APPROACHES TO PEST MANAGEMENT IN MUSEUMS (1998)

by

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PREFACE

The following text is the edited transcript of the presentation at the Museum Support Center of the Smithsonian Institution on July 24th, 1998. This presentation formed the core of a one day course (Preservation Fundamentals III: Pests #C98-17) aimed at conservators, collection managers, pest control operators and others involved in protection of museum collections and libraries against pests. The object of this presentation was to provide a verbal update of the book "Approaches to Pest Management in Museums" published by the Smithsonian Institution in 1985. That book pioneered the concept of integrated pest management (IPM) for museums, advocating the use of combinations of chemical and non-chemical methods in programs customized for the particular situation.

This presentation reviews the latest information on the biology and damage potential of key museum pests and for each pest outlines possible control measures. The scope of the original book is extended by including warehouse beetles, odd beetles and spider beetles. The various chemical and non-chemical measures are reviewed, with particular emphasis on new technologies, including the successful use of atmospheric gas fumigations and the more problematic role of pheromone traps.

The integrated pest management approach is considered in detail from its agricultural origins to its successful adaptation for urban pest management. The continuing pest problems in some museums are attributed not to any intrinsic flaws in the IPM approach, nor to lack of overall funding, but to unsatisfactory communication between departments and failure to use existing manpower resources. Pest management in museums and libraries should be seen as part of overall preventive conservation efforts involving all departments working in multi-disciplinary teams against pests and conditions which favor pests.

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Keith Story, 1998.

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APPROACHES TO PEST MANAGEMENT IN MUSEUMS (1998)

A. INTRODUCTION

It gives me great pleasure to be back here at the Museum Support Center and to be part of a program of disseminating information to help protect collections in America and around the world. It is more than 12 years since I first lectured here at the MSC. In those days there were not many of us advocating preventive conservation through programs of integrated pest management. Instead, there was a preoccupation with seeking more effective or safer ways of killing pests after they had arrived. In particular, there was a search for better fumigants to replace ethylene oxide or dichlorvos (DDVP) and, following the Montreal Protocol, a search for alternatives to methyl bromide.

The search for better products to kill pests is ongoing, but most of these products are aimed at dealing with crises when they arise, and crisis management is not the best way forward. The best way forward is crisis avoidance and this involves integrated pest management or IPM.

I have been encouraged that, as a result of our efforts and the efforts of other individuals and organisations, the past 12 years have seen a massive growth in awareness of integrated pest management (IPM) in museums, libraries and private collections around the world. Wherever I go, I encounter people involved in conservation who not only have heard of IPM but have attended courses in America, Europe and Australia focusing on IPM in museums.

Today I am going to talk at length about common museum pests and about integrated pest management. I assume you are here because you want to learn more about this subject. Let me say at the outset that I may not tell you everything you want to know. But you will have opportunities to ask questions, and if I don't know the answer I have little doubt there is enough expertise among you for someone else to suggest an answer. We are all here to learn.

While I may not tell you everything you want to know, I may well tell you things you don't want to know, but need to know. I am an independent consultant and, while this meeting is sponsored by the Smithsonian Institution, I am under no constraints about what I can say. I will of course try to be polite! I will use some case histories to illustrate certain points but, as a general rule, unless the information is in the public domain, I will not mention the names of any particular collection. While sharing information is vital in our field, we should respect confidentiality, and if any of you recognise any situations I mention, I would be grateful if you don't reveal the location.

Many of you don't know me, so I'll say something of my background! I have travelled in four continents and I have experienced a lot of pest problems first hand. I have been stung by African bees in Africa; I provided consultation at a well-known nightclub in Paris where cockroaches emerged when they dimmed the lights for the floorshow; and in Czechoslovakia the bugs in my hotel room were electronic! I have learned a lot from my travels - for instance I now know I am illiterate in at least 12 languages! Despite language problems, there is one thing which unites the people of all countries - a respect and love for art, literature and cultural items, and for natural history collections. My motivation is the desire to protect these collections, not merely for my own pleasure but for future generations, and I want to help you do your work more effectively.

I collect art and antiques myself, and one of my greatest pleasures is viewing the great public and private collections around the world. But when I visit museums and stately homes as a member of the public (not for a consultation), my pleasure is diminished because I can't help noticing some of the weaknesses in their defenses against pests. Over the years I have learned to notice pests, and conditions which favor pests. So when I approach a museum, my eyes stray to the roofline, the ledges and eaves, looking for perching or nesting birds. I then scan the building looking for open, unscreened windows. As I get closer, I look at the landscaping and note foundation plantings that might encourage pests. As I get closer still, I look for unscreened wall vents or crevices around windows and doors. I also look at the exterior lighting to see if it might attract pests to the building. And as I enter the doors, I check the weatherstripping, sweeps or gaskets which might have gaps permitting pest entry.

When I get inside the building, my eyes stray from the pictures to the picture frames, looking for tell-tale holes. And from there I can't help checking the tops of dado rails or baseboards for signs of wood dust. When I walk around the museum I look at the lint in floor or wall registers. And I check the windowsills for emigrating dermestid beetles. When I look up I check the light diffusers for bodies of insects. I also note the shop areas and food areas, often surprised that there is no attempt to discourage pests from moving from these areas into the galleries. Up until this point I have just begun to arouse the interest of the gallery attendants or guards. When I start peering closely at flower arrangements to see if they are real flowers or silk flowers, the attendant starts to pay even closer attention. And when I kneel down and start looking at the floor of a display case, that's when I hear a voice saying "Can I help you, sir?" At which point I might ask if there is someone from the conservation department I might speak with.

Up until this time I have been in the "front-of-house" area accessible to the general public. When I go "backstage" with a conservator, I often see far more conditions conducive to pests, and I begin to wonder about the museum's commitment to pest management.

Again and again I ask myself the question: "Why is it that, despite high levels of knowledge about pest management and a wider choice of pest control materials than ever before, pest problems in museums are often at unnecessarily high levels? Many conservators I know have read much of the literature and attended pest management courses. But when I visit their museums I still see avoidable conditions which favor pests.

Should I conclude that the literature isn't providing good enough guidance? I don't think so. As long ago as 1985 my book (Approaches to Pest Management in Museums) summarized 12 pest management approaches, with a strong emphasis on IPM. Now, as mentioned, we have several new pest control products, better traps, more knowledge of using atmospheric gases, more books on museum pest control and more awareness of IPM.

If it isn't the books or the products at fault, should I conclude that the training courses on museum pest management are not good enough? That's a harder question to answer. Telling people about pest management measures is a waste of time if people don't implement those measures when they return to their museums and libraries. The most advanced new technology will never be a substitute for good motivation and good management.

The question of motivation is complex. Unless there is an understanding of the value of a collection throughout the organisation, and an understanding of the risks of pests, people will not be fully motivated to prevent pest problems. And unless management gives priority to "backstage" measures as much as "front-of-house" activities, museums and libraries will continue to experience an unnecessary level of losses from pests.

I would not suggest that any of you lack motivation regarding pest management. After all, you are here. But the real proof will be what you do after today. Every one of you can make a difference, and I would like each one of you during the course of today to think about one thing you will change or implement to reduce risks from pests at your location. If we have time at the end of today, I may ask each of you to tell us in one sentence what you are going to do first as a result of this seminar. And if what you do is a result of something you learned from a colleague in a coffee break, rather than something you learned from me, that will make it worthwhile being here. But we will all have failed if we learn nothing from anybody or if we do nothing about what we have learned.

In my discussions with museum personnel involved in pest management, I frequently hear reasons for not doing more to prevent pest problems. So far this year, senior conservators at 6 important museums have said to me: "WE DON'T HAVE ENOUGH MONEY." But is this the only obstacle, or even the main obstacle? I don't think so.

I often see opportunities for reducing pest problems that have no cost implications, or which will actually save money. Examples include:

* Removing foundation plantings and substituting gravel. In one example, I complimented the conservators on the gravel strip around the base of the museum and they said: "It was nothing to do with us, the landscaping department just did it to save money!"
* Eliminating displays of fresh flowers will save money.
* Banning food and drink from sensitive areas costs nothing.
* Rescheduling garbage collections, so that food is not available to pests overnight, may cost nothing.
* Closing windows costs nothing, but will help keep out flying pests, such as carpet beetles. Put up notices to remind people.

Other measures might incur short-term costs, but can result in longer term savings. Such measures might include:

* Fixing leaks to discourage moisture-loving pests.
* Clearing gutters and drains to remove habitat favoring pests.
* Sealing windows and installing shades or air-conditioning in ancillary areas such as administrative areas. [Be bold. If windows should be shut but are always being opened and are not an emergency exit, buy some superglue and seal them yourselves!]

At this stage I want to start opening your minds to the things you can do to reduce pest problems. And remember, you don't need to have an active infestation in the collection now to have a problem. If your collection is vulnerable to pests, it is only a matter of time before it is attacked, unless you take preventive action.

I accept that you may not be able to do everything you want to do, or everything I recommend. In the 18 years I have been an independent consultant I have only had one museum director who said to me when he called me in for consultation: "Money is no object." Mostly I find that there is not enough money being spent on pest prevention, but this does not mean there is an overall shortage of money. I could argue that while there is any money for emergency pest eradication measures, there should be money for preventing the emergency. The money spent on fumigation bubbles will pay for a lot of pest prevention!

I could also argue that while there is any budget for acquisitions there is money for pest prevention. After all, does it make sense to bring a new vulnerable item into an environment where it may be at greater risk than if it stayed where it was or went to another museum with better protection? As for benefactors, who in their right mind would knowingly donate money to a museum or library to purchase items they cannot protect? Likewise, who would knowingly leave their collections (whether it be fine art or a case of rare butterflies) to an organisation that cannot protect them for future generations to enjoy and study?

Resources may be limited, but it is a question of priorities. If there is a real commitment to protecting the collection, the resources can be found - indeed, they may already be there in terms of financial and human resources. If you proclaim the need to protect collections and your commitment and skill in doing this, so that you can give assurances that collections are safe in your hands, benefactors will beat a path to your door.

I will return later to this question of commitment and resources, but it is important to know that commitment is more important than resources. If you have both that is the ideal. This man, General Norman Schwarzkopf, had both the commitment and the resources to (and I quote): "Kick Saddam Hussein's butt out of Kuwait." He succeeded. The Allies convincingly won the Gulf War.

Now think of another war, the Vietnam War where an alliance with superior technology and massive resources fought against an enemy with fewer resources, low technology but high commitment. The side with the high level of commitment won!

Finally, another military example to illustrate the importance of commitment. The year, 1836. The event, the battle at San Jacinto for Texas independence from Mexico. The Texan force of poorly armed, mostly raw recruits led by Sam Houston were outnumbered by more than 2 to 1 by better armed, veteran Mexican soldiers, led by General Santa Anna. To underline his commitment Sam Houston ordered to be destroyed the bridge over Vince's Creek preventing escape from the battlefield for either the Mexican army or his own men. That's what I call real commitment! And then General

Houston ordered his men to attack. Never before had raw militia attacked a professional army of greater number who were positioned in a fortified camp. The battle was won by the Texans in only 15 minutes. In that time 630 Mexicans were killed, 208 were wounded and 730 captured. The Texans lost only 6 men killed and 25 wounded!

That's why I say commitment is more important than resources. But you need to know your enemy and you need to know how to kill them or discourage them. I am now going to talk about pests, their biology, damage potential and outline control measures. I will later talk in more detail about the various pest management measures, with a detailed discussion of IPM. We will then consider museum pest management for the next millenium, going beyond IPM to an even more comprehensive approach involving total museum management. This will relate to the teamwork approach to preventive conservation that has been trialled in Europe. Finally, we will consider further aspects of commitment to protecting collections, and why your work is so important to future generations.

At intervals through the day we will pause for questions and hopefully I, or others here, will have answers. When preparing for today's seminar, two quotations by famous people kept coming into my mind. The first was by Davy Crockett whose guiding philosophy was: "Make sure you are right, then go ahead." The second quotation was by the British playwright, Oscar Wilde, who said: "It is always a silly thing to give advice, but to give good advice is absolutely fatal."

Well, since I'm in America I'm going to ignore Oscar Wilde and take ol' Davy Crockett's advice and "go ahead".

B. BIOLOGY, DAMAGE POTENTIAL AND OUTLINE CONTROL MEASURES FOR KEY INSECT PESTS OF MUSEUMS

OVERVIEW & DEFINITION OF MUSEUM PESTS

It is important to recognise that there are no unique museum pests. Any creature capable of entering a museum from the outdoor environment, or introduced on materials brought from other buildings, is capable of becoming a pest.

Even people can be pests, and sometimes they are the most dangerous pests. At the caves of Lascaux in France, Ajanta in the Western Ghats of India, and in various Egyptian tombs, human visitors have so raised the humidity by their breathing that the wall paintings have suffered irreparable damage. As a result, access to visitors has had to be denied or severely restricted in the interests of conservation.

In England, two of the most serious cases of damage to historic buildings and their contents were caused by people. This private house at Uppark was totally gutted by a fire in 1989, caused by a careless roofer repairing lead flashing on the roof. When he had finished he didn't know he had left a roof timber smouldering, but in the night a fire burst out in the roof and spread to the whole house. It cost $65 million to restore the house.

Uppark was one of the most beautiful houses in England, whereas this home in Windsor is one of the largest in England. Once again a human visitor caused a fire by moving a lamp too close to draperies. About 100 rooms were destroyed and the cost of restoration was $60 million.

On a smaller scale, throughout the world, visitors cause damage to collections. Some of the worst offenders are participants in functions held at museums and libraries. Despite notices to the contrary, they smoke and drop ash on valuable oriental carpets, and they put their drinks glasses on precious furniture in galleries. Most conservators I speak with don't even know about this damage and even deny it happens. But when I speak with people who are present at these functions, they say it happens, and I have seen it happen, even here in Washington. When I challenge gallery attendants and ask why they don't stop such practices, they say it's very hard to tell someone such as a benefactor or a minister from a foreign government to stop smoking or to keep their glasses off the Chippendale cabinet!

In some cases the damage is deliberate, such as at this building where the occupant decided to dye a valuable red and gold colored Persian carpet bright green in order to provide a visual link with the grass outside. In my opinion it would have been better to install Astroturf in this room and give the Persian carpet to a museum that would care for it!

Today I am going to present information about insect pests of museums, but I will take questions on other pests such as rodents. Hundreds of different insects may become pests, many of which may not normally be thought of as serious museum pests, but which may directly or indirectly threaten some collections.

The most obvious direct threats are from feeding, and almost any pest with biting mouthparts is capable of harming some items in museums. Of particular importance, because of their feeding activities in museums, are clothes moths, carpet beetles and other dermestid beetles (such as hide beetles, Trogoderma beetles or odd beetles), cockroaches, crickets, furniture beetles, powder post beetles, silverfish and booklice.

In addition to feeding damage, direct damage can also be caused by excretions or secretions from these pests, as well as from other pests such as flies or spiders, which don't chew exhibits but may leave fecal spots on them. Even when they die, the decomposing insect body may exude acidic liquids which damage some surfaces.

Indirect threats from insects can be just as serious as feeding damage or staining. For instance, I was called in to develop an IPM program in a building where a cockroach had caused an electrical short circuit which resulted in a million dollar fire. Incidentally, the insurance company refused to pay out on the claim, on the grounds that the customer had contributed to the fire risk by failing to have an adequate program of pest control.

Another indirect threat can arise when otherwise harmless insects die and their bodies then provide sustenance to major pests such as carpet beetles. For instance, accumulations of dead insects such as cluster flies in hidden roof or wall voids can become reservoirs of scavenging carpet beetles ensuring constant reinvasion of collections unless measures are taken against these reservoirs. Similar problems arise when rodenticides are used to kill rodents. The rodents may die in inaccessible voids and become a feeding site for insect pests which then spread to the collection. That's why it is preferable to use traps for rodent control, because you will always be able to dispose of the body before it becomes a feeding and breeding site for insects.

Clearly it is important to be able to recognise insects commonly found in museums and to know something of their life cycles and feeding habits. This will help you know what threats they pose to your collections and how to approach controlling them. In general, pests should be discouraged by focusing on aspects of the building's structure, maintenance, management, and external and internal environment. Use of pesticides should be focused on the building surroundings and on interior structural surfaces, crevices and voids. Many pesticides can stain or corrode museum objects, so direct treatment should be avoided wherever possible.

