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abstract: This section discusses the meaning of the term “patina”; the natural and artificial formation of patinas, including chemical patinas; basic techniques of patination, including various forms of coatings; and how to distinguish between different types of patinas.

short\_title: Patina

This section discusses the meaning of the term “%%patina%%”;thenatural and artificial formation of patinas, including chemical patinas; basic techniques of patination, including various forms of %%coatings%% (except for %%gilding%% and %%metal plating%%; for those see [I.7](#I.7)); and how to distinguish between different types of patinas.

## 1 What is patina?

The widely used but elusive term “patina”comprises at least three different meanings. One prevalent view is that every object—whether a %%bronze%% or marble sculpture, a piece of furniture, or a painting—acquires a patina over time, often perceived as a pleasing surface alteration that may add aesthetic value and, perhaps more significantly, forms part of its history.

Some use the term “patina” more strictly to refer to the chemical transformation of a metal surface to a mineral layer that usually has a different color from, and reduces the bright metallic reflectance of, the polished original %%cast%% surface (**fig. 306**).[[1]](#endnote-1) The resulting surface layer is often referred to as chemical patina. (Some people restrict the term “chemical patina” to intentional patina, but here we use it for any kind of patina resulting from a chemical transformation of the bronze surface, including %%corrosion%%.)

In addition to chemically induced patinas, the term can also encompass organic coatings applied to the surface of a sculpture to enhance and/or complement the form by changing its color, texture, saturation, and/or reflectance. A coating may be wax, varnish, lacquer, gum, oil, grease, or paint.[[2]](#endnote-2) The related term “patination” may be used as a synonym, though some investigators use it more narrowly to describe only an intentionally applied coating or an induced chemical alteration layer, or both, rather than for patinas formed naturally. The diagram in **figure 307** synthesizes both chemical actions and organic coatings in patina formation.[[3]](#endnote-3) For the purposes of this chapter, the term “patina” is used broadly to mean any kind of surface alteration on bronze other than gilding and metal plating[[4]](#endnote-4) or %%inlay%% (see [I.7](#I.7), [I.9](#I.9)).

### 1.1 Chemical patinas

#### 1.1.1 How do chemical patinas form?

Chemical patinas are produced by a chemical reaction, namely the transformation of the bronze surface, initially a metal, into nonmetallic compounds such as oxides. Chemical patinas can form naturally over time or be intentionally created by human intervention. Copper alloys develop surface alterations or corrosion layers almost immediately after cooling from the melt. Note that the very term “layer” may be misleading, as this process of mineralization can develop in all three dimensions rather than as a uniform stratification that follows the surface of the sculpture. Indeed, it may evolve along the complex microstructure of the metal and even take the shape of organic materials that are in close contact with the surface (as for example pseudomorphs, see [I.8§1.1.2](#I.8§1.1.2) below).

In addition, layers consisting of various copper corrosion products, of colors ranging from green and blue to red and black (such as copper chlorides, carbonates, oxides, or sulfates),[[5]](#endnote-5) can form naturally over time due to burial in soil (**figs. 308, 309, 310**), submersion in water in aerobic or anaerobic conditions (**fig. 311**), or exposure to the atmosphere either indoors or out (**fig. 312**).[[6]](#endnote-6) In this case, patinas are referred to as “natural.” Alternatively, it is also possible for a layer of copper corrosion products to be formed by an artist, %%founder%%, restorer, et cetera, using chemicals with or without heat to create a controlled corrosion of the surface that changes the color (**video 14**). In this case, the patina is considered “artificial.”[[7]](#endnote-7) It is perfectly possible, indeed common, for both artificial and natural patinas to occur together on the same sculpture.

Certain preparatory steps are involved in producing a stable, artificial chemical patina. Following casting, %%fettling%%, and %%chasing%%, the bronze may be cleaned in an acidic bath to strip away oxides or other residue from the casting process (**fig. 313**). This is current practice, but the use of acid for tarnish removal goes back to antiquity, and might also have been a method of cleaning the metal prior to patination. Patina creation begins when chemical solutions are applied either hot or cold to the surface and allowed to react with the metal (**video 14**).[[8]](#endnote-8) The final desired appearance is achieved using an often quite complex sequence of chemical applications selected for their specific color reaction with that particular bronze alloy.[[9]](#endnote-9) Indeed, the composition of the substrate metal will influence the color of the chemically induced patina (**fig. 314**). Particular combinations of chemicals and alloys have been established over millennia to create specific patina colors. A striking example of this are the so-called black bronzes from antiquity.[[10]](#endnote-10) Note also the well-documented phenomenon occurring in nineteenth-century Paris where patina creation became extremely elaborate and complex and drew on various patina technologies and fashions from diverse time periods and cultures around the world.[[11]](#endnote-11)

