation of Historic and Artistic Works

IIC-ITCC 2015 TRAINING PROGRAMME
Scientific Approaches to Preventive Conservation

Biological agents of deterioration

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Photos: ISIS in Mosul Museum [http://www.thetimes.co.uk/tto/news/world/middleeast/article4366431.ece].
Rat in NE England [http://www.chroniclelive.co.uk/news/north-east-news/councils-north-east-hit-top-6145452].
Moth and larva attack on feather [C V Horie],
Dry rot [http://www.smnf.fr/Photos_SMNF/Photos_SMNF_S/Textes_S2/Serpula_lacrymans.htm]

Topics

- Agents of deterioration
- Occurrence and growth
- Effects on objects
- Integrated “Pest” Management

Agents

- People
- Other mammals, particularly rodents
- Birds
- Insects
- Invertebrates other
- Plants
- Fungi
- Bacteria

People

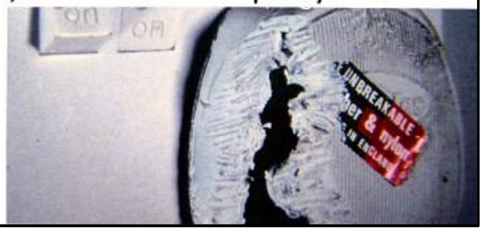
- Direct damage
  - Theft
  - Vandalism
  - Handling
- Indirect damage
  - Neglect
  - Misuse
  - Losing documentation
- Measures:
  - Collection care: Each country is developing its own methods to promote increasing standards of collection care . The UK has recently created formal (PAS197:2009 2009) and informal documents for professional use (Hillhouse 2009) (Cronyn 2006). Other countries are developing comparable guidance documents (CCI 2015).
  - There are other major problems such as illicit trade in heritage (Brodie and Renfrew 2005) and war (ICBS 2015).

Photos: Fingers wiped against polished furniture, which then attracts dirt. Fingerprints causing corrosion on a brass candlestick [https://ellencarrlee.wordpress.com/2009/11/21/polishing-liturgical-brass/].
Bubblewrap causing corrosion on a silver tray [C V Horie].
Corrosion under label of archaeological bronze buckle [C V Horie].

Brodie, N. and C. Renfrew (2005). " Looting and the world's archaeological heritage: the inadequate response." Annual Review of Anthropology **34**: 43-61.
CCI (2015). Framework for Preserving Heritage Collections C. C. Institute. Ottawa.
Cronyn, J., Ed. (2006). The National Trust Manual of Housekeeping : the care of collections in historic houses open to the public. London, Elsevier/ Butterworth-Heinemann.
Hillhouse, S. (2009). Collections Management: A practical guide. London, Collections Trust.
ICBS. (2015). "International Committee of the Blue Shield." 2015, from http://icom.museum/programmes/museums-emergency-programme/international-committee-of-the-blue-shield/.
PAS197:2009 (2009). Code of practice for cultural collections management. London, British Standards Institution.

Mammals

Of the mammals, rodents are the most common pests of cultural materials. Mice and rats live happily where people live. They make nests in undisturbed places, creating runs in covered places, opening up and investigating routes by gnawing through the structure, objects etc when most of the damage is done. The rodents are omnivores so will eat many of the organic objects in collections, then breed rapidly.



Photos: mice and rat damage. {Pinniger, 2008 #7793}

Birds (including bats)

- Mostly indirect damage
- Birds in the main do not directly damage cultural heritage, but their activities and parasites do.
- While perching on buildings and sculpture, they deposit acidic excreta causing significant soiling. Copper is corroded {Bernardi, 2009 #7798}, while fungi colonise the excreta and the acids produced dissolve the stone {Bassi, 1976 #7797}.
- Their parasites that cause the greatest problems to collections. Birds and their nests support an ecosystem of protein (e.g. feather) eating insects. These insects easily migrate into buildings and collection spaces, where they eat and damage objects.

Photos: James Watt with pigeon [http://www.birminghammail.co.uk/news/local-news/decaying-statue-of-james-watt-dismays-392018]
Bird nest debris in chimney [English Heritage]

Insects and other crawling/ flying invertebrates

- Insect infestations cause major destruction of cultural property.
- Larval stages of the insects cause the damage when feeding, building up resources to create the next generation. From egg to adult can take many years of feeding.
- Flying or crawling adults become visible when looking for a mate or a place to lay eggs. But they show that damage has already been done.
- Insects eat organic materials, so objects made of plant and animal products are vulnerable.
- Protein eating insects, e.g. moth and carpet beetles, eat and digest the wool, feather silk and skins. They thrive better in higher humidity and on soiled objects which provide other nutrients.

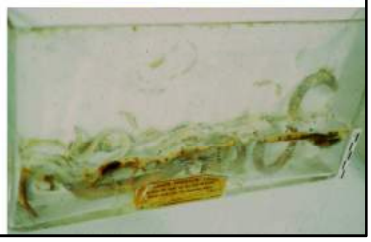
Photos: [Biology Curators Group v.1 (8) (1978)]. Asian termites [http://www.dailymail.co.uk/sciencetech/article-3012118/Termite-species-mix-Florida-reproducing-breakneck-rate.html].
Dermestid attack on insect collection [C V Horie]

- Cellulose based materials do not provide much useful food, so many insects living on plant based materials rely on fungi to degrade the substrate to chemicals they can digest.
- Woodworm *Anobium punctatum* causes damage by tunnelling through wood. It thrives better in wood that partly degraded by fungi {Bletchly, 1953 #7821} which grow in high humidities.
- Silverfish *Lepisma saccarina* graze on paper, again when damp.
- The species active in a local climate and geography have been specific to the area. But increasing international transport has introduced many new pest species which are attacking cultural property.

