History of Preventive Conservation

Jo Kirby Atkinson

故宫博物院
THE PALACE MUSEUM

Outline

- Introduction
- Early history
  - Treasuries, libraries and archives
  - Control of damage
    - Shutters and curtains
    - Pests and vermin
- Technological change
  - The Industrial Revolution
  - Scientific developments
- The growth of collections
- Pollution
- Light
- Relative humidity and temperature

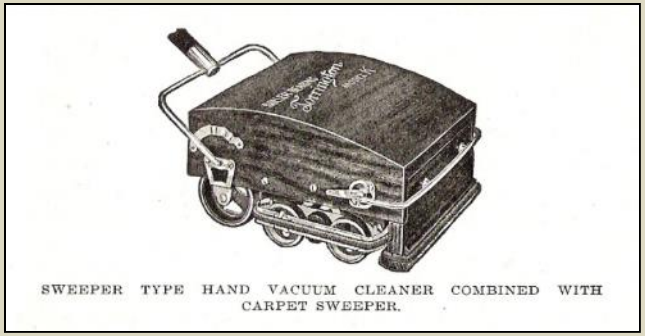
Introduction

Monk sweeping, *Hausbuch der Mendelschen Zwölfbrüderstiftung*, vol. 1, Nuremberg, 1426–1549. Stadtbibliothek Nuremberg, Germany, MS. Amb. 317.2 f. 96 v. (dated 1478). © Stadtbibliothek, Nuremberg.

Medieval title deeds and wooden storage box, Muniment Room, Magdalen College, Oxford University, England. © Magdalen College, Oxford, 2015.

Introduction

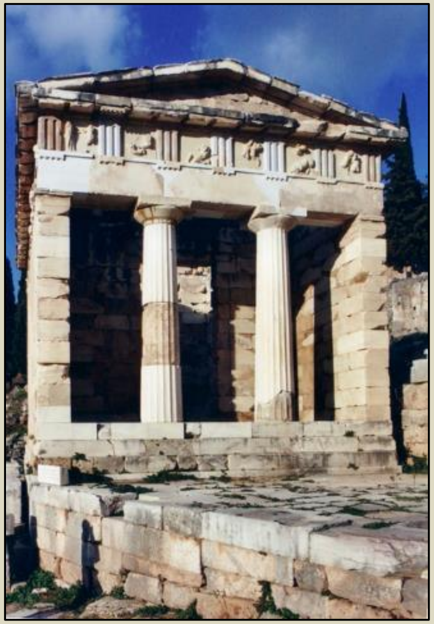
Women washing and drying clothes, from Salomon Trismosin, *Splendor solis* (Nuremberg, 1582), British Library, MS Harley 3469, f. 32 v. © The British Library, London.



Cleaning carpets: carpet sweeper / vacuum cleaner, 1920s.
19th-century carpet beater, National Museum of American History, Washington D.C., accession no. 1987 0794. © National Museum of American History, Smithsonian Institution.

Early history – treasuries, libraries and archives

Treasuries were built from early times to house precious items. Many were housed in cathedrals, palaces and public buildings.



The Treasury at Delphi, probably built after 490 BCE to house offerings made by the city of Athens, Greece, to the god Apollo.

View inside the Treasury, Cathedral church of Saint Stephen and Saint Sixtus, Halberstadt, Sachsen-Anhalt, Germany (built 1236–1491).

Early history – treasuries, libraries and archives

Example of a *kura* storehouse, the Shōsōin at Tōdai-ji, Nara, Japan, built in the *azekura* log cabin style, 756–759 CE. Note that the floor is raised on wooden pillars, allowing circulation of air under the building. The method of building is shown in the detail on the right, showing the corner of another *kura* building at Tōdai-ji.

Early history – treasuries, libraries and archives

Muniment Room, Magdalen College, Oxford University. Late 15th-century storage cupboards containing medieval wooden storage boxes for title deeds of properties owned by the college. © Magdalen College, Oxford, 2015.

Early history – control of damage

Damage by light, damp, dust, pests and mould was as unwelcome centuries ago as it is today and steps were taken to prevent it. These are some examples.

Altarpieces protected by shutters

In the 14th–16th centuries, northern European altarpieces (painted or sculpted religious images placed behind the altar in churches) often had wings on each side of the main panel that closed to cover it: shutters effectively protecting it from light, dust, humid air and candle smoke.

The 17th-century Florentine historian Filippo Baldinucci, writing in 1681, described these shutters as protection for the paintings:

> 'Among painters, these shutters ... are almost always called shutters made to cover these panels and pictures so as to protect the paintings from dust and, even more, from moist air ....'

Early history – control of damage

Altarpieces protected by shutters

The Brixen altarpiece

This example of an altarpiece with closing wings was made in the Alpine region of Europe known as the Tyrol, in Brixen (now Bressanone, Italy).

Ruprecht Potsch and Philipp Diemer (probably), *The Brixen Altarpiece*, c. 1500–1510. Carved, painted and gilded limewood and pine, 443.2 x 227 cm (predella). London, Victoria and Albert Museum (No. 192-1866). © Victoria and Albert Museum, London.

Early history – control of damage

Appearance of altarpiece with wings closed

The wings are now fixed, but originally would have closed to cover the central scene as indicated. In this altarpiece, the outer surfaces of the wings are also painted, with figures of saints.

Early history – control of damage

Curtains as protection

Valuable pictures needed protection. An inventory of the property of the London Guild of Merchant Taylors made in 1609 describes:

‘In the Parlour:

...

1 Picture of Mr. Dow, with a Silk Curtain to it

3 Great Mapps in 3 Great Frames, with 3 large Silk Curtains to them’

An inventory of the furniture and fittings of Salisbury House, which belonged to the Cecil Family, made in June, 1629, describes:

‘In the great chamber:

...

[A] picture of the Lord Darneley and his brother, with a curtaine of purple taffeta fringed with golde’

Early history – control of damage

Curtains to protect paintings

Sodoma, *St Benedict gives Posthumous Absolution to two Nuns*, 1505–8. Fresco, Chiostro Grande, Abbey of Monteoliveto Maggiore, Ascanio, Tuscany, Italy.

Detail showing altarpiece with curtain

Early history – control of damage

Curtains to protect paintings

Here, a dark-blue curtain partly covers the painting in the background; another appears to cover a small picture on the wall behind the man.

Gabriel Metsu, *A Man and a Woman seated by a Virginal*, about 1665 (NG839). Oil on oak, 38.4 x 32.2 cm, London, The National Gallery. © The National Gallery, London.

Early history – control of damage

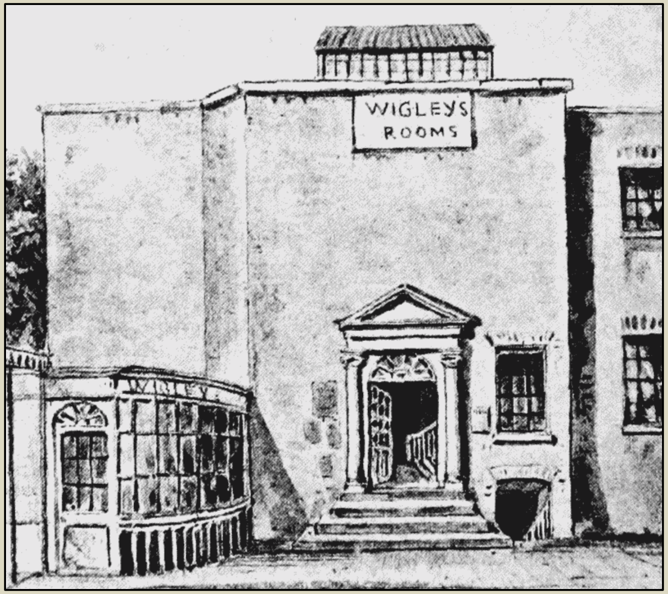
Curtains as protection during an 18th-century temporary exhibition

In 1772 James Cox, a 'Mechanician, Silversmith and Watchmaker', exhibited his collection of elaborate and expensive curios and models in the Great Room, Spring Gardens, London; this was a large room used for public concerts, meetings and exhibitions.