#### 1.1.2 What do chemical patinas look like?

The chemical alteration of a bronze surface may take many forms: a layer of corrosion may be smooth or rough (**fig. 315**), continuous or irregular (**figs. 316, 317**), powdery or well adhered (**fig. 308**). All have in common that they obfuscate the shiny surface of the polished metal, though the mineralized layer may be rubbed through on certain high points of a patinated form, either intentionally or through repeated handling or abrasion. On ancient and historic bronzes, a chemical patina can enhance value and beauty when the surface alteration is a continuous and smooth layer and preserves the original detail (**fig. 309**). Conversely, a thick, uneven corrosion buildup, sometimes amplified by additional surface accretions as on a bronze sculpture recovered from an underwater environment, can obscure, if not distort, the surface. Often such disfiguring features will be deemed as warranting partial removal (**fig. 311**).[[12]](#endnote-12) There is great risk, however, in removing such corrosion products, as the topography of the original surface may itself have been disturbed, and evidence of an original patina, paint, or other surface decoration may be irretrievably lost in the process.[[13]](#endnote-13) And it can also lead to the removal of invaluable, contextual evidence. In fact, under certain burial conditions, the copper corrosion products may seep into, and eventually take the shape of, animal or vegetable materials such as textiles that touch the surface, thereby forming pseudomorphs (**fig. 318**).[[14]](#endnote-14)

When it comes to intentionally created chemical patinas, a wide range of colors and effects may be produced.[[15]](#endnote-15) The patination process is highly specialized, and to create a range of color and depth that complements the sculpture is an art form in itself.

#### 1.1.3 Why apply an artificial chemical patina?

There are various reasons for the intentional application or creation of patinas on bronze sculpture. Primarily, these relate to the final appearance of the surface as desired by the artist or the commissioner (see [Case Study 7](#CaseStudy7)), as dictated by cultural or religious conventions,[[16]](#endnote-16) or as part of a conservation or restoration treatment (**figs. 306, 319**). More specifically:

* A freshly %%cast%%, unpatinated bronze surface (**fig. 313**) is highly susceptible to its environment and will immediately begin to react with the oxygen and chemicals in the air to form a protective mineralized layer or tarnish. This is usually considered undesirable, and to circumvent this natural corrosion, artists or founders impose their chosen surface by altering the color of the %%as-cast surface%% or by reducing the bright metallic sheen of polished metal, notably to enhance appreciation of the form (**fig. 320**).
* If the artwork is intended for display outdoors, a patina can serve to protect the surface from damage by exposure to the elements. This may be a chemical patina that forms a passive protective layer by slowing down further oxidation.[[17]](#endnote-17)
* Diverse patinas may be applied selectively to differentiate the color of different parts of a sculpture (**fig. 321**).
* Patinas may be applied for other aesthetic considerations, such as to make an object appear aged.[[18]](#endnote-18) For example, green patinas were intentionally created as early as the thirteenth century CE on Song dynasty bronzes[[19]](#endnote-19) to imitate much older bronzes from previous historical periods. Similarly, there may be curatorial consensus during conservation treatment of a damaged bronze surface that provides an acceptable rationale for re-creating an aged surface to conform to accepted ideas of how the piece should appear (**figs. 306, 322**).[[20]](#endnote-20) However, some curators and/or institutions do not agree with repatination, regardless of whether it is in imitation of existing remnants or in an attempt to re-create what was assumed to be the original surface treatment. In the nineteenth century some ancient bronzes were chemically treated and patinated black to reinstate what was believed to have been their original color.[[21]](#endnote-21) Archaeological bronzes were more likely to have been heavily restored in past centuries, while contemporary conservators generally favor a minimalist approach.
* Artificially aged surfaces are sometimes induced for willful deception, as in the creation of a forgery.[[22]](#endnote-22)

### 1.2 Applied coatings

#### 1.2.1 What are applied coatings?

Patinas also come in the form of organic coatings and may be applied by an artist, founder, restorer, maintenance worker, or others (**fig. 323**). These may also be referred to as “artificial patinas.” Applied coatings composed of natural substances such as resin, oil, wax, or, more recently, synthetic resins create distinct surface layers that are usually chosen to protect rather than react chemically with the metal surface. Such coatings may be chosen to produce a range of diverse effects:

* Most paints or lacquers loaded with pigment produce an opaque coating (**fig. 324**).
* Lacquers, resins, heated oils, waxes tinted with dye or translucent pigments let the underlying surface show through (**fig. 325**).[[23]](#endnote-23)
* Paint or lacquer mixed with metallic powders, mica, or shell gold lend a more sparkling, though not shiny, “metallic look” to a cast (**figs. 326, 327**).[[24]](#endnote-24)

Surface coatings may be applied directly to the polished metal, but they are often applied over chemically patinated surfaces as part of the original patination color/gloss/translucency scheme, or for added protection (see [I.8§1.2.2](#I.8§1.2.2)).

#### 1.2.2 Why apply coatings?

As with chemical patinas, coatings may be applied for both aesthetic and protective reasons:

* Outdoor sculptures now are often exposed to highly corrosive environments and can become severely disfigured and damaged (**fig. 317**), although prior to the Industrial Revolution outdoor bronzes left to their own devices could develop patinas described as “attractive” (**fig. 328**).[[25]](#endnote-25) Clear surface coatings may be applied over bright metal or intentionally induced chemical patinas to prevent corrosion caused by weather and air pollution.
* Coatings may protect indoor bronzes as well, notably from damage caused by frequent handling.[[26]](#endnote-26)
* Coatings can increase color saturation and surface gloss to change the aesthetic appearance of the object.[[27]](#endnote-27)
* Regular maintenance and application of protective coatings are important to preserve the bronze and the patina, a practice that has been in use since at least ancient Roman times.[[28]](#endnote-28) In spite of such maintenance, bronze surfaces may still change in appearance and color over time.
* Tinted surface coatings may also be applied over chemically patinated surfaces to hide casting flaws (**fig. 329**), to integrate uneven coloration of repairs, and/or later as a conservation or restoration treatment to visually integrate uneven weathering or wear.

### 1.3 Complex variations of patina

It is important to recognize that any given patina, whether chemical or coating or mixed, may be a complex multilayered sandwich whose layers could have developed naturally or could have been applied at different times by different people for different reasons.[[29]](#endnote-29) A patina may have changed considerably over time due to aging and/or various interactions, including handling, rubbing, or any other repeated contact. For instance it is becoming increasingly clear that some bronzes with natural chemical patinas formed during burial were also intentionally patinated at some point prior to burial. On occasion, a natural corrosion layer on an excavated bronze may have been deliberately removed and replaced artificially using chemicals and heat.[[30]](#endnote-30)

Some chemically induced surface changes occur unintentionally due to, for example, the reactions of the different components of the alloy with:

* remnants of %%core%% or %%investment%% material that were not completely removed after casting and, due to their hygroscopic nature, introduced moisture and encouraged chemical reactions (**figs. 330, 331**);
* residual chemicals from cleaning or other treatment (**fig. 332**);[[31]](#endnote-31)
* salts, oils, and acids on human skin that can lead to etching or corrosion (**figs. 141, 333**);
* air pollution (often sulfur compounds) indoors or outside (**figs. 316, 334**);[[32]](#endnote-32)
* the burial environment.

Chemically induced compounds and applied layers of organic coatings of various kinds (for instance resins or waxes) can be present on the same object, and could have been applied at the same time by the same person. For instance, one nineteenth-century French patination manual describes the smoking of bronze surfaces treated in special ovens with either chemical solutions, lacquers, or both to create a variegated greenish-to-black patina in imitation of antique sculptures.[[33]](#endnote-33)

Ritual practices may also contribute complexity to the patina (**fig. 335**). Conversely, repeated touching of raised areas of a sculpture can remove patina in discrete areas, exposing bare metal, which will then likely oxidize to a dull color (**figs. 266, 267**).

## 2 Why investigate patina? and other FAQs

An investigation of patina may answer a number of questions regarding attribution and more generally the history of a bronze sculpture. Bear in mind, though, that the history of a patina may be complex (see above), and the necessary technical investigation may be equally complex (see [I.8§3](#I.8§3) and [II.6](#II.6)). Even with the best technical analysis available, it may not be possible to characterize the patina.

