Course outline: Preventive Conservation

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Basic definition

Preventive Conservation is the mitigation of deterioration and damage to cultural property through the formulation and implementation of policies and procedures for the following: appropriate environmental conditions; handling and maintenance procedures for storage, exhibition, packing, transport, and use; integrated pest management; emergency preparedness and response; and reformatting/duplication. Preventive conservation is an ongoing process that continues throughout the life of cultural property, and does not end with interventive treatment.

A. RATIONALE

- To extend the life of cultural property.
- To reduce the risk of catastrophic loss of cultural property.
- To defer, reduce, or eliminate the need for interventive treatment.
- To extend the effectiveness of interventive treatment.
- To provide a cost-effective method for the preservation of collections.
- To maximize impact of the conservation professional.
- To encourage the conservation professional to employ the broadest range of preservation strategies (e.g., risk management, long-range planning, site protection).
- To encourage the conservation professional to collaborate with others who have responsibility for the care of collections and cultural property (e.g., security and fire prevention personnel, facilities or site managers, collections managers, maintenance staffs).
- To encourage the participation of others in the preservation of cultural property.

The purpose of the course is to discuss and practice the risk management approach to conservation of collections. Risk management can be understood not only as the management of rare catastrophes, but also as the management of slow continual hazards, and everything between. It becomes an integrated view of all expected damages and losses to collections. The course will review the risk management concept and its various current interpretations and applications in the field of cultural heritage. Participants will be introduced to a practical method to carry out a risk assessment survey for collections in museums. By the end of the course participants should be able to :

1- identify all agents of deterioration;

2-identify risk types;

3-estimate magnitudes of risks;

4-rank their relative importance;

5-Implement consistent environmental monitoring for temperature, relative humidity, and light levels in storage, exhibit, and work-processing areas.

6. Implement An <u>Integrated Pest Management (IPM)</u> program throughout the building in public, staff, and collection storage and exhibit areas.

7. Develop policies and guidelines for the safe handling, exhibition, storage, and research use of cultural objects.

8- Evaluate the relative costs, benefits and collateral risks of implementing the proposed mitigation measures.

Objective
By the end of the course, participants will be able to put into application the proper preventive conservation measures to safeguard collections under their custody.

Participants
The course is designed for collection managers, museum curators, museum technicians, and conservators. The course will also interest educators and professionals who teach collection management and preventive conservation, in either an academic or a vocational environment.

Course Materials

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CHAPTER 1

PREVENTIVE CONSERVATION: GETTING STARTED

1-1- Overview

This chapter will introduce you to the basic concept and methods of preventive conservation of cultural heritage in its broad sense. This includes museum objects, specimens and archival collections as well as cultural sites.

This chapter will give you information on:
· Preventive care and treatment for museum collections
· How to plan for object conservation
· The role of a collection management plan (CMP) in conservation planning
· The role of a collection condition survey (CCS) in conservation planning
· Balancing preservation of historic structures and museum objects

1-2-What is preventive conservation?

Preventive Conservation is the mitigation of deterioration and damage to cultural property through the formulation and implementation of policies and procedures for the following: appropriate environmental conditions; handling and maintenance procedures for storage, exhibition, packing, transport, and use; integrated pest management and emergency preparedness and response. Preventive conservation is an ongoing process that continues throughout the life of cultural property, and does not end with interventive treatment.

By using preventive conservation techniques, you can limit the imperceptible deterioration that occurs on a daily basis (but is cumulative over time) and the catastrophic damage that occurs occasionally. Only when preventive care techniques are not implemented or objects are inherently unstable, is conservation treatment necessary.

1-3- Rationale of Preventive Conservation

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1-4-How Preventive Conservation is practiced?

- Before considering interventive treatment, the conservator must consider whether preventive conservation options are more appropriate.
- In the process of developing and implementing preventive conservation, the conservation professional must collaborate with appropriate personnel.
- Before making recommendations for preventive conservation measures, the conservation professional must be conversant with the preservation-related conditions (e.g., temperature, relative humidity, pests, light, pollutants, housing materials) in which the cultural property or collection currently exists.
- Because many preventive conservation actions are carried out by others, the conservation professional must be responsible for setting the standards under which these measures are carried out and for periodically reviewing their implementation. These standards must be in writing.
- The conservation professional must employ or recommend only those preventive conservation measures that are currently accepted practice in the profession.

1-5- Recommended Practice

- Recommendations for preventive conservation should be in written form and supported by illustrative material where appropriate (format and level of detail may vary). These should specify:
  - Methods, procedures, and suitable materials;
  - Personnel requirements and qualifications (e.g., for in-house staff, contractor, volunteer).
- Following treatment, recommendations for preventive conservation measures should be included in the treatment report.
- The conservation professional should participate in the education and training of others involved in preventive conservation.

1.6-What are the Agents of Deterioration that should be Controlled in Preventive Conservation?

The agents of deterioration are forces that act upon objects causing chemical and physical damage. The agents of deterioration can be classified as:

· **Direct physical forces**, such as shock, vibration, and abrasion that can break, distort, puncture, dent, and scratch all types of objects. These forces may be *cumulative,* such as improper handling or support or *catastrophic,* such as earthquake, war, or shelf collapse.

· **Thieves, vandals, or careless individuals** who misplace objects. Some of these agents are *intentional,* such as criminals who steal or disfigure objects. Others are *unintentional,* such as staff or users who misfile objects.

· **Fire** that destroys, scorches, or deposits smoke on all types of objects.

· **Water** that causes efflorescence in porous materials, swells organic materials, corrodes metals, delaminates and/or buckles layered components, and loosens joined components.

· **Pests,** such as *insects* that consume, perforate, cut, graze, tunnel and/or excrete which destroys, weakens, disfigures, or etches organic materials. Pests also include *vermin* such as birds and other animals that gnaw organic materials and displace small objects, foul objects with feces and urine and *mold and microbes* that weaken or stain objects.

· **Contaminants** that disintegrate, discolor, or corrode all types of objects, especially reactive and porous materials. This includes *gases* (such as pollution, oxygen*), liquids* (such as plasticizers, grease), and *solids* (such as dust, salt).

· **Radiation**, including both ultraviolet radiation and visible light. *Ultraviolet* radiation disintegrates, fades, darkens, and/or yellows the outer layer of organic materials and some colored inorganic materials. *Unnecessary visible light* fades or darkens the outer layer of paints and wood.

· **Incorrect temperature** that can be *too high* causing gradual disintegration or discoloration of organic materials; *too low* causing embrittlement, which results in fractures of paints and other polymers; or *fluctuating* causing fractures and delamination in brittle, solid materials. Fluctuations in temperature also cause fluctuations in RH.
· **Incorrect relative humidity** that can be *damp (over 65% RH),* causing mold and corrosion, or *above or below a critical value,* hydrating or dehydrating some minerals and corroding metals that contain salts.
Organic materials will gradually disintegrate and discolor, especially materials that are chemically unstable at any RH level *above 0%*. *Fluctuating* RH will shrink and swell unconstrained organic materials, crush or fracture constrained organic materials, cause layered organic materials to delaminate and/or buckle, and loosen joints in organic components.
Most objects are affected by a variety of these agents of deterioration at the same time. As you improve preventive care of your collections, you will be addressing each of the agents of deterioration through a variety of policies and procedures.

1-7- What is conservation treatment?

Conservation treatment is the deliberate alteration of the chemical and/or physical aspects of an item from a museum collection, in order to prolong the item's existence. Treatment may consist of stabilization and/or restoration. **Stabilization** consists of those treatment procedures applied to maintain the integrity of a museum object and to minimize further deterioration. For example, when a conservator washes paper, the washing removes acidic by-products of deterioration. This is a method of stabilization. **Restoration** consists of those treatment procedures intended to return cultural property to a known or assumed state, often through the addition of non-original material. For example, to restore a broken ceramic pot a conservator might glue broken pieces together and fill the losses with plaster.
You should consider conservation treatment in the following cases:
· when preventive care measures are not enough to reduce the rate of deterioration to a tolerable level, such as deteriorating plastic objects
· when deterioration has proceeded to a point where the object is extremely fragile and is in danger in any circumstances, such as when paint is flaking from a picture
· when stabilization or restoration is required for exhibit
· when stabilization or restoration is required for research
Conservation treatment should be kept to a minimum. This approach reduces the chances of compromising the aesthetic, archeological, cultural, historical, physical, religious, or scientific integrity of objects.

1-8-Who is responsible for preventive conservation?
Preventive conservation is the responsibility of everyone who works in and around museum collections, including archivists, museum technicians, collection managers, conservators, curators, interpreters, maintenance personnel, preparators, and researchers.
The **collection management specialist (curator, archivist, collection manager)** is the person with primary responsibility for the day-to-day management of the museum collection. The duties of these professionals include:
· acquisition
· documentation
· Preventive conservation
· interpretation and exhibits
· research and publication
A curator has expertise in material culture studies and is trained and skilled in the history and philosophy of museums, as well as the practical aspects of preventive conservation.
The **conservator** is trained and skilled in the theoretical and practical aspects of preventive conservation and conservation treatment. Most conservators specialize in the treatment of specific groups of objects (for example, archeological objects, books, ethnographic objects, natural science specimens, fine and decorative art objects, photographic materials,

paintings, paper, sculpture, textiles, or wooden artifacts). There is some overlap among these groups, so one conservator may work on a range of these materials.

The collection management specialist (such as a curator, archivist or collections manager) and the conservator work together and with other professionals to develop a successful conservation program. Conservators are responsible for recommending and carrying out conservation treatments. Untrained staff should **NOT** attempt to do treatments. However, the collection management specialist has the ultimate responsibility for deciding on the care and management of the collections.

1-9-How Preventive Conservation is Generally Carried Out?
There are a variety of ways you can protect your collections from the agents of deterioration. There are four steps to stop or minimize damage:

· **Avoid the agents of deterioration.** For example, choose a site for your collection storage that is away from the flood plain of a river or stream. Build a storage facility that is properly insulated and does not
have windows in collections areas.

· **Block the agents when you cannot avoid them.** This is probably the main way most museums protect their collections. For example, if your collection storage area has windows, cover them with plywood. Place UV filters on fluorescent lights to block damaging radiation. Fill cracks and gaps in a building structure to limit entry to pests.

· **Test the methods you use to block agents of deterioration by monitoring**.
For example, set up an Integrated Pest Management (IPM) program to find out if you have pests. Monitor relative humidity and temperature to find out if your HVAC system is working properly.

· **Respond to information you gather with your monitoring programs.** Monitoring is a waste of time if you do not review, interpret, and use the information. Only if these first four approaches fail should you have to recover from deterioration. Recovery usually means treating an object. While a treated object may *look* the same, once damage has occurred, an object will never *be* the same. Your aim in caring for your collection should be to carry out preventive tasks so that treatment is not needed. Many objects will come to your museum collections damaged and deteriorated from use and exposure. Because of their history, even in the best museum environment, some objects will need treatment. You should develop a treatment plan for immediate problems in the collection. Your primary goal, however, is to create a facility that will minimize damage and maintain the collection through preventive measures.

These are a summary of the preventive conservation activities:

· Monitoring and assessing condition of collections

· Monitoring and evaluating museum environment and alerting staff to signs and causes of deterioration

· Practicing proper methods and techniques for storing, exhibiting, handling, packing and shipping of objects, and pest management.

· Developing and implementing ongoing Integrated Pest Management (IPM), and housekeeping/maintenance program for collections

· Preparing emergency operation plan for museum collections

CHAPTER 2

PREVENTIVE CONSERVATION IN MUSEUMS

2-1- What information will I find in this chapter?
This chapter will give you information on how to protect your collection from deterioration caused by interaction with the surrounding environment. From the moment an object is

created, it begins to deteriorate. The factors that can cause deterioration are called "agents of deterioration.
This chapter will address four agents that can be grouped under the term **environment**:
· Temperature
· Relative humidity
· Light
· Air pollution
Understanding how the environment affects museum and storage collections and how to monitor and control these agents of deterioration is the most important part of a preventive conservation program.
In order to understand how the agents of deterioration react with the objects in your collection, you must develop a "critical eye." This skill allows you to identify active deterioration and its causes. How you do this is described below.

2-2-What is the "Critical Eye?"
The "critical eye" is a way of looking at objects to evaluate their condition and identify reasons for changes in the condition. You develop this skill over a period of time through both training and experience. You must continually ask yourself the questions:
· What is occurring?
· Why is it occurring?
· What does it mean?