A catalogue of 'Cox's Museum', dated 1772, describes the whole room lit by large and small chandeliers

> 'wherever light is necessary to be transmitted; curtains of crimson are let down by machines to cover the pieces ... A carpet covers the whole room, also the stairs; and by a very curious contrivance, warm air is introduced into the room at pleasure.'

This temporary exhibition was held from 1772 until 1775.



The building was later leased by Charles Wigley, who used it for auctions; the illustration (from a watercolour) dates from this period.

Early history – control of damage

Control of pests and other damage

All objects made using organic materials – wood, paper, parchment, leather, fur, wool, silk, cotton, linen, feathers and so on – can be eaten or attacked in some other way by insects, rodents, moulds and other destructive agents. Historically, pests and vermin have been a constant nuisance. The agents used for their control included

- Plants

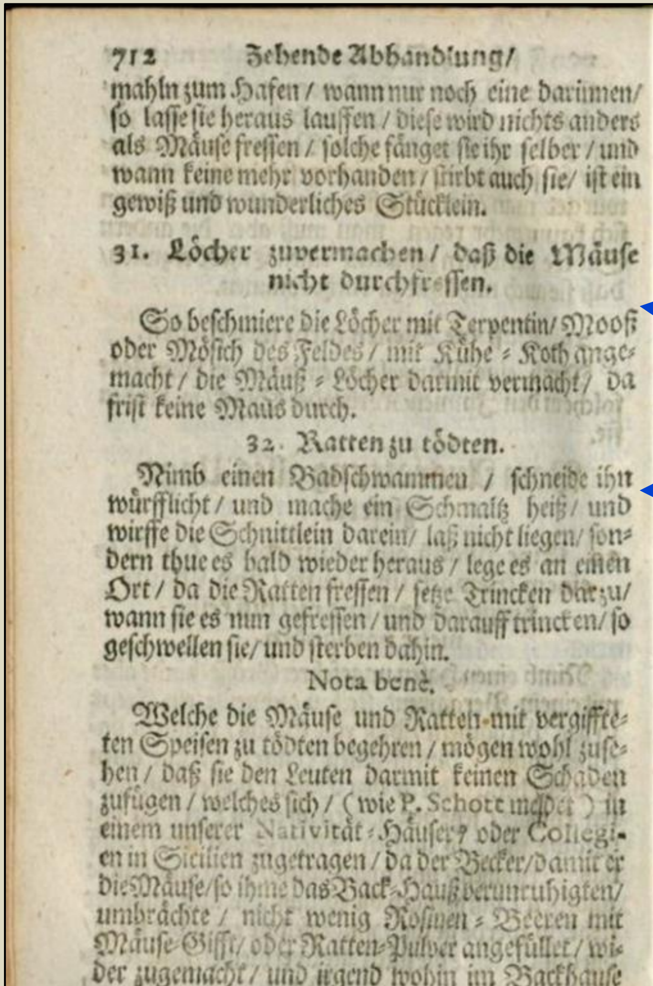
- Minerals

- Other substances (often from trees)

- Physical methods

Early history – control of damage

Control of pests and other damage – mice and rats


712 Zehende Abhandlung/

mahln zum Hafen / wann nur noch eine darinnen/ so lasse sie heraus lauffen / diese wird nichts anders als Mäuse fressen / solche fänget sie ihr selber / und wann keine mehr vorhanden / stirbt auch sie/ ist ein gewiß und wunderliches Stücklein.

31. Löcher zuvermachen / daß die Mäuse nicht durchfressen.

So beschmiere die Löcher mit Terpentin/ Mooß oder Mösich des Feldes / mit Kühe = Koth angemacht / die Mäuß = Löcher darmit vermacht / da frist keine Maus durch.

32. Ratten zu tödten.

Nimb einen Badschwammen / schneide ihn würfflicht / und mache ein Schmaltz heiß / und wirffe die Schnittlein darein/ laß nicht liegen/ sondern thue es bald wieder heraus / lege es an einen Ort / da die Ratten fressen / setze Trincken darzu/ wann sie es nun gefressen / und darauff trincken/ so geschwellen sie/ und sterben dahin.

Nota benè.

Welche die Mäuse und Ratten mit vergifften Speisen zu tödten begehren / mögen wohl zusehen / daß sie den Leuten darmit keinen Schaden zufügen / welches sich / (wie P. Schott meldet) in einem unserer Nativität = Häuser/ oder Collegien in Sicilien zugetragen / da der Becker/ damit er die Mäuse/ so ihme das Back = Hauß verunruhigten/ umbrächte / nicht wenig Rosinen = Beeren mit Mäuse-Gifft/ oder Ratten = Pulver angefüllet / wider zugemacht / und irgend wohin im Backhause

Neueröffneter curioser Schatz-Kasten
... (Nuremberg, 1706)

For example, p. 712:
Blocking mouse holes: So smear the holes with turpentine mixed with moss and cow dung; make over the mouse holes with this: no mouse will eat through it.

To kill rats: Cut a bath sponge into small pieces; mix with hot lard; put in a place where the rats eat. Add something to drink. When they eat it and drink, it will swell and kill them.

Early history – control of damage

Control of pests and other damage – mice and rats

Alternatively ...

Cat with mice, detail of manuscript initial, 2nd half 12th century.© The British Library, London.

Mousetrap, pine, 19th century. © Victoria and Albert Museum, London.

Mousetrap: detail from the *Merode Altarpiece*, Workshop of Robert Campin, *c*. 1427–32. © Metropolitan Museum of Art, New York

... and the rat-catcher

Early history – control of damage

Control of pests and other damage – moths and other insects

clothes moth

carpet beetle larva

woodworm

book louse

The larvae of insects such as clothes moths and carpet beetles primarily eat proteinaceous fibres – wool, fur and feathers, for example. Others, such as the many wood-boring insects, are responsible for destroying wood – lignified tissue. Yet others feast on paper. Taking moths as an example, the reports of damage in historical documents are constant. These are two examples from the 16th and 18th centuries:

Inventory of the goods of Richard Rawlins, Bishop of St Davids (Wales) made 7 March 1536, after his death:

> 'In the Wardrobe: A parliament robe of scarlet, eaten with a rat in the back, and perished with moths ...'

1 November 1715. A request from the Treasury of the British government to

> 'Sir Christopher Wren and the rest of the Board of Works of the petition of the Clerks of the Signet praying that the said Board may inspect their Office and the conveniences they now have and report a state thereof, with what is further necessary to be done for the preservation of the records from moths, dirt and filth'.

Early history – control of damage

Control of pests and other damage – moths and other insects

Plants used were chosen because of their scent or because they were poisonous, as in the case of the white hellebore

wormwood

mugwort

white hellebore

common lavender

spike lavender

Early history – control of damage

Control of pests and other damage – minerals, woods and other natural products

orpiment, arsenic sulphide, As_2S_3

cinnabar, mercuric sulphide, HgS

Neueröffneter curioser Schatz-Kasten, p. 722 on lice and other insects

‘Mercury mixed with butter, black soap or baked apples kills lice, nits, fleas, midges, flies and all other similar vermin.’

mercury

722 Zehende Abhandlung/

teiner und Griechen Thymus nennen/) ihnen verhasset/ und fliehen darvon.

