Appendix N: Curatorial Care of Wooden Objects

List of Figures

APPENDIX N: CURATORIAL CARE OF WOODEN OBJECTS

A. Overview

1. *What is covered in this appendix?*

This appendix deals primarily with the preventive conservation of wooden objects on exhibit and in storage. It discusses proper environmental conditions and details housekeeping procedures. In order to provide an understanding of how and why wooden objects react to the environment and to human intervention, the appendix includes:

- a discussion of the nature of wood
- typical fabrication techniques of wood objects, furniture, and associated materials
- types of deterioration that affect objects made of wood

2. *What types of wooden objects are found in museum collections?*

Park museum collections contain wooden objects in a wide range of forms:

- utilitarian objects, such as tools and farm vehicles
- religious objects, such as icons and altars
- furniture, significant for historical or decorative reasons

A large percentage of objects in NPS collections are composites—articles made of more than one type of material. Composite objects include:

- frames that house prints, documents, and paintings
- musical instruments
- rifles
- machinery, such as sewing machines and cameras

3. *How much care do wooden objects require?*

Both the nature of individual objects and how they are exhibited dictate how much and what kind of care is needed. Wooden objects are found under a wide range of exhibit and storage conditions.

- Furniture often is in open exhibits in furnished historic structures.
- Vehicles, totem poles, and gun carriages frequently are on exhibit outside, where they are exposed to the weather.
- Smaller objects may be more carefully exhibited in display cases in visitor centers and museums.

4. *Should I provide on-site care myself or contact a conservator?*

This appendix includes a discussion of how you can assess the condition of wooden objects and when to seek the advice of a conservator.

B. The Nature of Wood

To understand the behavior of wood and its requirements for long-term preservation, you should be aware of the physical and cellular structure of a tree. You will then know why wooden objects react to particular environmental conditions. Some wooden objects from prehistoric sites, such as tools from dry caves in the Southwestern United States, remain in excellent condition, while other wooden objects deteriorate rapidly. The condition of these objects depends on the type of environment in which they were housed.

1. *What is the structure of a tree?*

A tree can be described as a bundle of vessels, its walls composed of cellulose glued together with lignin. New cells grow around the circumference of the tree, forming a ring just within the bark. Wood cells are longer than they are wide and are oriented parallel to the long axis of the trunk and branches. The term *grain* in this appendix refers to the direction of the vessels. "Cross grain," then, refers to the horizontal plane, while "along the grain" refers to the vertical plane.

Looking at the end of a log or a cross-section of a tree, you can see an inner and an outer zone. The outer zone called *sapwood* is lighter than the inner or *heartwood* zone. These two zones serve distinct functions in the living tree and have very different characteristics that influence the behavior of wood even after it has been fashioned into objects. Sapwood is composed of newer living cells, which transport sap or water to the leaves and which store nutrients. As sapwood ages and becomes heartwood, *extractives* form within the cell walls, giving it color, durability, and dimensional stability. The chemical defenses found in the extractives help protect heartwood lumber from biological attack. Lumber from sapwood has no such protection.

2. *What are the three planes common to trees and lumber?*

Lumber has three planes, which are illustrated in Figure N.1:

- cross section
- radial section
- tangential section

The surface exposed in a cross-section is referred to as *end grain*. Because the cell cavities are exposed in end grain, water is both easily absorbed and given off. The surface is hard and prone to splitting. It does not take stain or finish well and cannot be sanded smooth.

The radial plane extends along the long axis of the tree, more or less perpendicular to the growth rings. The grain pattern on this vertical or edge grain is usually straight and regular. Boards cut along this plane are dimensionally stable and distort very little in response to changes in ambient relative humidity. They will also stand up to abrasion and weathering.

The tangential plane extends along the long axis of the tree and forms a tangent with the concentric growth rings. Boards cut along this plane will swell, contract, and become distorted at twice the rate of those cut on a radial plane.

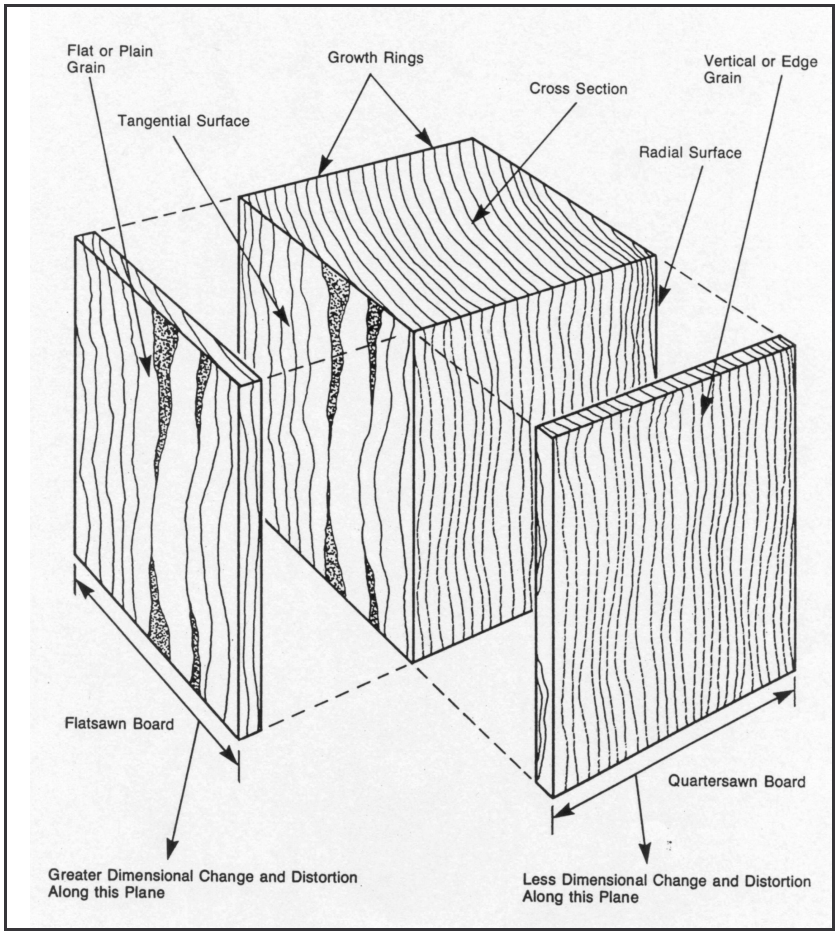


Figure N.1. The Three Principal Planes or Surfaces of a Typical Block of Wood: Tangential, Radial, and Cross Section

3. *What effect does water have on wood?*

There is a very strong molecular attraction between water and the cellulose in wood (called *hygroscopicity*). In freshly cut wood, water is found in both vessel cavities and cell walls. As the wood dries, the water in the cavities evaporates, but as long as the bound water remains in the walls, the wood will stay at the *fiber saturation point* and will not shrink. The moisture content at saturation is about 25%. When below this point, the wood will respond to changes in ambient relative humidity. Air-dried wood will reach a moisture content of 10%-12%, while kiln-dried wood will reach a moisture content of about 7%. This kiln-dried wood or the objects fashioned from it will absorb water vapor if placed in an environment with high relative humidity.

Wood will eventually arrive at equilibrium with its environment, neither absorbing moisture (swelling) nor giving off moisture (shrinking), as long as the RH remains constant. See Figure N.2 for a graph that illustrates the relationship between relative humidity and equilibrium moisture content in wood. This graph can help you calculate the amount of contraction or expansion that may occur in wooden objects.

When moisture is absorbed and released, the cell walls expand and contract. The cell length, however, remains nearly unchanged. Therefore,

dimensional change in wood is not uniform in all planes (see Figure N.1). While movement **along** the longitudinal plane (the long axis of the tree) is negligible (only about .1%), movement **across** this plane is significant. Along the tangential plane, dimensional change is the greatest, averaging about 8%. Along the radial plane, dimensional change averages about 4%.