### 2.1 Can one determine whether the original patina has been preserved intact?

Without a record of the conditions that the bronze has been exposed to during its lifetime, it is hard to reverse engineer its original appearance without documentation from the time that clearly describes what it looked like. As mentioned above, a number of factors may affect the appearance and chemical makeup of the original patina, and consequently complicate the assessment of the appearance of the original surface.[[34]](#endnote-34) Organic coatings can darken and opacify over time, and if reactive can cause unintended corrosion of the bronze surface. Weather, pollution, cleaning, handling, or burial for extended periods may result in extreme alteration of features, including total removal of the original patina (**figs. 267, 336**).[[35]](#endnote-35)

It has been normal practice since at least the Renaissance to repatinate—that is, to completely remove any remaining patina and begin again—often using materials and methods quite similar to those used originally. On occasion this might have been done for commercial reasons, with shortsighted focus on “improving” patina to enhance sales providing a powerful incentive for repatination. Therefore, the condition of the patina does not necessarily mean that it dates from either the initial fabrication of the sculpture or a more recent moment.[[36]](#endnote-36)

The identification of more recently developed chemical patinas,[[37]](#endnote-37) pigments, or resins in colored coatings on a historical bronze may be a sign that the work has been repatinated at a later date, restored, or in extreme cases faked. Traces of the original patina may be preserved in recessed areas that have been protected from touch and/or environmental change. If sampling by cross section down to the substrate metal is warranted, a multilayered patina may be found that retains original layers at the bottom of the section unless previous wholesale repatination destroyed them.

Sculptures intended to be displayed outdoors should be documented prior to installation and monitored carefully for patina changes, as regular protective coating maintenance will slow but not prevent alterations. If available, photographic documentation from the foundry or the dedication of a monument, for example, can assist in ascertaining the original appearance.[[38]](#endnote-38) Regular maintenance is key for optimal preservation of outdoor bronzes.

### 2.2 Can a later patina be distinguished from an original patina?

As mentioned above, this is complex. For modern sculpture, archival records may help determine an artist’s or maker’s original intent or concept for sculpture and offer informative comparison to the existing patina. Otherwise, if a patina is not appropriate for a known region or time period, the authenticity of the object or its surface may be called into question.[[39]](#endnote-39) However, the relative lack of detailed technical studies of well-provenanced bronzes limits our ability to draw firm conclusions (see [I.8§2.5](#I.8§2.5)).

### 2.3 Can a natural indoor patina be distinguished from an outdoor one?

Here, again, a variety of phenomena may interfere with common-sense perception. While natural patinas generally form much faster outdoors, indoor fountain sculpture and bronzes exposed to chemically treated water or indoor air pollution may also exhibit accelerated natural patina or corrosion formation (**figs. 316, 336**). Chemical color changes from indoor air pollution are well documented.[[40]](#endnote-40) Natural resin coatings can be expected to break down over time with exposure to heat, intense light, and/or elevated humidity. The presence of an intact organic coating may suggest that the sculpture has aged indoors.

### 2.4 Can a corrosion patina created naturally be distinguished from one created artificially?

Though the corrosion products produced—either naturally through exposure or burial, or artificially by human intervention—may be chemically similar, their formation and structure may differ.[[41]](#endnote-41) Artist- or foundry-made patinas are generally thinner and more homogeneous compared to naturally formed patinas, which can be quite lumpy and thick and mixed with nonmetallic inclusions (for instance soil) from the burial environment. However, this is not always the case. Notably, delicate and pleasing natural patinas may develop during burial (**fig. 309**).[[42]](#endnote-42) A clear understanding of the chemical and physical nature of the corrosion layers is often necessary to help identify the age of the patina.[[43]](#endnote-43)

### 2.5 Can a chemical patina be distinguished from an applied coating?

Generally speaking, an applied coating will be thicker than a chemical patina and sit on top of the surface. As it is not chemically bound to the metal surface, it may flake off with a distinct edge to the loss. Distinguishing between the two by eye may be difficult, especially if loss is due to wear. Organic solvents may help in this case because chemical patinas composed of metallic compounds are usually insoluble. But certain alkaline compounds, such as monoethanolamine, can change or strip a chemical patination from a bronze, as can strong acids. This is further complicated when in the presence of cross-linked organic coatings, as these may be insoluble in organic solvents.

### 2.6 Can the patina help with attribution?

Ensure, first, that the patina under investigation is original (see above). Specific types of artificial patinas were developed in different parts of the world over many centuries of practice, even as early as ancient Greece and Rome.[[44]](#endnote-44) Those dating from the Italian Renaissance and later periods are also sometimes documented and/or well known.[[45]](#endnote-45) At times their presence can indicate place of origin, or help in characterizing the work of individual artists and workshops.[[46]](#endnote-46) However, caution is again required, as with all comparisons, since the relative lack of detailed technical studies of well-provenanced bronzes limits our ability to draw firm conclusions.