Photos: Woodworm damaged wooden foot [J Kitchen]. Silver fish [Central Science Laboratory], Damage to paper caused by silver fish [D Pinniger]

Plants

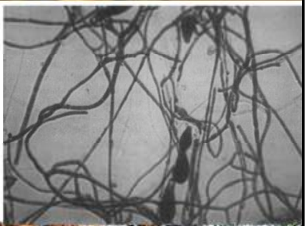
- Plants can range in size from single celled algae to mighty trees {Caneva, 2009 #7815}. Vascular plants, i.e. those with roots, grow upwards towards light and air, while their roots grow into the substrate to extract water and nutrients. It is largely the expansion of penetrating roots as they grow that causes the damage to monuments and archaeological sites.
- The small algae (and cyanobacteria) grow in water and air. These green algae are a major problem growing on damp masonry where they are disfiguring and assist in the colonisation by other plants, lichens etc. During the storage/treatment of water-logged archaeological objects algal blooms can develop which are unsightly and can interfere with the penetration of treatment chemicals.



Photos: Tree colonising a temple at angkor wat ta prohm temple [http://www.dreamstime.com/royalty-free-stock-image-ta-prohm-temple-angkor-wat-cambodia-image18330036].
Moss on tombstone (UK) [http://debsdustbunny.blogspot.co.uk/2014/04/visiting-ancient-ancestors.html].
Algal growth in neglected spirit specimen [C V Horie]

Fungi

- Fungi grow absorbing by soluble organic chemicals from the environment.
- Damaging fungi secrete enzymes which degrade and solubilise the substrate, which is then absorbed as food. Thus the substrate is weakened destroyed.
- The bulk of fungi are small causing local, but serious, corrosion on paper, stone etc.
- Larger fungi form extensive fibrous mycelium mats which penetrate, especially through wood, dissolving the cellulose, the lignin, or both. The fungi eventually produce fruiting bodies that give off spores, frequently coloured - such as the black spots on stone. Because fungi rely on solutions to excrete and absorb the chemicals, they need high humidities to grow. An exception is “Dry Rot” *Serpula lacrymans* whose mycelium is able to transport water from damp to dry areas.



Photos: Mouldy books [http://inspectapedia.com/mold/Moldy_Books_024_DJFs.jpg].
Altemaria sp. Fungi on marble {Diakumaku, 1995 #7817}.
Serpula lacrymans
[http://www.helsinki.fi/ajankohtaista/uutisarkisto/images/teksti_lahottajasieni.jpg]

Lichens

- A lichen is a symbiotic organism between a fungus and an alga. Lichens cause a small amount of damage directly to a substrate by producing organic acids.
- They form colonies on the surface providing foothold for other plants. In the process, considerable aesthetic change occurs.

Photo: Tombstone with lichens [http://debsdustbunny.blogspot.co.uk/2014/04/visiting-ancient-ancestors.html]

Bacteria

- Bacteria grow in wet conditions where there are nutrients. There are many types, some of which create acidity and assist in dissolving ions form stone etc.
- They can exude a polymers which help to hold them on the surface and form slimy coating, which can also be protective {Warscheid, 2009 #7825}. When storing waterlogged wood and similar materials, the slime becomes inconvenient by interfering with treatment and as a support for infestation by other microorganisms.

Photos: Cyanobacteria on temple at Angkor Wat [http://www.nytimes.com/2008/06/24/science/24micr.html?ref=science]. Halophilic bacteria in Austria [{Sterflinger, 2013 #7802}]

Tackling Biodeterioration

- All types of object can be biodeteriorate - severely, quickly.
- Some biodeterioration is obvious but much occurs out of sight.
- It is frequently spotted by accident.
- Better to plan to prevent than having to react to a crisis.
- So imagine that you are an organism who wants a free meal and a home in your museum.
- How would you get in and what would you eat? What would you describe as a good “home”?
- After the next slide, I shall ask each group for 4 answers.

Photos: Tree in Cambodia [Татьяна Неверко https://www.pinterest.com/pin/119415827594237762/]. Mummy foot with mould [C V Horie]

Knowing your

- Collection
- Building/ location
- Pests
- Environment
- Activities

Photo: Antelope stored in poor conditions [C V Horie]

Knowing your

- Collection
- Building/ location
- Pests
- Environment
- Activities

Photo: leaking downspout [C V Horie]

Knowing your

- Collection
- Building/ location
- Pests
- Environment
- Activities

Photo: Moth attack on pigeon wing on display [C V Horie]

Knowing your

- Collection
- Building/ location
- Pests
- Environment
- Activities

Photo: A school group in the museum hall, carrying their lunch boxes [C V Horie]

- Imagine that you are an organism who wants a free meal and a home in your museum.
- How would you get in and what would you eat? What would you describe as a good "home"?

- Each group should choose one organism and describe how it would be helped by the following factors:

- Collection
- Building/ location
- Pests
- Activities

Your answers are . . .

How do you assess the risks - Factors?

- What parts of the collection are most at risk?
- What parts of the building are most at risk?
- What activities provide an opportunity for attack?

How do you assess the risks? Assumptions

- Assessing risk is iterative.
- You start with a list of assumptions, test the presumed risks against reality, then construct a new list of risks.
- Because reality keeps changing, so must your testing of your (past) assumptions.
- And you need to document your findings at each stage.

How do you assess the risks? Knowledge gathering

- Initially carry out a bench exercise, gathering together your existing knowledge.
- A building plan is a good start. But these rarely show service ducts, and almost never show roof spaces or plumbing.
- What collections are in what spaces in the building? Remember that it is the materials, not the curatorial subjects that are eaten.
- What activities happen in what spaces in the building? Eating, drainage, object movements etc need to be understood.

How do you assess the risks?
Survey the site

- The first survey will check and update existing knowledge.
- With limited resources, you need to prioritise risks you discover; from high to low risk.
- Each time an observation is made, it will be recorded in a growing body of data. Isolated observations may not be significant but repeated observations, say every April, would be.
- A recording template needs to be set up and revised as necessary.

