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Reading Teeth: Ivory as an Artifact of Classed Whiteness

ABSTRACT

While artifacts made of ivory fill the shelves and storage rooms of museum collections across the world, ever more stringent legal measures restricting or banning the ivory trade have turned these objects into troublesome treasures. Ivory is a biological material derived from the tusks and teeth of several extant and extinct animals. The physical and aesthetic properties of elephantine ivory in relation to its use and symbolic significance shaped the material cultures of *classed whiteness* at the turn of the twentieth century. Ivory from elephant tusks displays a characteristic macroscopic motif known as the Schreger pattern, which is often used by conservators and forensic researchers as an identifying characteristic. First described by German odontologist Bernhard Schreger in 1800, this pattern of crossing dark and bright lines is attributed to an optical phenomenon of light refraction. By proposing a *refractive reading* of ivory, this article explores the role of animal-derived materials in the construction of human identities. This method of analysis allows the properties of ivory—luster, brilliance, whiteness, and toughness—to be seen as agentive material properties that historically co-produced human racial and classed ideals. Analyzing nineteenth- and early twentieth-century sources in dental anatomy, ivory commerce, and technical microscopy permits an unraveling of this animal material's ties to specific colonial regimes of trade and resource extraction, and its technical role in precursors to materials science. This paper is part of a special issue entitled "Making Animal Materials in Time," edited by Laurence Douny and Lisa Onaga.

KEY WORDS: ivory, elephants, race, class, refraction, authentication, colonialism

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INTRODUCTION

In the early nineteenth century, dental anatomists used the term "ivory" as a general descriptor of the partly mineralized dental tissue typically found in mammals. This yellowish, translucent substance was recognized as the main part of the tooth structure, and in scientific literature was referred to as "the bony part of a tooth,"[1] or in Latin *substantia eburnean* or *ebur*, directly translating into elephantine ivory.[2] In 1840, Richard Owen (1804–1892), a British comparative anatomist and paleontologist, introduced the term *dentin* because ivory was primarily associated with commercial material obtained from elephant tusks.[3] In his description of elephantine ivory, Owen highlighted "the characteristic appearance of decussating curved striæ, with oblique rhomboidal spaces, so conspicuous on transverse sections or fractures of ivory," and attributed this distinctive pattern to the refraction of light.[4] These so-called Schreger lines or pattern is unique to elephantine ivory (figure 1).

This motif, visible on the cross-section of the tusk as a grid of intersecting darker and lighter lines radiating from the axis outward and creating a stacked chevron pattern, has since served as evidence in forensics, archaeology, and species conservation. Museum conservators use Schreger lines for noninvasive diagnostics to differentiate elephant ivory from its imitations, and other types of ivory. Historically, this optical phenomenon has been explained through tusk morphology, and more recently, the biocomposite structure of the tooth that combines mineral and organic matter; however, its origin remains unknown.

This article explores the history of Schreger lines to show how imperial thinking and culture subconsciously manifested through popular uses of ivory in the nineteenth and early twentieth centuries. As an optical phenomenon, the Schreger pattern is attributed to light *refraction* that in physics is defined as "the change in direction of a wave passing from one medium to another caused by its change in speed."[5] The refractive properties of ivory studied by

1. John Hunter, *The Natural History of the Human Teeth: Explaining Their Structure, Use, Formation, Growth, and Diseases* (London: J. Johnson, 1771), 36.

2. Johann Karl Wilhelm Illiger, *Prodromus systematis mammalium et avium* (Berlin: Berolini, 1811), 20.

3. Richard Owen, *Odontography or, A Treatise on the Comparative Anatomy of the Teeth; Their Physiological Relations, Mode of Development, and Microscopic Structure, in the Vertebrate Animals* (London: H. Baillière, 1840), ii–iii.