### 2.7 Can we determine who was responsible for choosing an artificial patina?

This will usually depend on documentation such as correspondence between an artist and foundry, known foundry practices, or styles of patina.[[47]](#endnote-47) Conservation records may be a useful source of information if the object has undergone treatment for patina damage or instability. Identification of synthetic resins or pigments also provides clues. The technical study of a large number of bronzes produced for an artist by one foundry may reveal standard foundry practices or the preferences of the artist, as with Henri Matisse (French, 1869–1954) and Jean Arp (French, 1886–1966).[[48]](#endnote-48) Unfortunately such studies are rare.

### 2.8 Why are some outdoor sculptures green or brown, or show black stripes or other disfiguring patterns?

This is due to aggressive corrosion of the bronze by air pollution, especially sulfur compounds mixed with soot (**fig. 334**). Repeated washing by rainwater preferentially removes some of these compounds in more exposed areas of the bronze, leaving black crusts in more protected areas.

### 2.9 What is bronze disease?

Many forms of copper corrosion are disfiguring, and some are severely damaging. One specific type that has become infamous is a copper chloride corrosion termed bronze disease.[[49]](#endnote-49) Under favorable conditions of elevated relative humidity, it can rapidly progress and lead to loss of solid metal, causing not only disfigurement, but in the worst case the disintegration of an artifact. The term alone terrorized early collectors and curators—back in the early days of scientists tackling this issue, it was believed that the outbreaks were a kind of bacteria-like canker that could spread from one object to another—and the “disease” was frequently called corrosion “cankers.”[[50]](#endnote-50)

“Bronze disease” is caused by chloride salts, which are commonly introduced into corrosion layers during burial by surrounding soil or water, or if the object is near an ocean, although other causes are possible, including chloride-containing chemicals used during patination or chemicals in the environment (**fig. 337**).[[51]](#endnote-51) Within the corrosion stratigraphy, copper chloride (nantokite) typically forms on the surface of the metal. Ambient moisture causes this compound to disintegrate and in the process create small traces of hydrochloric acid, which dissolves further metallic copper from the substrate. Characteristic small mounds of light-green corrosion are indicative of this active corrosion, which can be confirmed by a chemical spot test.

Early treatments aimed at removing all corrosion layers through aggressive chemical or electrochemical treatment turned bronzes in many museum collections into thin-walled, porous, “stripped” metalware. Today, chloride corrosion on cupreous artifacts is controlled through desiccated microclimates or with chemical corrosion inhibitors and applied coatings (**fig. 315**). Depending on the location of bronze objects in less-controlled settings, such measures may be difficult to achieve and regular corrosion checks and retreatments are often necessary.

## 3 Checklist: How do we investigate patinas?

Most techniques are similar to those used for the characterization of gilding and metal plating, and are therefore presented extensively in [II.6](#II.6), including those selected below. A list of examinations and examination protocols for the characterization of a patina layer are presented in **figure 338**. Flowcharts set out in **figure 305** indicate what might be achieved depending on the possibility of sampling and the nature of the sample**.**[[52]](#endnote-52)For details of examination and analytical techniques please refer to **tables 13**, **10**,and **5**.

### 3.1 Visual examination (magnification, ultraviolet light)

Visual examination using a variety of lighting sources and angles (raking, specular) should always be the first means of studying a patina (see [II.1§2](#II.1§2)). Normal museum exhibition/gallery illumination levels are generally not sufficient to observe the subtle variations in patina color from golden to browns, reds, pale greens, deep greens and blues, to almost black. Raking light and ultraviolet illumination may help clarify the presence and/or nature of a patina, especially if there is an applied organic coating. Use microscopes and other magnification lenses with bright, adjustable light sources when possible.

