



# PRESERVATION EDUCATION CURRICULUM



NORTHEAST  
DOCUMENT  
CONSERVATION  
CENTER

CLASS 3 LESSON PLAN

## Structure and Deterioration of Paper-based Materials

### The Lesson

#### Part I: Introduction (15 minutes)

##### A. Organic/inorganic materials

All materials are categorized as either organic or inorganic. Organic materials are made (or extracted) from plants or animals. Inorganic materials are made from rocks and minerals.

Organic materials include wood, paper, textiles, and animal parts (ivory, bone, leather). They also include natural materials that are not obviously organic (such as coal and fuel oil, which are derived from fossilized plants and animals) and synthetic materials (such as plastics, which are made from chemicals extracted from plant and animal products). All organic materials deteriorate over time.

Inorganic materials include stone, metal, ceramic, and glass. Some inorganic materials are found in paper-based formats: photographs contain metallic particles; some pigments and inks contain minerals, metals, or metallic oxides; and metal particles are sometimes found in paper itself. Inorganic materials are generally stable individually, but they can react with other materials to cause deterioration. Some metals (particularly iron, copper, and platinum) react with the cellulose in paper to cause deterioration.

##### B. Chemical deterioration

Cellulose is degraded by three primary mechanisms: hydrolysis, oxidation, and elimination. Of these, hydrolysis, caused by contact with acid, is the dominant reaction and responsible for most of the degradation of paper. Oxidation occurs when cellulose comes into contact with metals or pollutants such as iron gall ink or ozone. Elimination is triggered by exposure to high pH and is generally not relevant in the care of collections. However, it can become a factor when considering conservation treatment such as alkalization.

Photographs containing silver image material are affected by oxidation-reduction (redox) reactions. In the oxidation-reduction process, the silver in the image is attacked by oxidants in the atmosphere (e.g., pollutants, ozone, paint fumes).

#### Part II: Component Materials (1 hour and 15 minutes)

Materials fall into general categories and can be characterized by their dominant features and characteristic forms of deterioration. In this part of the class, the instructor should cover the basics of paper deterioration, then tailor the discussion of the remaining types of materials to suit his or her specialties and/or interests.

By drawing correlations among the types of materials, students can begin to learn to apply knowledge about one type of material to new materials as they are encountered. The instructor should stress that knowledge about paper, leather, and inks is a rapidly expanding area, and students should understand that they have not learned absolute facts but, rather, the current state of knowledge.

#### A. Paper

1. History of papermaking
2. Deterioration mechanisms
3. Permanent paper

Paper is regarded as being comprised primarily of cellulose, and thus the study of paper is largely based on the study of the deterioration of cellulose. The discussion should cover sources of cellulose, basic processing as it relates to handmade and machine-made paper and deterioration mechanisms, paying particular attention to hydrolysis and oxidation. Good-quality cellulose, such as that found in cotton, is a relatively stable material, but the source of the cellulose has a great impact on the quality of the cellulose molecule. Cellulose derived from wood requires aggressive processing to be liberated from the structure of the plant, and it suffers damage in the process. Other factors to be considered are additives in the papermaking process, such as alum or calcium, and materials such as metals coming into contact with paper and causing deterioration.

#### B. Inks and colorants

1. Variety
2. Fading media
3. Deterioration from media (iron gall ink, copper colorants)

Colorants of various types are encountered in watercolors, pastels, prints, architectural drawings and reproductions, writing and drawing inks, and color photography. In general, colorants are divided into two categories, but the science of colorants is quite complex. The discussion of colorants should note basic problems such as the tendency of dye-based materials to fade, and transition metals to shift in color and to cause deterioration in cellulose.

Ink is essentially a liquid in which one of many possible types of pigments or dyes is suspended. In paper-based collections, ink is encountered not just in documents but also in printed items and artworks. Carbon-based inks, iron gall ink, colored inks, traditional printing inks, laser/inkjet printing, and fax printing are just some of the many variations of inks found in collections that should be addressed in this discussion.