Biodeterioration monitoring sheet

Recorder . . . . Date yyyy/mm/dd _ _ _ _/_ _/_ _

severity of risk: **H**igh; **M**oderate; **L**ow; **V**ery low

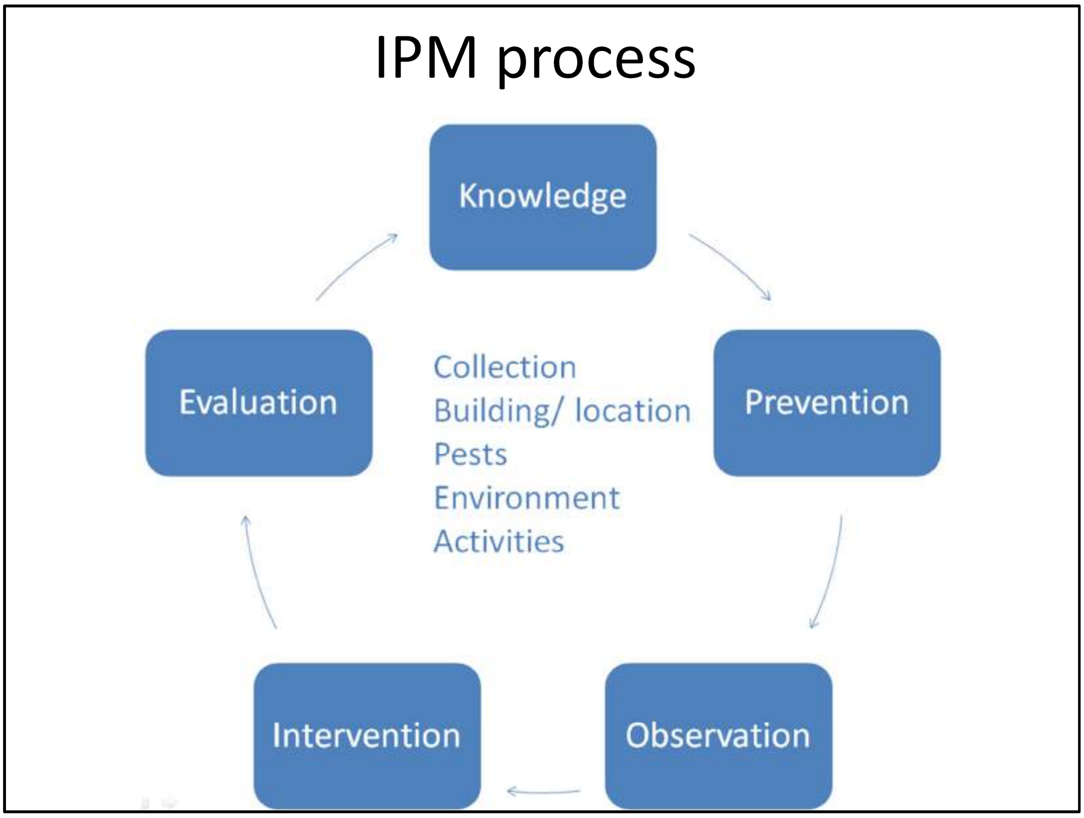
Room/ Location	material at risk	type of risk	Severity H,M,L,V	?active deterioration	?monitoring in place	recommended action

Each person will have one of these sheets to fill in tomorrow as you go round the Palace Museum. The members of each group will then combine their findings to report back on Thursday morning.

The Jade Garden Hotel has thoughtfully provided a torch so that you can investigate the dark places of the Palace Museum.

Integrated Pest Management IPM

- These are the first steps in IPM.
- IPM was initially developed in agriculture, when it was found that hitting a pest outbreak with a massive amount of poison frequently had major bad side effects, including not controlling the pest long term.
- The “pests” do not normally include plants and bacteria, but the same concepts can be used to address these risks.



Pinniger, D. (2015). Integrated Pest Management for Cultural Heritage. London, Archetype Publications.

IPM - insects

- Insects (and fungi) are the most commonly encountered pests.
- The tools and understanding for controlling insect infestations are the most developed so will be used as an illustration of what can be achieved with other agents of biodeterioration.
- The aim of IPM is to start with and maintain a collection free from damaging insects.

Insects

- Damaging insects are all around us in the external environment.
- They can (and often do) easily drift into collection areas.
- Insects can fly or crawl from the surrounding environment, or be brought in on contaminated objects, building materials etc.

Know your insects

- Because insects are of commercial importance, there are useful reference works available printed and on-line.
- Many insects are harmless for collections, and blunder into buildings. However they look similar to pest species
- There are hundreds of potential insect pests.
- Local insect pests are peculiar to the area, so one needs to use reference works designed for the area.
- [Collection Trust (UK)](http://www.collectionstrust.org.uk/collections-link/risk-management/pest-management/item/2154-pest-fact-sheets-1-12)

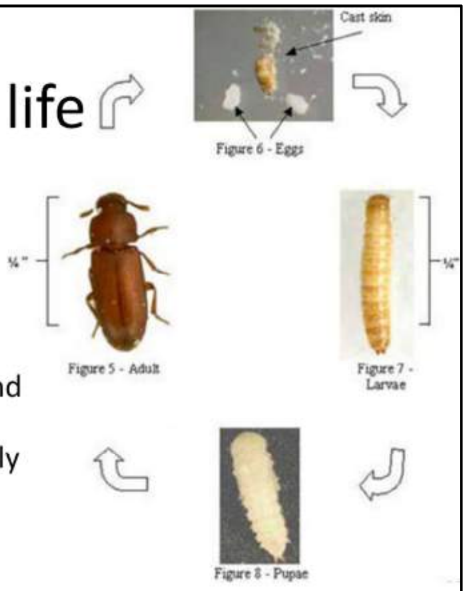
  http://www.collectionstrust.org.uk/collections-link/risk-management/pest-management/item/2154-pest-fact-sheets-1-12
- U of Illinois Library

Odd beetle *Thylodrias contractus*

Beetle, Rove *Staphylinidae*

Photos: Odd Beetle [http://www.dermestidae.com/Thylodriascontractus.html]. Rove beetle [http://www.dereila.ca/whispers/beetles2.html].