2.2.1-The critical eye is a trained eye.
Your trained eyes will focus on the materials and structure of the object and look for visual clues to the agents of deterioration in the environment. A person with a trained eye readily recognizes danger signs, records them and associates them with the condition of the museum collections, and
implements actions to slow down or stop deterioration. Examples of problems that you will see with a trained eye include:
· Sunlight falling on a light sensitive surface
· Condensation forming on cold surfaces
· Water stains appearing on ceilings or walls
· Insect residues and mouse droppings
You must learn about the following topics to develop your critical eye:
· Types of materials that make up a museum collection
· Inherent characteristics of objects
· Types of deterioration
The success of a preventive conservation program relies on the gathering, recording, and evaluating of all this information in order to implement solutions and to mitigate environmental factors that are harmful to a museum collection.

2-3-What Kinds of Materials Will I Find in a Museum Collection?
Museum objects are often divided into three material-type categories:
organic, inorganic, and composite. You must understand the properties of each of the materials in each of these categories.

2.3.1-Organic Objects:
Organic objects are derived from things that were once living — plants or animals. Materials are processed in a multitude of ways to produce the objects that come into your collections. Various material types include wood, paper, textiles, leather and skins, horn, bone and ivory, grasses and bark, lacquers and waxes, plastics, some pigments, shell, and biological natural history specimens. All organic materials share some common characteristics. They:
· contain the element carbon
· are combustible
· are made of complicated molecular structures that are susceptible to deterioration from extremes and changes in relative humidity and temperature
· absorb water from and emit water to the surrounding air in an ongoing attempt to reach an equilibrium (hygroscopic)

· are sensitive to light
· are a source of food for mold, insects, and vermin

2.3.2-Inorganic Objects:
Inorganic objects have a geological origin. Just like organic objects, the materials are processed in a variety of ways to produce objects found in your collections. Material types include: metals, ceramics, glass, stone, minerals, and some pigments. All inorganic objects share some common characteristics. They:
· have undergone extreme pressure or heat
· are usually not combustible at normal temperature
· can react with the environment to change their chemical structure (for example, corrosion or dissolution of constituents)
· may be porous (ceramics and stone) and will absorb contaminants (for example, water, salts, pollution, and acids)
· are not sensitive to light, except for certain types of glass and pigments

2.3.3-Composite Objects:
Composite or mixed media objects are made up of two or more materials. For example, a painting may be made of a wood frame and stretcher, a canvas support, a variety of pigments of organic and inorganic origin, and a coating over the paint. A book is composed of several materials such as paper, ink, leather, thread, and glue. Depending on their materials, composite objects may have characteristics of both organic and inorganic objects. The individual materials in the object will react with the environment in different ways. Also, different materials may react in opposition to each other, setting up physical stress and causing chemical interactions that cause deterioration.

2-4-What is Deterioration?
Deterioration is any physical or chemical change in the condition of an object. Deterioration is inevitable. It is a natural process by which an object reaches a state of physical and chemical equilibrium with its immediate environment.
The types of deterioration can be divided into two broad categories:
physical deterioration and chemical deterioration. Both types often occur simultaneously.

2.4.1-*What is chemical deterioration?*
Chemical deterioration is any change in an object that involves an alteration of its chemical composition. It is a change at the atomic and molecular level. Chemical change usually occurs because of reaction with another chemical substance (pollution, water, pest waste) or radiation (light and heat). Examples of chemical change include:
· oxidation of metals (rusting)
· corrosion of metals and stone caused by air pollution
· damage to pigments by air pollution or reaction with other pigments
· staining of paper documents by adjacent acidic materials
· fading of dyes and pigments
· darkening of resins
· darkening and embrittlement of pulp papers
· burning or scorching of material in a fire
· embrittlement of textile fibers
· bleaching of many organic materials
· cross-linking (development of additional chemical bonds) of plastics
· rotting of wood by growing fungus

2.4.2-*What is physical deterioration?*
Physical deterioration is a change in the physical structure of an object. It is any change in an object that does not involve a change in the chemical composition. Physical deterioration is often caused by variation in improper levels of temperature and relative humidity or interaction with some mechanical force. Examples of physical deterioration include:
· melting or softening of plastics, waxes, and resins caused by high temperature
· cracking or buckling of wood caused by fluctuations in relative humidity

· warping of organic materials caused by high relative humidity
· warping or checking of organic materials caused by low relative humidity
· shattering, cracking, or chipping caused by impact
· crushing or distortion caused by a harder material pressing against flexible material
· abrasion caused by a harder material rubbing against a softer material
· structural failure (for example, metal fatigue, tears in paper, rips in textiles)
· loss of organic material due to feeding by insects and/or their larvae
· staining of textiles and paper by mold

Physical deterioration and chemical deterioration are interrelated. For example, chemical changes in textiles caused by interaction with light also weaken the fabric so that physical damage such as rips and tears may occur.

2.5-What is Inherent Vice?

In addition to deterioration caused by the agents of deterioration, certain types of objects will deteriorate because of their internal characteristics. This mechanism of deterioration is often called ***inherent vice*** or ***inherent fault***. It occurs either because of the incompatibility of different materials or because of poor quality or unstable materials. In nature, materials often possess characteristics that protect them from natural degradation. Their structure and composition may include features such as protective layers, insect and mold resistant chemicals, and photochemical protection. Processing during object manufacture can remove these natural safeguards. Additives may be applied to give a desired result, without concern for long-term preservation. This processing results in inherently less stable materials or combinations of mutually incompatible substances that have damaging interaction.

2.6-Why is it important to understand the environmental agents of deterioration and how to monitor them?

If you understand basic information about the chemistry and physics of temperature, relative humidity, light, and pollution, you will be better able to interpret how they are affecting your museum collections. This chapter gives you a basic overview of these agents and describes how to monitor them. You will be able to tell how good or bad the conditions in a museum are and whether or not the decisions you make to improve the environment are working the way you expect. The rest of this chapter gives you guidelines for deciding on the best environment that you can provide for your collections. However, because of the huge variation in materials found in collections no strict standards can be set.

In the past, simplified standards such as 50% RH and 65°F were promoted. With research and experience, it is now understood that different materials require different environments. You must understand the needs of your collection for the long-term in order to make thoughtful decisions about proper care. You will want to develop microenvironments for storage of particularly fragile objects. A microenvironment (microclimate) is a smaller area (box, cabinet, or separate room) where temperature and/or humidity are controlled to a different level than the general storage area. Common microenvironments include:
· freezer storage for cellulose nitrate film
· dry environments for archeological metals
· humidity-buffered exhibit cases for fragile organic materials
· temperature-controlled vaults for manuscript collections

2.6.1-. Temperature

2.6.1.1-. *What is temperature?*

Temperature is a measure of the motion of molecules in a material. Molecules are the basic building blocks of everything. When the temperature increases, molecules in an object move faster and spread out; the material then expands. When the temperature decreases, molecules slow down and come closer together; materials then contract. Temperature and temperature variations can directly affect the preservation of museum collections in several ways.

2.6.1.2- *How does temperature affect museum collections?*

Temperature affects museum collections in a variety of ways.
· At higher temperatures, chemical reactions increase. For example, high temperature leads to the increased deterioration of cellulose nitrate film. If this deterioration is not detected, it

can lead to a fire. As a rule of thumb, most chemical reactions double in rate with each increase of 10°C (18°F).
· Biological activity also increases at warmer temperatures. Insects will eat more and breed faster, and mold will grow faster within certain temperature ranges.
· At high temperatures materials can soften. Wax may sag or collect dust more easily on soft surfaces, adhesives can fail, lacquers and magnetic tape may become sticky.
In exhibit, storage and research spaces, where comfort of people is a factor, the recommended temperature level is 18-20° C (64-68° F). Temperature should not exceed 24° C (75° F). Try to keep temperatures as level as possible. In areas where comfort of people is not a concern, temperature can be kept at much lower levels—but above freezing. Avoid abrupt changes in temperature. It is often quick variations that cause more problems than the specific level. Fluctuating temperatures can cause materials to expand and contract rapidly, setting up destructive stresses in the object. If objects are stored outside, repeated freezing and thawing can cause damage.
Temperature is also a primary factor in determining relative humidity levels. When temperature varies, RH will vary. This is discussed in more detail in the next section.

2.6.2- Relative Humidity

2.6.2.1-*What is relative humidity (RH)?*
Relative humidity is a relationship between the volume of air and the amount of water vapor it holds at a given temperature. Relative humidity is important because water plays a role in various chemical and physical forms of deterioration. There are many sources for excess water in a museum: exterior humidity levels, rain, nearby bodies of water, wet ground, broken gutters, leaking pipes, moisture in walls, human respiration and perspiration, wet mopping, flooding, and cycles of condensation and evaporation.
All organic materials and some inorganic materials absorb and give off water depending on the relative humidity of the surrounding air. Metal objects will corrode faster at higher relative humidity. Pests are more active at higher relative humidity. We use relative humidity to describe how saturated the air is with water vapor. “50% RH” means that the air being measured has 50% of the total amount of water vapor it could hold at a specific temperature. **It is important to understand that the temperature of the air determines how much moisture the air can hold.** Warmer air can hold more water vapor. This is because an increase in the temperature causes the air molecules to move faster and spread out, creating space for more water molecules. For example, warm air at 25°C (77°F) can hold a maximum of about 24 grams/cubic meter (g/m3), whereas cooler air at 10°C (50°F) can hold only about 9 g/m3. Relative humidity is directly related to temperature. In a closed volume of air (such as a storage cabinet or exhibit case) where the amount of moisture is constant, a rise in temperature results in a decrease in relative humidity and a drop in temperature results in an increase in relative humidity. For example, turning up the heat when you come into work in the morning will decrease the RH; turning it down at night will increase the RH. ***Relative humidity is* inversely *related to temperature. In a closed system, when the temperature goes up, the RH goes down; when temperature goes down, the RH goes up.***

2.6.2.2-. *What is the psychrometric chart?*
The relationships between relative humidity, temperature, and other factors such as absolute humidity and dew point can be graphically displayed on a **psychrometric chart**. The following definitions will help you understand the factors displayed on the chart and how they affect the environment in your museum.
· **Absolute humidity** (AH) is the quantity of moisture present in a given volume of air. It is not temperature dependent. It can be expressed as grams of water per cubic meter of air (g/m3). A cubic meter of air in a storage case might hold 10 g of water. The AH would be 10 g/m3.
· **Dew point** (or saturation temperature) is the temperature at which the water vapor present saturates the air. If the temperature is lowered the water will begin to condense forming dew. In a building, the water vapor may condense on colder surfaces in a room, for example, walls or window panes. If a shipping crate is allowed to stand outside on a hot day, the air inside the box will heat up, and water will and condense on the cooler objects.

· **Relative humidity** relates the moisture content of the air you are measuring (AH) to the amount of water vapor the air could hold at saturation at a certain temperature. Relative humidity is expressed as a percentage at a certain temperature. This can be expressed as the equation: RH = Absolute Humidity of Sampled Air x 100 Absolute Humidity of Saturated Air at Same Temperature Use the following example to understand how this concept relates to your museum environment.

In many buildings it is common to turn the temperature down in the evenings when people are not present. If you do this in your storage space, you will be causing daily swings in the RH. Suppose you keep the air at 20°C (68°F) while people are working in the building. A cubic meter of air in a closed space at 20°C (68°F) can hold a maximum of 17 grams of water vapor. If there are only 8.5 grams of water in this air, you can calculate the relative humidity.

The AH of the air = 8.5 grams

The AH of saturated air at 20°C = 17.0 grams

Using the equation above

RH = 8.5 x 100% = 50%

50% RH may be a reasonable RH for your storage areas. But, if you turn down the heat when you leave the building at night, the RH of the air in the building will rise rapidly. You can figure out how much by using the same equation. If the temperature is decreased to 15°C (59°F), the same cubic meter of air can hold only about 13 grams of water vapor. Using the same equation

The AH of the air = 8.5 grams

The AH of saturated air at 15°C (59°F) = 13.0 grams

RH = 8.5 x 100% = 65%

By turning down the heat each night and turning it up in the morning you will cause a 15% daily rise and fall in RH.

2.6.2.3-. *How do organic objects react with relative humidity?*

Organic materials are ***hygroscopic***. Hygroscopic materials absorb and release moisture to the air. The RH of the surrounding air determines the amount of water in organic materials. When RH increases they absorb more water; when it decreases they release moisture to reach equilibrium with the surrounding environment. The amount of moisture in a material at a certain RH is called the ***Equilibrium Moisture Content*** (EMC). Over time, these reactions with water can cause deterioration.

2.6.2.4-.*What deterioration is caused by relative humidity?*

Deterioration can occur when RH is too high, variable, or too low.

· **Too high:** When relative humidity is high, chemical reactions may increase, just as when temperature is elevated. Many chemical reactions require water; if there is lots of it available, then chemical deterioration can proceed more quickly. Examples include metal corrosion or fading of dyes. High RH levels cause swelling and warping of wood and ivory. High RH can make adhesives or sizing softer or sticky. Paper may cockle, or buckle; stretched canvas paintings may become too slack. High humidity also supports biological activity. Mold growth is more likely as RH rises above 65%. Insect activity may increase.