4. Ibid., 641.

5. *Encyclopaedia Britannica Online*, s.v. "Refraction | Physics." www.britannica.com/science/refraction

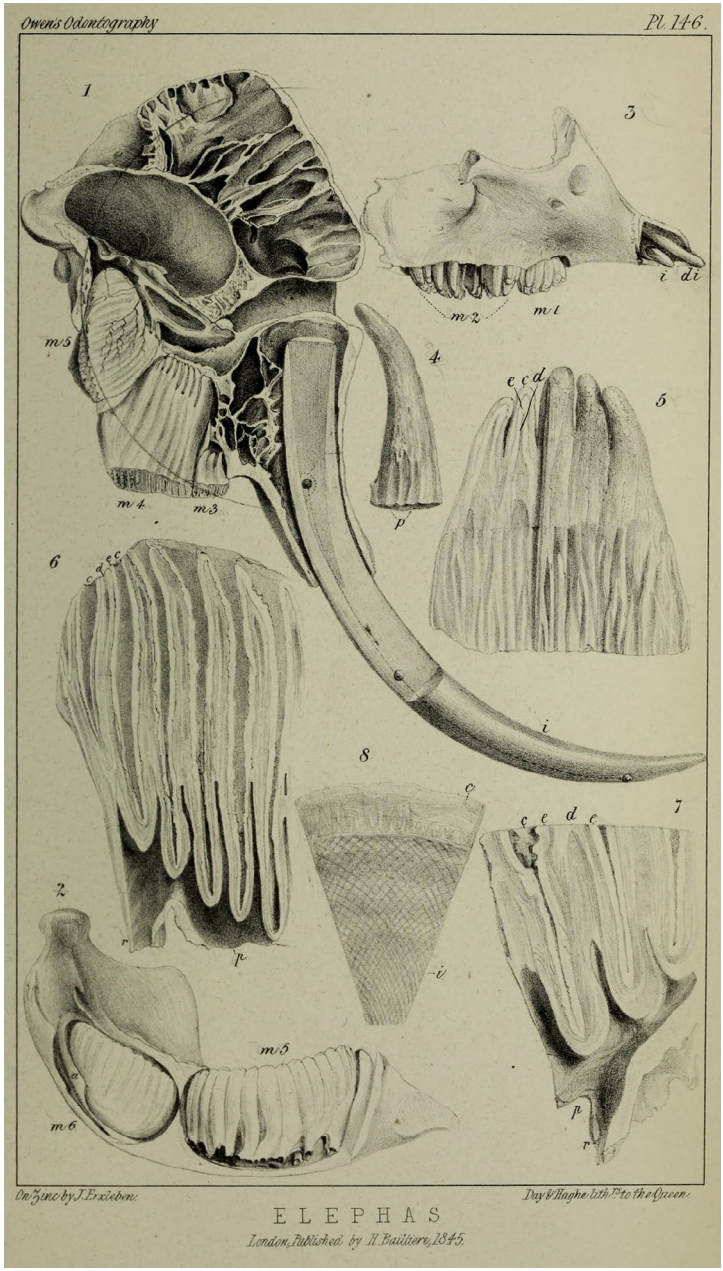

FIGURE 1. Plate 146 from Owen's second volume of *Odontography* (1845) showing the vertical section of an Asian elephant's skull with details of dental anatomy. Detail 8 shows the cross section of the tusk and the "decussating curved lines of the modified dentine, or 'ivory,'" also called Schreger lines.

naturalists and dental anatomists as well as mineralogists, gemologists, and art historians provide a model for understanding how dominant racial and class identities developed in relation to animal materiality, its economic value, and scientific measures. To this end, I employ a *refractive reading* of ivory to analyze it as a biological material overgrown with cultural meanings. Thus, in addition to anatomical studies into the structure of elephant tusks, I review colonial trade reports on procuring ivory and company records on working and advertising ivory artifacts.

Although the use of ivory in jewelry, carving, and decoration spans various geographies and time periods from antiquity, a focus on the role of the ivory trade for the manufacture of consumer goods after the 1800s illuminates the transformation of ivory from a luxurious to a quotidian commodity. It exposes the imperial stakes behind domesticating animal materiality in the bourgeois household. Mass production of ivory objects such as cutlery handles, combs, billiard balls, buttons, and other household objects made them accessible to a wide societal strata in Europe and North America, and implicated bourgeois consumers in imperial ideologies.[6] This is because the inclusion of ivory depended directly on colonial resource extraction and had ties to the slave trade (mostly out of Africa).[7] The transatlantic slave trade and the racialized hierarchies of life it established played a central role in the formation of European modernity.