Observations that assist in gathering data on the existence and nature of the patina involve:

* describing and mapping the color and texture variations (or lack thereof) on the surface, including examination of multiple locations on the object, such as in recesses where dirt or dust might accumulate, but which may also be protected from the wear that typically occurs on high spots (**fig. 323**). It is common practice to describe in broad terms the variable colors of the patina on a sculpture as part of the cataloging and/or treatment process. For example, an object may be pale green in one area compared to dark green with mottled black spots in another (**fig. 334**). However, there is no standard nomenclature for assigning exact color notations to the different elements of a patina with chromatic variations over a bronze. Color charts may be helpful.[[53]](#endnote-53) Precise color measurement by scientific instruments may be challenged by the interplay of various limitations such as colors, textures, and the size of the area of analysis (see [II.2§4](#II.2§4), **fig. 339**);
* noting whether the patina consists of a well-adhered layer, or if it is flaking or powdery and friable; lumpy or smooth; opaque, transparent, translucent, or variable;
* assessing whether the patination was potentially altered or added to, for example if different layers of color are visible, or if there are areas missing from layers that are evident on another part of the sculpture;
* searching for drip or brush marks that may indicate an applied coating or paint;
* comparing patinated areas to those where it is lacking, such as under the base or in areas of damage;
* examining (with magnification) the stratigraphy of the corrosion layers in an area of damage.

The accumulation of water on parts of an outdoor sculpture can result in areas exhibiting a different color and/or texture from areas that stay mostly dry. Areas that collect organic debris may have yet another appearance.

### 3.2 Analysis with and without sampling

As discussed in [II.6](#II.6), analysis without taking samples rarely provides sufficient data, although this will depend on the questions being posed.[[54]](#endnote-54) If sampling is possible and acceptable, a polished metallographic cross section through the entire patina layer, including the underlying metal, provides the most information. This can include an indication of the chronology of the patina formation in the location sampled. Numerous other useful analytical techniques may be applied to both cross sections and powder samples. Find more information, including some guidance for sampling, in [II.6](#II.6).