· **Too low:** Very low RH levels cause shrinkage, warping, and cracking of wood and ivory; shrinkage, stiffening, cracking, and flaking of photographic emulsions and leather; desiccation of paper and adhesives; and desiccation of basketry fibers.

· **Variable:** Changes in the surrounding RH can affect the water content of objects, which can result in dimensional changes in hygroscopic materials. They swell or contract, constantly adjusting to the environment until the rate or magnitude of change is too great and deterioration occurs. Deterioration may occur in imperceptible increments, and therefore go unnoticed for a long time (for example, cracking paint layers). The damage may also occur suddenly (for example, cracking of wood). Materials particularly at high risk due to fluctuations are laminate and composite materials such as photographs, magnetic media, veneered furniture, paintings, and other similar objects.

2.6.2.5-.*What are the recommendations for relative humidity control?*

You should **monitor** relative humidity and implement improvements to stabilize the environment. There are many ways to limit fluctuations, not all dependent on having an expensive mechanical system. For example, good control is achievable simply by using well-designed and well constructed storage and exhibit cases. Ideally, fluctuations should not exceed ±5% from a set point, each month. You should decide on a set point based on an evaluation of your particular regional environment. Establish maximum and minimum levels by assessing the nature and condition of the materials in the collection and the space where they are housed. For example, if you are in Ohio you may decide on a set point of 50%±5%. The humidity could go as high as 55% or as low as 45% within a month. If you are in the arid southwest you might choose 35% as your set point as objects have equilibrated at much lower RH levels. Be aware though, you should not allow your RH to go as high as 65% because of the chance that mold might develop. Below 30% some objects may become stiff and brittle. Over the year you may want to allow ***drift.*** Drift means that your set point varies in different seasons—usually higher RH in the summer and lower RH in the winter. Allowing drift will often save you money over the longterm as mechanical systems work less to maintain the proper environment. If your collections are housed in a historic structure, preservation of the structure may require drift. It is important to understand that these variations in RH and temperature should be slow and gradual variations (over weeks and months), not brief and variable.

Archeological Materials	
Negligible Climate-Sensitive Materials	30% – 65%
Climate Sensitive Materials	30% - 55%
Significantly Climate Sensitive Materials	30% - 40%
Metals...	<35%
Natural History Materials	
Biological specimens...	40% - 60%
Bone and teeth...	45% - 60%
Paleontological specimens	45% - 55%
Pyrite specimens	<30%
Paintings...	40% - 65%
Paper	45% - 55%
Photographs/Film/Negatives	30% - 40%
Other organics (wood, leather, textiles, ivory)..........................	45% - 60%
Metals..	<35%
Ceramics, glass, stone	40% - 60%

Relative Humidity Optimum Ranges for Various Materials

2.7- Monitoring and Controlling Temperature and Relative Humidity

2.7.1. *Why should I monitor temperature and relative humidity?*

You must monitor temperature and relative humidity so that you know what the environment in your storage and exhibit spaces is like over time. Monitoring helps you:

· set a baseline of temperature and humidity to see if the storage space is adequate
· identify variations in the temperature and humidity throughout collections areas
· monitor equipment to be sure it is working right
· help develop strategies to improve the environment
· identify whether your strategies are working to improve the environment

2.7.2-*What kind of monitoring equipment should I have?*

There are a variety of temperature and relative humidity monitoring tools that are available for monitoring the environment in your museum. They can be divided into two types: spot measuring devices and continuous recording devices. Each type is most effective for different specific tasks so you may need to purchase more than one of the following pieces of equipment:

· **Psychrometers:** All museums should have a psychrometer. There are two types: **sling psychrometer** and **aspirating psychrometer.** Of the two, an aspirating psychrometer is more accurate.

A psychrometer gives you the RH by comparing the temperature between a “dry bulb” and “wet bulb.” The dry bulb is a mercury thermometer. The wet bulb is an identical thermometer covered with a wetted cotton wick. Because of the cooling effect of evaporating water, the wet bulb reads lower than the dry bulb. The drier the air, the faster the water evaporates and the lower the reading. To take readings with a sling psychrometer, whirl it around for one minute to pass air over the wet and dry bulbs. Read the wet bulb immediately and record the results. Repeat the process until you get the same readings two times in a row. The aspirating psychrometer uses a battery powered fan to steadily blow air over the bulb at a set speed. Both these instruments are accurate to ±5%. The aspirating psychrometer is more reliable because it minimizes possible errors by the operator and ensures a constant air flow past the wick. Accuracy will also depend on the length of the thermometer and how accurately you can read the temperature. Before you use a psychrometer, be sure to read the manufacturer's instructions. To ensure you get an accurate reading keep the following points in mind:

- keep wick closely fitted to the thermometer bulb
- do not touch the wick
- keep the wick clean
- use only deionized water to wet the wick
- be sure that the aspirating psychrometer has a good battery

Accuracy of aspirating and sling psychrometers can be affected by altitude, especially at lower relative humidities. At lower atmospheric pressure water evaporates faster, lowering the temperature of the dry bulb more. If your collections are 900 meters or more above sea level, you should obtain pressure-corrected charts, tables, or slide rules or use a pressure correction formula.

· **Hygrometers:** You can use a hygrometer to measure relative humidity levels when you don't have a hygrothermograph or datalogger or in spaces that are too small for psychrometers (for example, inside an exhibit or a storage case). When you use a hygrometer, also record the temperature. There are three types of hygrometers: dial hygrometers, electronic hygrometers, and humidity strips. In a **dial hygrometer,** a hygroscopic material (often paper) is attached to a hand on a dial. As the hygroscopic material absorbs or gives off moisture, it expands and contracts, causing the hand to move across the dial. Dial hygrometers can be accurate to +5%, but they are very inaccurate at low (<40%) and high (>80%) RH levels. Often they are hard to calibrate, so over time will drift and become inaccurate.

Digital hygrometers often have a built-in temperature monitor. If you purchase one of these tools be sure it can be calibrated. They are often calibrated with saturated salt solutions provided in a kit by the manufacturer. Electronic hygrometers can be used to calibrate hygrothermographs if you are sure the hygrometer is in proper calibration.

Humidity indicator strips are a special kind of hygrometer that use paper impregnated with cobalt salts. A series of patches are labeled with RH, usually in 10% increments. The color is blue at low RH levels and pink at high RH levels. Read the RH at the point of change between pink and blue. These strips are inexpensive and can give you some basic understanding of your RH levels at a variety of spots around your building. If used in a moist environment, they can become inaccurate.

· **Hygrothermographs:** Hygrothermographs have been the basic monitoring tool in museums for some time. They give you a continuous record of temperature and humidity variations over a period of 1, 7, 31, or 62 days. The instrument consists of six major components:

- The housing
- A temperature element, usually a bimetal strip
- A relative humidity element, which may be a human hair bundle or a polymer membrane
- Linkage arms and recording pens
- A drive mechanism, which may be spring wound or battery operated, that rotates a chart
- A chart, which may be wrapped around a cylindrical drum or be a circular disk The temperature-sensitive element (the bimetal strip) and the hygroscopic material (for example, the human hair) are connected to arms with pens at their tips. The pens rest on a revolving chart and move up and down as the bimetal strip and the hair react to environmental changes. Hygrothermographs are accurate within ±3-5% when properly calibrated. They are most accurate within the range of 30-60% RH.

· **Electronic datalogger:** Electronic dataloggers have become common in museums. There are a variety of types of dataloggers available at a range of prices. A model that records temperature, relative humidity, and light will meet typical museum needs. The data must be

downloaded onto a computer. All datalogger companies provide at least basic software programs that allow you to manipulate the data to produce graphs and tables of information. Most allow you to transfer this information in ASCII format to a spreadsheet program. They require less calibration than hygrothermographs, though they must usually be sent back to the company for calibration. Many dataloggers do not display data so you will not have any indication of what is occurring in your environment until you download the data. Some now include a liquid crystal display unit.
Electronic dataloggers can be very useful instruments, but they are not exact replacements for hygrothermographs.

2.7.3-. *How do I read a hygrothermograph chart or datalogger graph?*
If you have spent any time inspecting hygrothermograph charts or datalogger graphs you may have observed readings that defy simple explanations. There are many variables that may account for unusual readings. Some of them include:
· The quality and condition of the building where your collection is
housed (the "envelope")
· Staff activity
· Public visitation
· HVAC equipment performance and failure
· Barometric pressure
· Weather
· The condition and accuracy of the monitoring equipment
· An unusual source for moisture such as curing concrete, underground cisterns, clogged drains. It is impossible to explain all of the patterns you may encounter in a monitoring program. However, some common patterns and causes can be explained:

2.7.4-. *How do I use the hygrothermograph or datalogger data?*
Imagine that the record reveals that the conditions within the structure are too damp for most environmentally sensitive objects (for example, furniture and wooden objects, textile and paper objects). Probably the basement will have consistently high RH levels, the first floor
will be somewhat drier, and the second floor might be drier than the first floor. If you do find that the building is too damp, there may be problems in your collections. You will need to look with a critical eye for evidence of mold and insect activity and/or damage and for sources of moisture in the structure's walls and basement. For example, rainwater runoff from the roof may be entering the basement through deep window wells and masonry cellar walls. Once you identify the problem you must take action. While waiting for modifications to correct the runoff problem, you could put a dehumidifier and fans in the basement. Be sure to seek advice on correcting the problem from others who can help.

2.7.5-*How do I organize and summarize the data from my hygrothermograph charts or datalogger graphs?*
You must organize the data recorded by each hygrothermograph or datalogger to make it useful in developing strategies. Keep a record of daily observations, noting occurrences, such as, unusual exterior climatic conditions, a leaky roof, re-calibration of the equipment, or an unusual visitation pattern. At the end of each month when you remove the hygrothermograph chart or download datalogger data, compare this information to the daily record. It may help to record unusual occurrences directly on the chart or graph so that it is easy to see how the environment affected temperature and relative humidity.

2.7.6-. *How do I summarize longterm data?*
You can use a table or graph to summarize relative humidity and temperature data. One way is to prepare a table that records information collected over a period of time (for example, four to six weeks). You can put the following information in a table:
· High temperature
· Low temperature
· Maximum diurnal (24 hour) temperature change
· High relative humidity
· Low relative humidity

· Maximum diurnal relative humidity change

You can also summarize the data using graphs. You can design your graphs in a variety of ways. For example:

· Record both temperature and relative humidity on the same graph.

· Record temperature for several different floors of a historic structure.

· Compare temperature or RH parameters set for a building against recorded data. You can also summarize data by preparing room-by-room records for a year. Each week, for each room or space:

· Record high/low readings for temperature and relative humidity.

· Record fluctuation patterns of temperature and relative humidity by correlating with the time of day.

· Note maximum diurnal RH fluctuations.

For example: Furnished Historic Structure. Room A Temperature: 18°-22°C (64°-71°F)

5/18-5/24 Gradual rise in relative humidity through week; no rapid fluctuations

Gradual daily fluctuations from 18°(64°F) to 22°C (71°F); low about midnight, high around 3 p.m. Relative Humidity: 22% -32% RH Maximum diurnal fluctuations: 10% RH You should summarize data gathered from instruments and recorded on your monitoring record. This helps you evaluate long-term trends and watch for problems. Summary information helps you develop new environmental control measures.

You can summarize your data for each space by season in the same format as above. A summary gives you an idea of the variation that you have throughout the year. Use the summary documents in a variety of ways:

· Identify problems with your environment.

· Build an argument about the need to get environmental upgrades or a new building.

· Evaluate whether or not changes you have made really do improve the environment.

2.7.7-. How do I control temperature and relative humidity?

2.7.7.1-General considerations:

When you control the climate surrounding museum objects, you provide a stable environment that eliminates rapid fluctuations and extremes in temperature and RH. When you develop a strategy to control the environment in your museum spaces, keep the following points in mind:

. There is no general solution to controlling your relative humidity. Every situation presents different variables that you must evaluate before setting standards. Base your standards on:

- The local climate (for example, tropical, temperate, arid)
- The nature and condition of the materials in your collection
- The nature and condition of the structure housing the collection
- The ability of HVAC equipment to maintain the standard
- The ability of staff to maintain equipment

· In order to develop an effective control program, you must have good information. Collect data for one year before establishing acceptable ranges and limits.

· Use a team approach in controlling relative humidity. Once you have gathered your data, discuss control strategies with your regional/SO curator, and others, such as conservators, historic architects, and mechanical engineers. Strategies for controlling levels of RH and temperature should keep energy costs in mind.