CLOTHES MOTHS

There are 3 main species of clothes moth: the webbing clothes moth, the casemaking clothes moth and the carpet (or tapestry) moth.

(a) Appearance and Life Cycles

1. Webbing Clothes Moth (*Tineola bisselliella* (Hummel))

The webbing clothes moth is a small moth with whitish wings 6 to 8mm long and dark eyes and antennae. There are no spots on the wings and it has a golden head and body, with a mop of reddish golden hairs on its head. The webbing clothes moth is capable of living outdoors, the larvae scavenging in such places as nests of birds. Buildings can be invaded by crawling larvae or by running or flying adults. The life cycle of the webbing clothes moth indoors is as follows:

Eggs are oval, 1mm long and are laid singly, or in groups of two or more, among the threads of cloth, fastened by a gelatinous material which prevents easy dislodgement. A total of 30 to 160 eggs are laid, with an average of 40 to 50, in a period from one day to 3 weeks. Eggs are laid as readily on cotton and silk as on wool. Eggs hatch into larvae in 4 days to 3 weeks, averaging 4 to 10 days in warm conditions.

Larvae are white, active and feed almost immediately, often spinning silk tubes or webbing, incorporating fragments of the infested medium and feces as they move across the material. They molt 5 to 45 times, depending on the duration of the larval period, which ranges from 40 days to over 2 years. They reach a final length of about ½ inch/12mm and then spin a silk web in which they pupate.

Pupae: the pupation period ranges from 8 to 44 days, being shorter at higher temperatures.

Adults emerge throughout the year in heated buildings. Males are attracted to females by a pheromone released from the female's abdomen. They have non-functional mouthparts and therefore do not feed. They live up to 4 weeks, but are often not noticed because they avoid bright light. If you see moths flying around lights they are not clothes moths.

2. Casemaking Clothes Moth (*Tinea pellionella*)

The casemaking clothes moth is slightly smaller and darker than the webbing clothes moth, and it has spots on its wings. It has a similar life history to the webbing clothes moth except for the following:

* larvae spin a case of silk and interweave in it some of the fibers on which it is feeding. When the larva moves it drags its case with it, and it dies if removed from the case. It is this case that gives this species its name.
* unlike the webbing clothes moth, the casemaking clothes moth rarely spins a web on the material it is eating.
* when the larva is ready to pupate, it often leaves its food source and seeks crevices on walls or ceilings. In seeking a place to pupate the infestation may spread to previously uninfested areas. Pupation takes place within the larval case.

3. Carpet or Tapestry Moth (*Trichophaga tapetzella*(L.))

The carpet moth is slightly larger than the other two species. It has a white head and the first third of the forewing is black, the remainder being mottled white. It has a similar life history to the webbing clothes moth. It does not make a case but forms tunnels in the infested material, which it lines with silk and in which it may feed throughout the winter.

(b) Feeding Habits and Damage Potential

The webbing clothes moth is the most common moth causing damage to textiles, but the casemaking clothes moth and even rarer carpet moth also cause damage. Damage is done by the larvae as they feed with their chewing mouthparts.

Larvae (at least of the webbing clothes moth) cannot complete their development on clean woolen fabrics and this may explain their preference for stained areas, perhaps because of their need for Vitamin B or salts which are found in sweat and urine.

Clothes moths have been reported to feed on furs, uncleaned skeletons, mammal and bird carcasses and skins, insect specimens, raw wool, beef meal, fish meal, casein, milk products, fingernail clippings, animal bristle brushes, carpets, woolen clothes, blankets, upholstery, stored yarn, piano felts, felts in display cases, hair filling of chairs and accumulations of lint.

Clothes moths and other tineid moths do not appear to feed on silk because they lack the enzymes required to hydrolyse the proteins found in silk (viz. fibroin and sericin).

Clothes moth larvae do not digest plant products, but as a result of exploratory feeding, or when plant fibers are coated with sizing or other attractants, they can damage cotton, linen and even paper. In these cases, as with animal fiber products, holes are eaten in the material. In fabrics made of mixtures of wool and synthetics, the synthetic fibers are also chewed, including nylon, Dynel, Dacron, Orlon, rayon, etc. These synthetics pass unchanged through the larval gut.

In severe infestations, dead moths and larvae can be an important food source. Sand-like particles on or below the larval feeding site are one of the tell-tale signs of a clothes moth infestation.

(c) Possible Control Measures

Possible control measures include numerous non-chemical and chemical measures. There are 15 non-chemical measures:

1. Thorough vacuum cleaning to remove lint and some of the pests from floor crevices, air ducts and other harborages.
2. Dry cleaning fabrics to remove nutritious stains and to kill larvae and eggs.
3. Removal of rodent and bird nests.
4. Brushing or combing fabrics and furs.
5. Using lighting to repel adult moths from vulnerable items.
6. Cooling items to about 48°F/9°C to prevent feeding and breeding.
7. Freezing items to kill all stages of these insects (e.g. -4°F/-20°C for 72 hours; in U.K. -30°C for 72 hours is standard).
8. Irradiating infested items using microwaves is reported to kill all pests but I have not seen proofs of safety to museum objects.

9. Heating infested items for 4 hours at 106°F/41°C at 70% RH is reported to kill all stages of the webbing clothes moth. The eggs are the most resistant stage and some have survived 4 hours at 104°F/40°C.
10. Removing wool felts and substituting acrylic felts in display cases.
11. Sealing items vulnerable to attack in insect-proof containers. (Re-backing tapestries with a very tightly woven cotton cloth can also deter moth attack.) It is important to remember the newly emerged larvae are so small they can enter anything with an opening greater than 0.1mm, so they are often found inside boxes used for storage.
12. Caulking crevices to reduce lint accumulations for all species, and to deny pupation sites for the wandering casemaking clothes moth larvae.
13. Sealing or screening routes of insect entry from outside.
14. Placing sticky traps baited with animal substances (e.g. fish meal) in dark places to attract adults and larvae.
15. Using clothes moth pheromone traps to intercept male moths for monitoring purposes and to disrupt breeding (available from AgriSense and Insects Limited).

There are 6 chemical approaches to controlling clothes moths. As already mentioned, as a general rule museum objects should not be exposed to any chemical treatment unless it is known to be safe to the object, or unless any adverse effects are acceptable. It should be remembered that adverse effects may result from the solvents and other so-called inert components, not just from the active ingredient. Chemical measures include:

1. Permanent mothproofers applied during wet cleaning. I believe only two are registered in the U.S.A: Mitin FF High Concentrate by Ciba Corporation and Edolan ETS by Bayer Corporation (Edolan is a 12% permethrin formulation).
2. Temporary mothproofers: aqueous formulations of permethrin applied as an aerosol to wool samples have given over 10 years protection against webbing clothes moth (when kept out of UV light which degrades permethrin).

3. Conventional fumigants: sulfuryl fluoride and methyl bromide are registered against clothes moths but webbing clothes moth eggs are very resistant to sulfuryl fluoride.
4. Mild fumigants: paradichlorobenzene (PDB), napthalene and DDVP strips are registered against clothes moths and can be useful in closed storage containers.
5. Residual insecticides: various insecticides are registered in the U.S.A. including pyrethroids, the carbamate insecticide bendiocarb and the chlorinated hydrocarbon methoxychlor. While some residual insecticides are labeled for use on fabrics, it is often more effective to use them to treat adjacent surfaces, as well as crevices and voids where clothes moths may be harboring. Two pyrethroid insecticides (cyfluthrin and deltamethrin) and bendiocarb are formulated as dusts for more effective treatment of voids. Inorganic dusts can also be effective.
6. Where museum objects are already infested with clothes moths, holding the object in an atmosphere free of oxygen (in other words, a nitrogen or argon atmosphere) is currently considered the safest means of pest eradication.

ANTHRENUS CARPET BEETLES

There are numerous species of carpet beetles and first I will deal with two species belonging to the family *Anthrenus*, the varied carpet beetle and the furniture carpet beetle. In England, another species of *Anthrenus*, the Guernsey carpet beetle (*Anthrenus sarnicus*) has become the dominant museum pest in London's South Kensington museums, and if any are found in your museums they were probably transferred from London! Carpet beetles and other dermestid beetles are a particular problem in natural history and ethnographic collections.

(a) Appearance and Life Cycles

1. Varied Carpet Beetle - *Anthrenus verbasci* (L.)

The varied carpet beetle is common outdoors where it is found on flowers (e.g. Spiraea, Viburnum) and in the nests of birds, rodents, bees and wasps. The adults which are oval shaped, 2 to 3mm long with irregular white, black and yellowish bands, are most numerous outdoors in Washington, D.C. in late spring and summer. The adults are attracted to blue and white colors. They fly fairly high and enter buildings through windows and other openings, especially in late summer and fall. There is usually one generation a year, both indoors and outdoors, but poor diet or low temperatures may extend the life cycle to two years.

Eggs: females lay about 40 eggs in a lifetime and these hatch in 10 to 20 days at room temperature. Eggs may be laid on food or non-food items.

Larvae: the larvae are brownish with bands of hairs and tufts of bristles, which has led to them being called "wooly bears" in some countries. They feed almost immediately, avoiding light, and passing through 1/5 to 16 larval stages (average of 7) reaching a length of inch/5mm. The larval stage usually lasts 200-300 days, but can be over 600 days. Outdoors, the larval stage is the overwintering stage.

Pupae: pupation takes place on the larval food, inside the last larval skin, and lasts 10 to 13 days.

Adults: adults remain quiescent for a few days before emerging and at first avoid light. But after laying most of their eggs they become attracted to light. Window ledges are a good place to check for the presence of carpet beetles, but by the time they reach there they may have already done their damage. Males live 13 to 28 days and females 14 to 44 days.

2. Furniture Carpet Beetle - *Anthrenus flavipes* LeC. [= *vorax* Waterh.]

The furniture carpet beetle is mostly found indoors, but adults are also found outdoors on flowers. In heated buildings all stages are found throughout the year, but adults tend to be most common in summer. The length of the life cycle ranges from about 20 weeks to 14 months. This species looks similar to the varied carpet beetle, but the adults have a more white underside.

Eggs: females lay 37 to 96 eggs in 1 to 3 batches. They are laid on larval food such as the pile of carpets and clothing. At room temperature they hatch in 9 to 21 days

Larvae: the larvae feed, grow and molt 6 to 12 times over a period of 70 to more than 300 days before pupating in the last larval skin.

Pupae: the pupal stage lasts from 14 to 19 days.

Adults: the adult passes through a quiescent stage (lasting from 6 to 71 days at room temperature), during which it rests in the last larval skin, and an active stage (lasting about 60 days). The adult is the overwintering stage under cold conditions.

(b) Feeding Habits and Damage Potential

While adults of *Anthrenus* carpet beetles feed with chewing mouthparts, it is larval feeding which takes place over a longer period and is most destructive in museums.

The varied carpet beetle is one of the most common carpet beetles in the U.S.A. and has been recorded feeding on a great variety of animal and plant products indoors, including carpets, woolen garments, skins, furs, stuffed animals, leather book bindings, feathers, horns, whalebone, hair, silk, fish manure, dried silkworm pupae, cereals and insect collections. Outdoors, the larvae often live as scavengers in nests of birds, rodents, bees, wasps and spiders. The adults have often been reported on flowers feeding on pollen.

The furniture carpet beetle is found throughout the U.S.A. and is also primarily destructive of animal products. It has been recorded feeding on wool, hair, fur, feathers, horn, leather, tortoise shell and silk. When cellulose materials such as linen, cotton, paper, rayon, jute and even softwood are stained with animal matter or when they enclose animal products, larvae will chew through them. They are also known to skeletonize dead mice, eat dead insects, dried cheese, old grain, casein, dried blood and the glue of book bindings.

In nature, carpet beetles and other dermestids are particularly important for clearing the landscape and recycling the billions of vertebrates and invertebrates that die each year.

(c) <u>Possible Control Measures</u>

As with clothes moths there are numerous non-chemical and chemical control measures for *Anthrenus* carpet beetles. These include 15 non-chemical measures:

1. Dry cleaning or washing infested textiles.
2. Physically removing carpet beetles from infested items and adjacent surfaces by vacuuming or brushing.
3. Vacuuming lint from crevices, edgesof rugs, air registers, etc. (if the vacuum cleaners have bags, these should be changed quickly and safely).
4. Removing accumulations of dead insects from window sills, catch trays of light traps, light diffusers and any other accessible location.
5. Removing bird or rodent nests and remains of vertebrate pests from the building and immediate surrounds.
6. Removing nests of wasps and bees, and spider webs in or near the building.
7. Prohibiting cut flowers and flowering pot plants in the building.
8. Keeping flowering plants and shrubs well away from the building and maintaining a clear strip (e.g. gravel) around the foundation.
9. Removing wool felts and replacing with acrylic felts.

10. Sealing or screening routes of beetle entry from outside.
11. Sealing vulnerable items in beetle-resistant cases and containers.
12. Cooling items to about 50°F/10°C to prevent feeding.
13. "Freezing" items to kill beetles. The eggs are the most resistant stage. Freezing regimes for carpet beetles range from 1 day at -4°F/-20°C to 3 days at -22°F/-30°C.
14. Heating items to kill beetles. Dermestid beetles are much more tolerant of heat than clothes moths and the temperatures necessary (131°F/55°C) may be unacceptable for many museum objects.
15. Using sticky traps for monitoring in areas vulnerable to beetle activity.

Chemical measures include:

1. Mothproofing confers protection against dermestid beetles as well as clothes moths.
2. Fumigating with the conventional fumigants sulfuryl fluoride (Vikane) and methyl bromide is effective. Methyl bromide is effective against all stages but can damage some objects. Sulfuryl fluoride is safer but less effective, requiring high doses and a second fumigation after egg hatch.
3. Fumigating with the mild fumigants paradichlorobenzene (PDB), napthalene and DDVP can be effective in enclosed storage containers, either killing or preventing feeding (beware corrosion of insect pins by DDVP).
4. Various residual insecticides are registered against carpet beetles and are best used on adjacent surfaces and in crevices and voids. These include organophosphates (chlorpyrifos), carbamates (bendiocarb) and pyrethroids (permethrin, tralomethrin/Saga, deltamethrin /Suspend and resmethrin). Dust formulations are most effective for treating building voids, particularly bendiocarb or pyrethroid dusts. Dessicant dusts, such as silica gel, are less effective against dermestid larvae, perhaps because their hairs and bristles reduce contact.

5. Atmospheric gases have been successfully used against carpet beetles: viz. 60% carbon dioxide for 20 days at 25°C; or anoxic conditions (argon or nitrogen) for 2 to 4 weeks.

Future research: antifeedants are being considered for incorporation in packing materials to deter entry by dermestid larvae. Pheromone traps for *Anthrenus* beetles have not been effective indoors.

BLACK CARPET BEETLES, WAREHOUSE BEETLES AND ODD BEETLES

(a) Black Carpet Beetle - *Attagenus megatoma* (F.)

1. Appearance and Life Cycle

Although the varied carpet beetle, furniture carpet beetle and other *Anthrenus* species are important pests, the black carpet beetle is the most widespread and destructive carpet beetle in the U.S.A. It is found outdoors on flowers and scavenging in birds' nests and on the remains of dead mammals and birds. Black carpet beetles are thought to mostly enter buidings by flying, but are also brought indoors on flowers.

The life cycle lasts from 1 to 2 years depending on temperature. The adults are larger than other common carpet beetles (3 to 5mm long) and are dark brown to black, not mottled or banded. They lay from 40 to over 100 fragile, pearly white eggs in hidden locations such as in lint along baseboards, air ducts and under furniture. The eggs hatch in 5 to 16 days.

The larvae feed and roam widely, molting 5-11 times over a period of 258-639 days at room temperature. They avoid light and pupate in the last larval skin.

The pupal stage lasts 6 to 24 days and in Washington, D.C. mostly occurs from April to June. The adults may remain in the pupal skin from 2 to 20 days before emerging and then may live another 30 days. The adults do not avoid light, at least not all their life and are sometimes found on window sills.