## Notes

1. For discussion of the metallurgical significance of patina see {Scott 2002} and {Aucouturier et al. 2003}. For example, the copper (Cu) surface may be transformed into cuprite (Cu2O) by a chemical reaction with oxygen (O2): Cu+1/2 O2 --> Cu2O. [↑](#endnote-ref-1)
2. For examples of patina in ancient Egypt see {Shearman 2010}. For ancient Greek bronzes see {Formigli 2013b} and {Descamps-Lequime 2015}. For Italian Renaissance see notably {Stone 2010}, 107–24; {Smith 2008a}, 18; {Motture 2019}, 68–70, with further references, esp. 242n155. For current practices in Nepal see {Furger 2017}, 116–31. [↑](#endnote-ref-2)
3. For a broad overview refer to {Scott 2002}. For more detailed historical focus see {Weil 1996}. [↑](#endnote-ref-3)
4. However, {Michel 1922}, 186 includes a patina recipe for bronze entitled “Imitation of Florentine Bronze,” for which the first step is to electroplate a thin layer of red copper to the surface of the bronze, over which is applied a paste of sanguine (iron oxide) and graphite, which is in turn covered with drying oil or varnish, followed by further application steps. [↑](#endnote-ref-4)
5. For a comprehensive list of all compounds that may be found in patinas see {Scott 2002}. [↑](#endnote-ref-5)
6. {Schweizer 1994}; {Robbiola, Blengino, and Fiaud 1998}; {Robbiola and Portier 2006}. [↑](#endnote-ref-6)
7. For a comprehensive and synthetic view on patina formation mechanisms see {Scott 2002}; {Aucouturier et al. 2003}; {Aucouturier 2007}. [↑](#endnote-ref-7)
8. {Fucito 2013}, 138–40. [↑](#endnote-ref-8)
9. See {Hughes and Rowe 1989}; {Kipper 1995}; {Motture 2019}, 70 (for summary of black and other Renaissance patinas with references and sources); {Runfola 2014}. [↑](#endnote-ref-9)
10. See {Craddock and Giumlia-Mair 1993}; {Chase 1994}; {La Niece et al. 2002}; {Benzonelli, Freestone, and Martinón-Torres 2017}; {Aucouturier, Mathis, and Robcis 2017}. [↑](#endnote-ref-10)
11. {Hughes 1993}, 10. [↑](#endnote-ref-11)
12. {Scott 2002}, 10 makes a distinction between patina, “a smooth, continuous layer that preserves detail and shape,” and corrosion, “mineral deposits that do not form a continuous and smooth layer.” [↑](#endnote-ref-12)
13. {Shearman 2010}, 48–49. [↑](#endnote-ref-13)
14. With careful preparation and examination, the fossilized vegetal or animal fiber may be precisely characterized ({Moulherat et al. 2002}). [↑](#endnote-ref-14)
15. A richly illustrated book on patinas is {Hughes and Rowe 1989}. See also {Adil and DePhillips 1991}. [↑](#endnote-ref-15)
16. See {Falaschi 2017} for a fascinating account of blue-colored Greek bronzes; {Furger 2017} for practices in Nepal; and {Oddy, Bimson, and La Niece 1981} for other observations on Himalayan bronzes. [↑](#endnote-ref-16)
17. The bronze sculpture of Horace Greeley cast in New York by the sculptor J. Q. A. Ward (American, 1830–1910), cast by the Henry-Bonnard foundry in 1890, was not artificially patinated before being placed outdoors in New York City. Presumably it was meant to develop a natural patina over time by exposure to weather; see {“Casting in Bronze” 1891}, 866. For an apparently similar approach by the sculptor Adriaen de Vries (Dutch, 1556–1626), see {Bassett 2008}, 270–71. [↑](#endnote-ref-17)
18. {Fucito 2013}, 137–38; {Craddock 2009}, 365–68; also {Risser and Saunders 2017}. [↑](#endnote-ref-18)
19. {Craddock 2009}, 356. [↑](#endnote-ref-19)
20. {Newman 2011}, 36. [↑](#endnote-ref-20)
21. {Craddock 1990}, 259–61. [↑](#endnote-ref-21)
22. {Weil 1996}, 403, avers that by the Renaissance, corrosion products had acquired value for their “antiqueness” so as to testify to the age of antique bronze. This new value spurred forgeries. [↑](#endnote-ref-22)
23. {Hiorns 1907}; {Michel 1922}. [↑](#endnote-ref-23)
24. {Lauffenburger 2006}, 76, found metal powders incorporated into varnish patinas on several sculptures by Antoine-Louis Barye (French, 1795–1875) cast by the founder Jean-Honoré Gonon (French, 1780–1850) in the 1830s. [↑](#endnote-ref-24)
25. {Weil 1996}, 397, describes these attractive patinas as thin, compact, translucent, generally red-brown, and more or less tinged with green, depending upon moisture levels. [↑](#endnote-ref-25)
26. Giambologna’s (Flemish, 1529–1608) apparent use of a transparent varnish seems to suggest the desire for sheen and protection when handling, while retaining the somewhat golden color of the bronze. See for example {Stone 2010}, 118–20, suggesting that the use of heat (or stoving) made the varnish more durable for handling. [↑](#endnote-ref-26)
27. {Stone 2011}, 178 believes that the vast majority of Italian Renaissance patinas were organic oil-resin varnishes and notes that although there were various chemical patination recipes in the Renaissance, “it has proven surprisingly difficult to find any undoubted examples of this method ever actually being employed. A conspicuous exception is the work of the sculptor Antico.” [↑](#endnote-ref-27)
28. {Descamps-Lequime 2015}; see also {Formigli 2013b}. [↑](#endnote-ref-28)
29. See above, and for example Massimiliano Soldani-Benzi (Italian, 1656–1740), who describes in a letter to his London agent how to refresh the patina on bronzes using clear walnut or linseed oil and red hematite (lapis rosso); unpublished document, referred to in a 1996 conference paper by Dr. Charles Avery in Berlin. We are grateful to Dr. Avery for allowing us to include his discovery prior to publication. [↑](#endnote-ref-29)