· You will need to develop both active and passive measures for controlling the environment. When adapting a historic structure explore the use of simple modifications to your structure or space and employ portable mechanical equipment (humidifier, dehumidifier, heater, and air conditioner) or passive storage controls.

· Once you have implemented strategies to improve the environment, continue monitoring to evaluate whether or not your strategies are working.

2.7.7.2-Maintain building envelope:

You must eliminate sources of moisture by repairing the structure or correcting drainage problems. Problems that may cause high levels of relative humidity include:

· leaking roof, ceiling, or windows

· Gaps in walls, floors, or foundation vapor barrier

· leaking plumbing
· damaged gutters and downspouts
· Wet walls and foundations from poor drainage
· Open water sources such as sinks or toilets

2*.7.7.3-Passive methods of control***:**
There are a variety of practices that you can adopt to passively control the temperature and RH. Carefully develop a plan to use passive controls. After adopting the practice, continue to monitor to be sure that the action improves that environment the way you expect it to.
· Avoid turning HVAC equipment on during the day and off at night. This practice causes daily fluctuations in RH levels.
· Limit the number of people in a room. Large groups of people can raise the relative humidity from moisture introduced by breathing and perspiring. You may have to open doors within a building to change the circulation of the air.
· Locate sensitive objects away from spotlights, windows, exterior walls, air vents, and entrance doorways. You can also limit increased temperatures caused by the sun by using existing blinds, curtains, drapes, or exterior shutters.
· In temperate zones, reduce temperature levels during the winter. Lowering the set point of the heating equipment by several degrees raises the interior relative humidity to stabilize conditions overall.
· Store objects in cases, boxes, and folders. Containers are a very effective method of buffering temperature and RH fluctuations. They also limit light damage and protect collections from pests.
· To control relative humidity levels for sensitive objects (for example, some metals, textiles, paper, pyritic mineral, and fossil specimens) you may need to create a microenvironment to stabilize and maintain conditions that are different from the general museum environment.
The use of a properly sealed storage cabinet or exhibit case with buffering material (for example silica gel) can provide a proper microclimate for sensitive objects.

2.8 -Using Silica Gel in Microenvironments
Regulating the relative humidity (RH) in your exhibit space and collection storage areas is an essential part of preventive conservation. Silica gel (silicon dioxide) is a material that can be used to control RH within microclimates in exhibit cabinetry and storage units. This man-made material can create and maintain both high and low humidity levels within well-sealed enclosures. If used properly, silica gel will reduce daily, weekly, and seasonal fluctuations in humidity. Silica gel is particularly useful in museum microenvironments because it is non-toxic, and does not give off gaseous pollutants. You can use it as a desiccant at moderate or high RH levels to prevent damage to metal objects that may rust or corrode. Because silica gel acts as both a moisture absorber and desorber it can be used as a humidity buffer, providing a stable environment for moisture-sensitive objects, such as glass, ivory, wood, leather, bone, and textiles. These objects often require moderate levels of RH and restricted fluctuation (e.g., 40% to 60% RH).

2.8.1-Types of Silica Gel
Silica gel is a hard, inert, crystalline material that can absorb up to 40% of its weight in moisture through millions of tiny pores. Traditional silica gel (commonly referred to as standard gel) acts efficiently as a desiccant to create drier microenvironments (e.g., below 40% RH). Newer hybrid gels are more effective as buffers in a museum environment than traditional silica gel. They are considered high-performance gels and are most effective between 40-60% RH. Standard silica gel is also available in a self indicating form, which will change from blue to pink when it reaches its absorption capacity near 40% RH. Therefore, indicating gel is not useful at very low RH levels. Although self indicating gel is more expensive than standard silica gel, small amounts of it can be mixed in with regular gel and still give effective readings. Hybrid gels are not available in a self-indicating form. Several commercial products are available in which materials such as paper or expanded foam have been impregnated with silica gel. Prepackaged silica gel is also available in heat resistant polyester or nylon bags of different sizes. Many museum staff, however, prefer to fabricate their own silica gel containers, customizing them to fit their individual exhibit or storage cabinetry. Custom-made

containers are also less costly than commercially-manufactured products. Instructions for constructing silica gel containers appear later in this leaflet.

2.8.2-Requirements for Using Silica Gel

Silica gel can only maintain a microenvironment in a well-sealed enclosure. To ensure that cabinetry has limited air exchange with the room, seal all leaks and use conservation-appropriate caulk sealant or gaskets where necessary. To remove or replenish the gel provide easy access to the areas where the gel containers will be located. When silica gel no longer maintains the required RH it can be reconditioned back to the desired RH.

Never let silica gel come in direct contact with museum objects. When working with silica gel use an approved dust mask and latex or nitrile gloves; the dust can cause lung damage.

2.8.3-Calculating the Amount of Gel Required

Numerous factors affect the quantity of gel required for a specific application: humidity vulnerability of the objects degree of RH restriction required RH differences between the enclosure and room volume of the enclosure permeability and air leakage of the enclosure stability of overall room temperature desired maintenance cycle When using hybrid gels, museums commonly use the ratio *114* lb. to *112* lb. gel per cubic foot of space. Determine the size of your storage or exhibit enclosure in cubic feet by multiplying length times height times width. It is recommended, however, that you consult the gel manufacturer for exact requirements.

2.8.4-Monitoring the Microenvironment

In order for any microenvironment to be successful, it is necessary to monitor it regularly. Use humidity-monitoring strips or a hygrometer to evaluate your microenvironment's climate. Self-indicating gel will alert you when standard gel is nearing its saturation point, but it won't reveal the exact RH. Check the RH level frequently.

2.8.5-How to Make Silica Gel Containers

In traditional applications silica gel has been spread loosely on trays or pans that are placed in cases or storage units. This approach will work, but is less desirable due to the risks from handling and the potential for spilling and airborne dust. The use of closed containers is recommended for convenience and to reduce the risks to adjacent objects. The thickness of any silica gel container should be less than two inches because gel is most effective when maximum surface area is exposed. Rigid, compartmentalized containers (called cassettes or tiles) are a good choice because they can fit into narrow spaces. Small fabric bags allow for effective surface exposure and are easier to handle than large ones. Tubular, snakelike bags can be fed through small doors and can bend around corners. Choose the type, size, and shape of container that best fits your application and cabinetry. Instructions for fabricating standardized containers follow. Bag Fabrication: Use non-woven, polyesterbonded fabric (e. g . , Tyvekm), nylon screening, or polypropylene screening to construct the bag: Sew together three sides of each bag with cotton thread, leaving one side open for filling and emptying. Fill the bag with silica gel, using a funnel under an exhaust hood or outdoors. Close the top with a hook and loop type fastener, or by sewing the open edge of material closed.

Use compressed air in a hood or outdoors to remove dust from open screen bags.

Large sized enclosures or cabinetry require larger quantities of gel. Oversized bags can be fabricated but need compartments to prevent the gel from settling along one edge or corner of a huge pocket. To create smaller compartments, begin by stitching through the two layers of fabric at several intervals. Leave the top outside edge of each section open for filling; after introducing the gel close the open edges as described above.

Making rigid tiles: Custom, thin-profile containers can be fabricated to hold standard amounts of gel (e.g., *112* to several pound units). These shallow containers provide a large amount of surface area, increasing the silica gel's responsiveness.

To fabricate use 112-inch square, acrylic light diffuser panels. These grid-patterned panels (referred to as "egg-crate") are conventionally placed over fluorescent lights and can be purchased at hardware or lighting supply stores. The most commonly available panel size is 2 x 4 feet. Cut the panel to size with a handsaw or electric saw. Size them to fit the cabinet. Grind or file off any remaining rough edges. Cover one side of the panel with fabric or screening. Glue the material into place with an acrylic adhesive (using a paint roller) or low melting point hot glue gun stick. Fill the squares of the diffuser panel with silica gel. Attach a top covering of fabric using the same adhesive or glue system as above. Rigid cassettes or tiles can fit vertically or horizontally into a storage container; in exhibit cases they can be installed in an environmental control maintenance chamber or can simply be hidden with a decorative fabric and left in the display area.

2.8.6-Conditioning Silica Gel

Silica gel must be conditioned to the desired RH before placement inside an exhibit case or storage unit. If you intend to use silica gel as a desiccant, a humidifier, or as a buffer the gel must be conditioned or "adjusted. " Conditioning silica gel involves either removing or adding water to adjust the gel's moisture content. Most silica gel is shipped in a desiccated condition. Some manufacturers pre-condition silica gel making it ready for use. In some instances, the gel can be sent back to the manufacturer for reconditioning. This service is convenient, but more expensive than purchasing unconditioned silica gel. To condition silica gel you will need to monitor the gel's moisture content, at the beginning and throughout the process. Do this either by weighing the gel or by monitoring the RH of the air that surrounds the gel.

Weighing Silica Gel: Choose one of two methods:

Weigh a known quantity of gel, and check it against a calibration chart that gives standard weights in relation to humidity level. Request a chart from the manufacturer if one does not accompany the silica gel products. As an alternative, the gel can be exposed to an environment that has the desired RH, such as a climate-controlled room or chamber. Weigh the gel repeatedly until its weight stabilizes, indicating that it has reached equilibrium with the RH of the room or chamber.

Monitoring the Air Around Gel:

Put a small amount of gel (about 112 cup) in a well-sealed jar or self-seal bag with a calibrated hygrometer. Do not let the hygrometer touch the gel. After two hours the hygrometer should give an accurate reading of the humidity level the gel is able to maintain.

2.8.7 Conditioning and Re-conditioning Techniques

Four different methods to condition silica gel:

1) Direct Heat Application. This technique is used when silica gel needs to be adjusted down and as much moisture removed as possible.

Conventional oven:

Spread loose gel to a depth no more than 112 inch in a shallow, heat-resistant pan.

Set oven to 150°F, and heat gel for four hours. Temperature and time may vary depending on the gel's moisture content, the RH required and the type of gel used. If you choose to heat silica gel in its bag or cassette, check with the manufacturer of the container to determine an appropriate temperature to avoid accidental melting or burning.

Microwave oven:

Spread loose gel in a shallow glass pan to a depth of no more than 112 inch. Heat in microwave for two minutes on high. Cool gel for one minute outside of the oven. Repeat 10 times or until dry.

2) Room or Chamber Exposure. This method can be used to adjust gel up or down. It may take several weeks, depending on how much change in RH is required. Use this technique when you want to buffer your silica gel to a specific level. Place silica gel in a room or chamber that is at the desired RH level. Position a fan near the silica gel, blowing air over it to decrease the conditioning time. Check RH daily; continue until desired level is reached.

3) Exposure to Water Vapor. This method is used for adjusting up. It will increase the gel's RH level. Spread the gel evenly in a shallow pan. Put the pan in a chamber or plastic bag. Place a container of water or wet sponge in the chamber or bag (the larger the surface area of the water, the faster the gel will absorb the moisture). Do not wet the gel. Note: If this method is used to recondition gel directly in storage or exhibit cabinetry, great care must be exercised to avoid a water spill or over humidification.

4) Gradual exposure to new gel. This technique can be used to adjust gel up or down. It is especially useful because it ensures slow and gradual change of the RH within a storage

container or exhibit case. Put a small amount of pre-conditioned gel (15-20% of the volume of gel you want to condition) into the cabinet or container. It should be fully saturated if you want to raise the RH, or fully desiccated if you want to lower the RH.
Place the new gel near the original gel, but in a separate container. Closely monitor the interior RH until desired RH level is achieved.

2.9-Active methods of humidity and temperature control.
A properly designed heating, ventilation and air conditioning (HVAC) system can maintain appropriate levels of relative humidity and temperature and filter particulate gases from the air.
Installing an HVAC system that achieves and maintains the environment to the levels described in this chapter is not easy. In some cases, especially with historic buildings, this approach can be detrimental to the historic building. Before embarking on a program to install, upgrade, or design a new HVAC system, assemble a team of experts and plan a system that protects both the collections and the museum building. Choose team members with expertise in historic collections care, preservation, mechanical, electrical, and structural engineering. You must have good information from your ongoing monitoring program to help you identify the needs and problems of your current system. Working from this information, your team can design a practical system that will preserve both the collection and the building. In some cases, you may choose to use portable humidifiers, dehumidifiers, heaters, and air conditioners. In the short-term this equipment can do a lot to improve the environment in a museum collection space. It is also less expensive than installing a new HVAC system.
Humidifiers quickly add moisture to the air. Use a humidifier in the winter to counteract the drying effect of a central heating system. Use only an unheated evaporative humidifier. This type of humidifier does not disperse minerals in the air, and if the humidistat (a switch that turns off the equipment when a certain RH is reached) malfunctions, this type of humidifier will not raise the RH level above 65-70%. Be sure air is well circulated. You may have to use fans for circulation. You must select the size and number of humidifiers based on the size of the space, the air exchange rate, differences between the inside and outside of the building, and the number of people using the room.
Dehumidifiers remove moisture from the air and lower the RH. Don't use this equipment as a permanent corrective measure – instead, find out why the air is so damp and work to remove the source of the water. There are two types of dehumidifiers:
- Refrigerant dehumidifiers work on the same principle as a refrigerator. Cool air cannot hold as much moisture as warm air and it condenses within the machine. Use this type of dehumidifier in warm climates. You must drain dehumidifiers at least daily.
- Desiccant dehumidifiers force air through a moisture-absorbing material (for example, lithium chloride) to reduce moisture. Hot air is blown over the desiccant to regenerate it. Desiccant dehumidifiers are useful in colder areas where refrigerant dehumidifiers may ice up and stop working.