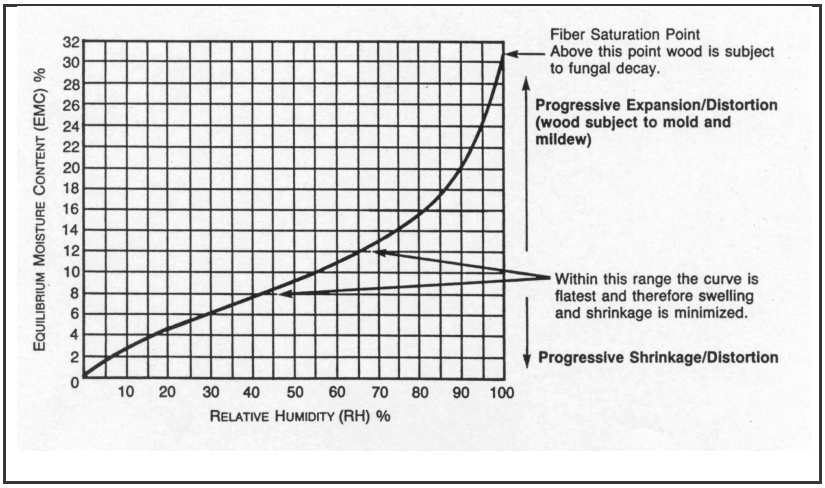


Figure N.2. Graph Illustrating the Relationship Between Relative Humidity and Equilibrium Moisture Content of Wood

4. *Do all types of wood react in the same way?*

No. The extent of dimensional change varies from species to species, making some kinds of woods more desirable in the making of furniture and wood objects. Teak, mahogany, and redwood are among the more stable woods. Walnut and cherry, popular woods with furniture makers, fall in the middle of the range.

5. *Where is the difference in dimensional change evident in museum objects?*

The rim of a turned bowl over time will move out of round, becoming slightly oval in shape because of the difference between tangential and radial shrinkage. For the same reason, turned feet become oval, and square legs take on a diamond shape on many pieces of furniture. Rungs and stretchers may become loose in chair legs because of the differential in shrinkage along and across the grain. Veneered surfaces may split or buckle because the grain orientation of the veneer is different from that of the underlying wood.

C. Agents of Deterioration

Wood decays both in nature and in museums as a result of:

- physical deterioration
- chemical deterioration
- biological deterioration

1. *What's involved in physical deterioration?*

There are three direct causes of physical deterioration.

- changes in relative humidity
- weathering
- human abuse

2. *How do changes in relative humidity cause physical deterioration?*

Shrinking and swelling, caused by changes in relative humidity, have been addressed in the discussion of the nature of wood. Because this reaction is not uniform across all planes, boards may become distorted or warped. The type of distortion will usually depend on the shape of the board and the orientation of the wood cells. See Figure N.3 for an illustration of characteristic shrinkage and distortion.

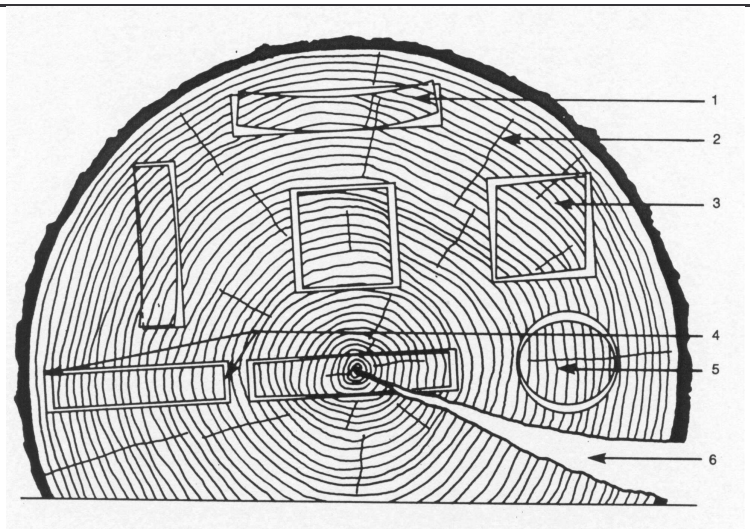
- *Cupping* is a deformation across the width of a board. It is often observed on wide, unrestrained boards, such as leaves on a drop-leaf table. This cupping can occur in the initial seasoning or later on in the life of an object. It can sometimes be caused by applying finish to only one side of the board. It may also occur when different microclimates are present on opposite surfaces. For example, the surface of a table leaf in the sun or near a radiator will become dryer than the surface underneath.

- *Checking* is also a result of uneven shrinkage. Stress can cause cells along the grain to separate, usually at the end grain or near the surface. Checking usually occurs during the initial seasoning, however, it can also occur if the relative humidity drops rapidly. Checks may extend just a short distance, causing only visual damage to the object, or they may extend an inch or more into the board causing actual structural damage.

- *Radial cracking* almost always occurs in logs that are left to dry. A pie-shaped crack will open from pith to bark edge to relieve the stress caused by the differential in shrinkage between the radial and tangential planes. Wood used in making objects that require a wide cross section, such as large bowls and three-dimensional sculpture, must be dried very slowly and carefully. Even with this precaution, the objects will always be prone to radial cracking.

- *Diamonding* is caused by the difference between tangential and radial shrinkage. A piece of lumber originally square (or rectangular) in cross section will become diamond-shaped.

A straight-grained, unrestrained board can usually withstand moderate fluctuations in relative humidty without damage. Because furniture is often made from various members that are connected across grain and are restrained from natural expansion and contraction by glue and nails or screws, the stress can become strong enough to cause the wood to split.



1. Cupping
2. End grain checking
3. Diamonding
4. Cross grain shrinkage
5. Distortion of cylindirical form
6. Radial cracking

Figure N.3. Characteristic Shrinkage and Distortion of Wood (Viewed from the Transverse Plane)

3. *What effect does weathering have on wooden objects?*

Wooden objects housed outdoors are subject to physical erosion from the action of rain and wind-driven particulates, though that erosion generally does not exceed ¼ inch of unprotected wood surface per 100 years. The weathering process also includes photochemical degradation. The wood surface generally takes on a silver-gray color and a striated texture as the softer earlywood wears away and the harder latewood is exposed. Ultraviolet light breaks down the lignin in the cell walls, which is then washed away by the rain. The silver-gray surface, which is only a few millimeters thick, is actually more resistant to biological attack than non-weathered surfaces.

Many wooden objects now in indoor museum collections spent their useful life outdoors. As long as the objects are free of fungal and insect damage, the weathered condition can be considered stable and the appearance should be preserved as part of the historical evidence.

4. *What types of deterioration are attributed to human abuse?*

Physical damage to wood objects in museum collections can result from improper handling and housekeeping procedures, and poor storage or exhibit conditions. Physical damage will occur more often in collections exhibited in furnished historic structures where the objects are exposed to more soils and dust in the environment and therefore require more frequent cleaning.

Poorly done repairs are another common cause of damage to wooden objects. Nails may split the wood and mar the surface; glue may leave misaligned surfaces and residue; original finishes may be removed mistakenly. Future conservation treatment may be made more difficult by the use of irreversible materials.

5. *What are the agents of chemical deterioration?*

There are five basic agents of chemical deterioration:

- ***Light*** causes deterioration of the cellular structure of wood, breaks down the lignin component, and bleaches its colors. The most harmful component of light is ultraviolet (UV) radiation. Light damage to wooden objects in furnished historic structures is most commonly caused by sunlight streaming through unshaded windows. It can also occur from excessive artificial light used to illuminate exhibits. Not only is light harmful, but the heat it generates also does damage, especially when lighting fixtures are placed inside exhibit cases.