2. Feeding Habits and Potential Damage

Black carpet beetle larvae are a minor pest of many plant products (e.g. flour, seeds, grains and cereals), but a major pest of animal products. They move around extensively, eating here and there (particularly in dark areas) unlike most fabric pests which stay close to their original feeding site. They have been recorded feeding on woolen rugs, blankets and clothes, silk, felts, furs, skins, yarn, velvet, feathers, hair-filled mattresses and upholstered furniture, wool and hair house insulation, meat, insect meal, kid leather, milk powders, casein, books, birds' nests and dead birds and mammals. The adults feed mostly on pollen.

Apart from direct feeding damage, larval feeding may breach containers and thereby make them vulnerable to insects that could not enter the unopened container.

3. Control Measures

Non-chemical and chemical control measures are the same as for *Anthrenus* spp. except that:

* the eggs of black carpet beetles are very fragile and more easily dislodged by brushing or vacuuming than the eggs of other carpet beetles or clothes moths.
* A freezing regime of 6 days at 0°F/-18°C has been reported to kill adults, larvae and eggs.
* A pheromone has been marketed for use in monitoring traps but has not been very effective because of the short period the adults are active. Sticky traps are useful year-round for monitoring larval activity.

(b) Warehouse Beetles - *Trogoderma ornatum* (Say) and *Trogoderma variabile* Ballion

Warehouse beetles are also dermestid beetles, slightly smaller, but otherwise similar in appearance and life cycle to the black carpet beetle. The adults are oval, blackish beetles (1/16 to 1/6 inch/1.6 to 4mm long) and the larvae are very hairy but lighter colored than carpet beetle larvae.

Like most other *Trogoderma* beetles, warehouse beetles occur naturally in deserted nests of birds, rodents, wasps, bees and tent caterpillars, scavenging on dead insects and other organic debris. They also live in hollow trees and other sheltered areas where there are dead insects to eat. From these outdoor sites they can invade buildings and are particularly common in attics of homes.

In warm buildings there can be at least two generations a year, but under adverse conditions, either cool conditions or where there is little food, the larval stage may last over 3 years (one larva of *T. ornatum* survived 5 years without food). The larvae do not move far if food is available where they hatch.

Warehouse beetles can be serious pests in museums and are a particular problem in mounted collections of insects. Larvae also eat wool, furs, feathers and leather, as well as wheat, spices, tobacco and other plant products. *T. variabile* is one of the main pests of food warehouses throughout the world.

Control measures are similar to those for carpet beetles In addition, a *Trogoderma* pheromone trap is available for monitoring the presence of adult male warehouse beetles and some other *Trogoderma* species. This trap is only effective when it is warm (72°F/22°C) and the beetles fly.

(c) The Odd Beetle - *Thylodrias contractus* (Mots.)

The odd beetle is another dermestid, notable because the adults do not look like other dermestids, and the males and females are dissimilar. Both sexes are small beetles (1/16 to 1/8 inch long), yellowish brown and thinly covered in pale hairs. The male has a long narrow body and long slender legs and antennae. The female is larva-like, with a broader body and shorter legs and antennae. The larvae resemble other dermestid larvae. Odd beetles have occurred as chronic, but persistent, low level infestations in many American museums. An odd beetle was recently reported from a London museum (perhaps transferred from America!).

Their normal food is dry animal matter and they have been known to feed on mummies, feathers and insect collections. They have also made holes in paper and garments.

Control of odd beetles should be easy because the females have no wings and most infestations probably arise because infested items are carried into premises from other infested premises. However, the larvae roam widely seeking food sources and can survive 3 or 4 years without food. This makes it hard for sanitation measures alone to eliminate an infestation. Fortunately adult male, females and larvae are easily captured on floor level sticky traps and trap catch data can be used to direct control measures to population reservoirs.

LARDER BEETLE - *Dermestes lardarius* (L.)

The larder beetle, *Dermestes lardarius*, together with the black larder beetle (*D. ater*) and the hide beetle (*D. maculatus*) are among the larger species of dermestid beetle. They are similar in size and shape, being oval and ¼ inch/7mm to ½ inch/14mm long. All 3 species are dark brown or black, but the larder beetle is distinguished by having a cream colored band with 6 dark spots crossing the front of the wing covers (elytra).

Larder beetles and hide beetles are cosmopolitan outdoor scavengers which frequently enter buildings by flying through windows or other openings or by being carried indoors on foodstuffs, flowers or wooden pallets. Once indoors they may be active throughout the year, but are usually most common in spring and summer.

(a) Life Cycle of Larder Beetle

Eggs are laid singly or in batches of 2 to 20 in food sources or in nearby crevices. Over 200 eggs may be laid and they hatch in 2 to 12 days.

Larvae are immediately active, feeding voraciously but avoiding light. The larvae molt 5 or 6 times, reaching a length of ½ inch/13mm in 30 days under warm conditions, but over 200 days in cooler conditions. A key feature of larder beetles and hide beetles is that prior to pupation the full-grown larvae leave their food and seek a place to pupate. Sometimes they wander over 30 feet in their search, often boring into hard materials such as wood or caulking to pupate.

Pupae: the pupal stage lasts 3 to 7 days.

Adults feed on the same materials as larvae. Within a few days the adults are ready to mate and during this period and during egg laying the adults avoid light. Later they seek light and are commonly found at windows. There can be 5 generations a year.

(b) Feeding Habits and Damage Potential

A key difference between larder or hide beetles and carpet beetles is that adult larder and hide beetles cause major feeding damage, as well as the larvae. However, most damage is caused by the larvae. Larder beetles scavenge on animal protein sources indoors and outdoors. They feed on hide and skins but prefer smoked meat, cheese and other food-stuffs. They can thrive on museum specimens including stuffed animals and insect collections. They commonly feed on accumulations of dead cluster flies or face flies in attics and wall voids, and on dead flies in the catch trays of light traps. While preferring animal proteins, they can eat tobacco and other plant material.

The burrowing of full-grown larvae when seeking pupation sites can be destructive. Wooden beams can be honeycombed by successive generations of beetles. The larvae can also penetrate lead with ease, tin with some difficulty, but not zinc or aluminum. They are also known to tunnel in upholstery.

(c) Possible Control Measures

Both non-chemical and chemical control measures are similar to those for other dermestid beetles. Because they are common scavengers outdoors and are strong flyers, preventive non-chemical measures will focus on removing outdoor organic debris (e.g. nests) and sealing and screening possible points of entry. Indoors, non-chemical measures will focus on removing unnecessary food sources, such as lint and dead insects from cracks, crevices and voids. Catch trays of electric fly traps should be emptied at least weekly Where an infestation exists, removal of unnecessary materials preferred for pupation (e.g. wood, Styrofoam) from the vicinity of vulnerable items will make control easier.

Chemical control measures include treatment of cracks and crevices with appropriately labeled residual insecticide sprays (e.g. bendiocarb/FICAM, cyfluthrin/TEMPO, lambda-cyhalothrin/DEMAND CS, deltamethrin/SUSPEND SC). Voids can be injected with dust formulations of bendiocarb, cyfluthrin and deltamethrin. Inorganic dessicant dusts, such as silica aerogel and diatomaceous earth, have not been very effective.

Where museum objects are infested, options might include cleaning, freezing or fumigation with atmospheric gases.

NON-DERMESTID BEETLES

In addition to beetles belonging to the family Dermestidae there are many non-dermestid beetles that can attack the contents of museums and libraries. Some of these other beetles are fairly general feeders, and these include the drugstore beetle, the cigarette beetle and spider beetles Other beetles specialise in feeding on wood and these include the furniture beetle and powder post beetles.

DRUGSTORE BEETLE - *Stegobium paniceum* (L.)

(a) Appearance and Life Cycle

The drugstore beetle is a brown, cylindrical beetle about 1/10 inch/2.5mm long. This beetle is a common pest of homes and storage facilities throughout the world. The adult keeps its legs and antennae close to its body when at rest and this makes it harder to see.

Females lay up to 75 eggs singly as they crawl on or bore through food materials. The larvae feed, grow and molt over a period of 2 to 5 months before pupating. The pupal stage lasts 12 to 18 days. The emerging adults feed. There may be 4 generations a year in warm buildings, but only 1 in a cool area.

(b) Feeding Habits and Damage Potential

The drugstore beetle has been described as eating "anything except cast iron". It has been known to pierce tin foil and lead sheet. It feeds readily on bread, flour, meal, breakfast cereals and spices. It is also recorded eating leather, wool, hair, manuscripts, books, drugs and mummies. It can tunnel in wood (drugstore beetles and cigarette beetles belong to the same family as furniture beetles, viz. Anobiidae); and it has been known to bore in a straight line through a whole shelf of books!

(c) Possible Control Measures

Non-chemical preventive measures should focus on keeping food items which may be infested away from collections. Vulnerable dried foods should be stored in sealed glass or metal containers. Rodent baits can introduce or support drugstore or cigarette beetles, and trapping is preferable for indoor rodent control.

Where objects are infested, freezing or fumigation can be used to eliminate the infestation. Nitrogen fumigation for 7 days at 20°C has been effective against all stages of drugstore beetles.

Appropriate formulations of residual insecticides can be used to treat cracks, crevices and voids which may harbor these beetles. This includes the insect growth regulator hydroprene/Gentrol. In addition, surfaces adjacent to vulnerable items can be treated to intercept approaching beetles Sticky traps can be used for monitoring these and other pests and for informing the use of any insecticides.

CIGARETTE BEETLE - *Lasioderma serricorne* (F.)

(a) Appearance and Life Cycle

The cigarette beetle is very similar in appearance to the drugstore beetle but does not have rows of pits on the wing covers.

While commonly infesting tobacco warehouses, cigarette beetles occur in many storage facilities. The adults are strong fliers and are active in subdued light at temperatures above 65°F/18°C. In temperate climates they can fly from infested buildings to nearby buildings in spring and summer, usually in the late afternoon and on cloudy days. In the U.S.A. there can be 3 or more generations a year in warm areas, but only 1 generation in cooler areas.

Females lay about 30 eggs over a period of about 3 weeks on tobacco or other food sources. The eggs hatch in 6 to 10 days and the emerging larvae avoid light and feed and complete their development in 5-10 weeks. At about 60°F/16°C the larvae become dormant and it is this stage which over-winters. The pupal stage lasts 1-3 weeks and is spent in a pupal "cell" in the food. In summer, adults live 1-6 weeks.

(b) Feeding Habits and Damage Potential

In addition to eating tobacco, this beetle is a serious pest of books, eating the binding and pages. It is the chief pest in herbaria, chewing holes in dried plant specimens. Other items eaten include spices, rice, raisins, dried fish, silk and even pyrethrum powder strong enough to kill cock-roaches. They can severely damage furniture stuffed with flax tow or straw. Most damage is caused by the larvae.

Cigarette beetles were found in the tomb of Tutankhamen and some think this pest originated in Egypt.

(c) Possible Control Measures

Control measures for cigarette beetles are similar to those for drugstore beetles except that a pheromone is com-mercially available which is effective both for monitoring and for control using a mass trapping technique. In addition the insect growth regulator hydroprene/Gentrol has been effective in controlling this pest in tobacco warehouses.

SPIDER BEETLES - Family Ptinidae

Spider beetles, as their name suggests, look superficially like spiders, with long legs and a rounded body.

There are many species of spider beetles, including the golden spider beetle (*Niptus hololeucus*), the American spider beetle (*Mezium americanum*), whitemarked spider beetle (*Ptinus fur*) and the Australian spider beetle (*Ptinus ocellus*). These and other species are found throughout America and in most other countries too. The adults of most species are about inch/3mm long.

The larvae and adults of spider beetles are omnivorous scavengers, feeding on both animal and plant materials. They can feed on dead insects and excrement, or remains of rodents and other animals. In the wild they are found in the nests of rodents, birds, bees and wasps, or where there are accumulations of droppings from birds or bats. In homes and warehouses they eat a range of stored food, including cereals, dried fruit and spices. They are often found in museums or libraries, feeding on leather, fur, wool, hair, feathers, textiles and books.

Their life cycle is similar to that of dermestid beetles and, like some of them, spider beetle larvae may tunnel into wood to pupate. A particular characteristic of spider beetles is their ability to stay active at low temperatures, even at freezing point.

Control Measures

Apart from being less susceptible to cold temperatures, they can be controlled in the same way as dermestid beetles. There should be a particular focus on eliminating debris from roosting or nesting birds, bats, rodents or insects, particularly nests near vulnerable collections.

Because adult spider beetles are quite mobile, often wandering on walls and floors at night, they are vulnerable to spot applications of residual insecticides such as bendiocarb/FICAM.

FURNITURE BEETLE - *Anobium punctatum* (DeG.)

(a) Appearance and Life Cycle

The furniture beetle is a cylindrical, brown beetle about 1/6 inch to 1/4 inch (4-6mm) long, with rows of pits along its wing covers. This species is common throughout the world, living outdoors in dead tree limbs but able to infest wooden building structures and contents. The adults are poor fliers and usually are brought into buildings on firewood, packing cases, wooden yard furniture and old furniture.

Females lay 20-60 eggs in cracks or exit holes in wood. Unfinished rough wood is preferred and eggs are not usually laid on painted, polished or varnished wood. The eggs hatch in 6-10 days, unless the humidity is less than 60% when no hatching occurs. The larvae feed by chewing tunnels in wood, producing frass containing oval fecal pellets. This "gritty" frass often falls out of exit holes and is a key clue to infestation, and is quite different from the fine powder produced by true powderpost beetles. The larval stage usually lasts 2 years indoors, but may last up to 5 years.

The full grown larva bores towards the surface of the wood and pupates just under the surface. Most adults emerge in the spring by chewing a round exit hole about 1 to 2mm in diameter. Adult males are attracted to females by a pheromone and mating takes place immediately on the wood surface or in crevices or exit holes.

(b) Feeding Habits and Damage Potential

Apart from the exit holes caused by emerging adults, it is the larvae that cause most tunneling. Furniture beetles mostly attack sapwood in both softwoods and hardwoods, but the damage may extend into heartwood. Wood with a moisture content above 15% is more vulnerable to infestation than drier wood, resulting in shorter life cycles and hence larger populations. In addition to structural timbers and furniture, these beetles have damaged picture frames and books.

(c) Possible Control Measures

Non-chemical control measures include:

1. Removing unneeded infested items, including dead tree limbs.

2. Avoiding bringing suspect items indoors without proper quarantining and treatment if necessary. This is particularly important for often overlooked items such as packing cases, pallets and wooden items sold in gift shops.
3. Reducing the humidity in display or storage areas to below 60% R.H.
4. Reducing the moisture content of vulnerable items, including structural timbers.
5. Maintaining low ambient temperatures to slow down or arrest development.
6. Freezing can be used to kill furniture beetles and is less likely to cause damage than heating. But freezing is not without risk and is not recommended for laminated material, wood under tension, or where there are joints, glues or high moisture content. (Freeze drying of wooden bowls from the "Mary Rose" ship caused warping.)

Chemical control measures include:

1. Furniture and other fragile items such as picture frames are best treated by fumigation. But fumigation with sulfuryl fluoride requires very high dose rates (10 times the rate for drywood termites). Furniture beetles and other wood-boring beetles are also hard to kill with atmospheric gases, nitrogen atmospheres requiring 3 weeks or more to achieve complete mortality at 68°F/20°C.
2. Sealing wood pores, exit holes and crevices with wax or other suitable materials will discourage egg laying by furniture beetles.
3. Painting or varnishing unfinished wood will prevent egg laying.
4. Spraying structural timbers with residual insecticides such as borates, permethrin, cypermethrin, bendiocarb or chlorpyrifos, will kill emerging or wandering adults and larvae feeding in the surface penetration zone.
5. Injecting residual insecticides into beetle tunnels via exit holes (or injection holes where this is acceptable).
6. Using *Anobium* pheromone traps for monitoring adults males (this pheromone is also reported to attract the drugstore beetle *Stegobium paniceum*).

POWDER POST BEETLES - *Lyctus* spp.

(a) Appearance and Life Cycle

True powder post beetles in the family Lyctidae are generally smaller than anobiid beetles, ranging up to ¼ inch/6mm long. They are brown to black in color and, unlike anobiid beetles, you can see their head from above. Their antennae end in a 2-segmented club rather than the 3-segmented club of anobiids.