30. {Risser and Saunders 2017}. [↑](#endnote-ref-30)
31. {Schrenk 1994}, 60, discusses supposed “protective” coatings, like neat’s-foot oil, often applied to Benin bronzes by collectors that have instead caused extensive disfiguring metallic fatty-acid corrosion products to form on the surface. {Michel 1922}, 160 describes a five-year-long experiment in Germany beginning in 1864 whereby daily washing and monthly application of grease to a bronze bust displayed outdoors resulted in the formation of a beautiful patina compared to ugly ones on the busts used as controls. [↑](#endnote-ref-31)
32. See also {Marabelli 1994}, 14, who found the surface of the equestrian monument of Marcus Aurelius, outdoors since late Imperial Roman times, to have extensive sulfation, including brochantite, antlerite, and chalcanthite. [↑](#endnote-ref-32)
33. {Debonliez and Malepeyre 1979}, 8. [↑](#endnote-ref-33)
34. For a thorough definition of the original surface of a bronze see {Bertholon 2004}. [↑](#endnote-ref-34)
35. For a brief case study of patina formation see {Scott 2002}, 328–29. [↑](#endnote-ref-35)
36. For a sample of bronzes in the Wallace Collection, London, where it seems evident that they have been repatinated, see {Warren 2016}, vol. II, esp. pp. 503–31, nos. 113–14; p. 474 (no. 108), p. 550 (cat. 117) on nineteenth-century patination; p. 666 (no. 137). [↑](#endnote-ref-36)
37. For modern patination recipes, see {Hughes and Rowe 1989}. [↑](#endnote-ref-37)
38. The sculpture of Thomas Hart Benton by Harriet Goodhue Hosmer (American, 1830–1908) was described at its unveiling as having a bright golden color ({Weil 1996}, 407). [↑](#endnote-ref-38)
39. {Schrenk 1994}. [↑](#endnote-ref-39)
40. {Grzywacz 2006}, 11–13. [↑](#endnote-ref-40)
41. See {Robbiola and Hurtel 1997}, a study carried out on the Roman busts of Livia (**fig. 309**) and Augustus that demonstrated that the “noble” patina originated from a natural corrosion process: a presence of compounds from the soil in the deeper layers and tin enrichment of the upper dark-green layer due to decuprification. [↑](#endnote-ref-41)
42. {Gettens 1970}. [↑](#endnote-ref-42)
43. Relatively few studies have been carried out on the subject; see {Graedel, Nassau, and Franey 1987}. [↑](#endnote-ref-43)
44. For the introduction of artificial patinas in the Hellenistic period see {Eggert 1994}; {Heilmeyer 1994}; {Descamps-Lequime 2015}, 151–65. [↑](#endnote-ref-44)
45. Pier Jacopo Alari Bonacolsi (known as Antico, Italian, ca. 1455–1528) is renowned for using a particular black patina; see **figure 293** and {Stone 2011}. Artists such as Giambologna, his followers, and later sculptors are known for the reddish Florentine/Tuscan patina (**fig. 325**); see for example {Stone, White, and Indictor 1990}; {Radcliffe and Penny 2004}, 162, 168,174, 179,190, 198, 202; {Stone 2010}; esp. 116; {Pitthard et al. 2011}. [↑](#endnote-ref-45)
46. See {Vauxcelles 1905}, 195, for a the lengthy description of the process for the “wet crow” patina applied to a cast of Rodin’s (French, 1840–1917) *Thinker*, made by the Hébrard foundry in 1905. An example of foundry practice is the French Valsuani foundry’s famous “noir Valsuani” patina used in the early twentieth century for bronzes by various sculptors; {Lebon 2003}, 260. [↑](#endnote-ref-46)
47. For example, Rick Stewart’s research on the bronzes of sculptor Charles Russell (American, 1864–1926) at the Amon Carter Museum in Fort Worth, Texas, revealed that in 1941 the collector who later sold them to Amon Carter had most of the collection repatinated at the Roman Bronze Works in New York. A green cold patina was applied over the original brown. {Stewart and Russell 1994}, 141. [↑](#endnote-ref-47)
48. {Boulton 2006}, 86; {Hamilton 2018}. [↑](#endnote-ref-48)
49. For a history of the treatment of this issue see for instance {Beale 1996}. [↑](#endnote-ref-49)
50. {Drayman-Weisser 1994}, 143. [↑](#endnote-ref-50)
51. For a case study of corrosion see {Scott 2002}, 334–38. [↑](#endnote-ref-51)
52. For a comprehensive and critical review of most available methods see {Stone 2010}; {Aucouturier 2007}. [↑](#endnote-ref-52)
53. Munsell color charts are currently being employed by Dorothy Cheng at the Smithsonian American Art Museum in Washington, DC, in her technical study of bronzes by the artist Paul Manship (American, 1885–1966). [↑](#endnote-ref-53)
54. The patina demonstration carried out during the October 2018 CAST:ING meeting (see **video 14**) and the subsequent analysis by Aurélia Azéma of LRMH provides a good example of how difficult it may be to characterize even a relatively simple patina. The patina consisted of subsequent hot application of three aqueous solutions, namely a copper nitrate, an iron nitrate, and a potassium polysulfide. Half of the lion was covered with wax at the end. Surface X-ray fluorescence spectroscopy (XRF) analysis was only able to detect the presence of iron, potassium, sulfur, and titanium. X-ray diffraction (XRD) analysis on powder carefully sampled under a microscope using a blade revealed a copper sulfate, a copper nitrate, and lead oxide. No wax could be detected. In this example it was impossible to reconstruct the exact patina process. [↑](#endnote-ref-54)