Ivory's physical and aesthetic qualities resonated with the specific desires and sensorial experiences of bourgeois white consumers, and understanding this is crucial for historical analyses of race and animal materiality.[8] To flesh out the relation between commodification of animal materiality and racial hierarchies, I rely on critical analyses of property relations developed in Black studies scholarship. As Zakiyaah Iman Jackson points out, "discourses on nonhuman animals and animalized humans are forged through each other;

6. For discussions on the uses of ivory by Asians and Africans, see Martha Chaiklin, *Ivory and the Aesthetics of Modernity in Meiji Japan* (London: Palgrave Macmillan, 2014), and Clapperton Chakanetsa Mavhunga, *Transient Workspaces: Technologies of Everyday Innovation in Zimbabwe* (Cambridge: MIT Press, 2014).

7. Edward Alpers, *Ivory and Slaves: Changing Pattern of International Trade in East Central Africa to the Later Nineteenth Century* (Berkeley: University of California Press, 1975).

8. See, for example, Sujit Sivasundaram, "Imperial Transgressions: The Animal and Human in the Idea of Race," *Comparative Studies of South Asia, Africa and the Middle East* 35, no. 1 (2015): 156–72; Yuka Suzuki, *The Nature of Whiteness: Race, Animals, and Nation in Zimbabwe* (Seattle: University of Washington Press, 2017); Bénédicte Boisseron, *Afro-Dog: Blackness and the Animal Question* (New York: Columbia University Press, 2018).

they *reflect and refract* each other for the purposes of producing an idealized and teleological conception of 'the human.'"[9] Inspired by Jackson's brilliant analysis of Afro-Caribbean literary responses to the "animalization of black(ened) being,"[10] I show how ivory was mobilized as a prop for crafting such idealized conception of the human, which I call here *classed whiteness*. Refractive reading of this animal material offers a materialist take on the privileged racial and classed categories that usually remain abstract and unmarked, a prerequisite for upholding racial hierarchies.

A historical analysis of ivory's physical features and cultural uses shows how animal materials can be read refractively to account for their transformations from animals to objects and as proxies for human identity constructs. Reading ivory refractively allows us to understand its valued properties such as luster, brilliance, whiteness, and toughness not as simple reflections of cultural ideals of race and class, but rather as animal materiality co-shaping these ideals. This becomes most apparent with ivory's use as a material for prostheses in plastic surgery, inscribing it into the history of biomaterials.[11] As teeth, ivories are natural biocomposites because they combine distinct materials to yield improved performance, and this is what makes them prime animal materials in the precursor of materials science.[12] Refractive reading treats both ivory and *classed whiteness* as biocomposites that fuse matter and meaning.

This refractive reading of ivory starts by mapping the colonial history of the ivory trade in the nineteenth and twentieth centuries to feature how merchants and dealers constructed the economic value of raw material in relation to its materiality and origin. Ivory's high value called for techniques of verification that I analyze in this article's second section, where I discuss how historical actors and later conservationists adopted scientific descriptions of Schreger lines to authenticate elephantine ivory. To problematize my own reading of animal teeth as historical evidence, I assess how refraction can be deceptive for attempts to understand the properties of animal materials in the verification of truth claims. The third section considers how manufacturers attributed differences in tusk properties to varying environmental factors, which they sought to

9. Zakiyyah Iman Jackson, *Becoming Human: Matter and Meaning in an Antiblack World* (New York: NYU Press, 2020), 23 (emphasis added).

10. Ibid., 2.

11. Buddy D. Ratner and Guigen Zhang, "A History of Biomaterials," in *Biomaterials Science*, 4th ed., ed. William R. Wagner et al. (Academic Press, 2020), 21–34.

12. Cyrus C. M. Mody and Joseph D. Martin, "Materials Science," *Encyclopedia of the History of Science* 3, no. 2 (15 Jun 2020). https://doi.org/10.34758/6afy-w006

standardize for mass production of ivory objects. The processes of determining salient properties, economic values, and scientific measures are indicative of how ivory's materiality retained colonial references to resource extraction. The final section returns to the properties of this animal material that consumers valued for their liveliness as they used ivory artifacts to construct their distinctive class and racial positions.