Under natural conditions powder-post beetles breed in wood such as dead tree limbs. They often enter lumber while it is being stored and cured, and later emerge from the finished product. They are also brought indoors on firewood. They are believed to attack only hardwoods, particularly those with large pores (such as oak, ash, elm and pecan) which provide sites for egg laying when the wood is broken or cut. Total development may take 2 to 4 years, but in the southern U.S.A. there may be 2 generations a year. Some species such as the brown lyctus beetle (*L. brunneus*) are cosmopolitan, while others such as the western lyctus beetle (*L. cavicollis*) from California and Oregon are regional.

The females lay about 50 eggs, singly or in small groups deep in the pores of wood or in old exit holes. Egg laying takes place in the spring outdoors, but at anytime in heated buildings. The eggs hatch in about 10 days and the emerging larvae bore along the grain to feed. The name of these beetles comes from their fine, talc-like frass, which contains none of the fecal pellets or fragments of wood seen in anobiid frass. The larval stage lasts from a few months to a few years depending on the species, temperature and condition of the wood. The fully grown larvae bore to within inch/3mm of the wood surface and excavate chambers in which to pupate.

The pupal stage lasts 12 to 30 days and the adults chew their way out leaving round exit holes, usually 1 to 2mm in diameter. As they emerge, they push out frass and this is often the first sign of infestation. The adults feed a little on the surface and mate. The adults live about 50 days and are most active at night when they are often attracted to lights. They are strong fliers and can infest buildings from distant dead branches and lumber yards.

(b) Feeding Habits and Damage Potential

Almost all damage is caused by feeding larvae. Unlike anobiid beetles they cannot digest the cellulose of wood, instead feeding on starch, sugars and proteins in the sapwood of hardwood with a moisture content of 8% to 32%. Live or newly cut wood has too high moisture content, and wood more than 10 years old usually has too low nutritional value (starch is converted to lignin as wood ages). Softwoods are not attacked because of insufficient starch and lack of pores for egg laying.

Preferred wood includes oak, ash, maple, hickory, walnut and bamboo, but almost any other hardwood is attacked. Feeding occurs throughout the year in warm conditions.

Indoor items attacked, or infested prior to manufacture, include furniture, tool handles, hardwood floors, wooden display cases and panelling. In museums, hardwood pallets or packing cases are sources of infestation. In addition lyctid beetles can be brought into museums on wooden sculptures sold in museum shops and in picture frames.

(c) Possible Control Measures

The possible control measures are similar to those for anobiid beetles, with the focus on relatively newly made hardwood items.

BOOKLICE OR PSOCIDS - *Liposcelis* spp. etc.

(a) Appearance and Life Cycle

Most species of psocids live outdoors on the bark of trees and shrubs, and on the ground among fallen leaves and organic mulches. They are all small, pale insects seldom more than 2mm long. The species found indoors are wingless and either enter from surrounding landscaped areas or are carried indoors on such items as books and cardboard boxes which have been stored in damp areas.

Breeding takes place throughout the year in warm, humid conditions and there can be several generations a year. In some species females can reproduce without mating. Under warm conditions the eggs (up to 50) hatch in 1 to 3 weeks. The emerging nymphs feed and molt a few times over a period of 1 or 2 months before becoming adults which may live another month. Outdoors, adults and nymphs of some species die in cold weather and only the eggs overwinter. Indoor species usually have a flattened shape and can easily enter narrow crevices, including book bindings.

(b) Feeding Habits and Damage Potential

Booklice feed mostly on microscopic molds growing in damp situations. They may become common in spring and summer when humidity and mold growth are maximal, and die out in winter when central heating creates a dry atmosphere not conducive to mold growth. In addition to eating molds, booklice have been observed feeding on the starchy paste and glue of bookbindings and wallpaper, as well as on starchy foodstuffs. They do not appear to cause holing of paper but dead booklice might cause staining of paper and their bodies could encourage other scavengers, which then proceed to attack collections.

(c) Possible Control Measures

Booklice are difficult to eliminate without major changes to the indoor environment, because they are numerous outdoors and can easily re-invade vulnerable buildings.

Non-chemical measures include the following:

1. Dehumidifying a building, including storage areas (levels below 50% R.H. are hostile to psocids).
2. Fixing moisture problems such as leaking pipes and condensation which create microclimates favoring psocids.
3. Discarding redundant materials harboring psocids (e.g. old cardboard boxes).
4. Storing items off concrete floors and maintaining good ventilation to prevent pockets of dampness.
5. Sealing cracks and crevices which provide the dark harborages preferred by psocids.
6. Removing leaf litter and organic mulches from the vicinity of the building.
7. Drying infested items to kill psocids (heating may harm books, and freezing may not kill eggs).
8. Physically cleaning mold and psocids from books.

Chemical measures include:

1. Fumigating (e.g. anoxic atmospheres; napthalene and paradichlorobenzene have also been effective).
2. Using mold-inhibiting interior paints to discourage psocids which infest damp walls.
3. Using residual insecticide sprays to treat building surfaces traversed by psocids (registered insecticides include: chlorpyrifos, cyfluthrin, diazinon and propoxur)
4. Using residual insecticide dusts to treat wall voids, between floors and behind power outlets and moldings (registered insecticide dusts include silica gel and boric acid).

SILVERFISH AND FIREBRATS

Silverfish and firebrats belong to the insect order Thysanura. All species in this group are wingless, with a flattened fish shape, with long antennae and 3 long appendages at the rear end giving them the common name of "bristletails". They are primitive insects with only 3 life stages: eggs, nymphs and adults. Several species of silverfish are common indoors and outdoors throughout the U.S.A. and other countries. Firebrats are seldom found outside except in hot areas. Because they avoid light and spend much time in crevices and voids, silverfish and firebrats are often not noticed, but they are among the most common pests in museums and libraries.

(a) Appearance and Life Cycles

Common Silverfish - *Lepisma saccharina* L.

The common silverfish is covered with shiny, silvery scales. It is the most slender of the pest species and at ½ inch/12mm long it is the smallest but most common in Europe Canada and the U.S.A. Silverfish adults alternately molt and lay eggs up to 50 times (1 to 3 at a time) in crevices or under objects. The eggs hatch in a few weeks and the emerging nymphs feed, grow and molt until they reach the adult stage in as little as 3 months, but as long as 3 years. The adults can live over 3 years at 72°F/22°C but only 2 years at 84°F/29°C. Optimal conditions for development and reproduction of the common silverfish are 72°F to 80°F/22°C to 27°C and 75% to 97% R.H.

Firebrat - *Thermobia domestica* (Pack.)

Firebrats are somewhat stouter, with a mottled silvery appearance. They have a similar life cycle to silverfish, the adults molting throughout their life, laying scores of eggs and living up to 2½ years. Nymphs mature in 2-4 months under optimal conditions. Firebrats prefer hotter areas than common silverfish - a temperature range of 90°F to 106°F/32°C to 41°C and humidity of 70% to 80% are optimal. As a result they are mostly found indoors around boilers and stoves.

(b) <u>Feeding Habits and Damage Potential</u>

The presence of silverfish (and sometimes firebrats) outdoors in nests of insects, birds and mammals, and under the bark of trees and leaf litter or mulches, and their ability to crawl through narrow crevices, provides a high risk of building invasion. In addition, they can easily be carried from one building to another, as eggs, nymphs or adults, on items such as cardboard boxes. Because they have chewing mouthparts and can eat both carbohydrate and protein-rich food they can cause extensive damage to collections.

Silverfish are particularly fond of sizing in paper, including starch, dextrin, casein, gum and glue. Paper itself is eaten and highly refined chemical pulp papers are preferred over mechanical pulp paper. Firebrats do most damage to medium typewriter bond paper, regenerated cellulose and linen Paper damage by bristletails includes irregular scraping, holing and "notching" of edges. They can chew book bindings and feed on the glue and paste in bindings. They can remove gold lettering to get at the paste beneath, and attack labels and wallpaper to reach the glue underneath.

Both silverfish and firebrats feed on textiles, preferring those of vegetable origin, including cotton, rayon and lisle, but preferring linen. Fabric damage is characterised by irregular feeding on individual fibers, by occasional yellowish stains and by feces and scales left by these insects. They seldom damage fibers of animal origin, but in the absence of preferred foods they may chew any textile, particularly if it is starched, sized or soiled. Items which are in constant use are damaged little; but items which are undisturbed for long periods, especially in dark humid situations, are particularly vulnerable to attack (e.g. books in some old, damp libraries).

The ability of silverfish and firebrats to run around quickly and find alternative foods, such as crumbs and lint in crevices or carpets, face powder in rest rooms or molds on the back of drywall in wall voids, aids their survival. In addition, silverfish are known to be very resistant to starvation, able to survive months without food or water, so sanitation measures alone will not quickly eliminate an infestation, but will discourage new infestations.

(c) Possible Control Measures

Non-chemical measures include:

1. Removing organic mulches and leaf litter supporting outside populations.
2. Sealing crevices allowing entry from outdoors.
3. Checking incoming supplies (particularly cardboard boxes from damp locations).
4. Caulking indoor harborages, especially moist areas (e.g. around sinks and areas of condensation near windows, etc)
5. Increasing lighting in vulnerable areas to repel bristletails (where collection won't be compromised by increased lighting).
6. Vacuuming regularly with a crevice tool to remove insects or food crumbs and lint on which they can feed.
7. Sealing vulnerable items in insect-proof containers.
8. Trapping - they are easily caught in sticky traps.
9. Reducing humidity of the air and damp microclimates caused by leaks or condensation. This is especially effective against silverfish.
10. Freezing easily kills nymphs and adults, but silverfish eggs are more resistant.

Chemical measures include:

1. Treating cracks, crevices and spots on structural surfaces with residual insecticides. These include carbamates (bendiocarb and propoxur); organophosphates (chlorpyrifos and diazinon); and pyrethroids (cyfluthrin, cypermethrin, deltamethrin, fenvalerate, lambda-cyhalothrin, permethrin, resmethrin and tralomethrin). The insect growth regulator pyriproxyfen (Nylar) is also available for silverfish control.
2. Using boric acid baits.
3. Injecting wall voids, pipeducts, attics and other voids with residual dusts (e.g. boric acid, bendiocarb, deltamethrin and silica aerogel).
4. Fumigating with atmospheric gases.

GERMAN COCKROACHES - *Blattella germanica* (Linn.)

(a) Appearance, Life Cycle and Habits

German cockroaches are the most reported insect pest of buildings in the United States and many other countries. Their success is due in part to their breeding faster and being more cryptic than other species. In addition, with an adult length of 2/3 inch/16mm, they are smaller than most other species and can therefore hide in smaller crevices. Their emission of an aggregation pheromone to signal good feeding and harborage sites, and a dispersant pheromone to signal unsuitable sites, both aid their survival.

Like most species, German cockroaches are primarily nocturnal. They spend most of their time in dark, undisturbed crevices and voids close to water. They are most common in food preparation areas because of their daily need for water and preference for warm areas near food. German cockroaches mostly inhabit buildings and cannot survive winters outdoors in temperate areas. In areas with hot, humid summers, such as the mid-Atlantic states, building populations may spread to outdoor areas, particularly where there are foundation plantings.

Breeding takes place throughout the year and eggs are laid in batches of 18 to 48 in capsules carried by the female until close to hatching time in about 2 to 4 weeks. The emerging nymphs are immediately active and feed and live in the same area as adults. The nymphs molt 6 to 7 times before becoming adults in about 2 months. The adults live about 6 months and in her life a female produces 4 to 8 egg capsules. Typically, at room temperature, there are 3 to 4 generations a year, and in one year a single fertilized female can result in over 10,000 descendants.

(b) Feeding Habits and Damage Potential

German cockroaches, and most other species, are omnivorous, with strong chewing mouthparts. Being good climbers and able to squeeze through narrow openings, they can spread from the original sites of infestation to other areas. In museums and libraries with restaurant facilities, or where galleries are used for catered functions, there may be opportunities for cockroaches introduced on food provisions to attack the collection.

Cockroaches are especially fond of starchy materials and meat products. In addition to human food they can eat leather, hair, paper, animal skins and dead insects. Items soiled with sweat are especially favored. In Washington, D.C they have eaten and scraped the covers of cloth-bound books. They also feed on book bindings, perhaps because of the glue. Damage to paper includes holing and notching of edges.

In addition to chewing damage, cockroaches can cause severe staining from vomiting, fecal deposits and secretions from abdominal glands. Indirect damage can result when cockroaches disrupt electrical equipment.

(c) Possible Control Measures

More control measures have been developed for cockroaches than for any other indoor pest. Despite the history of German cockroaches developing resistance to insecticides, there are now many chemical products which control them and numerous non-chemical methods for discouraging or killing them.

Non-chemical measures include:

1. Sanitation measures aimed at reducing unnecessary food and water sources (e.g. avoiding exposed food, water and garbage).
2. Maintenance or design measures aimed at reducing harborages and dispersal routes (e.g. caulking crevices, eliminating ceiling voids, hollow doors and insect-accessible power outlets).
3. Quarantining and, where necessary, rejecting food provisions.
4. Prohibiting consumption of food and drink in sensitive areas.
5. Trapping with unbaited sticky traps, jar traps or natural pheromone-baited traps.
6. High power vacuums have been effective in quickly reducing German cockroach numbers.

Chemical control measures include:

1. Applying residual insecticide sprays to structural cracks crevices or spots occupied or traversed by cockroaches (products include carbamates, organophosphates, pyrethroids and the insect growth regulators hydroprene/Gentrol and pyriproxyfen/Archer).
2. Applying insecticide dusts to structural voids serving as cockroach harborages (products include inorganics, carbamates and pyrethroids).
3. Applying insecticide baits containing hydramethylnon in tamper-resistant bait stations (Maxforce Roach Killer Small Bait Stations) or in forms for crack and crevice bait placement (Maxforce Roach Killer Bait Gel and Siege Gel Insecticide). Hydramethylnon is slow acting but has very low acute toxicity. Faster acting baits based on conventional insecticides are also available (e.g. boric acid, chlorpyrifos and propoxur). In the past year a new insecticide bait containing fipronil has become available and this combines the low toxicity of hydramethylnon with the speed of conventional insecticides (Maxforce FC Roach Bait Stations).
4. Using the insect growth regulators hydroprene (Gentrol) or pyriproxyfen (Archer) which are juvenile hormone analogs which disrupt insect development, resulting in sterile, often deformed adults. Control with these IGRs can take a year unless used in conjunction with conventional pesticides.
5. Using fungal toxins to kill them (Avert aerosol bait or spray contains abamectin, derived from the soil fungal microorganism *Streptomyces avermitilis*, which affects insect nerve function causing paralysis and death).

HOUSE CRICKETS - *Acheta domesticus* (L.)

(a) Appearance and Life Cycle

Adult house crickets are ¾ to 1 inch/19 to 26mm long, light brown with long antennae, powerful hind legs which enable them to jump, and well-developed wings. They live outdoors in warm weather but often enter buildings in cool weather. Because they are good fliers they can enter buildings at any level, from basement to attic. They are nocturnal and are attracted to lights, often flying through open, lighted windows.

House crickets lay eggs singly in crevices in dark places, such as behind baseboards and in corners of rooms. They are reported to lay about 100 eggs at room temperature and over 700 eggs at 82°F/28°C. The eggs hatch in 8-12 weeks and the emerging nymphs feed, grow and molt 7-11 times before becoming adults in about 8 months. The adults seek warm areas and feed actively during a lifespan of about 2 months.

(b) Feeding Habits and Damage Potential

Like cockroaches, house crickets are omnivorous, eating materials of animal and plant origin with their strong chewing mouthparts. They are predators and scavengers, eating other insects as well as our food, textiles and paper. They are particularly fond of textiles, especially if stained with sweat, grease or food. They are known to eat cotton, linen, wool, silk, furs and leather, and will even chew items of no nutritional value such as nylon, plastic and rubber. They have also gnawed wood and burrowed into the mortar of walls.

(c) Possible Control Measures

Indoor control measures are similar to those for indoor cockroaches. But, the emphasis should be on reducing the risk of crickets approaching and entering buildings. This can be done by reducing vegetation harboring crickets, reducing lights which attract them and closing or screening openings. For rapid reduction of outdoor populations of crickets, perimeter applications of various residual insecticides in the form of sprays (esp. wettable powders and encapsulated formulations, e.g. bendiocarb, cyfluthrin and lambda-cyhalothrin), granules (e.g. bendiocarb and deltamethrin) or baits (e.g. chlorpyrifos and hydramethylnon) are effective.