Insects- their way of life



- The life cycle of insects determines where and when you are likely to see them.
- The female adult lays the eggs on a suitable nutritional substrate.
- The eggs hatch into larvae and feed and grow.
- They larvae then pupate and eventually emerge as adults.
- The adults mate, and the cycle begins again.
- The details of this cycle determine at what stage a preventative conservator can make a useful intervention.
- Insects thrive better in damp conditions.

flour beetle *Tribolium* sp

Photo: flour beetle
[http://entnemdept.ufl.edu/creatures/urban/beetles/red_flour_beetle.htm]

Insects – what do they eat?

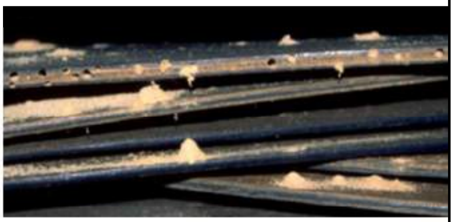
- Protein
  - Fur
  - Feather
  - Wool
  - Skin
  - Leather
  - Insects
- Carbohydrate
  - Dried plants and food
  - Paper
  - Wood

Insects how to find them

- Insects don’t like being found. So they hide in dark, undisturbed, places.
  - Under furniture, carpets, folded textiles.
  - Within objects such as wood or upholstery or taxidermy.
- The adult insects emerge when it is likely that other adults are also emerging. Woodworm emerges in spring/early summer. Moths emerge in warm weather (this could be whey the heating is switched on).
- The larvae of grazing insects such as moth or dermestid are frequently active on the (hidden) surfaces of an object, which is why lifting a carpet is usually so revealing.

Pest activity

- Insects are also seen by their effects, such as:
- Holes in objects
- Frass, i.e. their droppings
- Pupal cases, wings
- Flying or dead insects



Woodworm *Anobium punctatum*

Case-bearing clothes moth *Tinea pellionella*

Cluster fly *Pollenia rudis*

Photos: Woodworm [D Pinniger]. Case-bearing clothes moth [Pest Fact sheet No 5 Case-bearing clothes moth, Collection Link]. Cluster flies [D Pinniger]

Identification

- Each pest has its own favoured food source and environment.
- Each pest has its own way to be identified and controlled.
- A number of good guides are available for amateur use. However, it is not easy to use a picture for identification.
- A good entomologist is often needed to confirm an identification.
- Increasingly, alien insects are being found because global warming and transportation enable their introduction. These probably are not included in the conservation literature.

What is the problem

- How bad is the problem?
- Where is the problem?
- Where does it come from?

How do you assess the problem? Walk the site

- Rarely can you answer all this by yourself.
- You need help and knowledge from other workers in the museum.
- As you investigate the site, involve and ask questions of colleagues.
- Collection
- Building/ location
- Pests
- Activities

How do you assess the problem? Who can add knowledge?

- Which colleagues could help to add knowledge and test your assumptions?
- Each group will consider one factor and list 3 (or more) people who could add depth to the survey:
- Collection
- Building/ location
- Pests
- Activities

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Your answers are . . .

Preliminary data analysis

- You have gathered data from people who observe in the museum.
- You have collected samples of the insects spotted then identified them.
- You have documented this data: what, where, when.
- You have plotted the data on the building plan.
- You have identified any places or time where you have no observations.

Quantification

- The data should guide you to categorise the areas into high, moderate, low and very low risk.
- There are some areas that are always of high risk:
  - Eating
  - Waste collection
  - Educational handling
  - Case construction areas.

Traps

- Insect traps are used to catch and hold insects so they can be identified.
- The cheapest ones are sticky traps that catch insects that blunder into them.
- These catch primarily crawling insects that move from place to place. They are less effective in catching flying insects.
- One can use lures in the trap to attract insects into the trap.
- A more targeted method is to use a pheromone which attracts a specific male insect. These are then caught on a sticky trap. These traps are considerably more expensive.

These are available from conservation suppliers, such as Preservation Equipment Ltd, UK

Use of traps

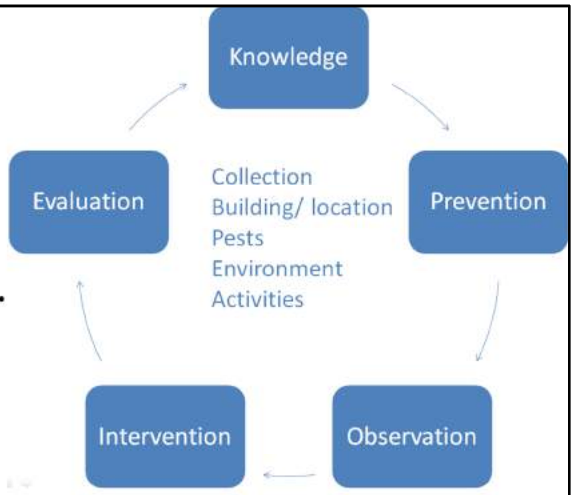
- Like light and RH measurements, a single reading is not very diagnostic.
- One needs to show trends over time, perhaps a year, in order to gauge the problem and its size. This requires a longitudinal campaign of placing traps and analysing the insects caught.
- In the UK, we have to lay and check traps at least 4 times a year, March, June, September, December, in order to identify the seasonal trends. This pattern must be adjusted to suit the climate and habits of the endemic pest species
- Similarly to show narrow down the likely activity of the infestation across a building, you need to use traps in and around the high risk area.
- Traps are a useful addition to regular inspections, but not a substitute.
- Your colleagues, and visitors, who have the interest to be aware of pests and have been trained to report these, are an essential source of information.

What will this tell you?

- The surveys, augmented by traps, builds up your database of insect activity and risk.
- What pests are present,
- Have the numbers increased,
- Where have they increased, and have they moved,
- If there been a recent infestation related to the season,
- If there is a sudden increase in one area,
- If a control measure failed.
- Do you need to do more, or less, monitoring? It can be very expensive in time and materials to monitor.