- ***Acids*** may deteriorate the cellulose in wood causing it to become brittle. Acid rain on outdoor objects can be a problem.

- ***Alkalies or bases*** degrade the hemicellulose and lignin component of wood and cause the wood to separate into individual fibers. Alkaline solutions are more damaging, as a rule, than acidic solutions.

- ***Salts*** can also result in defibration of the wood tissue, but exposure to salt is less common. It may be seen in wooden objects used in food preparation and in objects exposed to a maritime environment.

- ***Fire*** is the most dramatic and by far the most damaging form of chemical deterioration. Wood is a readily flammable material.

6. *What are the biological agents of deterioration?*

Wood is subject to deterioration from a number of biological agents. Damage to wooden museum objects often occurs before the object is placed in the museum setting and may happen even before the wood is sawn into lumber.

- ***Bacteria,*** which consumes the starches stored in ray cells, generally affects only water-saturated wood and is therefore not a problem in most museum collections. However, wood that has been made more permeable by bacteria previously can be vulnerable to fungal activity.

- ***Fungi*** cause more biodeterioration in wood than any other agent. Because fungi have no chlorophyll, they must live on other organic material. The plant consists of thin, thread-like material called *hyphae* that mat together to form *myceliu.* Fungi produce large numbers of *spores*. Three types of fungi affect wood:

  - *Mold fungi* live principally on the surface of wood and discolor it. However, they don't consume cellulose and therefore don't weaken the wood.

  - *Stain fungi* invade the cell structure of sapwood and live on stored carbohydrates.

  - *Decay fungi* actually consume the cellular structure of wood, totally destroying it in some cases. These fungi produce enzymes that break down the cells. The two major types of decay-causing fungi are brown rot and white rot. Brown rot consumes cellulose, leaving a brown color and checking both along and across the grain. White rot consumes both cellulose and lignin, causing the

wood to lose color and crack along the grain. Decay fungi, consequently, cause abnormal shrinkage of wood tissue.

Fungal spores are found in virtually every environment. In order to germinate, however, they require air, heat, moisture, and nutrients. By controlling these conditions you can prevent fungal growth on wooden objects in your collection. Ideally, relative humidity should be kept between 45% and 55%. RH must never exceed 65%.

Temperatures high or low enough to effectively stop fungal growth are impractical in a museum. However, maintaining a temperature of 68° F or below will retard the growth of mold. Decay fungi are problems only when the moisture content is at or above the fiber saturation point. The wooden object would have to be in contact with water to reach a moisture content over 30%. See *Conserve O Gram* 3/4, Mold and Mildew: Prevention of Microorganism Growth in Museum Collections, and Chapter 4: Museum Collections Environment.

- ***Insects*** both feed on wood and excavate it to shelter themselves. See Chapter 5: Biological Infestations, for a lengthier description of wood pests and instruction in integrated pest management.

  - *Beetles* do the most damage to furniture and wooden objects, particularly in temperate climates and an environment of high relative humidity. The adult lays its eggs in pores or checks in the wood surface. After the eggs hatch, the larvae excavate tunnels through the interior of the wood, eventually pupate, and then bore holes to the surface to fly off. The larval stage may last up to 10 years.

  - *Termites,* though less of a problem than beetles, can do considerable damage to stationary structures. Drywood termites, found primarily along the southern and southwest coasts of the U.S., do not need moisture and feed on the dry wood they infest.

  - *Carpenter ants* do not eat wood, but excavate large chambers for their colony.

  - *Carpenter bees* bore large chambers and use them for their eggs, but do not actually consume the wood.

- ***Marine organisms*** are a significant problem in wooden ships and other underwater artifacts. *Shipworm* and *gribble* are two of the most destructive marine organisms. Shipworm is a mollusc that lives on wood and plankton and makes channels in the wood up to 2.5 cm in diameter. Gribble is a small crustacean, barely 1/8" long, that tunnels narrow channels close to the surface of the wood.

- ***Rodents*** damage wood by their gnawing to get food and salts from the surface of wood or to get through to the food stored within. Museum furniture, such as pie safes and jelly cupboards, may have large holes through their backboards. Wooden food vessels that may contain food remnants on the surface or in the pores are vulnerable to rodent damage. Removing the food, however, also removes important evidence of historical or cultural use.

- ***Birds***, mainly woodpeckers, are a threat to outdoor wooden objects. They are drawn to wood that may have insect infestations.

D. The Nature of Furniture

Most furniture originally served both functional and decorative purposes. Once in a museum collection, furniture no longer needs to be functional. The conservator and curator, therefore, focus on preserving the decorative and historical aspects of the piece. A single piece of furniture may be formed from several components, each requiring special knowledge and treatment. These components may include joinery, metal fasteners, adhesives, veneer, finishes, hardware, and upholstery.

1. *What are the common types of joinery?*

Almost all furniture is made from two or more pieces of wood, joined together in some fashion.

- The ***mortise and tenon*** joint is one of the most common and earliest joints used in furniture construction. The mortise is a hole chiseled into a piece of wood, while the tenon is the projection on the end of another piece of wood that fits into the mortise. Because these two pieces of wood are at cross grain to one another, different degrees of expansion and contraction can cause problems. The tenon should be slightly smaller than the mortise to prevent the mortise from splitting. These joints are typically held together with glue, though in country pieces, it was common to drive square pegs into round holes drilled through the joint. See Figure N.4 for an illustration of a typical mortise and tenon joint.

- ***Frame and panel construction*** prevents the splitting that often results when wide boards are constrained at their edges. In this technique the frame is made from relatively narrow boards joined at the corners with mortise and tenon. The inner edge of the frame is grooved to hold the edges of a wide panel, which is free floating and therefore able to expand and contract freely with changing relative humidity.

- The ***dovetail joint*** is another traditional technique, generally used to join the edges of wide boards. The edges are cut and chiseled so that they interlock. This technique was typically used on the sides of drawers and chests. Dovetail joints are commonly glued. See Figure N.5 for an illustration.