Die Läuse zu töden / nimb anderthalb Unz schwartze Seyffe / und 1. qu. Schwefel / und so viel Läußkraut / mische es untereinander / und mache eine Salbe darauß / bestreiche darmit die lausigte Ort an Kleidern / und am Leib.

NB. Laußkraut/welches die Griechen Staphys-Agria oder Staphis, die Lateiner aber Pituliaria oder Pedicularis nennen / ist eine Art von Hunds-Kürbiß/ mit schwartzen und geraden Hülsen/Blättern wie wilder Weinstock / trägt vielmehr Hülsen als Kerne/die grün uñ den Kicher-Erbsen gleich sind.

Queckfilber mit Butter oder schwartzer Seyffen / oder gebratenen Aepffeln vermischt/ vertreibt Läuse/Nisse / Flöhe/ Mucken/ Fliegen / und alles andere dergleichen Geschmeyse.

Schweinen-Schmaltz / Queckfilber / und Salben miteinander vermischt/ und zu einer Salben gemacht / vertreibet die Läuse / wann man die lausigten Orte darmit beschmiert.

Desgleichen auch ein Sälblein von Venedischer Seyffe / und getödetem Queckfilber.

Desgleichen auch die Blumen von Tausendschön in Laugen abgesotten / wann man den Kopf darmit wäschet.

Ingleichen auch ein Sälblein von weichgesottenen Aepffeln / deme man die Haut und Kerne genommen / mit Queckfilber vermischt.

Wie auch ein Sälblein von gemeinem Oel drey Unzen / Wachs 1. Unz / Läußkraut 1. quintl. mit nüchternem Speichel getödtetes Queckfilber.

Early history – control of damage

Control of pests and other damage – minerals, woods and other natural products

white sandalwood, *Santalum album* L.

white sandalwood

camphor

Dryobalanops aromatica C.F. Gaertn.

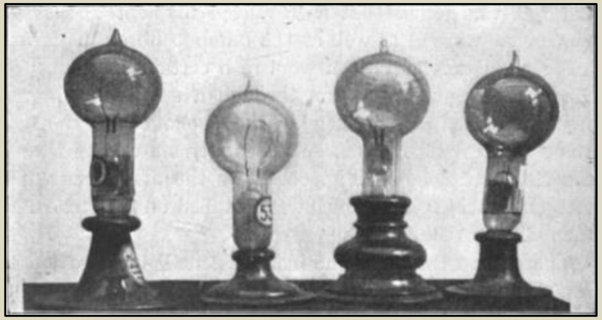
Cinnamomum camphora (L.) J. Presl.

The Florentine merchant Francesco Balducci Pegolotti described camphor in his handbook *La pratica della mercatura* (*c*. 1340): 'Camphor should be white and clear, and the more white and clear, and not yellow and dark, it is, the better ...'

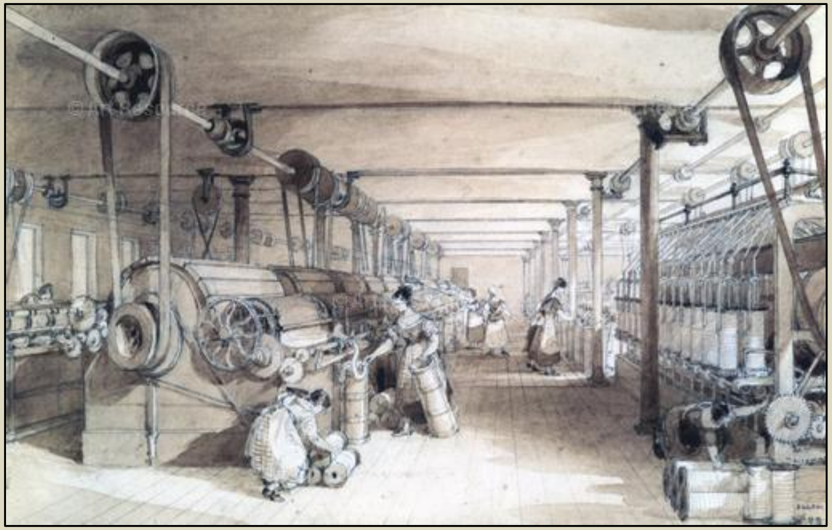
Technological change: the Industrial Revolution

- Artificial lighting
- More efficient heating
- Efficient manufacturing methods

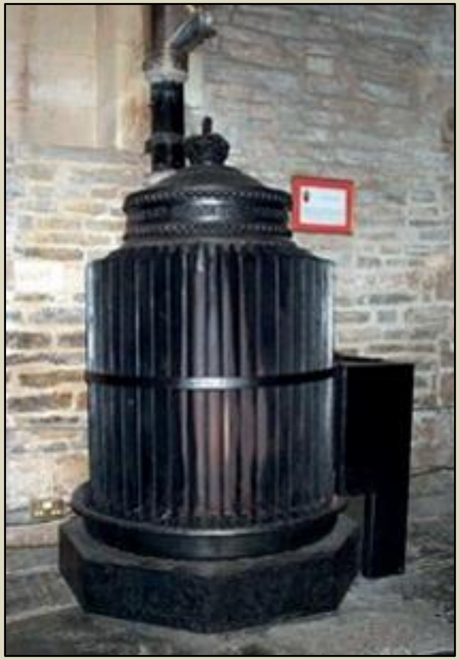
Late 19th-century domestic gas ceiling light



Edison's paper filament electric light bulbs, 1879



Thomas Allom, *Swainson Birley Cotton Mill near Preston, Lancashire*, 1834. Pencil, pen and wash. © Science Museum/Science & Society Picture Library



Gurney warm-air stove, Tewkesbury Abbey, *c.* 1875

Technological change: the Industrial Revolution

- Rapid methods of transport ...

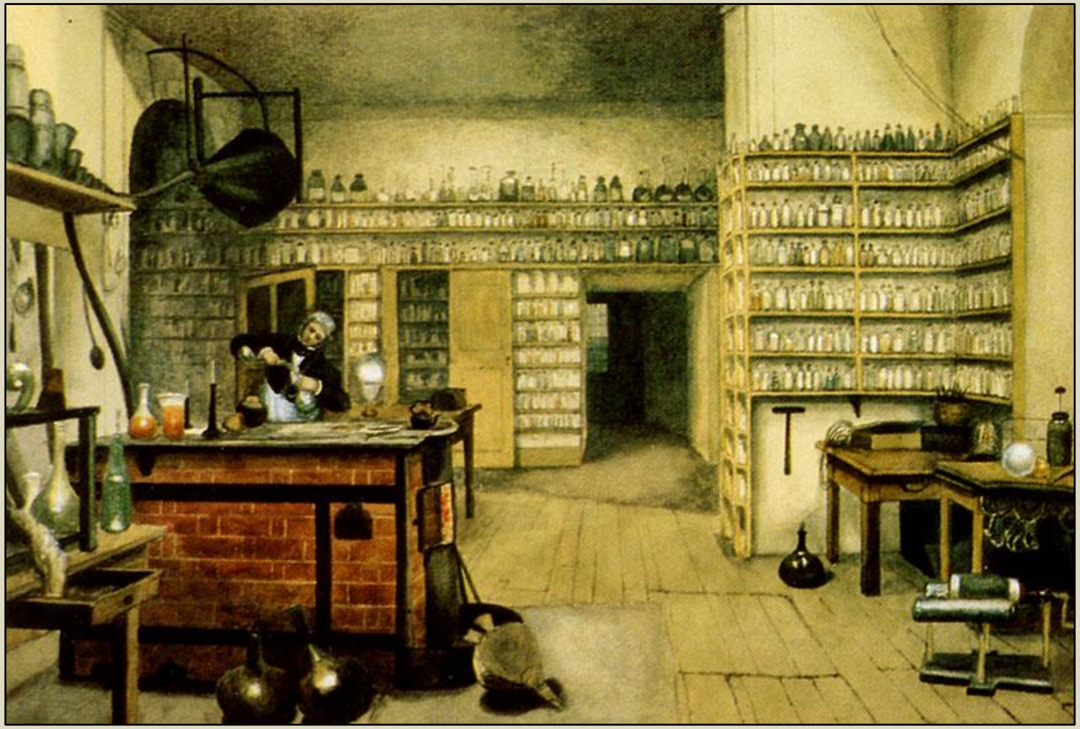
Joseph Mallord William Turner, *Rain, Steam, and Speed – The Great Western Railway, 1844* (NG538). Oil on canvas, 91 x 121.8 cm. London, The National Gallery. © The National Gallery, London.