C. INDIVIDUAL PEST MANAGEMENT APPROACHES

BACKGROUND AND OVERVIEW

In my book "Approaches to Pest Management in Museums" I recognised four broad categories of pest management measures. These were CULTURAL approaches (such as housekeeping or temperature and humidity changes); MECHANICAL approaches (such as sealing or screening out pests); TRAPPING approaches (such as sticky traps); and CHEMICAL approaches (such as using insecticides or fumigants). These broad categories were then divided into 11 more narrowly defined approaches and a 12th approach, the IPM approach, which used combinations of some or all of the first 11 approaches.

I am going to say something about each of these approaches, with particular emphasis on new materials and methods, and on IPM programs. It is still true that almost all the materials and methods used for pest management in museums were originally developed for other situations, particularly protection of wood, food and fiber products in residential and commercial buildings. However, methods developed for other industries cannot automatically be transferred to the museum field because objects in museums are often more delicate, more rare and more valuable than items elsewhere.

In considering pest management approaches in museums, I have more often been informed by experiences in other highly sensitive situations, such as intensive care units in hospitals or research laboratories, than by experiences in homes or food plants. In these ultra-sensitive situations, the focus is on pest prevention based on exclusion measures to prevent pest access, and environmental modification to discourage pests in or around the building. Given all the measures developed for pest management in other fields, the challenge for museums is to select and adapt these measures to fit the particular museum situation. We must bear in mind such factors as the principles and ethics of conservation, access and handling needs of researchers, public access, occupational and public safety, the actual infestation situation and the damage potential of particular pests.

In selecting pest management measures we have to accept that where human access to the collection is maintained, there are no zero risk options for protecting the collection. Simply examining or moving collections involves risk. But we must accept that to do nothing to protect a vulnerable collection is to condemn it to eventual destruction by pests.

USE OF INSECT-RESISTANT CONTAINERS

The simplest way to protect an item from pest attack is to enclose it in an insect-free, insect-proof container. This is the standard option chosen by the food industry for consumer food items. Canned food can remain edible for over 100 years, and I know someone who discovered in a walled-up cellar some bottles of wine 300 years old which were perfectly drinkable!

The same principle applies to collections. The Ancient Egyptians not only created amazing works of art, they protected them so well they are little changed after 4,000 years. The Egyptian artefacts were protected so well because the measures to prevent human access also prevented pest access and humidity changes. Since the Egyptian tombs have been opened, more damage has resulted in 40 years than in the previous 40 centuries, some of it in situ and some of it in museums.

Clearly our task is more difficult than the Ancient Egyptians' because we not only have to protect items, we need to allow access for researchers or the public. I'm not going to dwell on the various protective cases available for storage or display, or the microporous polyethylene wrappings which allow access for air but not larvae (e.g. Tyvek), because you will know more about them than I do. But I will remind you that unless they are sealed or extremely tight-fitting, pests will be able to enter. Many pests can penetrate gaps less than 1mm wide. And many pests can chew through wooden and cardboard containers. As already mentioned, some pests, such as hide beetles and drugstore beetles can even pierce lead and tin foil. If you are not sure your cases are secure against pests you will need to regularly monitor them, perhaps placing sticky traps inside them.

Before talking about the next pest management approach, I will just mention a type of container that represents a major risk to museums and libraries. These are the packing cases used for transporting items to and from museums. Often they are made of wood that has not been treated against wood-boring pests, and the quality of materials and construction allows pest entry through knotholes, splits and joints. The potential for stowaways entering these cases is high, particularly when no pest management measures may have been taken where these cases were made or stored. In addition, packing materials can support some pests. For instance German cockroaches and some dermestid beetles (e.g. warehouse beetles) thrive on the new environmentally-friendly type of foam pellets (e.g. ECO-Foam) used for packing. This new type of packing is about 95% cornstarch plus some polyvinyl alcohol, and it is an extremely attractive food source for some pests. So museum staff should be careful that such containers don't serve as "Trojan horses" and bring pests into the collection.

USE OF HEAT

Heat is the oldest and often the most satisfactory method used in the food industry to kill bacteria and insects With increasing restrictions on use of certain fumigants, heat is increasingly used in the food industry to disinfest whole buildings. Pest control operators are using heat to control termites, wood-boring beetles and stored product pests in structures, including the use of microwave irradiation for drywood termite control. However, while heat can be used to quickly kill all stages of all pests, it is known to harm many museum objects. In particular, increased temperatures accelerate all chemical processes, including oxidation. The temperatures sometimes used to kill pests are the same temperatures used by researchers to accelerate ageing of textiles and other items (viz. 50°C). In addition, high temperatures can cause dramatic harm to some composite materials and to such items as wooden objects with differential wood orientation. Even with adjustments in relative humidity to maintain the "equilibrium moisture content", to minimize risks to wooden objects it is necessary to check the adhesive flow temperature and the grain orientation across supports, braces and joints to ensure acceptable tolerances exist. N.B: high temperatures may accelerate vaporisation of chemicals previously applied to the object, which may increase risk of human exposure.

I have heard claims that virtually any museum object can be heat-treated without harm. However, I have not seen the evidence to support such claims and I am sceptical. I would not use heat to eliminate pests in my own ethnographic and art objects, or in my rare book collection. But there may be a place for using heat where items are less important and where there is a record of heat tolerance. An example might be sterilization of trays of mounted insects; but even here, heat may cause warping of the tray itself and facilitate future insect invasion through the openings created.

In defense of heat treatments, some scientists have pointed out that the temperature "excursion" (i.e. change) for heat treatments is much less than the temperature excursion using low temperatures. Typically, it might be a 30°C excursion for a heat treatment but a 50°C excursion for low temperature treatment. Moreover, the high temperature may only need to be held for 3 hours, compared with 3 days for a low temperature treatment. Nonetheless, I urge caution when using heat or any other method where you are treating the object rather than the building.

USE OF NON-HEAT FORMS OF RADIATION

Non-heat forms of radiation include visible light, gamma radiation and electricity. Visible light has been successfully used as a lure for flying insects which are attracted to light. Unfortunately, apart from some crickets, some species of cockroach (such as the American cockroach) and active adult cigarette beetles, most museum pests avoid light If it were not for the damage that high light levels can cause to textiles, artworks and many other objects, light could be used as a repellent to pests such as clothes moths. Strong lighting in ancillary areas, such as corridors and administrative areas, could discourage museum pests from using these areas as routes to the collections.

With the loss of ethylene oxide and the imminent loss of methyl bromide as fumigants, there has been increased use of gamma radiation for controlling pests and disease organisms in the food and health care industries. Unfortunately, many materials are damaged by gamma radiation, including some plastics, textiles and glass. As a result of this risk, and because other fumigants are now available, I envisage less interest in using gamma radiation for treating museum items.

Electricity has been successfully used to kill drywood termites and wood-boring beetles in some buildings and furnishings. Unfortunately, surface application of electricity using an "Electro-Gun" does not penetrate deeply enough to reliably kill insects more than ½ inch/13mm deep. To kill deeper infestations requires pre-drilling of small holes and insertion of lengths of copper wire into the insect galleries to serve as conductors of the current. Even with shallow infestations, this method may not be suitable for museum objects because some scorching of wood may result. To date, the best use of electricity for killing pests is in the electric grids in light traps.

USE OF LOW TEMPERATURES

As with high temperatures, all insects can be killed by low temperatures, but it takes much longer. The eggs and larvae of carpet beetles, and the larvae of clothes moths and wood-boring beetles are particularly tolerant of low temperatures. This reflects their need to survive sub-zero winter conditions outdoors.

Opinions differ as to what low temperature regimes are necessary to kill all insect pests encountered in museums. In the U.K., a regime of 72 hours at -22°F/-30°C has become the standard for many museums. But some museums are holding this temperature for only 2 days and others for 7 days.

In general, the faster the temperature drop is achieved, the faster and more certain the kill. If the temperature fall is slow, some insects, such as the larvae of wood-boring beetles, can purge themselves of water and enter a dormant state resistant to low temperatures. To reduce the risk of survivors, some museums use the technique of holding the object at a low temperature for say 2 days, then returning the object to room temperature for 1 day, then lowering the temperature again for a further 2 days. This has the effect of breaking any dormancy and killing the remaining survivors.

The use of low temperature for treating infested items has a particularly good safety record for textiles. Typically, there are no problems when the objects are bagged at room temperature, with a relative humidity no higher than 60%, and afterwards allowed to reach equilibrium with room temperature before being unbagged. Most conservators observe no condensation inside the bags, merely on the outside of the bags. Delicate textiles are often wrapped in acid-free tissue before bagging, and some people evacuate most of the air from the bag before sealing and placing in the freezer.

It should be borne in mind that some large items such as rolled tapestries or carpets may take many hours to reach the target temperature. Allowance should be made for this when planning the treatment to avoid insects surviving in the centers of these items.

Objects with a low water content are generally suitable for low temperature treatments. In the absence of any free water there will be no true freezing within the object, and therefore little risk of damage. However, while wooden objects are generally less harmed by low temperatures than high temperatures, harm can result where there are tensions in the wood, or where there are joints and adhesives. Composite items are particularly vulnerable to either lowering or raising temperatures, even when the humidity is regulated. There have been some spectacular mishaps with natural history specimens, including spalling of birds' beaks and shedding of teeth from mammals or reptiles. There has also been a suspicion that freezing accelerated lamination of ancient glass items and gelatine in photographs is reported to be adversely affected.

Low temperature can be used for more than killing insects on infested objects from the collection. It can be used as part of the quarantining program in a museum, whereby all suitable incoming objects such as accessions or returning exhibits are treated. I know of one museum which freezes incoming supplies for the gift shop and administrative departments, as well as accessions.

Low temperatures can also be used in a sub-lethal way to reduce pest problems. Because they are cold-blooded, insects are less active at lower temperatures; they move less, eat less and breed less. So lowering the temperature in a museum at least in storage areas, will reduce pest activity. With the exception of spider beetles, most pests found in museums are inactive at 50°F/10°C.

USE OF PARASITES, DISEASES AND PREDATORS

In agriculture, horticulture and less sensitive indoor situations, parasites, diseases and predators are playing an increasing role in pest control, sometimes achieving more effective and more economic control than pesticides (e.g. control of glasshouse whitefly by parasites). Unfortunately, the presence of predators such as spiders, or parasites such as certain wasps or mites pose their own problems. Their presence may be disturbing to visitors, their excretions and secretions can cause staining, and their dead bodies become another food source for pests such as carpet beetles which they don't attack.

Disease organisms don't have these disadvantages, but they have other problems. For instance, it is difficult to infect cryptic insects with a lethal dose of the disease organism, and it is difficult maintaining the viability of disease organisms until they reach the pest. Fortunately, these difficulties were overcome in the case of cockroaches, and in 1993 a product known as the "Bio-Path Cockroach Control Chamber" was introduced by EcoScience Corporation. This product contains the fungus *Metarhizium anisopliae*, which is commonly found in soils throughout the world. Special packaging ensures a 2 year shelf-life for the product The problem of getting the fungal disease organism to the cockroach has been solved by putting the fungus in a chamber which is an attractive harborage; so the cockroach finds the fungus. Inside the chamber, the internal geometry is such that the cockroach brushes against infected surfaces. Once a cockroach is infected, it passes fungal spores to other cockroaches as a result of its aggregation behavior.

This disease-based product has the advantage of good safety to the user and environment. However, because it may take several weeks to achieve a major reduction in the cockroach population, its use may be combined with faster chemical or non-chemical measures. Unfortunately, perhaps because of unreliability under field conditions, this product is no longer marketed.

MISCELLANEOUS NON-CHEMICAL METHODS

The success of pest management programs in museums depends not on a few sophisticated high-tech products or procedures, but on a host of less glamorous measures, such as sanitation and maintenance measures. Other measures may primarily be aimed at creating more favorable environmental conditions for the building or collection, but may have collateral pest control effects. These various measures include the following:

1. REDUCING OUTDOOR SITES OF PESTS:
   e.g. removing foundation plantings; choosing non-flowering plants; clearing debris from gutters and drains; removing birds nests and droppings from building; avoiding using organic mulches; removing accumulations of leaves or other debris; removing dead tree limbs and stumps: maintaining tightly closed garbage containers.

2. REDUCING OPPORTUNITIES FOR ACTIVE PEST ENTRY:
   e.g. keeping windows closed or screened; fitting self-closing devices and sweeps or gaskets on outside doors; screening vents; caulking crevices.

3. REDUCING OPPORTUNITIES FOR PASSIVE PEST ENTRY:
   e.g. checking incoming fresh flowers or replacing them with silk flowers; checking incoming food supplies; disallowing use of cardboard or wooden packing cases by caterers; checking incoming office or shop supplies; keeping food and drink away from collections, including conservation work areas; quarantining and checking accessions and returning exhibits.

4. REDUCING CONDITIONS FAVORING PEST SURVIVAL INDOORS:
   e.g. reducing air humidity; minimizing the availability of free water from condensation, leaks, etc.; sealing potential harborages such as cracks and crevices or plinth voids; keeping food and garbage in closed containers (especially not exposed overnight); regularly removing lint and other organic debris (e.g. dead flies) from corners, crevices, ledges and

floor and wall air registers; avoiding indoor use of rodent baits; using bagless vacuum cleaners or sealing and disposing of bags promptly; replacing surfaces favored by pests for food or harborage (e.g. wooden shelving, wool felts, cork mounts in insect collections).

5. PHYSICALLY REMOVING PESTS:
e.g. using high powered vacuum cleaners fitted with High Efficiency Particulate Air (HEPA) filters to remove pests from niches without creating airborne allergens (e.g. Lil' Hummer and Optimus machines). Note: In some cases, the objects themselves can be vacuum cleaned by trained personnel Whether vacuuming the building or the objects, care should be taken to avoid insect eggs being picked up on the nozzle and re-deposited on other objects or in other parts of the museum Washing the nozzles in hot water and detergent after use will reduce this risk. Other ways of physically removing pests include disposing of infested items (e.g. used vacuum bags, infested food, boxes, crates or packing materials); also removing or isolating infested or suspect exhibits; and using traps to catch pests for subsequent removal.

6. MONITORING PREMISES FOR PESTS OR CONDITIONS CONDUCIVE TO PESTS:
e.g. using sticky traps; regular inspections by curatorial or conservation staff; and daily feedback from support staff (including administrative, security, cleaning, maintenance and food service personnel).

USE OF INSECTICIDES AND FUMIGANTS

In the mid-1980s it was fashionable to make a distinction between conventional pesticides, such as organophosphates, and the new generation of pesticides, such as pyrethroids and insect growth regulators. There was an assumption, or at least a hope, that the new products would prove safer than the older, conventional pesticides. For various reasons, I think it is unwise to try to make such a distinction between older and newer chemicals. This is not because of trying to avoid "ageism" in chemicals, or any other form of political correctness! It is because experience has shown that all pesticides, old and new, should be treated with respect and with caution.

In my 1985 book I stated: "... it is impossible to prove that a chemical is not harmful. So instead of thinking of new chemicals ... as being harmless we should instead think that they have not yet been proved harmful ..." Thirteen years later, I will give some examples to illustrate the validity of that warning. First, in the past 2 years there has been evidence that metabolites of the insect growth regulator methoprene, which is used for control of fleas and mosquitoes (and formerly cigarette beetles), may cause deformities in wildlife (viz. frog deformities following treatment of wetlands with methoprene; perhaps because of interactions between sunlight and methoprene. New Scientist 9/13/97). Second, in 1996 Ciba voluntarily suspended sale of their new insect growth regulator fenoxycarb (Torus) for flea and cockroach control, because of unacceptable levels of tumor formation in exposed laboratory mice. Finally, despite all the enthusiasm accompanying the introduction of many new pyrethroids, there is a growing realization that they can cause various, sometimes serious, allergic reactions (e.g.lambda-cyhalothrin/DEMAND CS and tralomethrin/SAGA WP). Interestingly, each of these examples was promoted on grounds of improved safety!