#### C. Adhesives

1. Variety
2. Damage from plastics and adhesives
3. Selecting materials

Adhesives are substances that cause one material to adhere to another. They can be naturally derived, such as wheat starch paste, or synthetically derived, such as polyvinyl alcohol. Starch adhesives share some common properties with cellulose, and synthetic adhesives share many characteristics with plastics.

#### D. Skin materials

1. Parchment and vellum
  - a. History
  - b. Deterioration
  - c. Compatibility with other materials
2. Leather
  - a. History
  - b. Deterioration
  - c. Compatibility with other materials

Skin materials including leather and parchment are derived from animals. The type of animal and the method of processing determines the quality of the skin material. Leather is stable in a slightly acidic environment; parchment is a more alkaline substance. The characteristics of leather and parchment can be compared, both in terms of benefits and drawbacks as a covering material for books and regarding the interaction of each with paper. Cloth, while not a skin material, can be addressed briefly. Cloth can be made of natural or synthetic materials. Although much cloth is found in library collections, especially as a covering material for books, it is not generally responsible for many problems.

#### ***In-Class Activities***

- Examine a set of paper-based materials. You can do this using the images provided in the Image Library, but a more effective way is to supplement those materials with physical objects. Have students identify the components of each format, such as paper, ink, adhesive, and the like, and look for similarities and differences.

Examples:

1. The characteristics of papers in books will be much different from writing papers. Printing papers will have more tooth; writing papers will be smoother; magazine papers will be slick and shiny; older papers, pre-1800, will generally be in better condition than paper from the early 20th century.
2. The blue colorant in manuscript papers from the mid-1800s will turn brown and fade in a similar manner to blue writing inks of that period.
3. Iron gall ink corrodes in a similar manner to verdigris; the deterioration of the paper support of platinum prints shares some similar characteristics.

- Examine a set of paper-based materials, and divide the components into basic categories.

Examples:

1. Paper is made primarily of cellulose, although other materials are incorporated such as sizing and filling agents.
2. Carbon black printing ink is a metal and a binder.
3. Iron gall ink is made of iron particles and a binder.
4. Black-and-white photographs generally have metallic imaging compounds and paper supports; they usually have other layers as well.

### **Part III: Composite Structures (1 hour)**

#### A. Bookbindings

1. Book structure and components
2. Binding methods

- i. Sewn binding
- ii. Side-sewn
- iii. Stab binding
- iv. Oversewn
- v. Adhesive binding

*Please note that binding methods are also covered in **Class 8: Treatment Options** as they pertain to library binding and conservation treatment.*

This discussion should introduce students to the basic form and structure of the book, with a focus on changes in the materials and methods used in bookbinding through the years. Changes that have compromised the quality of the resulting bound volumes should be emphasized.

B. Reproduction processes (e.g., letter copying, hectograph process, blueprints, diazotypes, electrostatic copying process)

Beginning in the late 18th century, various reproduction methods began to replace hand copying of important documents. In the late 19th century, copying options were expanded and copying of original architectural drawings, plans, and maps also became common. Objects produced by some of these copying processes deteriorate more quickly than others, and some have detrimental effects on other collections if they are stored together. Therefore, identifying particular processes is crucial in making storage and other preservation decisions for these materials. A complete review of all copying processes is beyond the scope of this lesson, but a few of the most common (and their characteristic forms of deterioration) should be described.