2.9.1- *What are humidistatically controlled heating and ventilation systems?*
Humidistatic control is a way to control relative humidity in a building without using a HVAC system. The basic idea behind humidistatic control takes advantage of the inverse relationship between temperature and relative humidity. Humidistatically controlled heating is based on the idea that if the absolute humidity of a given volume of air changes, it is possible to maintain a stable RH by manipulating and varying the temperature. A humidistat
sensor adjusts the temperature up and down to maintain a stable RH. If the RH rises above a set point, the heat is turned on until the RH drops back down. However, using this system,
temperatures can drop very low, so this type of environmental control system is best used in areas that are infrequently accessed. Humidistatically controlled ventilation is used in areas with high relative humidity. If interior RH is lower than exterior RH, dampers are opened by
sensors and the air is circulated through the building. If exterior RH is too high, the dampers remain closed. Both of these techniques may be cost effective ways of improving the environment in historic buildings that were not built to house museum collections. They are generally less intrusive to the building fabric, and maintenance and energy costs are lower

than typical HVAC systems. If you are considering using humidistatic controls work with an engineer or architect who has experience with the technique.

2.10-Light

Light is another agent of deterioration that can cause damage to museum objects. Light causes fading, darkening, yellowing, embrittlement, stiffening, and a host of other chemical and physical changes. This section gives an overview of the nature of light. It will help you understand and interpret monitoring data and the standards given for light levels in museum storage and exhibits.

Be aware of the types of objects that are particularly sensitive to light damage including: book covers, inks, feathers, furs, leather and skins, paper, photographs, textiles, watercolors, and wooden furniture.

2.10.1. *What is light?*

Light is a form of energy that stimulates our sense of vision. This energy has both electrical and magnetic properties, so it known as electromagnetic radiation. To help visualize this energy, imagine a stone dropped in a pond. The energy from that stone causes the water to flow out in waves. Light acts the same way. We can measure the "wavelength" (the length from the top of each wave to the next) to measure the energy of the light. The unit of measurement is the nanometer (1 nanometer (nm) equals 1 thousand millionth of a meter). We can divide the spectrum of electromagnetic radiation into parts based on the wavelength. The ultraviolet (UV) has very short wavelengths (300-400 nm) and high energy. We cannot perceive UV light. The visible portion of the spectrum has longer wavelengths (400-760 nm) and our eyes can see this light. Infrared (IR) wavelengths start at about 760 nm. We perceive IR as heat.

The energy in light reacts with the molecules in objects causing physical and chemical changes. Because humans only need the visible portion of the spectrum to see, you can limit the amount of energy that contacts objects by excluding UV and IR radiation that reaches objects from light sources. All types of lighting in museums (daylight, fluorescent lamps, incandescent (tungsten), and tungsten-halogen lamps) emit varying degrees of UV radiation. This radiation (which has the most energy) is the most damaging to museum objects. Equipment, materials, and techniques now exist to block all UV. No UV should be allowed in museum exhibit and storage spaces. The strength of visible light is referred to as the *illumination level* or *illuminance*. You measure illuminance in *lux*, the amount of light flowing out from a source that reaches and falls on one square meter. We measure illuminance in museums because we are concerned with the light energy that falls on our objects, not how much light energy comes from the source. When you measure light levels, hold your meter at the surface of the object to catch the light that is reaching that surface. Illuminance was previously measured in *footcandles*. You may find older equipment or references that list footcandle levels. Ten footcandles equal about 1 lux. When considering light levels in your museum you should keep in mind the "reciprocity law."

The reciprocity law states, "Low light levels for extended periods cause as much damage as high light levels for brief periods." The rate of damage is directly proportional to the illumination level multiplied by the time of exposure. A 200-watt light bulb causes twice as much damage as a 100-watt bulb in the same amount of time. A dyed textile on exhibit for six months will fade about half as much as it would if left on exhibit for one year. So if you want to limit damage from light you have two options:

· reduce the amount of light
· reduce the exposure time

Note: Even small amounts of light will cause damage. Damage as a result of exposure to light is cumulative. It cannot be reversed. However, you can stop the continuation of damage by placing an object in dark storage. Cases, boxes, and folders are the first defense against light damage.

If lighting is too close to or focused on an object, IR can raise the temperature. It may also lower the water content of porous materials. You can get heat buildup from:

· Sunlight
· Incandescent spotlights
· Fluorescent ballasts

· Lights in closed cases
Design exhibits so there is no heat buildup from IR generated by lights.

2.10.2. *What are the standards for visible light levels?*

You can protect your exhibits from damage caused by lighting by keeping the artificial light levels low. The human eye can adapt to a wide variety of lighting levels, so a low light level should pose no visibility problems.
However, the eye requires time to adjust when moving from a bright area to a more dimly lighted space. This is particularly apparent when moving from daylight into a darker exhibit area. When developing exhibit spaces, gradually decrease lighting from the entrance so visitors' eyes have time to adjust. Do not display objects that are sensitive to light near windows or outside doors. Basic standards5 for exhibit light levels are:
· **50 lux maximum** for especially light-sensitive materials including:
- dyed organic materials, textiles, watercolors, photographs and blueprints, tapestries, prints and drawings, manuscripts, leather, wallpapers, biological specimens, fur, and feathers.

· **200 lux maximum** for less light-sensitive objects including:
- undyed organic materials, oil and tempera paintings, and finished wooden surfaces

· **300 lux** for other materials that are not light-sensitive including:
- Metals, stone, ceramics, some glass

In general don't use levels above 300 lux in your exhibit space so that light level variation between exhibit spaces is not too great. With this method, people's eyes will not have to keep adapting to changing light levels, and they will be able to see objects exhibited at lower levels much more easily. These standards should serve as a starting point for developing lighting standards for your collections. In order for collections to be seen and used in various ways (for example, long-term exhibit, short-term exhibit, research, teaching) you should take into account a variety of factors:
· Light sensitivity of the object
· Time of exposure
· Light level
· Type of use
· Color and contrast of object

2.11- Monitoring and Controlling Light

To be sure that light levels are at required levels and to be sure that any UV filtering material is still effective, you should measure light levels at least once a year. If you change lighting fixtures, take new measurements to be sure the changes are within recommended levels. If the source of light is daylight (for example, in a historic house museum) you should measure light in the morning and afternoon throughout the seasons.

2.11.1. *How do I monitor light levels?*

You monitor light levels using specialized equipment. This equipment is necessary because your eye is not a reliable guide as it easily adapts to changes in visible light and can't see UV or IR light. Use a visible light meter to measure visible light and a UV meter to measure ultraviolet light. Use a thermometer to measure heat buildup from IR. Several different meters are available for measuring visible and UV light..
· Visible **Light Meter:** Use a visible light meter to measure the visible portion of the electro magnetic spectrum. If you purchase a new meter, you should be sure to purchase one that measures in the standard unit, lux. The meter you choose should be sensitive enough to measure light levels as low as 25 to 50 lux with a reasonable degree of accuracy (10% or better).
· Ultraviolet **Meter:** The Crawford UV Monitor is the standard piece of equipment used in museums for measuring UV levels. This monitor gives UV readings in microwatts per lumen. Older models depended n adjusting a knob until one red indicator light jumped to another light, giving a fairly inaccurate measure. Newer models are more accurate, providing the reading on a direct analog scale. There are also models of UV meters from different manufacturers that will provide a digital readout. Use a standard set of procedures when monitoring light levels with either piece of equipment. Aim the sensor toward the light source

so you are catching the light that is hitting the object you are monitoring. Be sure no shadows from your hand or body are in the way. Make sure the sensor is parallel to the surface of the object and aimed toward the light source. If the object is larger than about one foot square, take several readings. Before using any equipment, carefully read the manufacturer's instructions for operation and maintenance.

2.11.2- *Is there any way to directly monitor light damage?*
You can directly monitor light damage by using Blue Wool light standards. Blue Wool light standards are specially dyed textiles made so that the most sensitive sample fades in half the time needed to fade the next most sensitive sample. There are eight samples to a set. You can use the Blue Wool standards in two ways:
· Place one set of standards at the place you want to measure. Place another set in total darkness.
· Place aluminum foil over one half of a set of standards. By comparing the two sets of standards, or two halves of one set, you can determine the light fastness of a material. The standards will not help you estimate how much exposure to light a material will stand in a particular situation. You can use Blue Wool standards to help you make an argument that light damage is occurring and that changes are needed to protect museum objects.

2.11.3-. *How do I control light levels?*
All light causes damage and the damage is cumulative. Therefore, you must control all light in museum spaces that contain museum objects. There are several control methods that you can use. Be creative and use a variety of strategies to minimize light. Always monitor before and after to be sure that your changes have really helped. Remember, your eye is not a good tool for measuring light levels—use monitors.
Visible light must be maintained at or below the recommended levels. You can obtain these levels using any of the control methods below:
· Use window coverings such as blinds, shades, curtains, shutters, and exterior awnings. Close window coverings as much as possible to prevent light from reaching museum spaces. If windows must be uncovered for visitors, install UV filters and work out schedules so that windows are uncovered for only part of each day.
· Use opaque dust covers (for example, cotton muslin or Gortex®) to cover light-sensitive objects, including floor coverings. Dust covers should be used whenever visitors are not present for extended periods. They are useful in storage areas and exhibit areas that are not open to the public for part of the year.
· You can use tinted light filters (for example, films or glazing) on windows or over artificial lighting. Don't use reflective films or tints that call attention to the windows or are historically inappropriate.
Consult the park or regional historic architect and your regional/SO curator to be sure filters are appropriate.
· You can reduce the amount of light from fixtures by using colored filters, lowering the wattage of incandescent bulbs, using fewer fixtures, using flood light bulbs instead of spots, and turning off lights when people are not present. You can install motion detectors in exhibit areas that activate lighting only when a person is present. You can attach timers so that lights are on only for a specific period of time.
· Use incandescent lights (which produce very little UV) instead of fluorescent lights.
Ultraviolet light should be completely eliminated. All of the techniques used to limit visible light will also cut down on UV light. To block the remaining UV light:
· Install filtering material. Types of filters include:
- UV filtering film for windows or glass on framed objects
- UV filtering plexiglass instead of glass
- filter sleeves for fluorescent tubes
- UV filtered fluorescent tubes

The plastic material that carries the UV filtering coating often breaks down faster than the filtering chemical. You should replace filters whenever they begin to turn yellow or crack. Monitor UV radiation at least every five years to be sure the filtering material is still effective.
Infrared radiation (heat) generated by natural or artificial lighting should also be controlled to prevent rapid changes in relative humidity. Window coverings and filters and good air

circulation systems (for example, fans and air conditioners) help control heat buildup. You can control the heat produced by artificial lighting fixtures by using filters and good air circulation systems, as well as keeping lights outside exhibit cases. Floodlights used for professional and motion picture photography and photocopy machines can cause excessive heat buildup. Discourage photography in museum storage areas. When photography is allowed in museum areas request heat absorbing light filters and be sure the area is well-ventilated with fans or air conditioners. Lights should be turned off whenever filming is not taking place. If lighted rehearsals are necessary, use dummy objects until the final filming will take place.

2.11.4-Choosing UV-Filtering Window Films

In the past 20 years, the market has become saturated with window films with different performance criteria. Some are designed to reflect sunlight and keep interiors cool. Others strengthen glass and help prevent damage from vandalism. Still others filter various parts of the light spectrum. The films that have been of interest in museums are the so-called "solar" screens that filter part or all ultraviolet (UV) radiation. Unfortunately, not all of the solar films meet museum standards, and the product literature available from the manufacturers is very often confusing and sometimes misleading.

Electromagnetic Spectrum

To understand how these films perform, you need to know something about the light spectrum itself. Light—both visible and UV— is a very small part of the electromagnetic spectrum, which ranges from cosmic rays on the short-wave end, to radio waves on the long wave end. All forms of electromagnetic radiation are classified according to wavelengths. Wavelengths are measured in nanometers (nm). A nanometer is one billionth of a meter. The only part of the light spectrum we can see is the visible segment (between 400 and 760 nm).