- ... but an increased possibility of damage both to buildings and to their contents

Technological change: Scientific developments

In parallel with industrial developments, great progress was being made throughout the 19th and early 20th centuries in physics and chemistry which enabled a greater understanding of both the properties of the materials from which cultural heritage objects were made and those of the agents that could cause damage: light, temperature, relative humidity, pollutants.

James Clerk Maxwell (1831–1879), with a colour wheel, *c*. 1855

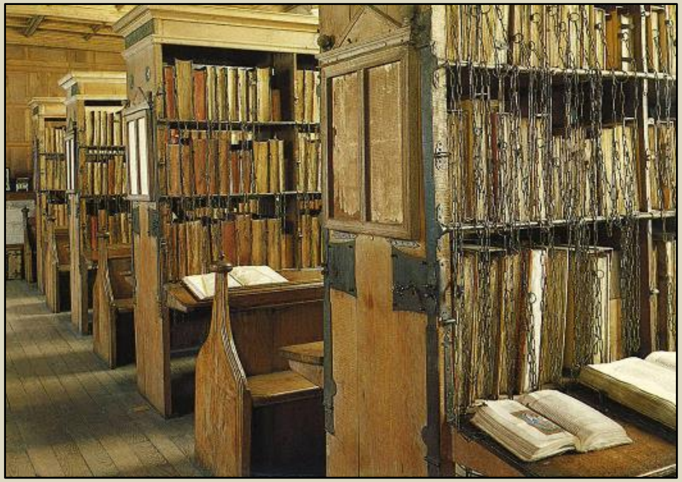


Michael Faraday (1791–1867) in his laboratory at the Royal Institution, London (from a watercolour painting by Harriet Moore, 1850s)

The growth of collections

The growth of large museums, galleries, libraries and other collections over the last 150 years or so has provided an impetus for many recent developments in preventive conservation, in particular the control of lighting, relative humidity and temperature, and pollution.

The medieval library of the Abbey of St Gallen, Switzerland. The redesign and reconstruction dates from the mid-18th century.



Chained library, Hereford Cathedral, England, dating from the 17th century. The chains are attached to the corner of the book cover so it can be read at the desk, but not removed. This method of securing valuable books was used from medieval times until the 18th century.

The growth of collections

Collections of paintings and objects – the Cabinet of Curiosities or *Schatzkammer* – were developed in Europe at the end of the sixteenth century and grew into the museums and galleries of today.

A natural history collection, with book cases on the right, built-in cupboards on the left and specimens on the walls and ceiling. Engraving from Ferrante Imperato, *Dell' Historia Naturale* (Naples 1599)

The growth of collections

Flemish School, *Cognoscenti in a Room hung with Pictures*, about 1620 (NG1287). Oil on oak, 95.9 x 123.5 cm. London, The National Gallery.

The growth of collections

This painting, by the Flemish artist Frans Francken II, shows a more varied collection.

The enormous collection of natural history specimens, plants, curiosities, minerals, books and other items (partly built from collections acquired from other people) made by Sir Hans Sloane (1660 – 1753) from the late 16th to the mid-18th century contributed towards the foundation of the British Museum.

Frans Francken II, *Cabinet of a Collector*, about 1620–5. Oil on oak, 74 x 78 cm. Vienna, Kunsthistorischesmuseum (Inv.-nr. GG_1048). © Kunsthistorischesmuseum, Vienna.

Pollution

Pollution from manufacturing trades had long been a recognised problem, particularly in urban areas. Some trades, such as leather tanning and dyeing blue with woad, produced offensive smells.

Jost Amman, The Tanner, from Hans Sachs, *Eygentliche Beschreibung aller Stände auff Erden* (Frankfurt-am-Main, 1568).

Konrad, dyer, *Hausbuch der Mendelschen Zwölfbrüderstiftung*, vol. 1, Nuremberg, 1426–1549. Stadtbibliothek Nuremberg, MS. Amb. 317.2 f. 37 v. (c. 1425). © Stadtbibliothek, Nuremberg.

Others, such as the manufacture of the red pigment vermilion (which involved the sublimation of mercury and sulphur), were dangerous to health. The 17th-century Dutch pigment maker Willem Pekstok, describing his factory, wrote:

> ‘The chimney must be thirty-five or forty feet high so that it smokes with little or no wind at all. Also, no smoke must break out below because it ruins one’s health.’

Pollution

Pollution from coal, its dust and its sulphurous fumes was recognised long before the advent of industrial manufacturing industries. Coal was already used in Great Britain in medieval times. In some parts of the country, coal can be found very near the surface and can be picked up on beaches. It was brought by sea to London and other ports from Newcastle.

Loading coal, Newcastle, mid 19th century

On 12 March 1298/9, during an appearance at court before the Lord Mayor of London, a group of men accused of holding an illegal meeting gave as part of their explanation that

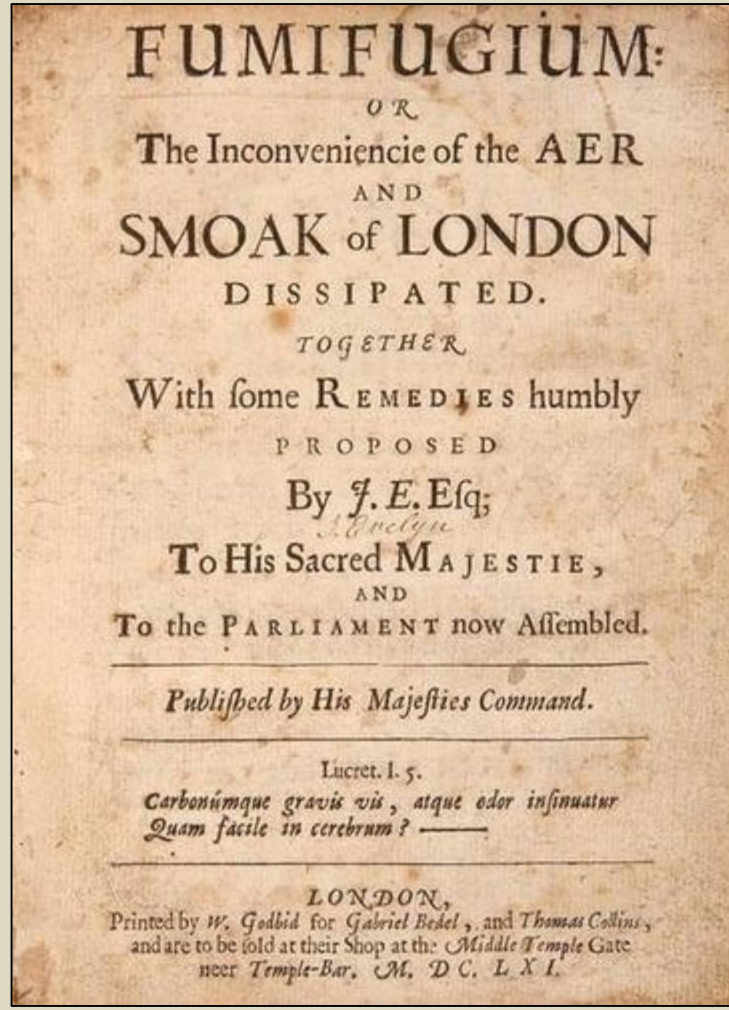
> 'none should work at night on account of the unhealthiness of coal (*propter putridinem carbonis marine* [sea coal]), and damage to their neighbours.'