Prevention

- So far, you have gathered knowledge.
- How are you going to apply these new insights into your previously unseen enemies?



Preventing pests

- Even the newest, most tightly closed, building has plenty of holes that these small insects can crawl through.
- One must assume that some insects will penetrate the outer defences.
- For these invading insects to thrive and breed, they need food, warmth, humidity and an undisturbed place. Not dissimilar from humans.

Food

- Human food remains are valuable to insects.
- Any remnants in food storage, preparation, eating and disposal areas will act as a magnet to the adventurous pests. These can then breed and move out into the rest of the building – and collection.
- This applies to all food: visitors wandering around galleries or staff drinking coffee at desks.
- Functions involving food close to collections (horizontally or vertically) should finish with thorough cleaning before closing the museum. Pests do not know about overtime.

Dirt

- Insects like clutter to hide in, and organic dirt is usually a food source.
- Most public areas are visible and are easily kept clean, as seen by the assiduous work by sweepers on Chinese streets.
- Less frequented and visible spaces tend to accumulate clutter, dust etc. Inaccessible places are behind display cases, in closed service ducts, at the back of cupboards etc. The least accessible ones are deliberately closed chimneys , roofs and between floors.

Photo: Bird nest debris [English Heritage]

Cleaning

- Removing the clutter, dust etc removes two elements of their requirements, and reveals the surfaces they need to walk or fly over.
- One should design rooms and equipment that are easy to clean and find dirt. Storage cabinets can be constructed to be insect proof.
- Collection areas and those near to them in any direction should be cleaned regularly. Removing dust by vacuuming is better than moving it around with a wet mop.
- The collection storage cabinets should be periodically emptied, cleaned and the objects repacked using clean packaging material that is not a food source.
- Chimneys, service ducts and similar should be deep cleaned every few years to catch any unobserved accumulated dirt, dust, dead birds etc.

Temperature

- Insects slow down when cold and speed up when warm, especially their breeding.
- Below 20°C, breeding is less likely. At 25°C, growth and breeding is much faster.
- Cool storage conditions (including display) will reduce the speed and likelihood of infestation.

Humidity

- Although many insects can survive in a low humidity, most prefer higher levels.
- Some such as silverfish need high humidity >70%RH and furniture beetle >60% to breed.
- But the biscuit beetle breed at <60%, though more rapidly above this.
- Keeping a low humidity will reduce the rate of attack, but not eliminate it.
- High humidity in areas, such as by outside walls or leaking pipes, will encourage pest growth.

Anobium punctatum

Stegobium paniceum

Photos: woodworm [http://www.completepestcontrol.co.uk/furniture-beetle-control.php] . Biscuit beetle [https://commons.wikimedia.org/wiki/File:Stegobium.paniceum.jpg]

Housing for insects

- Pests will hide and develop in undisturbed places.
  - Ducts
  - Cavity walls,
  - Cracks between floorboards
  - Neglected rooms
  - Under/behind large objects and cases
  - Within felt case seals
  - Discarded material still hanging around
  - Flowers and plants
  - Cracks and gaps in storage furniture
  - Carpets (especially wool) are a bad idea

Quarantine

- The Museum was given a collection of leather objects collected by an academic in Ethiopia. After a couple of months on display, it was put into a crowded store. 2 years later, the store had a bad infestation of larder beetle.
- Objects coming into the museum, even from other “reputable” museums, must be treated as suspect.
- They should be inspected closely

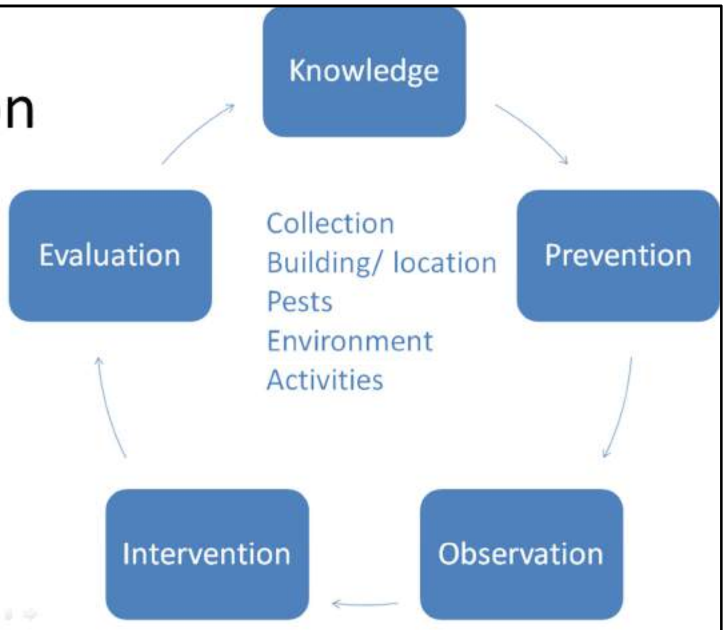
Dermestes lardarius

Photo: Larder beetle [https://commons.wikimedia.org/wiki/File:Larder_beetle_grub.jpg]

Keeping pests out

- New buildings should be designed for insect resistant openings, whether for people or air or services.
- Old buildings are much more difficult to insect proof.
- Good maintenance is the first step, making sure that deteriorating doors, windows, walls, ceilings, floors are well sealed.
- Retrofitting insect proof seals around doors etc should be carried out with respect to the fabric and aesthetically acceptable.
- Vegetation (which frequently houses pests) should be cut back at least 3m away from the building.