We are all aware, however, of the harm done by UV radiation. This is the part of the spectrum that we try to eliminate completely in a museum setting. The atmosphere filters the shorter end of UV radiation. Window glass filters a bit more, so we are only concerned about the radiation with wavelengths from about 325 to 400nm. Almost any solar film on the market filters to about 380nm. Very few films filter the **complete** UV spectrum. Most of the product literature for solar films states "98% of UV filtered." The question is 98% of what? Although not stated in the product literature, most films filter 98% of UV in the range of 325 to 380nm. For a museum, this is not enough. There is another source for confusion. We don't measure UV in a museum in nanometers. The UV meters measure in microwatts per lumen (□watts/lumen). This is a measure of the *proportion* (or percentage) of total UV in the light you are measuring.

In the late 1970s when the standards for museum lighting were first consolidated in: *The Museum Environment* by Garry Thomson, the standard was based on the amount of UV radiation put out by an incandescent light bulb. That amount is between 40 and 70 watts/lumen, and as a result, the level thought to be acceptable was set at 50 watts/lumen. Since that time, technology has improved substantially, and there are light bulbs and filtration methods available that reduce UV to 5- 10 watts/lumen. This is far below the commonly accepted and current NPS standard to not allow UV radiation to exceed 50 watts per lumen.

Choosing UV-filtering Window Films

Place film over a window or over a fluorescent lamp. Make sure to block out the light around the film so that the reading from your meter is accurate. (Put the meter directly against the film to make sure that you are not measuring light that isn't being filtered.)

A "Crawford-type" meter that uses a dial only gives a range instead of a specific number of watts/lumen. In general, if a film is performing to standard, you won't be able to get a low number reading on a Crawford meter because the film is filtering all of the UV that the meter can read. This means that the film meets museum standards. The newer, electronic meters give a specific number of □watts/lumen. This figure should be at 50 or, preferably, lower.

Film Characteristics

In addition to the filtering capability, there are aesthetic choices to consider when choosing films. Some of the films that are effective in controlling UV have metallic surfaces or are very dark colors. These would be inappropriate for a historic house. Other film characteristics such as shatter resistance may be desirable, but unavailable on films that filter the full range of UV light. The effects of UV radiation on museum collections can be eliminated with the technology we have available today. Compared to other forms of environmental control and with an effective life of 8-15 years, purchase and installation of UV filtering films on windows and in front of artificial light sources is a relatively inexpensive aspect of collections care.

2.12. Dust and Gaseous Air Pollution

Air pollution comes from contaminants produced outside and inside museums. Common pollutants include: dirt, which includes sharp silica crystals; grease, ash, and soot from industrial smoke; sulfur dioxide, hydrogen sulfide, and nitrogen dioxide from industrial pollution; formaldehyde, and formic and acetic acid from a wide variety of construction materials; ozone from photocopy machines and printers; and a wide variety of other materials that can damage museum collections. Air pollutants are divided into two types:

- Particulate ***pollutants*** (for example, dirt, dust, soot, ash, molds, and fibers)
- Gaseous ***pollutants*** (for example, sulphur dioxide, hydrogen sulphide, nitrogen dioxide, formaldehyde, ozone, formic and acetic acids)

2.12.1.What are particulate air pollutants?

Particulate pollutants are solid particles suspended in the air. Particulate matter comes both from outdoor and indoor sources. These particles are mainly dirt, dust, mold, pollen, and skin cells, though a variety of other materials are mixed in smaller amounts. The diameter of these pollutants is measured in microns (1/1,000,000 of a meter). Knowing the particulate size is important when you are determining the size of air filters to use in a building. Some particles, such as silica, are abrasive. Pollen, mold and skin cells can be attractive to pests. Particulates are particularly dangerous because they can attract moisture and gaseous pollutants. Particulates can interact with gaseous pollutants and cause deterioration in three different ways. Particulates may be:

· A source for sulfates and nitrates (These particles readily become acidic on contact with moisture.)
· A catalyst for chemical formation of acids from gases
· An attractant for moisture and gaseous pollutants

2.12.2-*What are gaseous air pollutants?*

Gaseous pollutants are reactive chemicals that can attack museum objects. These pollutants come from both indoor and outdoor sources.

Outdoor pollutants are brought indoors through a structure's HVAC system or open windows. There are three main types of outdoor pollution:

· Sulfur dioxide (SO_2), and hydrogen sulphide (H_2S) produced by burning fossil fuels, sulfur bearing coal, and other organic materials
· Nitrogen oxide (NO) and nitrogen dioxide (NO_2), produced by any kind of combustion, such as car exhaust as well as deteriorating nitrocellulose film, negatives, and objects
· Ozone (O_3), produced by sunlight reacting with pollutants in the upper atmosphere and indoors by electric or light equipment, such as photocopy machines, printers, some air filtering equipment

When sulfur and nitrogen compounds combine with moisture and other contaminants in the air, sulfuric acid or nitric acid is produced. This acid then causes deterioration in a wide variety of objects. Ozone reacts directly with the objects causing deterioration.

The main sources of **indoor air pollution** come from building materials and include:

· Wood, which can release acids
· Plywood and particle board, which give off acids from wood and formaldehyde and acids from glues
· Unsealed concrete, which releases minute alkaline particles
· Some paints and varnishes, which release organic acids, peroxides, and organic solvents
Fabrics and carpeting with finishes, such as urea-formaldehyde, and wool fabrics that release sulfur compounds.
· Glues, used to attach carpets, that can release formaldehyde
· Plastics that release plasticizers and harmful degradation products such

as phthalates and acids. Museum objects themselves may also contribute to indoor air pollution. For example, many plastics are inherently unstable and as they deteriorate they give off acidic by-products. Examples of sources of pollutants from museum objects include:
· Celluloid and other unstable plastics used to produce many 20th-century objects
· Cellulose nitrate and diacetate plastic, used for film
· Pyroxylin impregnated cloth used for book bindings
· Residual fumigants, such as ethylene oxide

2.13-. Monitoring and Controlling Particulate and Gaseous Air Pollution
As with problems from other agents of deterioration, you need to monitor your collections to identify whether or not air pollution is causing damage to your collections.

2.13.1-*How do I monitor air pollution?*
There are a variety of monitoring devices that can be used to directly measure pollutants in the museum. If you feel direct measurement is needed, contact your regional/SO curator for assistance. There are other steps you can take to identify and understand air pollution levels.
· Inspect storage spaces (for example, floors, open shelving, tops of cabinets and tables) for dust. Note how much dust has built-up since the last cleaning. Watch for increased insect activity using your IPM program. Increased insect activity is often related to an unacceptable accumulation of dust.
· In coastal areas, watch for pollution from chlorides by observing and noting active corrosion on metal objects. Chlorides will react with unpainted iron or steel objects, causing rust.
· Observe and document a building's air control system and the nature of the structure. Concrete walls and adobe are sources of high levels of dust. Some concrete dating from 1940-1975 contains asbestos, making it a health risk as well as a source of particulates. Improperly filtered air intakes can transfer high levels of pollutants into museum spaces.
· Identify exhibit cases, storage cabinets, and shelving made out of untreated wood or painted with the wrong paints that can outgas formaldehyde and acetic acid.
· Watch to see how much dust and dirt is tracked into spaces by visitors and employees.

2.13.2-*Are there ways to monitor for air pollution?*
There are several ways to monitor air pollutants that are simple to use in museums. Each has good points and bad points so before you choose one method, investigate each type of monitor and evaluate the type of information you want to recover.
Oddy tests: Oddy tests have been used for some time as a simple method of evaluating materials that are used in contact with objects in storage or on exhibit. In this test, metal coupons (small samples of metal) are placed in a closed container with the material being tested and a small amount of moisture. The container is slightly heated and after a set amount of time, the metal is examined for corrosion. It gives you some idea of how 'safe' a material is and whether or not it will cause deterioration? Problems with this test include:
· Unusual reactions—because heat and moisture are raised in the container, reactions may occur that would not happen in a normal museum environment
· Little reproducibility—for a variety of reasons, results from this test are widely variable
Passive sampling devices: These are devices that absorb particular pollutants. They are placed in the area you want to test for some period of time and then removed and sent to a lab to be tested for presence and levels of pollutants. Each passive sampling device measures one type of pollutant. For example, one device will measure for formaldehyde, another for acetic acid. However, there are problems with these devices:
· They may require off-site analysis.
· The devices have varying sensitivities. Use devices that can detect gaseous pollutant in parts per billion (1:1,000,000,000 ppb) or lower levels.
A-D strips. These strips detect acetic acid. They were developed to detect and measure acetate film deterioration or "vinegar syndrome" in film collections. They change color as the level of acidity increases. They are used to set priorities for film reformatting.

2.13.3-*How do I control air pollution?*

Eliminate gaseous and particulate pollution to the lowest practical level." There is no minimum acceptable level of pollution. You can do the following to reduce levels of air pollution:

· In storage spaces, keep floors, tops of cabinets, and work surfaces clean to minimize dust accumulation. Work with custodial staff to keep areas clean. Use high efficiency particulate air (HEPA) vacuums which catch more particulates. Regular vacuum cleaners simply throw many smaller particles up into the air.

· Separate office and curatorial work spaces from museum collections storage spaces. Areas that are not accessed often will stay cleaner than high traffic areas.

· Upgrade and maintain seals and weather stripping around doors and windows to keep pollutants out.

· Store sensitive objects in appropriate museum specimen cabinets. Maintain sound gaskets on all storage cabinets. Replace old gaskets with neoprene gaskets.

· Store archival materials in boxes, map cases, and folders.

· Use dust covers to protect objects on open shelving. Dust cover material should be chemically and physically non-damaging and provide as complete a dust seal as possible, while allowing easy access. Use clear polyethylene sheeting.

· Segregate objects that outgas pollutants (for example cellulose nitrate negatives or objects, diacetate negatives, or hardwoods such as oak, birch or beechwood) from other objects.

· Store, exhibit, and transport objects in appropriate cases. Avoid using exhibit materials (for example, hardwoods) that outgas organic acids. The adhesives used in plywood and veneers may be a source of pollutants.

· In areas with high air pollution levels you may want to install pollution filtering in your HVAC system. These filters extract gaseous and particulate pollutants before they get into a museum space. Work with HVAC engineers to design a system appropriate to your facility. Do not use filtering systems that generate damaging ozone.

· You can use portable air filters with activated-carbon filters to remove particulates from the air. These filters will also remove some gaseous pollutants.

Storage and Exhibit Construction Materials Known to Release Harmful Substances

Materials Harmful Vapors

Wood (particularly oak, birch, beech) organic acids, Wood panel products organic acids, formaldehyde, Protein-based glues, wool volatile sulfides, Vulcanized rubber volatile sulfides. Some dyes sulfur compounds, cellulose nitrate nitrogen oxides, cellulose acetate acetic acid polyvinyl chloride hydrogen chloride, and polyurethanes volatile additives

Storage and Exhibit Construction Materials That appear to be Safe

Metals, glass, ceramics, inorganic pigments, polyethylene and polypropylene, acrylic solutions (some acrylic emulsions are suspect), polyester fibers, cotton and linen

Note: while these materials are considered safe, manufacturing processes may add coatings and additives that can damage museum collections.

CHAPTER 3

PREVETION OF BIOLOGICAL INFESTATIONS

3.1- What information will I find in this chapter?

This chapter contains information on:

- pests that can damage museum collections
- setting up an Integrated Pest Management (IPM) plan for museum collections
- Mold and other microorganisms identification and control

3.2-What are museum pests?

Museum pests are biological agents that can cause damage to museum collections. Insects, mold, mice, rats, birds, and bats are all museum pests. The damage pests do comes from

feeding or nesting behavior or by attracting other types of pests. Pests that regularly damage museum collections can be roughly grouped as:
fabric pests, wood pests, stored product pests, moisture pests, and general pests
Identifying an insect and its life stage is critical in determining what is happening in the areas being monitored. This chapter gives only brief descriptions of some types of pests. Many other pests may be found.