Pollution

By 1661, John Evelyn described the smoky air of London as ‘the pernicious Smoake which sullyes all her Glory, super-inducing a sooty Crust or Fur upon all that it lights ... tarnishing the Plate Gildings and Furniture ... and executing more in one year, than exposed to the pure Aer of the Country it could effect in some hundreds.’

He ascribed this largely to the burning of sea coal and suggested

- that industries using sea coal be moved out of the City
- the planting of plots and gardens of sweet-smelling shrubs and flowers around the city



FUMIFUGIUM:

OR

The Inconveniencie of the AER

AND

SMOAK of LONDON

DISSIPATED.

TOGETHER

With ſome REMEDIES humbly

PROPOSED

By *J. E.* Eſq;

To His Sacred MAJESTIE,

AND

To the PARLIAMENT now Aſſembled.

Publiſhed by His Majeſties Command.

Lucret. l. 5.

Carbonúmque gravis vis, atque odor inſinuatur
Quam facile in cerebrum? ——

LONDON,

Printed by *W. Godbid* for *Gabriel Bedel*, and *Thomas Collins*, and are to be ſold at their Shop at the *Middle Temple* Gate neer *Temple-Bar*. M. DC. LXI.

Pollution

1840s – Michael Faraday and others gave evidence to a government committee investigating smoke pollution, although no smoke-abatement legislation was passed.

1850 – *Select Committee on the National Gallery, Report, 25 July 1850*. Because of public concern on the state of the pictures a commissioned report was included as an appendix (*Report on the Subject of the Protection of the Pictures in the National Gallery by Glass*).

- The problems were:
  Smoke from chimneys
  A large number of visitors
  The need for ventilation,
  therefore open windows
- The results:
  Dirty pictures presenting 'the appearance of being covered with a thick film'
  Dust in which 'the constant emanations evolved in the rooms are condensed'

Honoré Daumier, *Free Day at the Salon,* in *Le Charivari,* 17 May 1852.

Pollution

- The recommendations of the report
  - Pictures protected by glass were in better condition so more should be glazed, although sun shining on the glass would cause higher temperatures; this should be avoided
  - The pictures should be backed with an impermeable material

1853 – *Select Committee on the National Gallery, Report, 4 August 1853*. The situation was not much improved, although backing of the pictures was being carried out. However, the backs of the pictures were still dirty; dusting was inadequate.

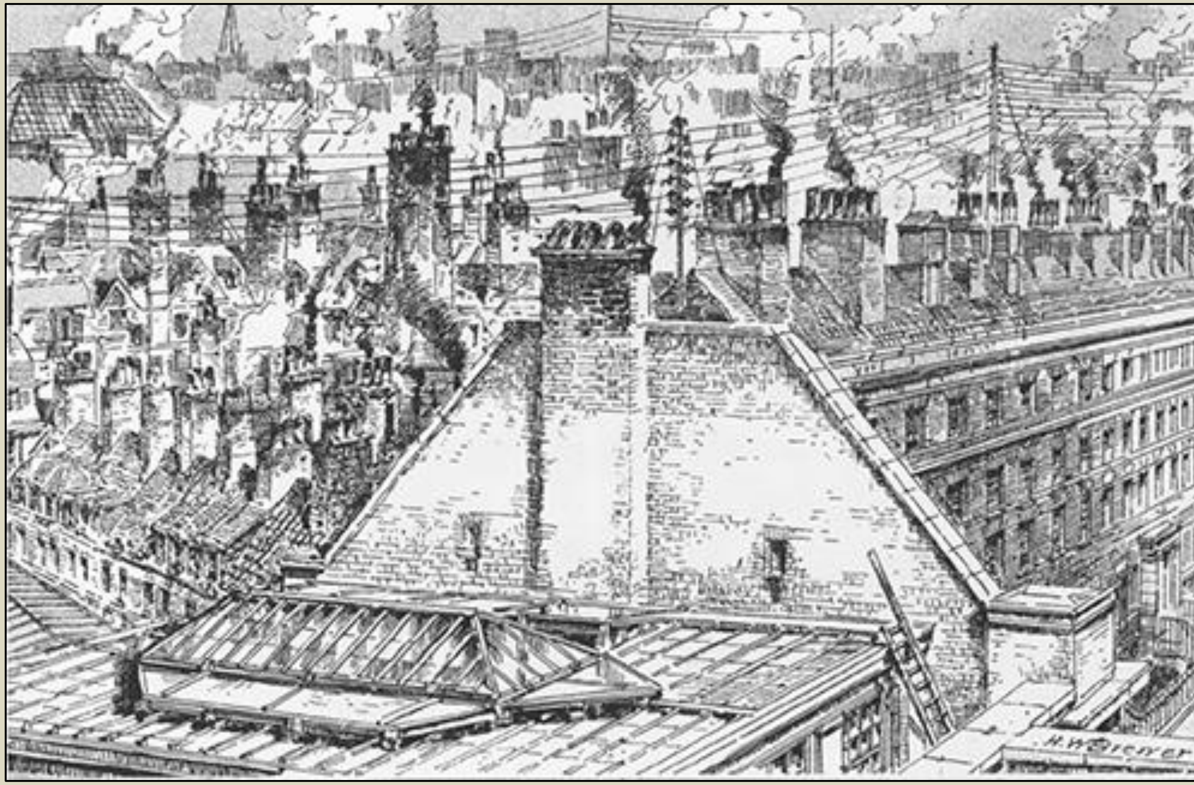
- The recommendation? Move to a less polluted area of London – Kensington Gardens. This did not happen.

In later decades, progress was made in reducing dust; ventilation remained a problem.

Were problems of poor ventilation, dust and gaseous pollution from smoke and other sources unique to the London National Gallery? No, although they were made worse by its location in a busy, central, smoke-filled part of the city.

Pollution

View across the roof of the National Gallery, London, looking towards the heavily polluted area of Trafalgar Square, from *The Daily Graphic*, 6 June 1895, p. 968. © The National Gallery, London.
Note the telegraph wires and smoking chimneys.



In 1850 Michael Faraday observed that the ‘sulphurous acid ... in the atmosphere’ largely derived from the burning of coal and noted the damage this caused, as well as the blackening effects of hydrogen sulphide on lead white pigment, widely used in painting. 20th-century research has revealed far more on the damage caused by acidic gases, sulphur and nitrogen dioxides.

Light

In 1817–19, Robert Grosvenor, 1st Marquess of Westminster had a gallery built onto his house in Park Lane, Mayfair, for his collection of pictures. The gallery was lit by natural light; however, lighting for evening receptions was provided by a cut-glass gas chandelier. At a reception held in 1819, comments were made on the ‘mild yet brilliant light’ and ‘sun-like brightness’ of the gas chandelier, but none on the appearance of the pictures by gas light. Gas, the first efficient form of artificial lighting, was a rapid success.