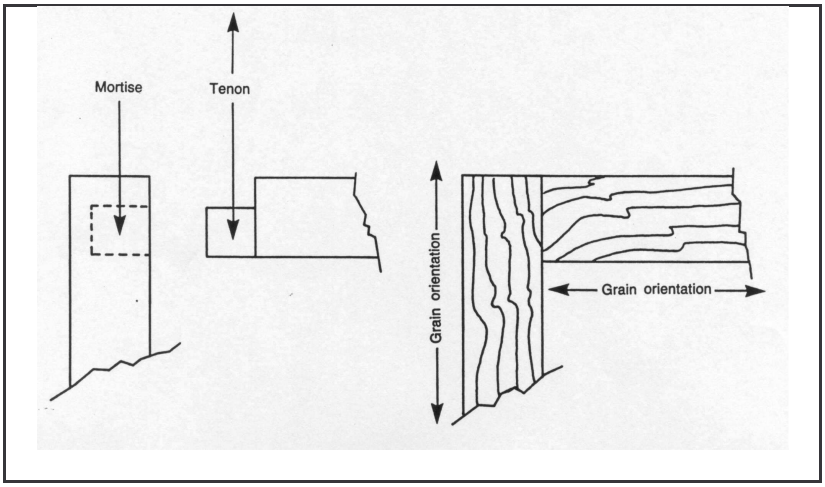


Figure N.4. Typical Mortise and Tenon Joint

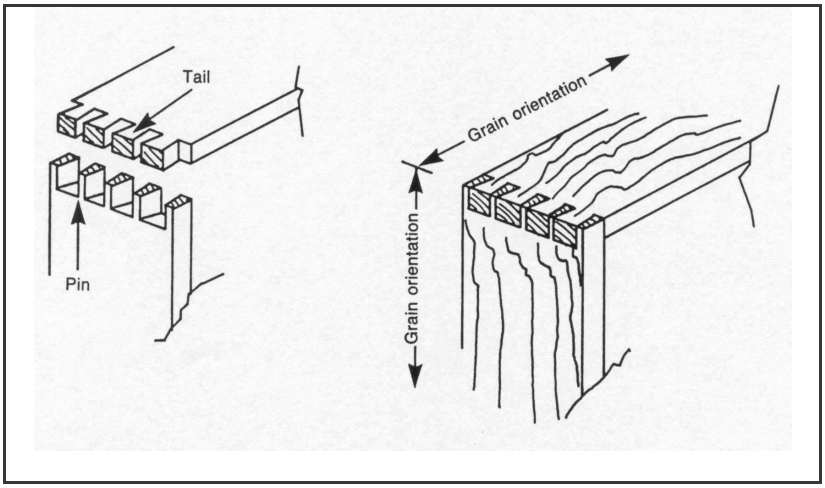


Figure N.5. Typical Dovetail Joint

2. *What should I know about metal fasteners?*

Various types of metal fasteners have been used in furniture construction, including nails, screws, and bolts. Hardware can be useful in dating furniture. For example, nails became more frequently used when they were first mass-produced in the late 1700s. Screws were not commonly used until the 1840s, when the technology to manufacture them with gimlet points was developed. (A gimlet point is one that can readily penetrate wood.)

Fasteners are most often made from ferrous metals, which corrode in high relative humidity. This corrosion can spread, damaging the appearance and structure of the wooden object. Severely corroded metal will expand, crushing and splitting the surrounding wood. *Corrosion jacking* is most likely to occur at the coast, where there is exposure to salts in the environment. Iron salts, often present at contact points between wood and ferrous metals, degrade and discolor wood. Woods with high tannic acid levels, such as oak, are very susceptible to damage from iron salts. Contact between some woods and metals also will accelerate the oxidation of the metal.

3. *What types of adhesives are used in creating wooden furniture and other objects?*

Adhesives, used alone or in conjunction with fasteners, come in three basic types:

- **Protein-based glues**

  Animal products are the primary ingredients in protein-based glues. Historically, the two most commonly used varieties were hide glue and fish glue. These were heated to a gel before use. The glue set as it cooled and the water content evaporated. Because this type of glue is readily resoluble and has a long setting time, it is often used in the conservation treatment of furniture and other wood objects.

  Though strong in a proper environment, protein-based glues are water-soluble and therefore fail in high relative humidity. At the other extreme, very low relative humidity, the glue will dry and crack causing the joint to fail. Casein glue, made from milk curds, is occasionally found in furniture and wood objects. It is more resistant to the effects of moisture than the other protein glues. Another disadvantage of these substances is the attraction they hold for insects.

- **Vegetable glue**

  Vegetable glues, such as starch paste, though seldom used for gluing wood joints, can be found adhering paper labels or paper coverings to wooden surfaces. Other types of vegetable glues, like gums and resins produced by trees, are commonly found on ethnographic wooden objects, but not in Western furniture. Like hide and fish glues, vegetable glues are sensitive to changes in relative humidity and are susceptible to biodeterioration.

- **Synthetic resins**

  Synthetic resin adhesives have become increasingly common since the 1940s. They harden either through the evaporation of a solvent, like water, or a chemical reaction between a hardener and a resin. Many post World War II objects in museum collections are constructed with these adhesives. Most synthetic resins form a very strong bond, are durable, and are relatively insensitive to environmental conditions. These qualities become disadvantages when objects need conservation treatment for it is nearly impossible to separate these joints without causing damage to the wood surface.

4. *What is veneer and what are the problems associated with it?*

Veneer is a thin layer of wood glued to a solid base material for decorative purposes. It ranges in thickness from 1/32" to 1/8". Older veneers were sawn by hand and are thicker than contemporary ones and often irregular. They were often attached with hide or fish glues. Expensive woods (for example, rosewood and mahogany) are typically used for veneering. Many small pieces of veneer are used in marquetry, inlay, and banding to create intricate patterns and pictures.

Generally the grain of the veneer on tabletops and other large, flat surfaces lies in the same direction as the grain of the underlying wood. In other areas the grains may lie perpendicular to each other, or as in marquetry and inlay, at almost any angle. Fluctuating humidity levels can cause severe damage as the woods expand and contract along different planes. See Figure N.6 for common applications of veneer.

Some areas of veneered furniture are more likely than others to receive damage. For example, the veneer on drawer rails and the bottom rails of case furniture, such as chests and sideboards, is very vulnerable. As the underlying wood shrinks, a lip of veneer forms along the top and bottom edges. The drawer, as it moves in and out, can easily snag the protruding veneer and tear it off. Dust cloths can catch on loose veneer and pull off pieces. Mops, brooms, and vacuum cleaners often cause irreparable damage to the lower edge of bottom rails during routine housekeeping.

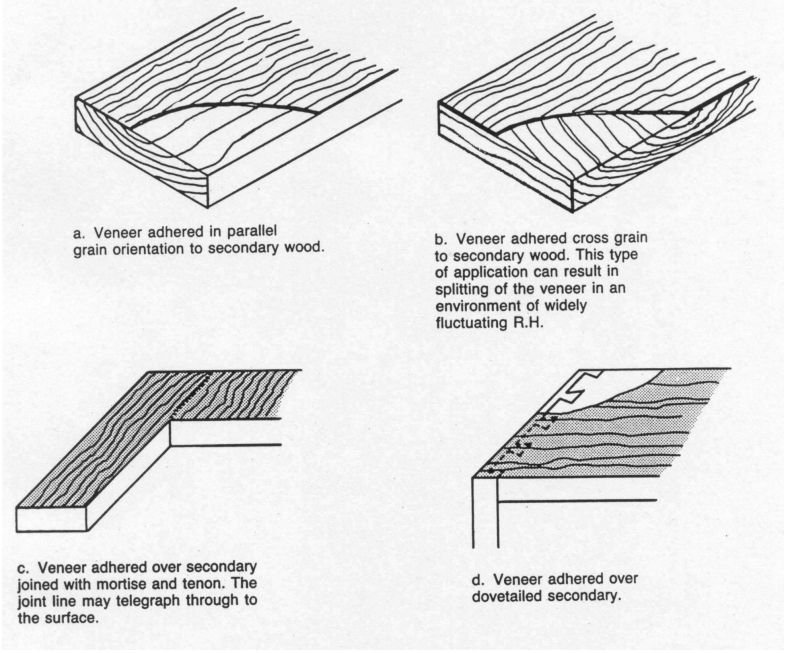


Figure N.6. Common Veneer Applications

5. *Why are finishes applied to furniture and wooden objects?*

Stains and dyes are often applied to wood to enrich or darken the color. They penetrate the surface but do not leave a film. Alcohol- and water-based stains are sensitive to light damage. Oil-based stain is more resilient.

Transparent or pigmented finishes are applied to wood for more than one reason. They are used aesthetically to bring out the color and grain pattern. In other cases the finish may be strictly utilitarian. They preserve the wood by protecting it from spills and light damage and by slowing the transfer of water vapor from the environment.

6. *What types of finishes are used?*

Among the most common finishes found on museum pieces are varnish, oil, shellac, wax, paint, and gilt.

- ***Liquid finishes***, including varnishes, oils, and shellacs, are divided into three broad categories: resins, polymers, and paints.

  – *Resins*, such as spirit varnishes, are either dissolved or dispersed in solvent. They harden as the solvent evaporates. Shellac is made from the resinous secretion of insects and is the most common finish found on furniture in park museum collections. It was

particularly popular in the 19th and early part of the 20th centuries. Resins are susceptible to damage from water and alcohol.