C. Photographic prints: black and white (in brief)

1. Basic photographic structure/process
2. Image-forming materials (e.g., metallic silver, platinum, iron salts, pigments)
3. Binder materials (e.g., gelatin, albumen, collodion)
4. Support materials (e.g., paper, poor-quality board, resin-coated paper)

*As noted in the introduction to this lesson, photographic prints should be covered in this lesson because they are paper-based objects. Photographic negatives will be considered in **Class 4: Multimedia Materials**.*

Each photographic process has unique characteristics that affect its deterioration, storage, and handling. In order to care properly for photographic collections, students must understand how photographs are made and learn how to identify their various types. They must also become familiar with problems related to the physical and chemical composition of the materials in their collections. This discussion cannot cover every photographic process in detail, but it should address the vulnerabilities of commonly encountered photographs and direct students to further resources. Owing to their prevalence in collections, mention should be made of daguerreotypes, ambrotypes, and tintypes, even though they are not paper-based images.

D. Photographic prints: color/digital (in brief)

1. Characteristic deterioration of traditional color prints (e.g., dye fading, highlight staining)
2. Vulnerabilities of digital color prints

Again, this discussion should provide an overview of the vulnerabilities of color prints and guide

students to additional resources. The discussion should include the potential vulnerabilities of digital color prints printed on home printers. Using the right combination of paper, printer, and ink is crucial to digital print longevity; reference should be made to the work of Wilhelm Imaging Research in testing papers, inks, and printers, as well as to Monique Fischer’s “Creating Long-Lasting Inkjet Prints” (see [Resources for the Teacher](#)).

### ***In-Class Activity***

- Examine a set of paper-based objects and ask students to try to identify different types of structures. Again, this can be done using the images provided in the Image Library, but the exercise is more effective if supplemented with physical objects.

Examples:

1. Provide examples of different types of book structures.
2. Have students identify different photographic processes.
3. Show various types of reproductions (e.g., maps, letters).

### **Part IV: External Factors (30 minutes)**

- A. Climate
- B. Light
- C. Pollutants
- D. Storage and handling

These issues are considered in more detail later in the course. This class should emphasize the roles played by temperature, humidity, light, pollutants, storage, and handling in accelerating the chemical and physical deterioration processes described earlier in this class.

Generally speaking, higher temperatures accelerate the chemical reactions that cause deterioration in paper-based collections, while humidity (moisture in the air) provides water to fuel the chemical reactions that cause deterioration. Excessively low humidity may cause materials to become brittle and more susceptible to cracking, particularly during handling. Fluctuating humidity levels also cause damage, since most materials expand and contract with small changes in humidity. Light energy, in the form of waves, is absorbed by molecules within an object, which activates a variety of chemical reactions that have the potential to damage paper-based collections. Various types of gaseous pollutants also initiate chemical reactions that contribute to deterioration. Materials particularly vulnerable to any of these risks, such as photographs, should be noted.

### ***In-Class Activity***

- Provide examples of deteriorated collections, and have students brainstorm about what types of damage could have been caused by (or worsened by) exposure to external agents such as high temperature and humidity, light, and/or pollutants.

### **Suggested Graded Assignments**

- Examine a discrete collection at the student’s workplace or a local institution of interest, and determine the most vulnerable elements. Identify the general types of materials and the most likely problems that are evident or will be likely to develop.

**Examples:**

1. Historical book collection
2. Archival collection
3. Photographic print collection
4. Collection of maps, plans, and/or architectural drawings
5. Scrapbook collection
6. Collection of art on paper

**Suggested Term Projects**

- Create a detailed listing of a specific collection at the student's workplace or a local institution of interest, noting the types of materials included and the general condition of each category of material. Write a paper summarizing the problems and suggesting priorities for preventing additional damage and dealing with damage that has already occurred. Provide suggestions for storage, handling, environmental control, reformatting (if appropriate), and conservation treatment.

**Examples:**

1. Historical book collection
2. Archival collection—note the various types of materials included (e.g., documents, photographs, pamphlets, small books)
3. Photographic print collection—note the types of photographic processes that are included
4. Collection of maps, plans, and/or architectural drawings—note the types of reproduction processes included
5. Scrapbook collection—note the types of materials included in each scrapbook (e.g., photographs, ephemera, documents, clippings)
6. Collection of art on paper—note the media (e.g., paint, watercolor, pastel) and support used