The picture gallery, Old Grosvenor House, London, completed *c.* 1819 and redesigned 1825–6, looking west in 1849. Note skylights for natural light and large chandeliers.

Light

Lighting and pollution

1859 – *Report of the Commission appointed to consider the subject of Lighting Picture Galleries by Gas*, 30 July 1859. The Commission examined paintings in the gallery at the house owned by the financier Thomas Baring at 41 Upper Grosvenor Street, Mayfair, London, built in 1849–50 and lit by gas. The commission was unable to find any deterioration in the pictures.

On the other hand, the concerns over the introduction of gas lighting at the National Gallery in London in the late 19th century were

- the risk of fire
- the fear that the gas or the products of combustion, summarised by A.H. Church in *The Chemistry of Paints and Painting* (London, 1890) as 'sulphuric acid, sulphurous acid, carbonic acid and the moisture, which is formed at the same time' would damage the paintings. All these products should be removed as soon as they were formed.

Experimental work on the effects of light mentioned (and carried out) by Church represents some of the early science contributing to preventive conservation.

Light

Light (in the broadest sense, including UV and IR – heat – radiation) causes damage: colouring matters fade; some materials yellow; many deteriorate.

Cushion cover depicting Esther and Ahasuerus in wreath with birds and flowers, Northern Netherlands, 1650–80. Tapestry woven in wool on woollen warps. London, Victoria and Albert Museum, T. 31-1946. Left: front; right: reverse. © Victoria and Albert Museum, London.

Light

Detail of Esther, showing fading. Yellow and pink dyes from natural sources are particularly vulnerable (note the change in the green areas); the pale blue has also faded.

Light

19th-century experiments on the effects of light on pigments

A page from George Field's 'Practical Journal 1809': experimental notes on three of his own madder lakes

TABLE I.

Of Pigments, the colours of which suffer different degrees of change by the action of light, oxygen, and pure air; but are little, or not at all, affected by shade, sulphuretted hydrogen, damp, and foul air:—

- Yellow: Yellow Lake. Dutch, English, Italian Pink. Yellow Orpiment. King's Yellow. Chinese Yellow. Gamboge. Gallstone. Indian Yellow. Quercitron Lake.
- Red: Rose Pink. Carmine, Common, Florence, Scarlet, Hamborough, Kermes Lake. Rouge.
- Blue: Indigo. Intense Blue. Antwerp Blue. Prussian Blue.
- Orange: Orange Orpiment. Golden Sulphur of Antimony.
- Green: Sap Green.
- Purple: Purple Lake. Burnt Carmine. Lac Lake.
- Brown: Brown Pink. Cassea Fistula. Light Bone Brown, &c.

George Field, *Chromatography* (London, 1835), p. 184: one of the tables summarising experimental results

Light

1886 – Dr W.J. Russell and Captain W. de W. Abney began their work on the action of light on watercolours in response to concern over proposed evening opening of the South Kensington Museum, London (now the Victoria and Albert Museum):

- Modern watercolour paints (Winsor & Newton), including commonly used mixtures, applied in a series of 8 tints; half of each sample strip shielded from light
- Sunlight as light source, calculating the effects of blue sky, gas light, electric light using red, green and blue glass filters
- Compared (by calculation) the effect relative to that of exposure to light under the normal museum conditions
- Dry air
- Moist air
- Moist hydrogen
- In a vacuum
- Electric arc light
- Burning gas
- Mixtures with white

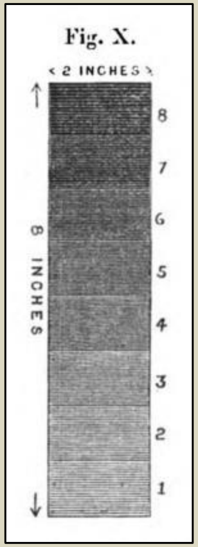
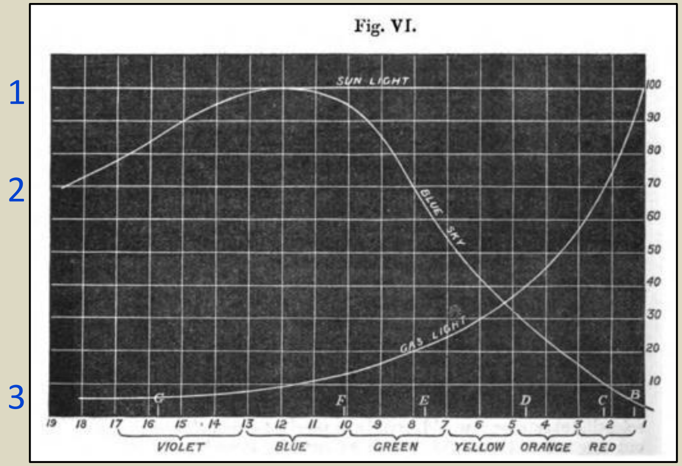
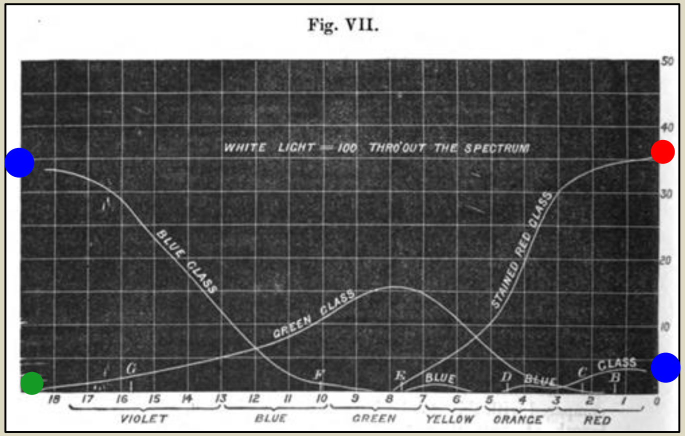


Diagram of a sample strip



The spectra of 1) sun light, 2) light from blue sky, 3) gas light



Transmission of light through coloured glass filters

Light

The results:

- In most cases moisture and oxygen were needed for the observed change (usually fading), which did not take place in a vacuum
- The blue and violet components of white light were the most damaging. These predominated in light from the sky (less from diffused cloud), but were present in comparatively small proportions in the artificial light sources then used (gas, electric arc light, incandescent filament lights)
- In a mixture of pigments with no chemical action on one another, the least stable pigment disappears

TABLE I.
OPEN TUBE.

Name of Colour.	August 14th, 1886.	March, 1888.	Remarks.*
Carmine	Gone	Gone	—
Crimson Lake	Gone to 7	Gone	—
Scarlet Lake	Pink gone, Vermilion left.	Gone	—
Vermilion	No change	Gone black	—
Rose Madder	No change	Faded to 4, and bluer.	—
Madder Lake	No change	Sl. faded	—
Indian Red	No change	No change	—
Venetian Red	No change	No change	—
Brown Madder	Changed to 4	Faded to 3	—
Burnt Sienna	No change	No change	—
Gamboge	Faded to 2	Faded to 7	—
Aureolin	No change	Faded to 4	—
Chrome Yellow	No change	No change	—
Cadmium Yellow	No change	Gone	—
Yellow Ochre	No change	V. sl. faded	—

Left: Part of table of results of fading samples in sunlight and exposure to air; right: order of instability of colours in open air. It is interesting to compare this table with Field's.

TABLE II.