3.3- What do I do if I find live pests in the museum?
Follow these steps to stop an infestation and prevent it from recurring.
-Don't panic. If you rush to kill the pests you may cause more harm to the artifact (and to yourself) than if you leave the pests alone for a short time. Be thoughtful about each step you take. Remove pests safely and set up a program to keep the infestation from recurring.
-If an infestation is found on objects, isolate them immediately. Put the infested objects in a sealed plastic bag. Don't carry infested material through the collection without isolating it. You can drop eggs or larvae that can spread the infestation.
-Identify the pests. You may find that insects you see are not museum pests. More information on pests and identification is included in later in this chapter.
-Determine the extent of the infestation. Start at the site where the first infested object was found and inspect the collections/areas in ever widening circles. Isolate infested materials as they are found and document the findings.
-Determine the source of the infestation. If the problem is gaps in the building structure, collaborate with appropriate staff and make repairs to the building. If infested materials were brought into the collection, evaluate and modify the policies and procedures that allowed this to happen.
-Develop a treatment strategy. Include the following steps:
–Identify and document the pest and its development stage.
–Identify the materials in the infested object.
-Based on these findings, answer the following questions:
–Can you simply remove the pest?
–Are eggs present?
–What is the least damaging approach to treatment?
-There are a number of options for treatment described below. Only after you've considered all options should you treat the object.
-After treatment, clean the artifacts to remove dead pests and waste. Dead pests, larval skins, and nests can all attract new pests.
-Document the treatment. More information on documentation is
included later in this chapter.

3.4. Identification of Museum Pests
3.4.1. *What are fabric pests?*
Fabric pests are protein eaters. The two main groups are carpet beetles (of the family Dermestidae) or clothes moths (of the family Tineidae). The larvae of these types of insects feed on animal products used in museum collections, such as wool, fur, feathers, and horns.
-Carpet beetles are also commonly known as dermestids. Carpet beetle larvae cause damage by feeding on a wide variety of materials including fur, feathers, wool and silk cloth, wool felt, hair, study skins, and trophy mounts. They may not be seen because they hide from light, burrowing deep into artifacts. The larvae shed their skins as they grow and these skins are one of the signs of infestation to watch for. The adults are attracted to light and come out of hiding to mate. They may collect along windowsills. There are many species of carpet beetles, the most common of them **Black carpet beetle** (*Attagenus unicolor*), **Varied carpet beetle** (*Anthrenus verbasci*), **Common carpet beetle** (*Anthrenus scrophulariae*) and **Furniture carpet beetle** (*Anthrenus flavipes*)
-Clothes moths are small, silvery-beige moths with a wingspan of less than 1/2". They have narrow wings fringed with long hairs. Small grain- and flour-infesting moths are often confused with clothes moths, however, clothes moths have different flying habits. They avoid light and are rarely seen flying. They prefer dark corners, closets, and storage areas, and usually remain out of sight. The primary food of clothes moth larvae is soiled woolens, but they also feed on

silk, felt, fur, feathers, and hairs. In museums they often damage wool clothes, feather hats, dolls and toys, bristle brushes, weavings, and wall hangings.

3.4.2. *What are wood pests?*
Materials made of wood are susceptible to attack by a number of wood infesting pests. The culprits in museums are usually wood boring beetles or Dry wood termites. Both can severely damage valuable artifacts while remaining invisible to the untrained eye.
-Woodboring beetles are a group of beetles in the insect families Anobiidae (anobiid, furniture, and deathwatch beetles), Lyctidae (true powder post beetles), and Bostrichidae (false powder post beetles). The term "powder post" comes from the fact that the larvae of these beetles feed on wood and, given enough time, can reduce it to a mass of fine powder. Wood boring beetles spend months or years inside the wood in the larval stage. Their presence is only apparent when they emerge from the wood as adults, leaving pin hole openings, often called "shot holes," behind and piles of powdery frass (digested wood that looks somewhat like sawdust) below. Items in museums that can be infested by wood boring beetles include wooden artifacts, frames, furniture, tool handles, gunstocks, books, toys, bamboo, flooring, and structural timbers.
-Drywood termites, unlike their cousins the subterranean termites, establish colonies in dry, sound wood with low levels of moisture, and they do not require contact with the soil. The termites feed across the grain of the wood, excavating chambers connected by small tunnels. The galleries feel sandpaper smooth. Dry, six-sided fecal pellets are found in piles where they have been kicked out of the chambers. The pellets may also be found in spider webs or in the galleries themselves. A swarming flight of winged reproductive termites can occur anytime from spring to fall. Most drywood termites swarm at night, often flying to lights.

3.4.3. *What are moisture pests?*
Not only is moisture a threat to museum specimens on its own, it may attract a number of moisture-loving pests that can do additional damage.
Molds can be a big problem in damp conditions and can attract insects in the order Psocoptera that feed on those molds.
Molds are fungi that can cause damage or disintegration of organic matter. Basically plants without roots, stems, leaves, or chlorophyll, molds occur nearly everywhere. When moisture and other environmental conditions are right, molds can appear and cause significant damage to wood, textiles, books, fabrics, insect specimens, and many other items in a collection. Their growth can be rapid under the right conditions. It is important to realize that fungal spores, basically the "seeds" of the fungus, are practically everywhere. Whether molds attack suitable hosts in a museum depends almost exclusively on one factor—moisture. When moisture becomes a problem, molds will likely become a problem too. For this reason museum objects should not be stored in humidity above 65%. Be aware, however, that some molds can grow at a lower humidity.

3.4.4. *What are general pests (perimeter invaders)?*
Any household pest may become a pest in a museum. Many kinds of pests can get into a building that has not been well sealed. Cockroaches, crickets, silverfish, ants, millipedes, and other common pests can invade and infest a museum as well as a house or other structure. Mice, rats, birds and bats can also infest museum collections and buildings. They can cause direct damage to collections through nesting and feeding behavior. Their
nests will also attract many other kinds of insects that can then move into the collections.
German cockroaches (*Blatella germanica)* are omnivorous. They are familiar as they are the most common cockroach found in the United States. They feed on leather, paper, glues, animal skins, and hair. Damage to objects is caused by chewing. They are especially attracted to objects stained with sweat. They can also stain objects by depositing various bodily fluids.
House crickets (*Acheta domesticus)* commonly come into buildings at the onset of cold weather. Like german cockroaches they are omnivorous and will eat protein and cellulosic materials. These include textiles (wool, silk, linen, cotton), leather, and animal skins and fur. They are especially attracted to stains.

Silverfish (*Lepisma saccharina*) and firebrats (*Thermobia domestica*) will eat fabrics, paper and sizing, and glue and paste in book bindings. They are omnivorous, so will eat protein materials as well as cellulose. They are especially damaging in dark, damp storage areas. They have a distinct carrot shaped body, short legs, long slender antennae, and three tail-like appendages.

3.5- Integrated Pest Management (IPM)

3.5.1. *What is Integrated Pest Management?*
Integrated Pest Management (IPM) is a decision-making process that helps you determine if, when, and where you need pest suppression. It helps you develop a strategy to keep pests from attacking collections. IPM uses a variety of techniques to prevent and solve pest problems using pesticides only as a last resort. It depends on knowledge of a pest's habits, ecology and the environment in which it thrives and survives. IPM is also site specific and adaptable to any museum. It provides a structure in which to make responsible decisions about treating pests. Museum IPM has two goals:
-protect the museum and its collections from pests
-reduce the amount of pesticides used in collections

3.5.2. *Why should I use IPM?*
Pesticides can be health hazards for staff. Exposure to pesticides used incorrectly can cause acute symptoms such as nausea, vomiting, and breathing difficulty. Exposure can also cause chronic effects such as seizures, skin and eye irritation, and memory defects. Many pesticides are carcinogens or suspected carcinogens and human teratogens. For your own safety, as well as that of your offspring, visitors, and researchers, pesticide use should be carefully considered and only applied following label directions.

3.5.3. *What types of damage can pesticides do to museum objects?*
Pesticides can cause the following damage:
-metal corrosion, including iron, brass, and other light color metals
-deterioration of proteins, such as fur, feathers, leather, wool, horsehair
-deterioration of paper
-shrinking, stiffening, or softening of plastics
-color change in dyes and pigments
-staining from surface and vapor contact
Museums have routinely used pesticides in collections for years. Many of these materials leave residues on museum artifacts. Search collection documentation for records of previous pesticide use. Be aware, however, that users often did not record pesticide use. Be sure to take precautions when handling the objects.

3.5.4. *What are the components of an IPM Program?*
Each of these components is on-going and the whole process is cyclical in nature. To carry out an effective IPM program you should:
-***Build consensus*** by working with other staff in the museum. IPM requires coordinated strategies to be effective.
-***Identify*** pests that can cause damage to your collections.
-***Review NPS policy*** to understand how IPM works and your responsibilities when using chemical treatments.
-***Establish priorities*** to focus on tasks in an organized fashion. For example, set up a monitoring program in areas of the collection that contain sensitive botanical specimens first.
-***Establish action thresholds***. How many insects in a collection are too many?
-***Monitor*** pests and environmental factors.
-***Implement non-chemical management***. Modify pest habitats, use good housekeeping, and use non-chemical treatments such as freezing and anoxic environments. If needed, review and obtain approval for an appropriate chemical pesticide. Treatments should only be done when pests have been found and identified.
-***Evaluate*** results to be sure your strategies are working.
-***Document*** monitoring and treatments.

3.6. Monitoring

3.6.1. *Why should I monitor for pests and monitor the environment?*
Monitoring for pests and monitoring the environment provide you with different kinds of information. This includes baseline information on your museum, the insects in your collection environment. How pests got into the museum? If conditions will support pest activity, where pests are in the museum, whether your actions are changing the environment, and how many pests there are in the museum and if your control strategies are working. Taken together, these two types of monitoring can help you determine strategies to eliminate future access and survival of pests in the collection. Monitoring can also help you evaluate the effectiveness of any treatment action you take.

3.6.2. *How do I know where to monitor?*
When developing a monitoring strategy, think about the resource that you are trying to protect and the kinds of pests that will cause damage to the resource. For example, will you expect mostly protein eaters because of lots of wool textiles? Are the collections in a historic, poorly sealed building with a damp basement? Think through what kind of pests will be attracted to your collections. Also think about the kind of pests that will be supported in the environment in your building. Then aim your monitoring strategy to find out if those kinds of pests are present. Work with your park and regional IPM coordinators to develop a thoughtful strategy to identify pests for the collections in your museum.

3.6.3. *What does pest damage look like?*
Different pests cause different types of damage. Evidence of pests includes:
- holes
- chewing marks
- hair loss
- webbing
- cast skins
- "grazed" surfaces
- frass (insect waste, which is usually a soft powdery material)
- fecal pellets

3.6.4. *How do I monitor for pests?*
Monitoring relies on a variety of techniques.
- ***Routine inspection of objects:*** Visually inspect the collection to look for cast larval skins, holes in textiles, piles of frass, cut hairs around and below artifacts. Do spot checks at least every six months; check more vulnerable objects like biological specimens and ethnographic objects more often.
- ***Routine inspection of the building:*** You must also routinely inspect the building to look for signs of insects that may get into your collections. Check windowsills and door jams especially carefully.
- ***Trapping:*** Identify pests moving into and throughout the building. Using traps allows you to "zero in" on problem areas where pests may be getting into a building, or where you have infested collections.
- ***Documentation:*** Document your inspection and trapping program carefully so that you have a record of problems that can be evaluated over time.

3.6.5. *What kinds of traps should I use?*
There are three main types of insect traps. Use them in combination. Decide which kind of trap is most appropriate for a particular place and for the problem you have.
- **"Sticky traps"** collect bugs on an adhesive base. They are sometimes known as roach motels and come in a box or tent shape. They are available from a wide variety of manufacturers. For general purpose the tent shaped traps are the best. Replace them regularly as the adhesive will dry out and become ineffective.
- **Pheromone traps** are usually sticky traps that include a pheromone attractant specific to one species of insect. These are only available for webbing clothes moths, drug store beetles, cigarette beetles, and the German cockroach.

- **Light traps** are useful for detecting and controlling flying insects. They emit ultraviolet light (black light) that attracts flying insects, particularly flies and moths. The insects are drawn toward the light and trapped by a glue board or in a bag. Windows also act as passive light traps so windowsills should also be carefully monitored.

3.6.6. ***What actions should I take to keep pests out?***
Cultural controls and mechanical controls are two basic types of actions you can use to prevent insects from getting into and thriving in your collection. Cultural controls are policies and procedures that you can implement. Mechanical controls are techniques to limit pest habitats and close off areas where pests get into the building. Cultural controls include:

- inspecting any material (new accessions, loans, storage material) before it comes into collections areas
- developing good housekeeping and interior maintenance programs
- restricting food and smoking in the museum
- barring live and dried plants inside and eliminating plants and mulch next to the building
- developing environmental controls for a stable, low humidity
- putting objects into closed storage and exhibit cases whenever possible

Mechanical controls include:

- installing self-closing devices, sweeps and gaskets on exterior doors
- installing screening on floor drains
- removing ivy and plants growing on the structure
- cleaning gutters regularly
- closing windows and installing 20 mesh screening
- eliminating clutter, including cardboard, which is very attractive to insects
- minimizing dust
- using a vacuum cleaner instead of a broom to clean floors and structures
- caulking or otherwise blocking all holes in the building structure
- using sodium vapor lighting, which is less attractive to insects, for exterior fixtures

3.6.7. ***How do I know when I have a problem and must take some action?***
Set a **threshold**. A threshold is the point at which you will take some action to remove or prevent the pest. Decide how many pests you must see or trap in an area before taking action. The action will usually not be a pesticide treatment. Establishing a regular vacuuming program is also an action. The threshold is site-specific for each museum. For example, finding one insect near the door may not warrant action, but it does warrant increased vigilance. Finding an insect in a closed cabinet warrants action. You can expect to trap more insects in historic buildings than in new visitor centers. Decide on your thresholds before you start a monitoring program.