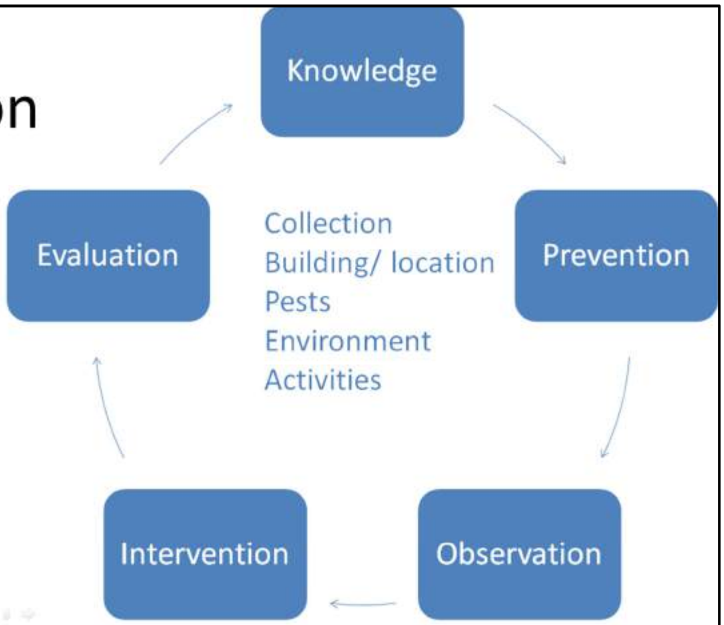
Observation



Continue with the survey

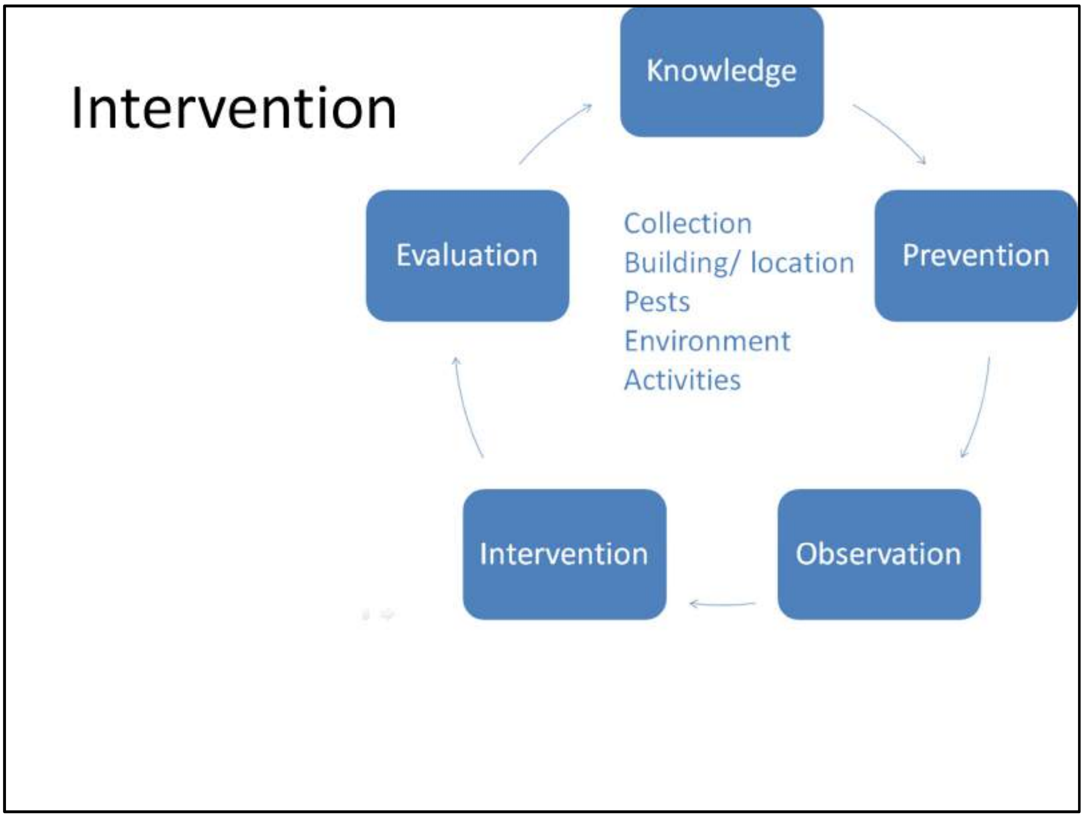
- While this prevention work is being planned, funded and carried out, the monitoring of the building and collection will continue.
- It is common that the work will disturb pest colonies that have been secure and content in hiding. The survey may reveal a sudden increase of infestation. Not an easy message to sell to the boss.

Intervention



Isolation

- Objects or cabinets etc that are found to be infested should not be moved until they have been bagged in a insect resistant plastic.
- Most insects can chew through plastic sheet, especially at mating time, so subsequent decisions may have to be prompt.
- The area around the contamination should be cleaned and contaminated material disposed of, outside the museum – preferably burnt.
- Objects that are suspect, such as loan items, should also be isolated until no infestation is proved.


Intervention
Knowledge
Evaluation
Prevention
Collection
Building/ location
Pests
Environment
Activities
Intervention
Observation

Treating objects

- The methods and materials for killing insects have changed markedly in recent decades.
- Most new methods have far less potential effects on the materials of the object.
- Physical methods, cold or hot.
- Chemical methods, poisons and other interference with the metabolism.

Physical methods - cold

- Low temperatures will kill insect eggs, larvae and adults. The internal temperature has to be reduced to -30°C for 3 days for a reliable kill, as some insects are more resistant to cold.
- The object should be wrapped in two layers when bagged to prevent internal condensation when cooling. Then allowed to warm up slowly to room temperature before opening.
- A commercial freezer is need to achieve these temperatures.
- There are some objects, such as plastics, that may be harmed during the change in properties.

Bergh, J.-E., K.-M. V. Jensen, et al. (2006). "A contribution to standards for freezing as a pest control method for museums." Collection forum **21**(1-2): 117-125.
Ishizaki, T. (2003). "Experimental study of physical effects of the freezing method for insect control on artefact materials." AICCM bulletin **28**: 62-66.
Strang, T. J. K. (1997). Controlling Insect Pests with Low Temperature. C. C. Institute. Ottawa.