Carmine.	Permanent Blue.	
Crimson Lake.	Antwerp Blue.	
Purple Madder.	Madder Lake.	
Scarlet Lake.	Vermilion.	
Paynes Grey.	Emerald Green.	
Naples Yellow.	Burnt Umber.	
Olive Green.		
Indigo.	Yellow Ochre.	
Brown Madder.	Indian Red.	
Gamboge.	Venetian Red.	
Vandyke Brown.	Burnt Sienna.	
Brown Pink.	Chrome Yellow.	
Indian Yellow.	Lemon Yellow.	
Cadmium Yellow.	Raw Sienna.	Show no change.
Leitches Blue.	Terra Verte.	
Violet Carmine.	Chromium Oxide.	
Purple Carmine.	Prussian Blue.	
Sepia.	Cobalt.	
Aureolin.	French Blue.	
Rose Madder.	Ultramarine Ash.	

Of these 39 single colours 12 were not acted upon at all by light, and two others were only after this long exposure to direct sunlight very slightly faded.

Light

Later work has looked more closely at

- The characteristics of the source of light: intensity and spectral distribution and for how long the object is exposed
- The material exposed, notably dyes and pigments
- The conditions of exposure
- Appropriate levels of illumination

Much work on illumination levels, from the point of view of both the vulnerability of the object and the sensitivity of the human eye, was carried out in the 1950s and 60s. This table summarises the position by 1960; see, for example, the 50 lux level recommended for watercolours.

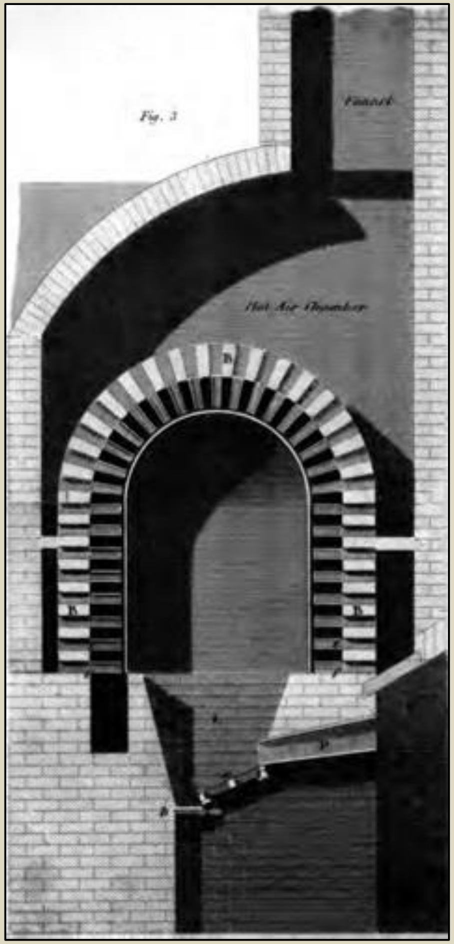
RECOMMENDED MAXIMUM ILLUMINATION AND TYPES OF ILLUMINANT

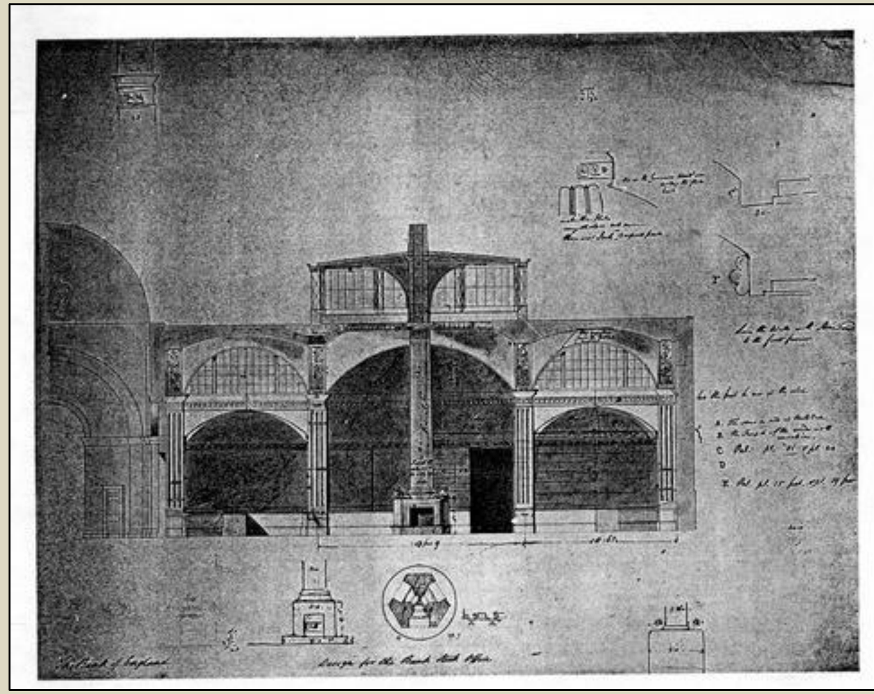
Objects insensitive to light (e.g. metal and stone)	Daylight. Fluorescent light at about 6500°K or about 4200°K.	Rarely necessary to exceed 300 lux (30 lm./sq.ft.), except for special emphasis
Most museum objects, including oil and tempera paintings	Daylight. Tungsten light. Fluorescent light at about 4200°K.	Not more than 150 lux (15 lm./sq.ft.)
Specially sensitive objects (water-colours, textiles, tapestries, etc.)	Preferably tungsten filament lamps	Not more than 50 lux (5 lm./sq.ft.), and less if possible

G. Thomson, 'A new look at colour rendering, level of illumination, and protection from ultraviolet radiation in museum lighting', *Studies in Conservation*, 6, 1961, pp. 49 – 70: Table 2, p. 52.

Relative humidity and temperature

19th-century heating





Above: Sir John Soane, *Study for central stove column for the Bank of England Stock Office*, probably 1790s.

Left: Section through stove at Derbyshire General Infirmary, 1807, designed by William Strutt, from G. Sylvester, *The Philosophy of Domestic Economy* (Nottingham, 1819). Similar systems were used in textile mills such as Cromford and Masson, Derbyshire.

Relative humidity and temperature

19th-century cooling

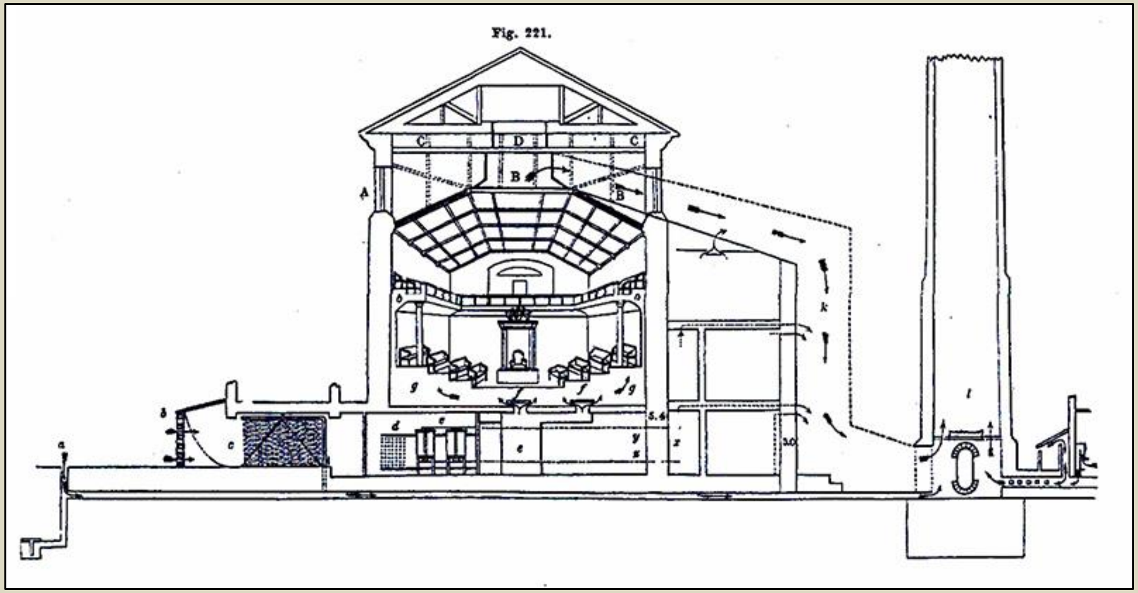
The Former Marine Police Headquarters Compound (前水警總部), Hong Kong, built 1884 (now renamed 1881 Heritage)

Ventilation portals below the level of the ground floor for cooling and to prevent decay of the wooden floor joists. The ground floor of the building is about a metre above the ground.