3.6.8. ***How do I know if the IPM strategy is effective?***
Regularly evaluate your strategy. Analyze your survey forms. Are you seeing fewer pests in your traps? Have you stopped infestations? ***If your strategy is working, all your time will be spent on prevention and maintenance and none on dealing with live pests and infestations in the collections.***

3.7.-Controlling Insect Pests: Alternatives To Pesticides
This is an overview of techniques that can be used instead of pesticides when a pest infestation is found in collections. It will help you decide on an appropriate treatment when a pest infestation is found in collections. Treatments such as these should only be considered as part of an overall Integrated Pest Management (IPM) strategy to protect collections.

Even with IPM, infestations can occur. When infestations are discovered, choosing the pest control method best suited to a particular problem can be a difficult decision. Prevention is always better than the cure, but when pests are found in objects or in the building some remedial action may be necessary. When you find pests: I Isolate any objects suspected of being infested to prevent spread of infestation to other objects. Some objects can be sealed in polyethylene ziplock bags for monitoring and to prevent insects from spreading. When you find a pest

- l Identify the pest and its biology (life cycle and behavior).
- l Clean infested areas and destroy insect bodies and debris.
- Decide on the most appropriate treatment for the object and environment.

Consideration must be given to the object's general composition and condition and so consult with a conservator before deciding what to do. The use of an inappropriate method can cause damage to collection materials and serious health hazards to the staff and public. Because of the health and environmental risks posed by the use of poisonous fumigant gases there has been a great deal of effort in the museum world to search for safe and effective alternatives. Each of the following options to the higher risk toxic fumigants have advantages and disadvantages which must be carefully evaluated in light of the type of the collections, the individual situation and the resources available.

3.8-Temperature Treatments

3.8.1-Low temperature.

Freezing kills insects by rapid temperature change. It is a widely used treatment for many objects such as natural history specimens and textiles but, unless proper procedures are observed, some damage can occur to objects. Composite, fragile or unstable materials should not be subjected to extremes of temperature. Temperatures in the freezer should be -18^{O}C or below. It is better to use a deep freeze unit rather than a common household freezer and self-defrosting freezers should never be used. The freezer should be capable of reducing the temperature in the objects within 24 hours to be effective. If the items are stored in cold climate and then frozen very slowly, some insects will become acclimated and will not succumb to freezing. It may take much longer for the cold to penetrate large objects or tightly rolled tapestries and skins. The temperature in the center of test materials should be recorded to check that the target temperature has been achieved. It is not advisable to freeze wet specimens unless this is to prevent bacterial and fungal decay. The objects must be sealed in polyethylene plastic bags prior to freezing to prevent damage by RH changes and moisture migration. An absorbent organic buffering material, such as acid-free paper, can be added to the bag to help control the RH. In the past it was thought a double freezing at -18OC was necessary to kill all stages of insects but more recent work has shown that a single exposure for at least 2 weeks at - 18OC will kill all of the pest species. If the freezer can reach colder temperatures (-30°C) an L exposure of at least 3 days should be enough. When removed, objects must not be unsealed from the bags until they have reached room temperature to prevent condensation on the object. However, if there are many insects in the building then objects can be left in the polyethylene bags to provide some protection from further insect attack.

3.8.2-Heating.

Heating will kill insects much more rapidly than freezing but it is essential to ensure that elevated temperatures do not harm objects. In the past a number of museums used ovens to disinfect insect collections and this often resulted in brittle specimens and cracked storage drawers. Recent work has shown that damage due to shrinkage and distortion can be eliminated by controlling the humidity around the object. If objects are bagged when they are heated to 55^{O}C then humidity in the enclosure is stable and the object is not damaged. As with low temperature treatments, it is inadvisable to subject composite, fragile, or unstable materials to extremes of high temperature. This method offers possibilities in the near future for rapid and safe treatment of some objects. Until specific techniques are developed and published heat treatment should not be used except with guidance from a conservator with experience in heat treatment. Microwaves have been used for rapid treatment of books, papers and herbarium specimens but there can be undesirable side effects as the heating may be uneven and localized overheating may occur. In addition, unnoticed metallic objects such as paperclips may cause sparking and ignition of specimens and paper. This technique is not considered safe for use with museum collections.

3.8.3-Modified Atmosphere Treatments

Modified atmosphere treatments have been developed as a direct replacement for fumigation with toxic fumigants and the techniques and procedures used are in some cases very similar.

3.8.4-Anoxia.

The procedure kills insects by the exclusion of oxygen (anoxia), and therefore oxygen levels must be very low, less than 0.1% **.** This can only be achieved in an airtight chamber, or in individual bags made of a special oxygen barrier film. The speed of the treatment in killing insects is dependent upon temperature, at temperatures of 25OC and above, 2 to 3 weeks should be sufficient to kill pests. However, at temperatures of 20°C or below, very long exposures of 4 or 5 weeks may be needed to kill some species such as wood borers. Large objects can be treated using nitrogen from cylinders.

Small objects can be treated in sealed bags using an oxygen scavenger such as Ageless TM (produced by the Mitsubishi Gas Chemical Company).

Nitrogen. Nitrogen has proven to be a very effective and safe method for treatment of sensitive objects. Building a nitrogen treatment chamber may be expensive because of the need for absolute gas-tightness. Conversion of an existing fumigation chamber used for ethylene oxide or methyl bromide is feasible but also can be expensive because of the need for additional sealing and pipework. A cylinder and bag method is less expensive to set up initially. An accurate oxygen meter must be purchased and gas 1 cylinders must be stored in compliance with local fire and safety regulations. An important consideration is that the relative humidity (RH) of nitrogen gas is less than 5 %. which would be detrimental to the materials being treated. It is therefore essential to add a simple humidification system to the gas supply line. This technique is probably beyond the resources and needs of most small museums of Ageless may be high if large objects are

treated. Some museums use a combination of nitrogen flushing and Ageless for treatment of large objects. Ageless will also slow any degradative processes requiring oxygen, such as mold growth or oxidative chemical reactions. other types of Ageless will absorb both oxygen and moisture and therefore have applications for collection care other than insect eradication. Small museums can use Ageless to treat individual objects. A number of museums now use Ageless, a scavenger of gaseous oxygen for treatment of individual specimens. Ageless is composed of moist, active, iron oxide powder encased in a porous packet. Oxygen in the atmosphere penetrates the packet and further oxidizes the powder. A slight amount of heat moisture is produced by the reaction, but if the and packets are spaced apart and kept out of contact with objects then heat and moisture do not build up enough to damage the material being treated. The small amount of additional moisture will have no measurable effect on

well-buffered absorbent materials such as textiles or natural history specimens but it is better to wrap more sensitive non-absorbent material in buffering cloth or acid-free tissue paper. Ageless will work most effectively only by enclosing the object to be treated in a bag made from a special oxygen barrier film. It is useless to use ordinary polyethylene, as this is porous to oxygen. The bag should be big enough to accommodate the object to be treated with a few inches excess, which will become the seam of the bag when it is heat-sealed. The number of Ageless packets to be used should be calculated from the type of packet and the volume of the bag. An indicator called "Ageless Eye" can be used to show that levels of below 0.1 o/o oxygen have been achieved. Objects should be left for at least three weeks at 25^{O}C to kill all stages of insect pests. With this system, set-up costs are lower than with the cylinder treatment but costs

3.8.5-Carbon dioxide.

Carbon dioxide treatment has been widely accepted in the food industry for many years and the technique has been adapted for use by museums. The treatment procedure used for CO_2 is similar to that used for nitrogen in chambers or bubbles. As with nitrogen, the gas works slowly, particularly at low temperatures and some treatments' add slight heating of the chamber to 30°C to increase insect metabolic rates. This method also requires use of a meter to monitor the percentage of CO_2 in the chamber during the exposure period. Levels of CO_2

need to be about 60% and unlike nitrogen, the treatment is effective even with some leakage of oxygen into the enclosure. Because of this, CO_2 is far more practical than nitrogen for treatment of large objects and enclosures. However, it is important to check on local safety procedures and regulations before proceeding, as there may be some restrictions on the use of this treatment in some states. There have been some concerns that CO_2 will react with water to produce carbonic acid but there is no evidence that this will happen at the usual range of humidities and moisture contents used for treatment of museum objects.
Contact your IPM coordinator or local pest control company for more information about the use of CO_2.

3.8.6-Other gases.
Argon and other inert gases have been used with varying degrees of success but because they are more expensive than nitrogen or carbon dioxide, it is difficult to justify their use.

3.9-Prevention Of Microorganism Growth In Museum Collections
Mold is the common term used to describe a downy or furry growth on the surface of organic matter, caused by fungi, especially in the presence of dampness and decay. A fungus (pl. fungi) may be any of a large number of microorganisms that are parasites feeding on living organisms or dead organic matter. ***Mold*** is often used interchangeably with the word ***mildew. They*** are the generic terms that describe a variety of microorganisms, including fungi, algae, rusts, yeasts, and bacteria, that are agents of deterioration for museum objects. They produce irregular stains that can permanently damage an object. Collection managers must be able to recognize signs of these problems and be prepared to take preventive actions.

3.9.1-The Microorganisms
Fungi are simple-celled organisms that do not need energy from light for growth. The fungi bear microscopic spores that are produced in enormous quantities, are always present in the air, and spread via air currents. They are often water repellant and are resistant to desiccation (drying out). Extreme cold and heat will destroy them. When the spores are in a favorable environment, they will germinate. What constitutes a favorable environment is different for each species. After landing on a host material, a spore must obtain sufficient moisture to
germinate and find enough food. Without moisture, the spores will lie dormant until favorable conditions occur. For this reason, it is important to control the environmental conditions where museum collections are stored or exhibited. It is recommended that temperatures not exceed24°C (75°F) and relative humidity (RH) not rise above 65%. These conditions are maximum levels and only reduce the potential for microorganism growth. They do not eliminate the threat. Some microorganisms can grow in significantly lower temperatures and at lower RH levels. Certain materials need to be stored with lower RH levels to prevent growths.
Microorganisms need organic materials to supply nutrients and, therefore, museum objects composed of organic materials are potentially at risk. Cellulose-based materials, such as cotton, linen, paper and wood, and proteinaceous materials such as leather and hair cloth are particularly susceptible to direct attack by microorganisms.

3.9.2-Damage
Microorganisms will permanently damage the materials supporting them. They will stain textiles and decrease the strength of the fabric. The scattered spots known as foxing on paper prints or drawings is damage resulting from these growths. Leather is particularly susceptible to the actions of microorganisms and will be stained and weakened by them. As a by-product, fungi can produce organic acids that will corrode and etch inorganic materials.

3.9.3-Detection
Often the first indication that a microorganism problem exists is a characteristic musty odor. A careful visual examination will generally locate stains that are clearly visible as pigmentations on a surface. Another means of detection is by the use of ultraviolet (UV) light. Under UV light, a microorganism growth will appear luminescent.

3.9.4-Prevention

The best means to prevent or control the spread of microorganism growth is to deny the spores the moisture necessary for germination. Therefore, regulating the environment, especially the RH, is essential for preventing the deterioration of a museum collection from microorganism growth. RH levels should be routinely monitored. Spore germination is less likely to occur if RH is controlled between 45 % and 55 %, but RH should be kept below 65%. When RH levels rise above 65 % , the use of portable dehumidifiers will be necessary to reduce the moisture content of the air. A temperature between 18°C and 20°C (64°F to 68°F) should be targeted. These levels only decrease the potential of germination and growth; they do not eliminate it. Therefore, other factors, such as adequate air circulation should be maintained; a fan will help to increase circulation. Problem environmental conditions that may contribute to higher humidity levels need to be corrected. Repair leaking pipes, gutters and downspouts, cracked windows, a problem roof, deteriorated brick, masonry pointing, or cracked walls. It is also important to keep any area that houses museum collections clean and free of dust and dirt and organic debris that can nourish spores. Silica gel and other buffers can help adjust RH conditions within a sealed space, such as in a storage cabinet or exhibit case. These buffers will absorb or release moisture into the surrounding atmosphere. The quantity of buffering material to place within the space must be customized for each situation and a conservator should be consulted for assistance in determining this need. It takes time, experience, and careful monitoring to ensure that the buffers are performing as intended.