- *Polymers*, which include most oil finishes, harden by means of chemical bonding (polymerization) and/or oxidation. Linseed oil and tung oil are commonly used oil finishes. They penetrate the wood but do not provide as hard a finish as resins. Linseed oil, particularly, darkens over time as it oxidizes. Misused in the past, in combination with turpentine and beeswax, it has caused damage to many museum pieces. Though serviceable in moderation, in excess linseed oil remains tacky, gathers dust, and severely darkens the wood. Oils are very difficult to remove without damaging the underlying finish. **Do not apply oil to finished wooden surfaces.**

- *Paints* consist of pigment particles in suspension in a binding medium and a solvent. Most paints are relatively stable, however, calcimine and distemper used during the eighteenth and nineteenth centuries were made with a protein glue binder and therefore dissolve in water. **These soluble finishes should be dusted only**.

A few finishes, such as oil-resin varnishes, are a combination of the two.

- ***Waxes*** are softer and more plastic than other finishes and are readily soluble in most organic solvents. There are few, if any, examples of objects with original wax finishes in park museum collections**. Do not clean a wax finish as you would a hard finish.** Consult a conservator for advice.

- ***Gilt*** may have been used as a decorative accent on furniture or as a finish over the entire surface. It was most commonly used on ornate picture frames. A gilt finish consists of a gesso layer, a sizing layer, and silver or gold leaf that is metal-hammered into extremely thin sheets. Silver and lesser grades of gold oxidize rapidly. Sometimes the leaf was painted with pigmented shellac to protect it.

  Gilt is the most fragile of all finishes, extremely susceptible to damage from rough handling and improper housekeeping. Skin oils can accelerate oxidation, so do not touch the gilt surface. The gesso layer is brittle and often cracked from the expansion and contraction of the underlying wood. Under very humid conditions the gesso will absorb enough water vapor to soften and expand so that it eventually chips away from the wood. **Dust these surfaces gently with a soft bristled brush and a low power vacuum held at least 1/2 inch away.**

7. *What is patina?*

Patina refers to the distinctive appearance of older finishes. It is used to describe a worn finish, but one with warm tones and satin luster. There is a fine line between patina and a damaged finish. It is important to recognize and protect an unstable finish that may deteriorate further under the existing environmental conditions.

8. *What happens to finishes as they age?*

The aging qualities of finishes vary. Oriental lacquer, for example, is very sensitive to moisture and light damage. Shellac, on the other hand, is relatively resistant to light damage because it allows the light to pass through and consequently harm the stain and wood beneath.

All finishes are damaged to some extent by exposure to high light levels because light accelerates oxidation. Oxidation prevents the finish from expanding and contracting freely with the wood beneath. Minute cracks, called crazing or "alligatoring," may result. Some light-damaged finishes are dull and chalky, while other more severely damaged finishes become unstable, flaking or breaking down into "islands" that lift at the edges.

Fluctuating relative humidity will worsen the condition of finishes made unstable by exposure to high levels of light. High humidity can cause white "blooms" and mildew damage on even stable finishes.

9. *What should I know about the hardware on wooden furniture?*

Drawer pulls, knobs, escutcheons, locks, and other types of hardware are typically made out of brass on decorative pieces and ferrous metal on functional pieces. Brass, an alloy of copper and zinc, will dull and darken as it oxidizes. Polishing brass can damage both the hardware and the surrounding wood. Rubbing with abrasive polishes eventually will wear away the surface of the brass. If the hardware is not removed from the piece for cleaning, the wood finish around and beneath the hardware will likely be damaged or even entirely worn away. Hardware that is not washed after polishing will often show a white or green residue. Green residue indicates the presence of ammonia, which will continue to react with the brass.

Pigmented shellac frequently was applied to brass to protect the shine and give it a more golden tone. This coating, however, is easily scratched. Occasionally the brass on very decorative pieces was given a thin coating of gold in a process called fire gilding. This bright, shiny gold layer will prevent oxidation, but like the shellac is easily damaged. Do not clean fire-gilded brass until you have consulted a conservator.

10. *What potential sources of damage should I look for in upholstered furniture?*

Like wood, upholstery is subject to deterioration from:

- high temperature, which can leave the fabric brittle
- high humidity, which promotes biological activity
- visible and ultraviolet light, which causes all fabrics to fade
- chemical reactions
- bacteria and fungi
- mechanical abuse
- termites and woodworms
- rodents

In addition, look for deterioration from agents that more typically attack textiles. See Appendix K, Section D, for a comprehensive discussion of these:

- pollution, such as dirt and pollen, industrial emissions, and smoke
- fiber-eating insects, such as moths, silverfish, cockroaches, and carpet beetles
- inherent vice, particularly the addition of metallic compounds during manufacture
- oxidation, which discolors white and natural cloths

See *Conserve O Gram* 7/4, Upholstered Furniture: Agents of Deterioration, for a more thorough discussion.

11. *Should I ever replace the upholstery?*

Yes, under certain circumstances. An upholstered piece in a museum collection may have been re-covered several times during its period of use. The current upholstery fabric may not be appropriate for the period of interpretation or it may be very worn. Because the wood frame might have been damaged by repeatedly attaching the upholstery with tacks, consider using a non-destructive technique when re-covering the piece. See Calinescu and others (1996), for an example of a low-interventive upholstery technique.

E. Preventive Conservation: Controlling the Environment

1. *What elements of the environment should be controlled?*

To provide a stable environment for wooden objects, control these factors:

- relative humidity
- temperature
- light
- ambient air quality

2. *What is the ideal relative humidity for furniture and other wooden objects?*

The ideal relative humidity level in most areas of the country for wooden objects is 50% plus or minus 5%. In dry climates, such as the southwest, 35% to 40% is acceptable. These levels are difficult to achieve in very dry climates because the moisture content in wood drops rapidly below 35% RH, causing splits. Below 30% the glue may desiccate, joints may loosen, and finishes will become brittle. Along the coast, 55% to 60% is acceptable, but above 70% mold and insects may become problems. When humidity is this high, glue may weaken, finishes may bloom, hardware will corrode, and wood fibers will swell excessively.

Rapid changes in relative humidity, as mentioned earlier, may cause severe damage to furniture. An increase in RH from 30% to 70% can cause wood to expand as much as 2% across the grain. In this case a 2-foot panel could expand almost 1/2 inch causing splitting, veneer loss, and joint failure.

Avoid temporarily heating, air conditioning, or humidifying spaces that house wooden objects. Do not turn off heat or air conditioning at night.

3. *Why is temperature important?*

Temperature is important primarily because it affects relative humidity. Though changes in temperature alone also will cause some expansion and contraction of wood, this is a relatively minor concern. Elevated temperatures will speed fungal and insect activity as well as oxidation. High temperatures associated with high relative humidity can cause some old finishes to become tacky.

- Consider installing a humidistat to override the thermostat in spaces housing wooden objects.

- Maintain the temperature at the lowest comfort level in exhibit areas and even lower in storage spaces, but be sure to keep it above freezing at all times.

4. *What effect does light have on wooden objects?*

Light will change the natural color of heartwood, making light woods darker and dark woods lighter. It will fade stains and embrittle finishes. It also will fade and embrittle the fabric or leather on upholstered furniture. The level for unfinished wooden objects should not exceed 300 lux. The light level for most finished wood objects should not exceed 200 lux. Objects decorated with fugitive stains and dyes and light sensitive fabrics, such as silk, are more prone to light damage and the allowable light level should be even less.

Limit exposure of wooden objects to both natural and artificial light:

- Install UV filters on windows and florescent lamps to reduce most of the harmful UV radiation.

- Use blinds, shutters, curtains, and roller shades in historic structures to reduce visible light.

- Use reproduction slipcovers to protect upholstered furniture.