Relative humidity and temperature

Air conditioning with humidification

The Houses of Parliament: ventilation system incorporating methods for moistening, drying and cooling the air in the House of Commons building. D. Boswell Reid, *Illustrations of the Theory and Practice of Ventilation* (London, 1844), Fig. 221.



- Filtration of outside air
- Heating and moistening the air in a chamber below the floor
- Introduce air into the House of Commons Chamber through holes in the floor and risers; motive power for the ventilation from the fire at the base of the chimney
- Heated air could be mixed with unheated fresh air
- Cooling by ventilation at night; evaporation; run cold water through heating pipes; use of ice if necessary
- Speed of air flow could be controlled

Relative humidity and temperature

1890s: Alte Pinakothek, Munich – a low pressure steam heating system with some humidification was recommended following a report stating that the heating should not cause harm to the paintings due to inappropriate temperature or incorrect air humidity; preservation of the pictures should take priority over human comfort and the humidity of the air should be permanently at 50% saturation

Gallery VII in the Alte Pinakothek in 1929; the padded seating disguises radiators above which are water containers to humidify the air by evaporation. ©Doerner Institut, Melanie Eibl, Andreas Burmester.

1908: Boston Museum of Fine Arts – humidification; air washing and aeration. For paintings and people, the optimum level for relative humidity was 55–60% regardless of temperature or time of year. It was necessary to double-glaze exterior windows to prevent frost in winter.

By 1930s: Many collections and museums in Europe and the USA had some degree of environmental control (temperature and/ or RH; air conditioning …)

Relative humidity and temperature

The beneficial effects of storage of the collection of the National Gallery, London, in stable conditions of relative humidity and temperature in the Manod slate quarry, near Blaenau Ffestiniog, Wales from 1941–45, by comparison with the unconditioned gallery rooms. Values of 58% RH and 17 °C were chosen based on pre-war research on the behaviour of blocks of appropriate woods placed in gallery rooms, which indicated an optimum value of 55–60% RH for this building. Air conditioning based on the same value range began to be introduced from 1950.

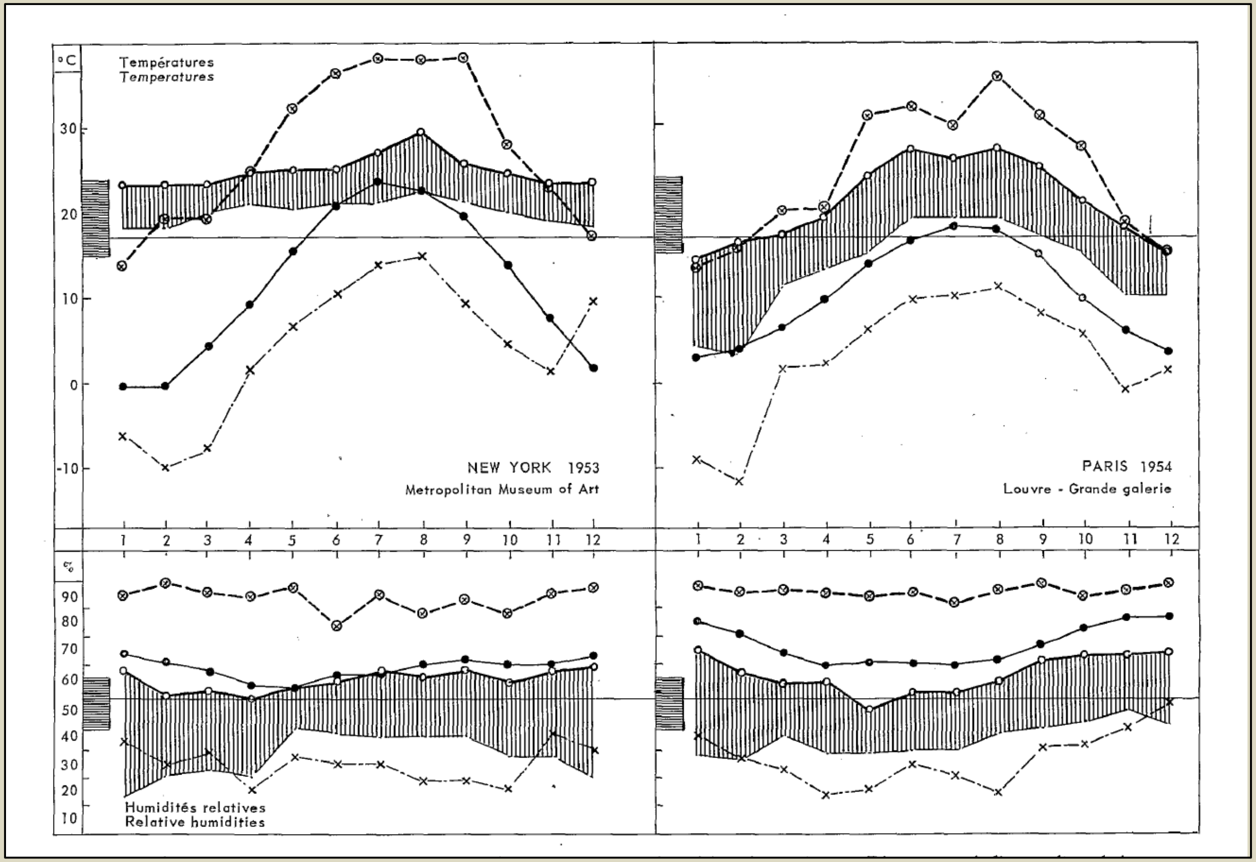
Unloading cases at the quarry entrance, February 1943. ©The National Gallery London

Paintings in storage in the quarry. ©The National Gallery, London

Relative humidity and temperature

1960 – Harold Plenderleith and Paul Philippot published a survey of museum conditions in Europe and North America; this included information on local annual climatic variations.

Most preferred a range of values for relative humidity around 40–70%, generally within or overlapping the 50–60% range.
This example shows a comparison between climatic conditions inside and outside two museums: the Metropolitan Museum, New York and the Louvre, Paris



Relative humidity and temperature

1960s – Average values for RH around 50–60%, although not always achievable or satisfactory in cold climates

Garry Thomson, *The Museum Environment*, London, Butterworths, 1978, 2nd edition 1986

For most temperate climates and many types of object, particularly those made of hygroscopic materials, he suggested:

- A set point of about 50–55% relative humidity (RH)
- Temperature about 20 °C
  - depending on the class of building
  - other values suggested for other climatic conditions

Later recommendations have made use of more recent scientific studies of materials and their behaviour.