WHITE GOLD: THE VALUE OF IVORY

The term "ivory" typically applies to commercially significant natural material that can be used for the manufacture of goods. An expensive and sought-after commodity, it earned the moniker "white gold." Images of stockpiles of slightly curved white tusks that can reach over three meters in length might give a false impression that ivory is bone.[13] However, ivories are mammalian teeth from several different species: elephants, mammoths, mastodons, wild boars, warthogs, hippopotami, walruses, whales, and narwhals. Ivory from elephant tusks, due to their large size, was considered the most valuable, and in historical literature is often called true or genuine ivory. These enormous upper incisor teeth grow throughout an elephant's lifetime, and thus larger tusks come from older individuals. The lifespans of elephant species vary: the bush or savannah African elephant (*Loxodonta africana*) and the forest African elephant (*Loxodonta cyclotis*) can reach the age of seventy years, and the Asian elephant (*Elephas maximus*) up to fifty years. In the two African species, both males and females grow tusks, whereas usually only male Asian elephants develop them. For centuries, Indian and Chinese artisans have preferred the cheaper and softer African elephant ivory over the Asian one because the larger tusks of the older elephants offer more carving possibilities.[14] Cutting and carving transform elephantine teeth into commodities; in the process, even ivory dust becomes a valuable byproduct.

The raw material of ivory was a fickle commodity entangled in a complex network of economic dependencies. Trade in elephantine ivory is as old as

13. *Tusks in Ivory Vault at Deep River Factory*, 1890, The National Museum of American History, Archives Center, Series 3: "Pratt, Read Corporations Records, 1838–1990," Box 61, Folder 5.

14. Philip Gooding, "The Ivory Trade and Political Power in Nineteenth-Century East Africa," in *Animal Trade Histories in the Indian Ocean World*, ed. Martha Chaiklin, Philip Gooding, and Gwyn Campbell (Cham: Palgrave Macmillan, 2020), 247–76.

human history and spans almost the entire globe. Worked ivory objects supported various mercantile economies and hold different cultural meanings in each destination, be it Gothic ivories from tusks imported by Venetian merchants via the Atlantic route,[15] or carved items in Song-dynasty China made from Zanzibar ivory supplied by Arab traders.[16] The most robust ivory trade in East Africa was primarily organized along caravan routes led by Arab traders who ventured inland, while Indian merchants dominated the coastal trade for centuries before the arrival of European explorers.[17] Historian Abdul Sheriff describes the nineteenth-century ivory trade as a "moving frontier," expanding as hunting pressure drove elephant herds inland.[18] It was mostly indigenous hunters who supplied the tusks, which had to be carried to port cities, as their value increased the closer they were to the coastal markets.[19]

This is also when ivory started to be dubbed "white gold" in direct reference to "black ivory," as slaves were often described at the time.[20] The knot that held ivory and slavery together tightened with reports by European explorers such as David Livingstone, who famously recounted that slaves carried ivory tusks on their own backs. [21] British abolitionists frequently quoted this observation as a commentary on the bloody price for a luxurious commodity. However, historians of East Africa paint a more complex picture of trade and labor relations among the various ethnic and indigenous groups involved in the caravan expeditions.[22] Raymond W. Beachey argues that "the view, summed up in the slogan 'black and white ivory,' that slaves captured in the interior

15. Sarah M. Guérin, "Avorio d'ogni Ragione: The Supply of Elephant Ivory to Northern Europe in the Gothic Era," *Journal of Medieval History* 36, no. 2 (2010): 156–74.

16. Charles Platten Woodhouse, *Ivories: A History and Guide* (New York: Van Nostrand Reinhold, 1976), 80.

17. Pedro Machado, *Ocean of Trade: South Asian Merchants, Africa and the Indian Ocean, c. 1750–1850* (Cambridge: Cambridge University Press, 2014).