Physical methods -hot

- Most pest insects will be killed by heating to 52°C.
- Parching grain over a fire was an ancient technique for preservation.
- For humidity sensitive objects, this is done commercially in the ThermoLignum process, though it can be carried out in an oven if properly bagged.
- Home made ovens have been constructed using solar heating for de-infesting objects in the tropics

Brokerhof, A2002 Solarisation: A cheap but effective method to disinfest museum objects In: Pre-prints of the ICOM Committee for Conservation, 13th Triennial Meeting, Rio de Janeiro, 22-27 September 2002, vol I 15-20. International Council of Museums, James and James London

http://www.thermolignum.com/home/

Asphixiants

- Insects need oxygen though some, such as wood worm, need less.
- Carbon dioxide: Exposure ≥ 60% carbon dioxide for 3+ weeks has been shown to be effective to kill all stages. However, maintaining these levels needs special gas tight plastic bags and sealing.
- Nitrogen: Exposure ≥ 99.7% nitrogen for 3-5 weeks has been shown to be effective to kill all stages. However, maintaining these levels needs even more special gas tight plastic bags and sealing.

Selwitz, C. and S. Maekawa (1998). Inert Gases in the Control of Museum Insect Pests. Los Angeles, Getty Conservation Institute.

Fumigants

- Both methyl bromide and ethylene oxide were commonly used fumigants in the past. However, methyl bromide has been show to be an ozone depleting chemical so has been banned. Ethylene oxide too flammable for widespread use.
- Phosphine is still used for some textiles and natural history collections.

Kigawa, R., T. Strang, et al. (2011). "Investigation of Effects of Fumigants on Proteinaceous Components of Museum Objects (Muscle, Animal Glue and Silk) in Comparison with Other Non-chemical Pest Eradicating Measures." Studies in conservation **56**(3): 191-215.

Health and Safety

- All the treatments described need to be carried out by trained and experienced workers. In the UK and other countries, a government license is needed.
- Pests have been attacking museum specimens since they were first collected, which is why the preserved dodo did not survive.
- People have been using the available toxic chemicals to prevent or control pests.

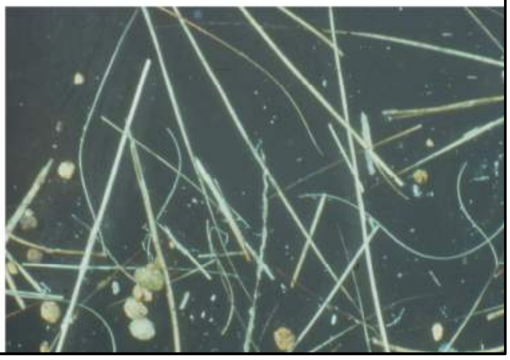
Poisons

- As an example, arsenic soap was a traditional and effective curing agent for taxidermy skins. Arsenic trioxide was brushed into fur and feather and prevented insect attack, except at the ends which were grazed by fool hardy insects.
- At The Manchester Museum arsenic oxide stopped being applied in the 1950s in favour of DDT, which was sprayed on annually.

A nineteenth century bison needed cleaning.

The dirt, arsenic, DDT and broken hairs being blown away. The hair collapsed to a mush when it became wet.

Sample of the hair. The nodules of DDT are attached to the hair, with small flecks of arsenic oxide and dirt.
The hairs have been degraded by light damage, and possibly hydrochloric acid from degraded DDT.



Pesticide treatments

- All treatments of objects should be recorded in the object record, especially those using persistent treatments but also including the use of asphixiants.
- Pesticide treatments may conflict with the values of the cultures creating the object. Both the application and remediation of such objects may need to be negotiated with the current members of the culture.
- Many pesticide treatments in the past were not recorded, so the object will need to be tested for toxic chemicals.
- Examples of past insecticides include : mercuric chloride (especially on herbarium sheets); lindane; borax

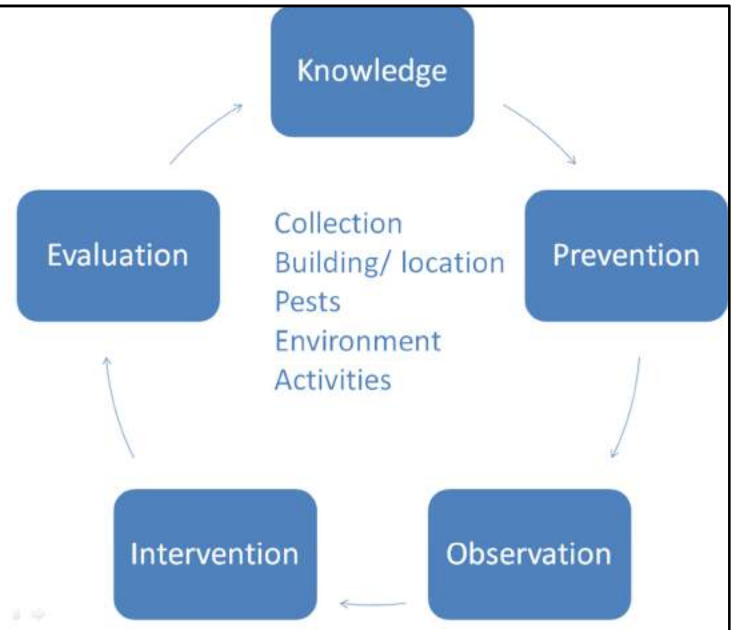
Clavir, M. (1999). Museum changes to First Nations objects, and their physical and conceptual reversibility. Reversibility-does it exist? W. A. Oddy and S. Carroll, British Museum**:** 169-172.