You might think that if synthetic pesticides cannot be regarded as safe, perhaps inorganics such as boric acid are safe. Wrong again. Less than half a teaspoon of boric acid powder can kill a child and some poison control centers have reported most poisoning incidents arise from use of boric acid for pest control. If synthetic pesticides and inorganic pesticides may cause problems what about natural insecticides Well pyrethrum, the most widely used natural insecticide, has the worst safety record of all. Millions of people have suffered various degrees of allergic reaction to pyrethrum, and it causes liver enzyme changes and is a suspect carcinogen. Other natural pesticides have also caused safety problems, including those based on eucalyptus, pennyroyal, rosemary, Melaleuca oil and oil of citronella.

Does the possibility of safety problems from pesticides mean they should not be used? No. There is increasing evidence that we should be no more fearful of pesticides than any other chemicals, including natural chemicals. Comparative toxicity tests indicate that in high dose tests 30% to 50% of both natural and synthetic chemicals are estimated to be carcinogens, mutagens, teratogens, or clastogens (Ames, et al. 1990. Nature's chemicals and synthetic chemicals: comparative toxicology. Proc. of the National Academy of Sciences of the U.S.A. 87(19):7782-7786).

There is a saying: "One man's meat is another man's poison." I prefer the adapted quotation by the American humorist and writer, Carolyn Wells, who said: "One man's fish is another man's poisson!" Clearly we should not assume any chemical is safe, because overexposure to anything can be harmful. This is summed up by the phrase "the dose makes the poison". We are all familiar with fatalities arising from drug overdoses or alcoholic poisoning. But it is perhaps more surprising to learn that if you ingest half a cup of apple seeds or one cup of salt you are likely to die - quite quickly in the case of apple seeds because they contain cyanide! I once saved the life of a man who went into anaphylactic shock after eating 5 to 10 sesame seeds; for him because of his sensitivity, just a few seeds constituted an overexposure.

So, is anything safe? When I tell you that if you quickly drank 2 gallons of water you could die of water toxicosis, you might think nothing is totally safe, and you would be right. Each year a few hospital patients die and many suffer irreversible brain damage from water toxicosis because the flow rate on their intra-venous drip is too high. And if you inhale water it is even more dangerous; there is enough water in the Potomac river tidal basin to kill everyone in Washington, and it doesn't even have a warning label!

For pest management we will sometimes need to use chemicals (pesticides), just as in medicine we sometimes need to use chemicals (pharmaceuticals). Indeed, pesticides and medications are sometimes based on the same chemical. For instance, Vitamin D is the active ingredient in Quintox rodenticide; warfarin which is commonly used for blood circulatory problems, is also used as a rodenticide; and the chemical 1,1,1-trichloroethane used to remove the adhesive left on skin by surgical dressings, was used as a pest fumigant until it was banned on safety grounds! Even DDT was used for chemotherapy, and it is one of the few chemicals proven by the National Cancer Institute not to be a carcinogen.

I'm not saying you should not be concerned about the safety of pesticides. I am saying you should not be <u>over-concerned</u>. Now that we have ceased using some of the old inorganic pesticides, such as lead arsenate, and some of the old botanical pesticides such as nicotine and strychnine, hardly anyone is killed by pesticides. Looking at the broader picture we see that in the United States, life expectancy continues to rise and deaths from cancer continue to fall. But we should never be complacent about pesticides, or about other chemicals you may be exposed to, such as solvents used for cleaning oil paintings.

Because most pesticides have not been exhaustively tested regarding their safety to materials, I have already stressed it is safest not to directly expose the collection to them. Instead, pesticides should be applied to the building or other surfaces to kill the pests before they reach the collections. Of course there may be some exceptions, such as in open-air exhibits of replaceable items (e.g. display of food items in annexe to medieval kitchen). This principle of non-exposure also applies to human safety. To minimise risks it is best to use formulations and application methods which reduce human exposure. Fortunately, over the past two decades, there have been major advances in technology which help achieve this. These include:

1. INSECTICIDE BAITS for improved targeting.
   - bulk baits for outdoor perimeters (e.g. chlorpyrifos/ CB Strikeforce, propoxur/Baygon).
   - injectable baits for crevices (e.g. abamectin/Avert, hydramethylnon/Maxforce).
   - containerized, tamper-resistant baits (e.g. hydramethylnon/ Maxforce, Siege, and sulfluramid/FluorGuard).

2. INJECTION EQUIPMENT for placing insectides in cracks, crevices and voids where pests hide and where there will be less degradation by cleaning or UV light (e.g. crack and crevice injection attachments for sprayers and dusters; Actisol and Micro-Injector power aerosol injectors).

3. MICROENCAPSULATED FORMULATIONS which reduce user hazard (e.g. chlorpyrifos/Empire 20; diazinon/Knox-Out 2FM; lambda-cyhalothrin/Demand CS).

4. DOSE PACKAGING TO REDUCE HANDLING RISKS (e.g. dose packets - bendiocarb/FICAM W; cyfluthrin/Tempo 20WP; dose tablets - lambda-cyhalothrin/Demand Pestab).

Where it is necessary to use insecticides on surfaces which may be contacted by people, an effort should be made to choose products which are non-allergenic. Also, where extensive use of an insecticide is planned, I prefer selecting products for which there is an antidote. However, it is important to choose products that work, even if there is no antidote. So in situations where there is a problem of decay fungi and wood-boring beetles or termites in the timbers of a historic structure, and where I wanted longterm protectant properties as well as eradicant properties, I might choose borate insecticides (e.g. disodium octaborate tetrahydrate/ Tim-Bor or Bora-Care).

Finally, it should not be necessary to point out that we should only use pesticides which are legally permitted for a particular use. But occasionally, I encounter people who still have a small stock of pesticides which are no longer registered for use. Periodically, manufacturers allow registrations to lapse for economic reasons. In either case, we should no longer use them. Next week (July 28th, 1998) the Science Advisory Panel of the EPA is meeting to review toxicity data on DDVP (Vapona/dichlorvos) submitted by its registrant (AMVAC). Their findings will be published later this year and may lead to some or all uses being withdrawn or cancelled. This insecticide has been used for museum pest control, particularly for its fumigant properties in confined spaces. However, DDVP always had some disadvantages, particularly its reactivity with some synthetic dyes and its corrosiveness to mild steel, brass, silver, tin and lead. For instance, its use in trays of mounted insects often led to the mounting pins rusting. If DDVP ceases to be registered for museum use, alternatives are available. Among conventional fumigants, sulfuryl fluoride (Vikane) has the best record of safety to materials and, unlike methyl bromide is not thought to reduce stratospheric ozone levels.

USE OF ATMOSPHERIC GASES

Because conventional fumigants are highly toxic to people, damaging to some materials and highly regulated, the use of some atmospheric gases as fumigants has attracted increasing interest. In the museum field, the cessation of use of ethylene oxide, the phasing out of methyl bromide and the difficulty of achieving insect egg mortality with sulfuryl fluoride, has accelerated the trend towards using atmospheric gases.

The atmospheric gases currently being used are carbon dioxide, argon and nitrogen. Of these, only carbon dioxide can be regarded as a true fumigant, achieving insect kill by its toxic action. Nitrogen and argon are virtually inert and are used in high concentrations to achieve an anoxic or hypoxic atmosphere, so that mortality is achieved by suffocation, not by toxic action.

Carbon dioxide fumigations were pioneered by the Australian grain industry and were first used commercially in Australia in the 1970s in hermetically sealed grain bins. In 1981, carbon dioxide was first registered as a fumigant in the U.S.A. One of the key advantages of carbon dioxide over other atmospheric gases is that the concentration required is less critical. Concentrations as low as 30% can achieve control, though for most pests a concentration of 60% maintained for 4 days at 70°F/21°C is necessary. As with other gases, control takes longer to achieve at lower temperatures. Curiously, concentrations of carbon dioxide above 60% may be counterproductive. This is perhaps because carbon dioxide causes mortality not simply by direct toxic action, but by accelerating respiration, resulting in a massive loss of precious water reserves. But if the carbon dioxide level is too high the insect may enter a state of torpor and survive.

Some larvae of carpet beetles and wood-boring beetles have survived two weeks exposure to 60% carbon dioxide; so while it is generally faster acting than other atmospheric gases, it is still much slower than conventional fumigants.

As with conventional fumigants, care must be taken when using carbon dioxide, and in many countries operators need to be licensed fumigators. Although there is a permissible exposure level of 5,000 ppm, it is toxic to humans and can cause severe breathing difficulties and dizziness which could lead to secondary injury from falls. Nonetheless, as with other atmospheric gases, carbon dioxide can be vented easily and leaves no odor or residues. From the viewpoint of safety to materials, while it is theoretically possible that carbon dioxide could combine with available moisture to form carbonic acid which might corrode susceptible materials or react with some dyes and pigments, this is unlikely. I don't know of any such occurrences and the necessary moisture levels would not normally be present.

The use of anoxic or hypoxic atmospheres for pest control were again pioneered by the grain industry, which held grain in gas-tight stores in an atmosphere of nitrogen. To achieve insect mortality in nitrogen or argon atmospheres, it is preferable to reduce the oxygen level to below 0.1% for many days. There has been much innovation in developing sufficiently gas-tight conditions for treating museum objects ranging from modifying old ethylene oxide fumigation chambers to custom building fumigation bubbles from polyethylene/ aluminum laminate.

On a small scale, individual objects can be heat sealed in an oxygen impermeable bag (e.g. ACLAR from Sealpak Co.), together with an oxygen scavenger (e.g. Ageless from Mitsubishi) which absorbs the oxygen (and carbon dioxide), leaving the object in an almost pure nitrogen atmosphere. It must be borne in mind that the reaction of oxygen scavengers with oxygen is exothermic and the packet of oxygen scavenger will become at least warm and, in the presence of a lot of oxygen, very hot. To minimize problems from warming, the oxygen scavenger should never be placed on an object, and the amount of oxygen to be absorbed can be reduced by evacuating some of the air before sealing the bag. When using trapped air as the source of nitrogen, the air volume will gradually diminish as the oxygen is absorbed and this will result in a rise in relative humidity in the bag. Conditioned silica gel can be used to buffer humidity changes, using a hygrometer to monitor conditions.

On an intermediate scale, rigid chambers for holding objects in a hypoxic atmosphere have been made from fiberglass water tanks and even sewer pipes, which are a convenient shape for rolled carpets or tapestries. When using such rigid chambers for treatment, it is unwise to put in an oxygen scavenger before flushing out the air with nitrogen. This is not only because of the excessive amount of heat that would be generated, but also because the reduction in air volume could cause implosion of the chamber.

In my home town, the Museum Services Unit uses a 1 metre square chamber for hypoxic nitrogen treatments. The chamber is a simple fiberglass tank with a perspex lid fastened by stainless steel yacht clamps against a Neoprene seal set in a groove around the rim of the tank. The seal is smeared with silicon grease to ensure a tight fit. The whole set-up is beautifully simple. After loading the chamber, nitrogen gas is first passed through three humidifying bottles to raise its humidity from 0% to 55%. The humidified nitrogen gas is introduced at the bottom of the chamber through a one-way truck tire valve. Air is flushed from the chamber from a valve at the top. When the chamber is full of nitrogen, the top valve is closed and the surplus nitrogen is passed down an exterior pipe through a water trap on the floor which prevents backflow of air. This water trap also provides visual and auditory proof that there is a positive pressure of nitrogen in the chamber. Monitors inside the chamber provide readings on oxygen concentration, temperature and humidity which are fed to a computer and, via a modem, to the conservator's home for night-time supervision. With this simple, cheap system, even with objects which trap a lot of air, it is possible to reach oxygen levels of less than 0.1% in half a day and the normal operating concentration is 0.02% A slight continuous flow of nitrogen is maintained and there is no need to use an oxygen scavenger. Typically, objects are held in this chamber for 7 days at 20°C, but certain pests require much longer.

On a larger scale, because leakage has been a problem with some older fumigation chambers, there has been a rapid adoption of the laminated controlled atmosphere bubbles developed by Rentokil. These bubbles range from standard prefabricated bubbles with a volume of 7 to 30 cubic meters, to custom bubbles built on site as large as 600 cubic meters. A Rentokil case history involving 43 oil paintings from churches in southeastern France can be cited to illustrate the use of custom built bubbles. These paintings ranged in size from about 1 meter square to 5 X 3 meters (about 16 X 10 feet) square. *Anthrenus* carpet beetle larvae were feeding on the canvases and emerging through the paintings, and the frames were infested with *Lyctus* powderpost beetles. A pilot treatment of a few paintings in individual bubbles was found too time-consuming, so it was decided to build 3 bubbles to contain all the paintings at a secure, air-conditioned warehouse. The bubbles were made from an oxygen barrier film consisting of a polyethylene/aluminum laminate in sheets measuring about 16m X 12m. After thoroughly cleaning the warehouse floor and checking the sheets for imperfections, each sheet was laid on the floor with the polyethylene side upwards. Purpose-built racks were then carefully placed on the sheet, protecting their legs with foam rubber. The "surplus" area of sheet was rolled up to keep it out of the way until the racks were loaded. Once each rack was loaded with paintings, the sheet was unrolled and draped over the rack of paintings and the edges welded together with a continuous temperature hand-held heat sealer. Air was pumped out of each bubble through a pre-fitted gas-tight port at one end to achieve a slight negative pressure. This port was then closed and the bubble left for a few hours and then checked to confirm there were no leaks. Pure nitrogen was then introduced through a gas-tight port at the other end of the bubble, first passing it through a humidifier to avoid hygrometric shock to the paintings. The bubble was inflated until the surface could be depressed by about 6 inches (15cm) then the nitrogen supply was turned off and the vacuum pump re-activated until the bubble had deflated to the starting dimensions. This filling and evacuation cycle was repeated 6 times and, after this flushing, a trace oxygen analyser was connected to a gas sampling port. The first reading gave an oxygen concentration of 1.5%, so three further filling and evacuation cycles were conducted which brought the oxygen level down to 0.16%. Overnight, the oxygen level rose to 0.87% as a result of the emergence of interstitial air from the wooden frames. After more flushing to achieve a stable low level of oxygen, a small slit was made in the side of the bubble and 2.8 kg (in 80g sachets) of a proprietary oxygen scavenger were introduced. This is also the time to introduce a suitably programmed data logger to monitor the temperature and humidity over the treatment period. After quickly resealing the bubble, the oxygen level quickly fell to the required level and an average oxygen level of 0.05% was held for 30 days, which is thought to be sufficient to control all stages of all insects for which data is available. Where necessary, more nitrogen and more oxygen scavenger can be introduced during the treatment period.

In a similar controlled atmosphere bubble treatment this year in Singapore, heritage items were held in a nitrogen atmosphere for 42 days at an average oxygen concentration of just under 0.2%, at 23°C and 67% R.H. In this case, *Anobium punctatum* and *Anthrenus verbasci* were used as biological monitors and all stages of both pests were killed.

These custom built aluminum laminated bubbles are usually intended for one use only and are then destroyed. However, heavier duty bubbles supported on a purpose built frame can be constructed for longterm use. These can be used for quarantining and, if necessary, treatment of suspect items. Such free-standing bubbles fitted with a zip-closable door can also be used for longterm storage, safe from pest invasion. When fitted with a dehumidifier, they can also be used for storage of books and other items at risk from molds. Controlled atmospheres can also be maintained in hermetically sealed display cases, though to avoid risks from pressure changes when removing oxygen, or because of temperature and pressure changes in the museum atmosphere, the case must be fitted with a compensating flexible bellows.

The use of controlled atmospheres clearly has an important part to play in museum pest management. But as with all gases used as a control agent, there is no residual protection. It is therefore important to ensure that when objects are removed from the controlled atmosphere, they are not transported or placed in an infested environment.

USE OF CONVENTIONAL CHEMICALS IN NON-CONVENTIONAL WAYS

There is little new to say about the use of conventional chemicals in non-conventional ways, except there is growing disquiet among scientists about incorporating residual insecticides in paints, lacquers and varnishes. This is because there is a fear that the longterm presence of insecticides on exposed surfaces encountered by fast-breeding pests such as cockroaches will increase selection of resistant strains. This would then make it harder to achieve control with more targeted applications of these pesticides, such as injection of crevices and voids.