5. *How can I control ambient air quality?*

Most modern museums have a variety of filters in their HVAC systems to clean the air and filter out dust and other particulates. In addition, many objects in these buildings are displayed in protective exhibit cases. Historic structures, on the other hand, seldom have good air filtering systems and the furniture is displayed openly. More particulates are generated simply because of the nature of the buildings. Not only is dust abrasive and therefore harmful to wooden surfaces, it is a source of food for mold and is attractive to insects.

F. Preservation Through Good Housekeeping Practices

1. *What housekeeping practices should I follow?*

The conditions in historic furnished structures require intensified housekeeping both in procedure and frequency. Good housekeeping is essential for aesthetic and preservation reasons. It should be carried out on a regular schedule. See Chapter 13: Museum Housekeeping, to learn about developing a museum housekeeping plan.

Keep this tip in mind when handling wooden furniture and objects:

Don't wear gloves when handling furniture with fragile veneer that might snag or when moving heavy wooden pieces requiring a sure grip. **Do wear them** when handling gilt finished objects or unfinished objects made from light colored wood that might stain.

> ***Frequent and proper housekeeping is critical for the preservation of collections in historic structures.***

2. *What are the best ways to remove dust?*

Because dust is not only abrasive but also attracts moisture, it should be removed periodically to prevent damage as well as to improve the appearance of objects. Remove it from the environment as completely as possible.

- ***Use a vacuum*** to remove the dust from wood surfaces if possible. (See *Conserve O Gram* 7/5, Dusting Wooden Objects, and *Conserve O Gram* 1/6, Choosing a Vacuum Cleaner for Use in Museum Collections.) Hold the brush attachment just above the wood surface. Use a soft bristled brush to sweep the dust out of crevices and intricately carved areas and toward the vacuum brush. Also vacuum upholstery. (See Appendix K for guidance.) **Keep the vacuum clean.**

- ***Use a clean cotton cloth*** when vacuuming is not an option. Turn the cloth frequently so that accumulated dust does not scratch the object's surface. Wash the cloth after every use. You may dampen the cloth with water or spray it sparingly with a light mineral oil product, such as Endust®, where low relative humidity creates a static charge, causing the cloth to repel the dust. If using water, be sure to dry the surface immediately. **Do not** use scented oil products.

- ***Don't use feather dusters.*** They scatter the dust rather than collect it. Broken feathers may scratch the surface.

- ***Don't wipe unstable finishes.*** This will cause more harm to flaking and lifting edges or surfaces that have loose veneer or splintered corners.

- ***Use compressed air*** on very fragile objects and irregular surfaces. Limit pressure to about 10 pounds and use away from exhibit areas.

3. *Do furniture and wooden objects require more than thorough dusting?*

Yes. Periodically these require cleaning to remove oils and grime. Objects in storage may need to be cleaned only every ten years while those on exhibit will require cleaning approximately every three years. More frequent cleaning may be necessary if visitors occasionally touch the pieces.

- Use mineral spirits, such as Stoddard solvent or naptha, on greasy types of soils and hand oils. First test a small inconspicuous area with a cotton swab dipped in mineral spirits. If the finish does not get tacky and no finish comes off on the swab, you may begin careful cleaning with a cotton cloth dampened with mineral spirits. Work in a well ventilated area and wear vinyl gloves. Turn the cloth frequently and wipe the object down with a clean, dry cotton cloth after cleaning. **Note:** Some 18th century pieces may still have their original wax finish. Consult your regional/SO curator and a conservator before cleaning furniture that you suspect has an original wax finish.

- Use soap like Vulpex®, Ivory®, and Orvus® and water to remove smoke and soot from stable finishes. Follow manufacturer's instructions for dilution. Never use detergent because it will leave a film on the surface. Again, test a small inconspicuous area before cleaning the entire surface. Wring the cloth well before wiping. When finished, wipe the piece again with a cloth dampened in clear water and then again with a dry cloth. **Do not moisten a damaged, veneered, or inlayed surface.**

Only furniture with a sound finish should be cleaned.

4. *Should furniture be waxed?*

Yes. The application of wax to clear finishes is recommended for these reasons:

- Wax enhances the appearance of the surface by filling in voids and small depressions, creating an attractive level surface.

- Wax helps protect the surface from abrasive dust and handling.

- Waxing makes dusting easier.

- It slows the penetration of water and water vapor, which will cause the wood to swell.

Note: Always rewax the finished surface after cleaning, since mineral spirits will dissolve and remove wax**.**

5. *What kind of wax should I use?*

The paste waxes recommended for use on wooden objects in museum collections are made with weak organic solvents, such as turpentine or mineral spirits. When the solvent evaporates, the wax film that remains is lustrous, slippery, and plastic. Waxes are derived from animal, vegetable mineral, and synthetic sources. Natural waxes, like beeswax, have been used for centuries. Most commercial paste wax products are mixtures of various waxes.

- **Don't use** paste wax made with strong solvents, such as xylene and toluene, because they can damage some finishes.

- **Don't use** liquid polishes. They do not offer the same protection as paste and most contain silicones. Silicone migrates into the finish and complicates any future conservation treatment.

6. *What precautions should I take when waxing furniture?*

Apply wax only to stable, clear finishes, such as shellac, varnish, and modern lacquer. **Don't** apply paste waxes to unfinished objects because it will penetrate into the pores. Wax applied to unfinished wood surfaces cannot be completely removed.

Cover the upholstered parts of the piece so that you don't accidentally get wax on the material.

Be careful not to get wax into cracks or splits in the wood. Later attempts to repair the crack with glue would be very difficult.

7. *How often should I apply wax?*

The frequency of waxing will depend on environmental factors, such as dust, relative humidity, and light, and on the amount of handling. When museum objects are used or touched, be sure to wax often enough to protect the underlying finish. Most wood objects in furnished historic structures, however, will require rewaxing just every one to four years. Objects in well-gasketed exhibit cases may only require waxing every ten years. As a general rule, rewaxing is not necessary if the existing wax layer can be buffed to a sheen.

8. *What is the recommended method of applying wax?*

Always follow these procedures:

- Clean the object to remove the existing wax. Waxing over dirty surfaces will produce a grimy buildup and eventually obscure the color and grain of the wood.

- Apply new wax sparingly with a clean, cotton cloth, rubbing first in a circular motion and then along the grain. Wait at least an hour or two for the solvent to evaporate and then buff the wax with another clean, cotton cloth. If the luster is uneven, repeat the procedure. ***Note:*** It is preferable to apply two thin coats rather than a single thick coat.

- On a carved or irregular surface, apply the wax with a soft toothbrush or shoe polish applicator and buff it out with a soft fiber shoe brush. Tape foam padding to the wooden ends of the brush to avoid damaging the object while buffing.

- Don't apply wax when it is hot and humid. The wax may turn white and cloudy. If this happens, remove the wax with mineral spirits and rewax when the environment improves.

- Remove white specks from pores and recesses left by light-colored waxes with a wooden pick or use a pigmented wax on dark wood.

Refer to *Conserve O Gram* 7/2, Waxing Furniture and Wooden Objects, for more guidance.

9. *What commercial brands of wax can I use?*

There are several good paste waxes on the market. These include Staples®, Butchers®, SC Johnson®, and Trewax®. Renaissance Wax®, a good synthetic with no perfumes or pigments, is frequently used on museum objects. It is durable and highly water resistant. It is recommended for smaller wooden objects, however it can be difficult to buff evenly on large, flat surfaces, such as tabletops.

10. *How do I care for the hardware on wooden furniture?*

The best way to care for hardware on museum pieces is to clean and polish it once and then spray it with a lacquer containing corrosion inhibitors. This treatment requires specialized equipment and the experience of a conservator, but applied correctly, the finish should last up to 20 years.

If this conservation treatment is not feasible, the following on-site treatment is the next best solution.