Treating the surroundings

- Insects live where it is difficult to get to.
- It is unwise to place materials toxic to humans in spaces where unsuspecting workers may go in the future.
- For grazing insects, there are some low (human) toxicity insecticides: dessiccant powders that kill by dehydration; pyrethroids and carbamates that attack their nervous system.
- These pesticides need to be placed where insects will crawl or land, in all the dead spaces, under coverings, in cracks etc.
- Timber boring insects cannot be controlled with surface treatments, because many do not eat when emerging. Penetrating insecticides, usually persistent ones, need to be injected into the wood.
- There are a large number of traditional materials used e.g. lavender oil; cedarwood, sandalwood
- Biological control is also possible. Spiders are traditional predators for insects but are not efficient. Most predators need a good population of pests to survive.

Agrawal, O. P. (2013). "Appropriate" Indian technology for the conservation of museum collections (1981). Historical perspectives on preventive conservation. S. Staniforth. Los Angeles
California
United States, The Getty Conservation Institute: 42-49.
Brennan, J. M., N. Pianprasankit, et al. (2014). Before they are gone: capturing and sharing the traditional methods of textile preservation in Thailand. ICOM-CC 17th triennial conference Melbourne 15-19 September 2014: preprints. J. Bridgland. Paris
France, ICOM Committee for Conservation.
Jin, Y.-h. and X.-c. Li (2013). "A preliminary study on reconstruction of yinghuang (hard yellow) paper with hot wax graft)." Wen wu bao hu yu kao gu ke xue **25**(3): 20-24.

Evaluation


Knowledge
Prevention
Observation
Intervention
Evaluation
Collection
Building/ location
Pests
Environment
Activities

Evaluation

- Applying a treatment is not certain. Some insects will escape and continue breeding and feeding. New insects may replace the previous population.
- All the interventions and experience gained will feed into increased knowledge.
- IPM in an institution is part of ongoing maintenance. Neglecting this (like many other aspects of care) creates problems for the future.

Other agents - People

- Most people are respectful of cultural objects but need to be informed about the effect of their individual actions on the long term survival of the objects.
- This applies to politicians, managers, visitors, and museum staff.
- Engaging and involving them in the care of the objects can be difficult but frequently has long term benefits.

Other agents - Rodents

- The Palace Museum employs its cats.
- However, one needs to test the effectiveness of any treatment by independent trapping and evaluation.
- Rats and mice use hidden ways to move around the site, and often make use of discarded food remains. So cleanliness of the site, as seen here, helps to reduce its attractiveness.

Other agents – Birds and bats

- Birds create considerable soiling of roosts. If they find their way into structures, they can cause considerable damage internally. Bats in the UK are protected and a number of churches have been made unpleasant by the bats droppings.
- Birds are also associated with protein eating insects, which can easily migrate into museums.
- For both reasons, birds and their nests should be removed from on and around museums.

Other agents - Invertebrates

- Wood boring marine molluscs are often present in water logged wood objects on excavation. They continue their work in storage before conservation treatment.
- Gamma radiation was proposed to kill the pest to prevent further deterioration.

Jones, E. B. G., A. Pitman, et al. (1993). "New storage and conservation treatments of waterlogged Mary Rose timbers." Record of the annual convention of the British Wood Preserving and Damp-Proofing Association(44): 37-44.
Pitman, A. J., A. M. Jones, et al. (1993). "The wharf-borer Nacerdes melanura L., a threat to stored archaeological timbers." Studies in conservation **38**(4): 274-284.
Pournou, A., A. M. Jones, et al. (1999). In situ protection of the Zakynthos wreck. Proceedings of the 7th ICOM-CC Working Group on Wet Organic Archaeological Materials conference = Actes de la 7ème Conférence du Group de travail Matériaux archéologiques organiques humides de l'ICOM-CC: ICOM-CC WOAM 98: Grenoble, France 1998. C. Bonnot, X. Hiron, Q. K. Tran and P. Hoffmann. Grenoble France, Atelier régional de conservation-Nucléart. CEA/Grenoble**:** 58-64.

Other agents – Plants

- Picturesque
- Grass growing in between tiles on rood at Palace Museum
- These destroy the mortar, allowing water into the underlying timber and cause decay.

Photos: Trees growing in the remains of Llanphor 1777 P.Sandby [C V Horie]. Grass growing in roofs at Palace Museum Beijing [C V Horie].

Bacteria

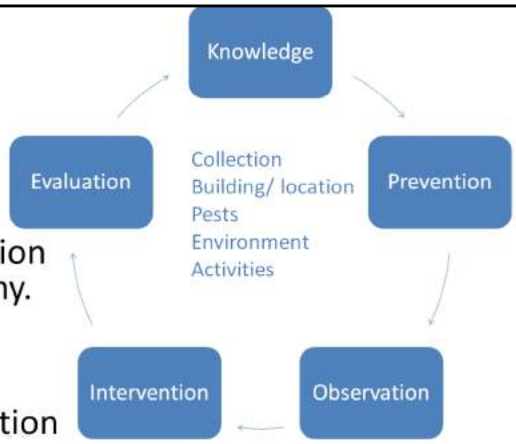
- These cyanobacteria and algae grow in damp conditions and can be removed temporarily by washing (Sterflinger and Piñar 2013). However, they will regrow unless the underlying dampness is removed.
- Bacterial growth in waterlogged wood storage can be tackled using snails which graze on the slime, but do not affect the wood (Jones, Mouzouras et al. 2003).

Photo: Green algal and cyanobacterial stains on mortar surfaces

Jones, A. M., R. Mouzouras, et al. (2003). Preserving the timbers of the Tudor warship Mary Rose. Art, Biology, and Conservation: Biodeterioration of Works of Art. R. J. Koestler, V. H. Koestler, A. E. Charola and F. Nieto-Fernandez. New York, Metropolitan Museum of Art: 28-49.

Sterflinger, K. and G. Piñar (2013). "Microbial deterioration of cultural heritage and works of art — tilting at windmills?" Applied Microbiology and Biotechnology **97**(22): 9637-9646.

IPM



- Dealing with biodeterioration means knowing your enemy.
- Preventing it taking hold.
- Keeping a constant watch
- Taking prompt effective action
- Working out what worked and didn’t
- Involving everyone who can contribute.

And don’t let it slip.