There is much scope for using appropriate insecticides to create an insect killing ground around objects. This would provide a last defense of the object without treating the object itself. For instance, in the furniture gallery of one major museum, the furniture was openly displayed on plinths covered in wool felt, which served as a nutritious route and potential reservoir of pests. While the longterm strategy was to remove all wool felts from the museum, in the meantime it was sprayed with permethrin to kill any crawling pests approaching the furniture. Likewise, the linings of display cases, whether natural or synthetic, can be pre-treated with appropriate residual insecticides to reduce the risk of any insect which enters the case reaching the objects

Normally, when treating surfaces near or on which objects stand, the object would be removed during the treatment. With liquid applications, the surface would be allowed to dry completely before replacing the object. Where there is a risk of chemical effects, such as corrosion of brass furniture casters by chlorpyrifos, a protectant material would be placed between the object and the treated surface.

There are often concerns about spray applications of insecticides because of fears of contamination of non-target surfaces by air-borne droplets. There might be particular risks where sensitive items cannot be removed during a pesticide application. In some cases this problem can be avoided by using a paint brush to apply the insecticide in a very directed manner. This technique has been useful in some high tech situations where it was important not to contaminate sensitive equipment.

For some years various chemicals have been explored for their antifeedant properties. Antifeedants could be incorporated in storage boxes, bags, wrapping materials and protective coverings to discourage pests. Many insecticides, including pyrethrum and some pyrethroids, have antifeedant properties at dose rates which are not lethal to insects. In June this year, Sumitomo Co. announced the successful use of red pepper as a rodent antifeedant when incorporated in the outer casing of electric cables. However, in view of the known carcinogenicity of some peppers (e.g. black pepper), I don't know whether it would meet the safety criteria for registration for pest control in the U.S.A!

USE OF PHEROMONES

Pheromones are chemicals secreted by insects to communicate with others of the same species. They include sex attractants, aggregation or dispersant pheromones, pheromones which stimulate mass attack or feeding, and those which simply mark territory boundaries. Over 1,000 insect pheromones have been identified and some of these have been extracted or synthesized for pest management. Sex or aggregation pheromones have shown most promise in pest management.

Insect adults which are short-lived and require no feeding for reproduction, rely on sex pheromones for communication. These insects include moths, anobiid and dermestid beetles, and their sex pheromones are usually produced by the female to attract males. Insect adults which are long-lived and need to feed before reproduction rely on male-produced aggregation pheromones which attract both males and females to feeding sites where mating encounters take place. Grain and flour beetles produce such aggregation pheromones. German cockroaches also produce an aggregation pheromone which attracts males, females and nymphs.

The greatest use of pheromones for pest management has been their incorporation in traps (sometimes with additional food attractants), for the early detection of infestations. The traps can also be used to help pinpoint sources of infestation and to help monitor the success of pest control measures. The traps for museum pests incorporate a sticky surface for holding attracted insects, and are designed to protect the sticky surface and the pheromone lure from dust and degradation. For museums, sex pheromone-based traps are available for:

* webbing clothes moths (*Tineola bisselliella*)
* warehouse beetles (*Trogoderma* spp.)
* cigarette beetles (*Lasioderma serricorne*)
* drugstore beetles (*Stegobium paniceum*)
* black carpet beetles (*Attagenus megatoma*)
* varied carpet beetles (*Anthrenus verbasci*)
* furniture beetles (*Anobium punctatum*)

Recently, a German cockroach aggregation pheromone lure has been patented and incorporated in a German roach trap marketed by Woodstream Corp. This pheromone has also been combined in larger traps with food attractants to attract other species, such as American and Oriental cockroaches.

There is no doubt that pheromone traps can catch more of their target insects than ordinary sticky traps in the same location. For instance, the Victor German cockroach pheromone trap is reported to catch 3 times as many German cockroaches as plain sticky traps, and traps with the webbing clothes moth lure caught about 20 times the number of moths caught on similar but "unbaited" traps. However, as with other traps, the effectiveness of pheromone traps will depend a lot on how they are used and the environmental conditions.

In general, pheromone traps should be placed in locations likely to be sought by the target pest and sheltered from physical disturbance, including strong air currents. The sex attractant pheromones are more powerful than aggregation pheromones or food attractants and can attract the target flying insect from up to 50 feet/15m or more. For this reason they should be placed away from doors, windows and other openings to avoid luring insects into a museum from outside. Likewise, if there is an ongoing infestation in part of a large building it could be unwise, without additional precautions, to use pheromone traps in the areas without a history of that infestation, in case it helps spread the infestation.

In addition to the risks of luring pests into an uninfested area, there are other limitations to the sex phero mone traps. The most obvious limitation is that they only attract adult males and will not indicate the presence of females or the larvae, which often cause most damage. In addition, they are only effective during the time of the year and at the temperature when the male insects are active. For instance male warehouse beetles and cigarette beetles may be present, but at temperatures below 72°F/22°C they may not be able to fly to the traps. Even with webbing clothes moths, results are only good at temperatures of 73°F to 81°F/23°C to 27°C, which is their optimal temperature for flying.

Another drawback with sex pheromone traps is that target insects may approach the trap but not enter it. It has been reported that cigarette beetle traps captured only 1 insect out of every 8 that approached the traps. This clearly has risk implications if there are vulnerable objects near the traps upon which the beetles might settle.

While adult clothes moths avoid bright light and are best trapped in low light areas, other pests are attracted to light and this affects catches by pheromone traps. For instance, cigarette beetles and warehouse beetles can be lured by light as easily as by pheromone traps. And drug-store beetles are much more attracted by light than pheromone traps. In these cases, light traps or sticky traps at windows could be more effective than pheromone traps.

Just as light traps need routine replacement of lamps and emptying of catch trays, and sticky traps need replacement, so do pheromone traps need routine servicing to replace exhausted lures as well as to record catches. Depending on the pheromone used, the lures usually last 1 to 2 months.

Despite the limitations I have mentioned, with good placement and routine replacement, pheromone traps can be extremely helpful in museum pest management. As well as helping early detection of low levels of pests, they can be used to identify particular problem areas in large buildings. This is done by placing traps in a grid pattern at intervals of 25 to 50 feet. The traps are checked weekly and if catches occur they are recorded and more traps are brought to that area, so that there is a progressive tightening of the grid in that area until a possible source is identified. Visual inspection can then confirm the source, which might be a particular exhibit or a structural void, such as a vent, which can then be subjected to control measures. Trapping should continue, to confirm the efficacy of the control measures, ideally removing trapped pests after each count to allow better interpretation of the next catch.

Pheromone traps can be used for more than just monitoring pests. They can be used more directly to kill pests. Field tests in public housing have shown that intensive use of Victor Roach Pheromone Traps can achieve higher levels of German cockroach control than some standard pesticides (79% reduction with Victor Traps vs. 48% reduction with Maxforce Bait Station - Purdue University field tests). Mass pheromone trapping, combined with use of light traps to capture adult females, has also achieved significant control of cigarette beetles in warehouses. Mass trapping to achieve control with sex pheromone traps is likely to be most success ful with species where males emerge before females, so that the males are captured before any females can compete with the traps (e.g. warehouse beetles and black carpet beetles).

While such mass trapping may be impractical in public areas of museums, pheromone traps can be used in conjunction with insecticides to achieve improved rates of kill. This technique, which has been dubbed Pheromone Enhanced Mortality (PEM) involves treating surfaces adjacent to each pheromone trap (e.g. the wall) with a residual insecticide. Insects which are attracted to the area but don't enter the trap are killed when they settle on the nearby treated surface. Insecticides which are not repellent, such as bendiocarb wettable powder, are likely to be most effective. If there is no suitable nearby surface to treat with insecticide, the pheromone trap could be placed on or near a piece of cardboard treated with the insecticide.

Perhaps the most important thing to remember when using pheromone traps is that the absence of trapped insects does not mean there are no pests present. Pheromone traps are only available for a few species, and even those species might reach museum collections before they reach the traps. In addition, care should be taken when discarding old lures and traps so that trash bins do not attract pests. You should also be careful when handling pheromone lures; always wear rubber gloves and dispose of them carefully afterwards. This is because pheromones can enter the body, so that a contaminated person becomes a walking lure for months and sometimes years. One lab worker, who worked with gypsy moth pheromone, is still attracting these moths 17 years after ceasing work with this pheromone! In another case, a well known consultant is a lure for Indian meal moths. For this reason, and because I visit many museums, I have never handled any uncovered pheromone lures.

D. USE OF COMBINATIONS OF METHODS IN INTEGRATED PEST MANAGEMENT (IPM) PROGRAMS

IPM ORIGINS

The development of integrated pest management (IPM) has been described as the single most important event in pest science in recent years. Many people involved in urban pest management regard IPM as a relatively new concept and, in the absence of any single definition of the term, some special interest groups have attempted to hijack the concept and suggest it means pest management without pesticides. Well, it is not a new concept and it is not pest management without pesticides, though it may result in less pesticide use. To think of IPM as a new concept may discourage use of old measures which are still relevant; and to attempt IPM without even considering use of pesticides may result in unacceptable costs and ultimate failure. It is important to understand IPM because, as I stated here in 1985, of all pest management approaches only IPM is applicable to all pest problems.

The term IPM originated in post-1950s agriculture and it described an approach to crop pest management that maximised profits by improving the efficiency of pesticide use and integrating such use with non-pesticide measures. For centuries, farmers had used combinations of chemical and non-chemical measures for pest management. But with the development of much more effective pesticides from the 1940s, many cultural approaches were neglected in the rush to adopt pesticides as the panacea for all crop pest problems. This increased reliance on pesticides led to increased problems of pest resistance, some safety problems and rising crop production costs. With crops such as cotton, citrus or apples, pest control was often achieved by routine preventive applications of broad spectrum insecticides throughout the season. In the United States, cotton crops were typically sprayed 12 to 16 times between planting and harvest, with reduced effectiveness and rising costs from season to season.

Agricultural IPM addressed this problem of rising costs by establishing an "action threshold" for each pest on each crop. Below this threshold level of pests it is not economic to apply a pesticide, but above this threshold there would be a net increase in profit from application of an appropriate pesticide. To help keep crops below this action threshold, economic cultural measures are used (such as improved irrigation), to discourage pests or to enhance the crop's natural resistance to them.

In such agricultural IPM programs there is no routine application of pesticides. The only routine is the routine inspection of the crop by a crop scout who assesses the type and level of pests and recommends the most appropriate treatment, targeted as narrowly as practical, when an action threshold is reached.

I can testify that agricultural IPM works, because I was implementing IPM as a crop scout in Africa more than 30 years ago. In my work I routinely inspected 20,000 acres of cotton and, by good timing and selection of pesticides, I could bring a crop to harvest with only 4 sprays of pesticide, and achieve higher yields than in U.S. crops sprayed routinely 16 times. This resulted in much lower costs and higher net profits, and there were collateral benefits in terms of environment, crop and human safety. However, it is important to recognise that agricultural IPM is profit driven, not driven primarily by safety issues.

URBAN IPM

It might be thought that urban IPM is quite different from agricultural IPM. For instance, agricultural IPM is based on the concept of action thresholds, which implies that certain levels of pests are acceptable; whereas, in urban indoor situations it might be expected that no pests are acceptable. The urban reality is often different from this expectation and many residents, particularly dog owners, accept a few pests, and most commercial food handling establishments accept a certain level of pests. Indeed, the USDA and equivalent agencies in other countries formally permit certain levels of pests in stored food commodities. And unless government agencies accepted some pests in commercial food service establishments, there would hardly be a single restaurant in any city in the world.

While it is clear that a certain level of pests is often acceptable indoors, it is also clear that, as in agriculture, there are action thresholds for indoor pests. The huge sales of retail pesticides, as well as the substantial professional pest control industry, are proof that some levels of urban pests are not acceptable. However, whereas in agriculture the action thresholds are well researched and based on objective cost/benefit data for each crop and pest, in urban situations we are concerned with more than economics. We are concerned with human health, fears and aesthetics as well as economics. In the case of pests such as termites, the dominant motivation is economics, and with pests such as yellow jackets or scorpions the main concern is human safety, and in these cases most people have a low action threshold. But with pests such as fleas, flies, spiders, sowbugs and even cockroaches, the levels of tolerance vary widely from person to person and from situation to situation. Personally, I am tolerant of a few small house spiders in my home but I will not tolerate a single flea or cockroach. But I know people who tolerate quite large numbers of fleas and cockroaches in their homes, but who are terrified of a single spider.

In institutions and commercial establishments, degrees of pest tolerance also vary widely. In my work I have inspected hundreds of food service establishments, but I have only inspected one restaurant where the management had a zero tolerance of pests and where they achieved zero pest levels through the rigorous implementation of an IPM program. At the other extreme was a notable restaurant in Paris which simply employed a young man to raise the covers of dishes before they were taken from the kitchen to the dining room and brush the cockroaches off! Most restaurants are somewhere between these extremes.

Whatever the action threshold, IPM is as relevant to urban situations as to agriculture because above all, IPM is about more efficient pest management. I said there is no formal definition of IPM but in 1992 the EPA published a guide for schools called "Pest Control in Schools: Adopting Integrated Pest Management." This guide was based on inputs by scientists, school officials, pest control professionals and environmental activists. That guide contained the following definition: "Integrated Pest Management, or IPM, is an effective and environmentally sensitive approach to pest management. It relies on coordinated use of pest and environmental information and the best available pest management methods to prevent unacceptable levels of pest damage by the most economic means and with the least possible hazard to people, property and the environment." I think this is a good definition of IPM. This EPA guide is particularly useful because it supports the concept of combining chemical and non-chemical methods where necessary. It also states that IPM programs can be implemented by in-house staff, or by contractors or by combinations of in-house and contracted services.

The EPA definition of IPM refers to preventing "unacceptable levels of pest damage" and we must consider what levels are unacceptable in museums and libraries. It might help to know that in some other indoor situations, such as hospital operating theaters or medical research laboratories, there is no acceptable level of pest damage and therefore no acceptable level of pests. I once visited a facility researching biological warfare, and the only acceptable level of pests there was zero. After all, you wouldn't want your anthrax or plague bacteria escaping on the back of a cockroach, would you? So what level of pests is acceptable in the Library of Congress or in the National Gallery or in the National Museum of American History? I would suggest that no level of pests is acceptable. Just as protecting the lives of patients from pest-borne diseases is important in a hospital, so is it important to protect the life works of people in our museums and libraries.

Before defining the key elements of an IPM program, I want to mention the common misconception that IPM is more expensive than conventional pest control based solely on pesticide applications. You will remember that the prime purpose of agricultural IPM was improved profitability through reduced pest control costs. Likewise, urban IPM can be cheaper than programs which rely solely on routine use of pesticides. For example, taking a small component of a pest management program, it is cheaper to close a window to keep the bugs out than to routinely spray around the window frame with a residual insecticide. In other situations there may be initial retrofitting or maintenance costs, but indications from IPM programs in schools and other sectors suggest that long-term costs are often less than programs that rely solely on pesticides.

ELEMENTS OF AN IPM PROGRAM

Buildings vary so much with regard to their location, construction, maintenance levels and uses, that IPM programs must be customised to each situation. However, all IPM programs will require 4 key elements:

1. INSPECTION AND DIAGNOSIS of the actual or potential pest problems.
2. PLANNING OF PEST MANAGEMENT MEASURES - chemical and non-chemical.
3. IMPLEMENTATION OF PEST MANAGEMENT MEASURES: in-house and contracted.
4. EVALUATION OF RESULTS AND FOLLOW-UP.

For buildings, as for perennial crops, IPM programs are continuous. After evaluating the results of initial pest management measures, there would be follow-up inspections to note changes in the situation prior to planning and implementing further measures.

Both the initial inspection and diagnosis, and subsequent inspections, are vital to the success of an IPM program We have already considered the scores of chemical and non-chemical measures for killing or discouraging particular pests. But unless you find out which pests are present, where they are present, what conditions favor them and what objects are vulnerable to them, it will not be possible to plan appropriate measures against them. So I'm going to focus on inspection and diagnosis because this is something that everyone can play a part in. You don't need to be a pest management professional to make useful observations. And observations should not be limited to routine in-depth formal inspections or checking of traps. Anyone can make observations every day as they carry out their work or when simply walking around and through the building. It is a matter of learning to "walk with a purpose". For such ancillary observations relating to pest management to be most useful, they need to be reported and recorded to help in planning pest management measures. Such records might take the form of a log book of pest sightings and conditions conducive to pests, or annotations on a plan of the building.