- First, remove the hardware if this can be done without damage. Tag it to document its original location. If it cannot be removed easily, slip Mylar® sheets behind the hardware, curtting out slits to get by bolds or bails.

- Determine the type of metal and clean it accordingly.

  – Clean brass hardware with alcohol or stoddard solvent, if necessary, to remove fingerprints.

  – Soak iron hardware for several days in kerosene to remove rust and dry it thoroughly. Dip badly corroded iron hardware into a metal preservative called Ospho to prevent further deterioration.

  – Softly brush gilded bronze with a weak solution of amonia and distilled water (1 part amonia to 40 or 50 parts water). Rinse it with clean distilled water and dry it with a warm, not hot, air-blower.

- After cleaning, you may polish brass hardware with a mild abrasive, such as artist's whiting, that **does not** contain ammonia. **Do not** polish gilded bronze. Be sure to remove all of the polish residue. Use a solvent and wash with distilled water.

- Last, wax all accessible surfaces of the hardware with a microcrystalline wax, such as Renaissance Wax®. Wax will retard oxidation, though not as effectively as lacquer.

See Appendix O for further guidance on cleaning, polishing, and coating metal objects.

G. Preventive Conservation

1. *How can I provide a protective environment for wooden objects in storage?*

Protecting objects in storage is much easier than protecting them while on exhibit. First of all, you can eliminate the warm temperatures and light that often cause damage during display. There are a few requirements, however:

- Storage spaces need to be easily accessible. When storing furniture, avoid areas with narrow stairwells and doors.

- Never store wooden furniture directly on concrete, stone, or brick floors. The end grain on furniture legs and feet will soak up moisture, causing fungal damage and staining. Store on shelves or blocks.

- When using storage shelves, place large and heavy objects on the lowest level. (Slotted metal angle storage systems can be adapted for furniture storage. Be sure to pad the edges.)

- Store wood frames on stationary or moveable racks, like those used to store framed paintings.

- Don't stack furniture.

- Don't store objects in the drawers of period furniture.

2. *What is the best way to move large pieces of wooden furniture?*

Because furniture is particularly prone to damage while it is being moved, it is important to carefully plan and execute any move.

- Examine the furniture carefully to detect any structural instability, such as broken or loose joints or splits that may not stand the stress of moving.

- Secure doors, drawers, and drop lids or leaves before moving the piece. Use cotton twill tape rather than twine to avoid scratching the finish. **Never use adhesive backed tape**. Remove drawers if weight is an issue.

- Remove marble tops and store them on edge while you move the base. Large marble tops may fracture from their own weight if held horizontally and supported only at the ends.

- Plan your route and measure doorways, stairways, and aisles along the way to make sure the object and the carriers will fit. (Measure the width of a couch or large chair by placing it against a wall and measuring from the wall out to the middle of the seat rail.)

- Use a dolly.

- Don't attempt to move heavy or awkward objects by yourself.

- Never slide furniture across the floor. Sliding puts too much stress on joints and fragile areas and can cause the feet or legs of dressers, tables, chairs, etc. to break.

- Grasp furniture for lifting where it is strongest, usually the lowest horizontal structural member. For example, lift a table by its apron, a case piece by its bottom rail, and a chair by its side seat rails, being careful not to dislodge the slip seat. Never lift a sofa by its arms—grasp the bottom rails, instead. Moving a particularly large and heavy sofa may require four people.

See Figure N.7 below for the proper moving techniques.

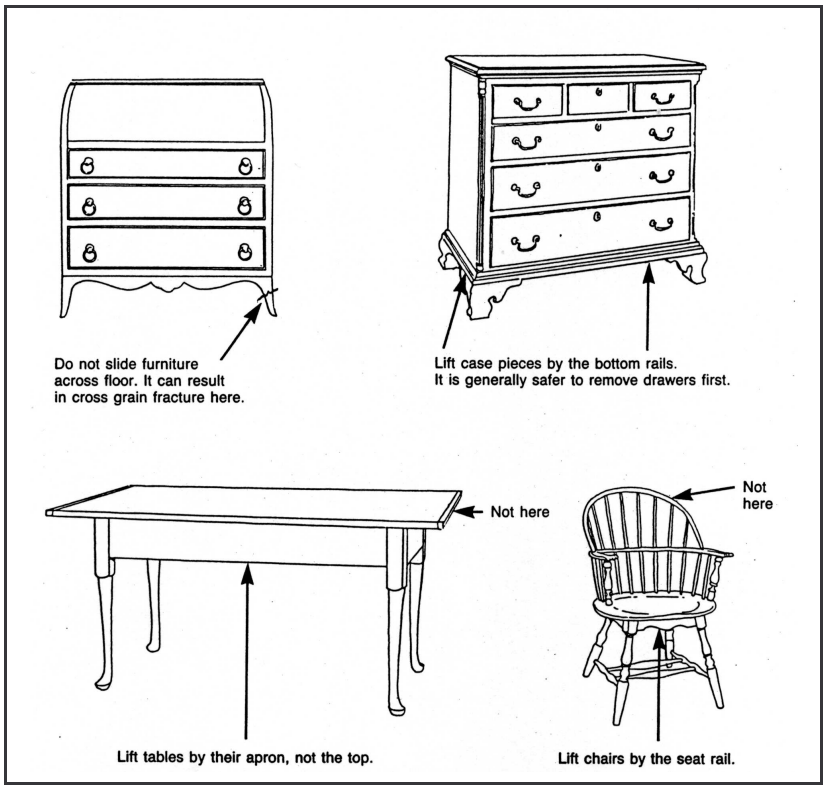


Figure N.7. Proper Techniques for Moving Furniture

3. *What should I do if a part of the wooden piece becomes loose or falls off?*

If small parts become detached because of glue failure, structural failure, or accidents during moving or cleaning, place them in a closable polyethylene bag with a label that documents the date, location from which the piece came, and the catalog number of the object. Keep the bag with the object, if possible, and contact a conservator.

If there is an urgent need to repair the piece, consult the regional/SO curator and seek permission to use a ***reversible*** glue (for example, hide glue) to reattach the part temporarily. **Do not tack the loose part back into place.**

If more than one piece becomes detached, it usually indicates a problem with either the environment or the housekeeping procedures. The object may be too unstable for exhibit. Seek conservation treatment as soon as possible.

4. *Is there a special technique for removing mold from wooden objects?*

Because mold growth is the result of environmental factors, your first step is to improve the environment.

- Lower the relative humidity level and increase the air circulation.
- Isolate the object from the rest of the collection and place it where it will receive more light.

- Use a HEPA vacuum to remove the mildew from the object and discard the bag, or brush it off, capturing the spores on a drop cloth. A dust mask or respirator may be necessary (see *Conserve O Gram* 2/13, An Introduction to Respirator Use in Collections Management). Dispose of the cloth in a plastic bag.

- Wipe the remaining mold from the object with a solvent-dampened cloth. Use a 50% mixure of alcohol and water on all but shellaced surfaces. Use mineral spirits to clean a shellac finish. Dispose of the cloth.

5. *How can I determine if a wooden object has an active beetle infestation and what should I do about it?*

Evidence of active wood boring beetles, the most common museum insects to attack wooden objects, is easy to spot.

- Examine the surfaces of the piece carefully for *flight holes*—the holes made by these insects as they exit. If there are "bright holes" with sharp edges, the infestation is probably current.

- Look for *frass*, a light-colored powder produced by the larva as it eats the cellulose. It may be found on the floor nearby or on the lower horizontal members of wooden objects.

- Check the windowsills for beetle carcasses during the spring.

- Listen carefully. Some species of wood boring beetles can actually be heard as they chew.

If you suspect an active infestation, isolate the object immediately. Place it on a dark paper or other surface, wrap it with polyethylene sheeting, and monitor it carefully for new frass accumulations. Be careful not to jar the piece, since movement may dislodge older deposits of frass.

Refer to Chapter 5: Biological Infestations, for guidance if you determine that beetles are currently at work.

H. Conservation Treatment

The preservation of wooden furniture and other wooden objects is the responsibility of both curator and conservator. The curator must know how far to go with hands-on housekeeping and when to call the conservator for advice or treatment.

1. *How do I assess the stability of a wooden object?*

Most furniture and other wooden objects in museum collections show evidence of much use and at least some damage. You must be able to determine whether or not that damage makes the object unstable.

An object should be considered unstable when further deterioration is likely to result if the condition is not corrected.

- ***Examine the object carefully for structural stability***. Look for:

  – glue failure

- mechanical joint failure
- missing and loose elements
- cracks and splits
- fungal or pest activity

Loose joints usually indicate environmental problems that have caused the glue to dissolve or become brittle and fail. Not only is conservation treatment needed to stabilize objects with loose joints, but also the environment must be corrected to prevent the problem from recurring.

Missing parts *may* cause structural instability. A lost finial will not; a lost leg will. If a crack or split occurs in a structural member that must support the weight of the object, conservation treatment is needed. If movement is possible on either side of the split, the object should be treated.

Make sure you can distinguish between decay fungi and mold and mildew. Decay fungi consume cellulose and lignin and will eventually cause severe deterioration. Mold and mildew, on the other hand, disfigure the surface of the wood, but do not cause instability. Decay fungi can be detected by the presence of cracks along and across the grain of the wood, a "dead" sound when tapped, loss of weight, a friable surface, and its characteristic odor. If the decay has not progressed too far, the wood can be consolidated during conservation treatment and a degree of structural stability restored.

Like decay fungi, insects can also cause severe damage to wooden objects. The presence of numerous exit holes on the surface of an object indicates the need for a thorough structural examination. See Section H.4 above.

- ***Examine the finish carefully***. Crazing may or may not require conservation treatment. If the finish is still tightly bonded to the wood surface, it is probably in fairly stable condition. If , however, the islands of finish are loose or are beginning to discolor along the edges, treatment is recommended.

- ***Examine the hardware***. Look for active corrosion. Dull, oxidized hardware is not necessarily unstable, but active green corrosion on brass or copper hardware should be corrected by conservation treatment. On ferrous hardware, a coating or red or red-orange rust also indicates active corrosion. If corrosion is not stopped, it will deteriorate the metal and may stain the underlying wood.

2. *How should I document the condition of furniture and wooden objects?*

Periodic documentation should be both written and visual. Measured drawings, sketches, and photographs are very useful when they accompany written descriptions.

- Note the occurrence of obvious damage, such as loss of veneer or scratches from cleaning equipment.

- Note deterioration that takes place over a longer period of time, for example, progressive crazing or fading of finishes. Take photographs and date them for comparison.

- Record the length and width of any split you might see. If it is larger on the next inspection, call a conservator for treatment.

- Compare your documentation of condition with the records from environmental monitoring. Seasonal variations in relative humidity may be responsible for the deterioration.

3. *What will a conservator do in the course of treating wooden objects and furniture?*

The conservator's treatment will be determined by the condition and intended use of the object. Typically a conservator will follow these steps:

- ***Examine the object thoroughly*** with the aid of microscopes and specialized photographic techniques to:

  – determine the stability of the structure and the finish

  – determine the causes of deterioration

  – look for evidence of insect and fungal decay

  – identify the type of wood, finish, and adhesive and joinery techniques

- ***Clean the object carefully*** by mechanical and chemical means to:

  – remove foreign soil buildup

  – remove stains and paint deposits

  – remove unwanted (post-period) surface coatings

  The conservator preserves important signs of use.

- ***Make structural repairs*** by restoring structural integrity, but not necessarily appearance.

  Repairs are reversible so that they can be removed if necessary.

- ***Replicate missing elements*** when desirable with in-kind materials and techniques or modern ones.

  The decision to replace missing elements is made jointly by the conservator and the curator. It will depend, in part, on the object's significance and whether or not the size, shape, and design of the missing element are known. Replacements should be:

  – documented in writing with accompanying photographs

- labeled with maker and date
- removable
- unobtrusive to the museum visitor, but discernable to the curator
- added with a minimum of damage to the object
- reasonable in cost

- ***Consolidate damaged fibers*** when the wood has been damaged by fungal activity, insect attack, or chemical action. Consolidants can be made from a number of natural or synthetic resins and a variety of solvents. The process, however, results in a visual change to the wood surface and is never completely reversible. Therefore, the decision to use consolidants should be carefully weighed.

- ***Preserve the existing finish*** or replace it if necessary. If the existing finish is original, or at least appropriate, and salvagable, preservation is the preferred course. Preservation may involve:
  - cleaning and waxing, if the finish is stable
  - partially dissolving the finish to lay it down if it is lifting and unstable
  - amalgamation of crazed surfaces
  - filling in areas of stain loss with a reversible finish

  Refinishing is preferred if the existing finish is either inappropriate or almost completely worn away. Conservators will use the least harmful means of finish removal and a new finish that is resoluble. A small area is usually left intact to document the finish history of the object. The curator and the conservator should carefully consider the decision to refinish.

- ***Apply a surface barrier*** to protect against moisture, dust, light, and staining. Wax is generally the choice for finished wood surfaces. In some instances, a sheet of acrylic may be used to protect wood surfaces from marring or abrasion.

I. Emergency Procedures for Wooden Objects

1. *What is the most common type of emergency?*

Most emergencies that affect museum objects involve water. Refer to Chapter 10 for guidance on emergency planning. See Chapter 8, *Conserve O Gram* 7/7, Emergency Treatment for Water-Soaked Furniture and Wooden Objects, and *Conserve O Gram* 21/6, Salvage at a Glance Part III: Object Collections, for emergency treatments for wood objects. You will probably need to contact a conservator to take care of the preservation problems created by any disaster.

2. *What preservation problems will I encounter during a flood?*

Water damage usually affects the finish and causes wood to swell. If there is standing water on the floor for a period of time, the water and any salts that may be dissolved in it will be carried up through the end grain of the feet and legs of furniture creating "tide" lines as the salt effloresces. Floods and water-damaged ceilings may deposit mud, plaster, or gypsum on furniture surfaces. The high relative humidity levels often result in mold growth. Upholstery fabrics will stain and probably shrink. Hardware will rust.

Moving furniture after a flood subjects it to even more potential damage. Move it only if necessary. Your focus should be on removing the water instead.

3. *What should I do in the event of a flood?*

Take action immediately:

- Remove all water on and around the object as quickly as possible. Lower the relative humidity level slowly to acceptable levels.

  Dry out wet wood objects slowly.

  It may be necessary to cover affected objects with a polyethylene tent so they will not dry out too quickly.

- Remove drawers and open doors to dry all surfaces evenly. If drawers and doors stick because of swelling, **do not** force them open.

- Raise all objects off the floor so that the water will not migrate up the feet and legs.

- Use fans to improve ventilation and therefore decrease the likelihood of mold, but **do not** aim the fans directly at the furniture.

- Remove ferrous hardware to avoid stains, especially on woods with high acid levels like oak. Tag all hardware, furniture elements, and loose pieces as you remove them.

- Remove the outer fabric, padding, and support from very wet upholstered furniture. Saturated fabric left in place may split as it dries. The padding can be dried relatively quickly without damage. Feather cushions can be dried in a clothes drier at a low temperature.

- Gently sponge any mud or plaster from stable wood surfaces with clean, cool water. Rinse the sponge often. Gritty sponges and dry cloths will scratch the wood. Wait for a conservator's assistance to remove mud and plaster from fragile and unstable finished surfaces, such as gold leaf.

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