While such ancillary observations are useful, there is no substitute for detailed inspections by people who recognise major pests and understand their habits and needs. You don't need to be an entomologist to do this, and most pest management professionals are not. The best inspectors are those who have learned to "think like a pest"; and to do this you need to respect them, particularly their abilities to hide, gain access, find food and breed. Two examples from my own experiences will illustrate the value of pest knowledge in identifying problems. In the first example, I was called in by a museum which had noted a sudden outbreak of webbing clothes moths in a special exhibition area of a gallery. There was no history of infestation by this pest in this gallery, so I suspected some of the exhibition items. When the gallery was closed for the day, I sat a short distance from the exhibits and quietly watched. I saw nothing happen for about 20 minutes. Then I saw a moth emerge from an exhibition object in a brightly lit part of the exhibition and fly towards some textiles in a dark corner at the back of the exhibition area. I followed the moth, confirmed it was a webbing clothes moth and killed it. I then backtracked to the object it had flown from and found more evidence of infestation. Knowing that webbing clothes moths don't like brightly lit areas, it was reasonable to suppose the moth had flown from that object because that object was the source of the infestation. Subsequent inquiries revealed that this infested item had come from an outside collection where pest management was inadequate and it had not been checked or treated before being exhibited.

The second example occurred a short time ago when I was visiting some government archives. Before my visit I had been told they had no pest problems and therefore did not have an ongoing pest management program. This interested me because I am always keen to learn from places which have no pest problems! When talking with the chief conservator in the conservation studios I noticed a sanitation problem in the form of dirty floors, and asked if I might walk around the studios. I soon found an accumulation of dust in a corner near a floor length window, together with live adult carpet beetles which I later confirmed was *Anthrenus verbasci* In only 15 minutes I had found a pest which loves leather book bindings, in an area which conserves and restores leather bound books, and in a building which houses thousands of vulnerable historical manuscripts. The conservator was very surprised, but I was not, because the pest was where I would be if I was an adult carpet beetle in spring seeking a way out to the garden, after spending my youth digesting historic documents! So you use your knowledge of pests to find the source of the problem. One other example will illustrate this. Suppose German cockroaches were reported in the Oval Office at the White House. You would go straight to the small adjoining kitchen, because this species needs water every day and that's where you would find water.

A building such as that government archives building requires a thorough initial inspection. Some government buildings require several days to inspect. Even a large private home may take a while, such as one English home which has: about 200 rooms, 400 windows, more than 100 chimneys, over 1 mile of corridors, 359 doors and 27 baths. But there is a lot of interest in inspecting the "goods and grates of the great and good!" Large or small, the same inspection principles apply. The inspector will require access to all areas, including the roof, and an outline plan of the building to facilitate reporting. If the inspector is an outside contractor and there are security issues, such plans can stay on-site. The inspector also needs to gain a working knowledge of the systems within the building, including all utilities, heating and air-conditioning systems, and information on food flow and garbage or trash flow through the building, as well as procedures for receiving shop or office provisions and items for the collection.

The inspector will need such tools as a flashlight, inspection mirror, flushing agent, screwdrivers, hand lens and specimen bottles. Inspecting can be hard, dirty work and kneepads and other protective clothing may be needed. But the main requirement is an eye for detail and an inquiring mind. As well as gaining information from visual inspection, additional information can be obtained by talking to occupants of the building and using traps in suspect or vulnerable areas.

An initial inspection will start on the outside, noting potential pest harborages such as vegetation, dumpsters, drains and bird nests. Potential entry points for pests will also be noted, including gaps under doors, unscreened vents and windows, and gaps around entering utility pipes or lines. Inside, the inspection will focus on areas near potential entry points, including goods receiving areas, and on areas where there is a history of infestation or conditions favoring infestation. Special attention should be given to food preparation and food service areas, including staff break areas; to quiet areas such as mechanical rooms, restrooms and janitorial closets; and of course to vulnerable sections of the collection, such as textiles, books, ethnographic items and natural history specimens. The type and extent of any infestation should be recorded, as well as any sanitation, design or maintenance problems, and any practices or procedures which encourage pests. Where an outside expert conducts the inspection, I recommend he be accompanied by a knowledgeable member of staff, for an immediate exchange of information, and so that member of staff is better informed for conducting future inspections independently.

The inspection findings and diagnosis of actual or potential pest problems form the basis for planning chemical and non-chemical measures. The exact measures will need to be worked out after broad consultation with management, curators, conservators and those who will implement or be affected by the measures. The various measures will be prioritized and decisions made on who will implement them and when. The original inspection report and diagnosis will serve as a benchmark for evaluating the pest management measures. In addition to a program of evaluating any newly implemented measures, a long-term program of checking the status of the building should be scheduled, based on periodic visual inspections, as well as continuous monitoring with traps based on weekly trap checks, and organised feedback from building occupants. Instances of sanitation, maintenance or other problems should be entered into a log or marked on the building plan as an aide memoire for carrying out remedial measures.

Increasingly, in large facilities, such as food warehouses and processing plants, where there are long-term infestations of pests, a permanent grid of traps is maintained. The weekly counts from these traps are recorded, sometimes using a software program for easier record keeping, mapping and reporting, e.g. Israeli program: Prog. to Kill Monitoring Software, e-mail address: (prog2kil@iol.co.il). Traps can even be bar coded with a specific location label for easier computer record keeping. Such technology is useful where there are frequent trap catches by hundreds or thousands of traps. One tobacco company is reported to use more than 100,000 pheromone traps a year and the data generated helps in understanding the seasonality of some pest problems and in planning the insecticide fogging schedules for the buildings. However, in museums and libraries, unless something is very wrong with the preventive pest management measures, there should not be such an avalanche of trap catch data. And remember, just because you find a particular bug in a trap does not mean it is the only type of bug in your museum, or even the most important type. I learned this lesson a long time ago during the days of the Cold War when I travelled behind the Iron Curtain. The hotel rooms had electronic bugs, but the ones you found were not likely to be the ones that were working; they were just intended to give you a false sense of security when you found them.

THE TEAMWORK APPROACH TO IPM

In most museums and libraries I have visited, only a few people are involved in pest management, even where there is a nominal IPM program. In some of these places there is an acceptance of an ongoing low level population of pests which are inexorably damaging the collection - a little damage here a little damage there, but over a long period it adds up to an unacceptable level of damage. I understand the difficulties. Even in a purpose-built facility with no initial pest problems, things can go wrong; screens on windows may break, the foundation may develop cracks, the air-conditioning break down or you may be flooded

I do not pretend that getting rid of an infestation and preventing reinfestation is easy. The task can be compared with that of a sculptor starting with a jagged rock and wanting to create a smooth sculpture. He gradually chips away, week after week, month after month, and sometimes year after year. So it is with IPM. You may achieve a lot of progress in the initial months, but the final problems may take a long time to work out and solve, and then you have to maintain your achievements. But just because it is difficult is no reason not to try. That famous American Homer Simpson said: "Trying is the first step on the road to failure." Well, I suggest you forget that philosophy, because it's not the kind of philosophy that won the War of Independence or which will win your war against pests. You must try, try and try again, but your job will be easier if you have more people to help you.

I am going to quote some of the things that conservators have reported to me recently:

1) "Our work has low priority compared with 'front-of-house' activities."
2) "I don't have access to the roof area; in fact we don't have any lines of communication with the building maintenance people."
3) "We don't have any voice in the management of the restaurant."
4) "We don't have any involvement in running the shop."
5) "We have no involvement in managing office supplies."

6) "We have little involvement in social functions at the museum - we never have any of our people attending."
7) "We don't get involved in floral displays, they have a separate budget."
8) "We are only involved in cleaning of the objects, not the building."
9) "We don't have anything to do with the landscaping. We certainly can't control what is planted."
10) "We were only involved in planning the museum extension at a late stage."

These sorts of comments suggest to me that in some museums and libraries the various activities are not only managed separately, but there is little communication between those managing, cleaning or maintaining the building, and those more directly caring for the collection.

My work has involved inspecting numerous types of premises - literally an "A to Z", from abattoirs to zoos, public housing to palaces, and mausoleums to museums. Among the things I have learned is that wherever food is stored, prepared or served there is an increased risk of pests, including pests such as cockroaches, silverfish and beetles which can threaten collections. Yet I see increased use of museums and libraries for catered social functions, with often little consultation with conservators about resulting risks to the collection, and few extra resources allocated to prevent food related pests spreading to the collection. An analogy would be the chicken farmer who decides to earn some extra money by raising foxes as well; in such a case the secondary activity could compromise the primary activity!

Another observation I have made is that many private collections I've visited are cared for better than many public collections. Is this because ownership confers a greater sense of commitment or duty to protecting the collection? I have certainly found that in some private collections the staff as well as the owners feel a sense of pride and proprietorship in the property, which results in a team effort to care for it.

I know you care about your collections. But I have often found that, in large public institutions, ancillary staff regard their work as just a job, not a vocation. I have observed not only poor communications but also buck passing when things go wrong. I have also observed ignorance of the collection among ancillary staff and I ask myself: "If employees don't even know the collection, how can they respect it and be committed to a team effort to protect it?"

In 1994, ICCROM (the International Centre for the Study of the Preservation and the Restoration of Cultural Property) which has had excellent inputs from Smithsonian staff, started a pilot project in a few European museums. This project was called "Teamwork for Preventive Conservation in European Museums". The aim was to develop and implement preventive conservation plans in each museum, using a primary team involving every necessary staff member. These primary teams then held sessions to create awareness and participation among the entire staff, and to form multi-disciplinary teams for detailed preventive conservation efforts. These "Teamwork" pilot projects for preventive conservation have a broad focus and are not just concerned with pest prevention. But many of the areas identified for action have collateral pest control effects: viz. cleaning in stores and galleries, improving housing for objects, improving environmental monitoring and control, and quarantining accessions and returning loans. In one participating museum a new staff member has been recruited with a special remit for pest monitoring as part of preventive conservation.

I believe the whole subject of integrated pest management needs to be part of a team effort for <u>total building management</u> - rather like "total quality management" in the manufacturing sector. You might call this Integrated Building Management or IBM, but I believe someone has already used that acronym! With such a team effort, everyone is "on-message", everyone is involved. Then, when problems occur you don't look for someone to blame; instead you examine the problem and work as a team to solve it, because everyone is responsible.

Conservators can play a key role in establishing such a team approach, not least because conservators know the collections, they know what conditions suit the various items in the collection, and they know what threatens them. But to date I have only encountered one museum where the building manager was a conservator with full authority over cleaning and maintenance measures, as well as specific pest control measures. I have noticed that advocacy is not a typical strength of conservators. But conservators need to argue for what is necessary and test the limits of their responsibilities. There are lots of pushy pests out there; in fact world wide, the biomass of insects is estimated to outweigh the bio mass of humans by a ratio of 12 to 1. What we need is more pushy conservators. I think an important function of conservators is the recruitment of existing employees (such as cleaners, maintenance people and gallery attendants), as well as other professionals (such as curators, building engineers, function managers, shop or restaurant managers), to a preventive conservation team. I think everyone should be involved and should be committed to the conservation goal. And, as General Sam Houston found in 1836, a team of people that is committed, but with limited resources, can achieve more than an uncommitted team with plenty of resources.

LOOKING AHEAD - WHY WE MUST BE COMMITTED TO CONSERVATION

I think the more we value the collections we care for, the more we will be committed to protecting them. When I talk about value I am not talking about monetary value, I am talking about cultural value. I differ from most of you here because I come from the United Kingdom. But we all belong to a much larger kingdom, the Animal Kingdom. As a zoologist I have learned what a remarkable species we are and how we differ from other animals. To understand this difference you also need to know what we have in common with other animals.

Like other animals we all need to eat, some of us more than others. You might think we are different from the rest of the Animal Kingdom because we can <u>grow</u> our food. But there are some animal species which also grow their food, such as the leaf-cutting ants which grow fungus gardens. And many people hunt their food, just like some other animals.

Most people and most animals share the need for shelter. You might think we are different from other animals because, whereas we build our homes, other animals just find natural shelter, such as hollow trees or caves. But I've seen where people still live in caves, and many animals can build their homes too, often using the same type of building materials as people (e.g. the mud nests of mud dauber wasps and oven birds vs. the mud huts in Africa or adobe homes in New Mexico; also birds nests made of sticks and straw vs. African straw huts). And if you think we are the only species which builds communal homes, consider the communal homes of some weaver birds, or the nests of bees, wasps and termites.

Another thing we share with other animals is the need to reproduce our species. You might think our mating preliminaries are more elaborate than other species, but consider the mating displays of some animals and the elaborate preparations of bower birds.

So if we share so many characteristics with other animals, what makes us different? Just a few decades ago, it was popular to separate human beings from other animals by saying we were the only species which made tools. But now we know that several other species make tools, including some of our close relatives.

What really distinguishes us from other animals is our creativity. Quite simply, we are animals that make things that are not just functional. This creativity extends right back to the roots of our civilization, when we even decorated our bone tools and the walls of our caves. And when we began to build our homes, we didn't just build the bare essentials we built them as beautifully as resources allowed. I've seen beautiful tepees and beautiful palaces. Native Americans considered that artistic expression was as necessary to their spiritual well-being as hunting buffalo was to their physical survival. And the people who live in palaces are no different than you or I, they just chose their ancestors more wisely! We are all creative. Some of us express creativity in the presentation of food; others express it through clothing or patchwork quilts. My main creative outlets are landscape gardening and room decoration, and I accept that my efforts are poor compared with some of the artists and artisans of the past.

It is because of the uniqueness of our creativity that we should be committed to preserving the creative genius of centuries, and the record of our whole civilization. It may not even be obvious to us which cultural items are worth protecting. In his lifetime Vincent van Gogh's paintings were literally worthless. He couldn't sell a single painting at any price. Now his works are widely regarded as great art, perhaps because they so poignantly reveal the human creative urge. So what we conserve now may be even more highly appreciated in future.

In caring for collections our task is difficult because we have to consider the long-term consequences of our actions In conventional pest management, a PCO may be concerned about not scorching a shrub, or tainting some food, or staining a fitted carpet. But if he makes a mistake the damaged item can usually be replaced. In our work, replacement is seldom an option, so we typically consider whether what we do might harm something over a 500 year period. To many people 500 years is an inconceivably long time - even one generation is a long time. I was reminded of this recently when I asked a teenage friend of my daughter what music she liked, and she said she liked "old" music. I asked which old music, expecting her to say Mozart or Beethoven, or at least Tchaikovsky or Strauss, but she said she liked the Beatles! For her, 30 years was a long time - for me it was a fresh memory of dance halls in Liverpool and elsewhere.

While we might pat ourselves on the back for trying to think 500 years ahead, let me suggest that even 500 years is a short time when considering our responsibility to future generations. We have already benefitted from items passed down to us from thousands of years ago, and we should look just as far ahead. As we approach another millenium there will be many people forecasting various doomsday scenarios, perhaps based on meteor strikes or global warming. None of these forecasts will provide a real basis for planning. What we do know is that in geological terms we are in an interglacial period. The last Ice Age ended about 10,000 years ago and the next one may be less than 10,000 years ahead. When it comes we will need to relocate populations to gentler climes. Chicago, Detroit, Boston, even New York, will cease to exist as habitable areas, just as in the last Ice Age. But from our viewpoint, buildings are expendable - they are just the receptacles for the contents. The relocation of populations and collections may seem daunting, but it will be well within Man's capability. For thousands of years populations and collections have been relocated, often at very short notice in times of war. Relocation due to climate change could be much better planned because the timescale would be more protracted, perhaps over hundreds of years. Our challenge, and that of our successors is to preserve our cultural and scientific heritage so that, in the distant future, there is something left which can be relocated.

You are all professionals, and many of you may have learned nothing new today. But I hope I have reminded you of what you already know, and that your emphasis should be on preventing pest problems by decreasing pest resources and access. I hope I have encouraged you not to become too preoccupied with seeking new wonder products; because they will never be a substitute for your most important resource, the people, all the people, in your own organisation who can work as a multi-disciplinary team against pests.

If only one of you, as a result of today's seminar, goes back and improves protection of your collection, it will have been worthwhile. And as for those millenium doomsayers, the most urgent issue is to deal with the "millenium bug" threatening many computers. But that is one bug for which I have no special knowledge and must refer you to others.

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