18. Abdul Sheriff, *Slaves, Spices, & Ivory in Zanzibar: Integration of an East African Commercial Empire into the World Economy, 1770–1873* (London: James Currey, 1987).

19. "The Supply of Ivory," *Zanzibar Gazette*, 7 Jun 1893, 73266J-00, British Online Archives.

20. El Zubeir-Pasha, *Black Ivory and White, or the Story of El Zubeir Pasha, Slaver and Sultan, as Told by Himself*, trans. H. C. Jackson (Oxford: B.H. Blackwell, 1913).

21. David Livingstone, *The Last Journals of David Livingstone in Central Africa from 1865 to His Death*, vol. I (London: J. Murray, 1874), 232.

22. See, Raymond W. Beachey, "The East African Ivory Trade in the Nineteenth Century," *The Journal of African History* 8, no. 2 (1967): 269–90; Stephen J. Rockel, "Slavery and Freedom in Nineteenth Century East Africa: The Case of Waungwana Caravan Porters," *African Studies* 68, no. 1 (1 Apr 2009): 87–109; Alexandra Celia Kelly, "Western Activism and the Veiling of Primitive Accumulation in the East African Ivory Trade," *Historical Archaeology* 53, no. 3–4 (2019): 575–90.

carried most of the ivory to the coast is much exaggerated,"[23] pointing out that the labor in transporting ivory was mostly provided by professional porters and slaves hired out by their masters. Nonetheless, the "white gold" versus "black ivory" juxtaposition reverberated with European and North American white consumers at the turn of the twentieth century.

Straddling the line between natural history and market research, studies such as *Ivory and the Elephant in Art, in Archaeology, and in Science* (1916) provide comprehensive information on commerce and the consumption of ivory in Europe and North America. Its author, George Frederick Kunz, was a mineralogist who oversaw the U.S. mining exhibits at several World's Fairs and was employed by the luxury goods retailer Tiffany & Co. He focused mostly on the growing American and European sales markets, with the London market alone showing a progressive increase from an annual average of 192,000 pounds throughout the eighteenth century, to 1,000,000 pounds imported in 1864, followed by 1,434,900 pounds in 1890.[24] Such enormous quantities of elephant tusks arriving at European ports illustrate the scale of ivory extraction that affected primarily the African elephant populations. Additionally, these figures indicate changes in the main distribution points and supply chains in the course of the "Scramble for Africa." For instance, the opening of a new ivory market in Antwerp in 1888, intended to compete with the main European distribution center in London, was followed by increased exports of ivory from the Belgian Congo.[25] In Africa, the chief points of the ivory trade also shifted in the last decade of the nineteenth century from Zanzibar, which had furnished 75 percent of the world's supply of ivory in 1891, to Mombasa.[26]

Although elephant tusks were not perishable cargo, unlike other colonial commodities shipped alongside them such as food or live animals, they still needed to be transported and stored under proper conditions. European and North American dealers determined the value of ivory by the materiality of the tusks: if they were fractured due to careless handling, or if a sudden change in temperature had caused them to warp or crack, their market value dropped. The most important factor impacting value was the size of tusks because larger

23. Beachey, "The East African Ivory" (n.22), 276.

24. George Frederick Kunz, *Ivory and the Elephant in Art, in Archaeology, and in Science* (Garden City, NY: Doubleday, Page and Co., 1916), 437.

25. Henry C. Morris, "Ivory Trade of Antwerp," Consular Reports: Commerce, Manufactures (Ghent: U.S. Government Printing Office, 5 Mar 1895), 174.

26. Beachey, "The East African Ivory Trade" (n.22), 289.

pieces allowed a wider range of use. Wholesale companies typically displayed impressive specimens at their entrance or in showrooms as trophies and business tokens.[27] Whole tusks were distributed among specialized processing industries: Sheffield in England was the world leader in the production of cutlery handles; Dieppe in France had a long tradition in carving crucifixes, hand-held fans, and miniatures; Erbach in Germany was famous for its ornamental pieces; Deep River and Ivoryton in Connecticut were home to the biggest manufacturer of combs and piano keytops for the expanding market in the United States.

Sold by weight, colonial traders categorized the tusks into various grades and classes: by size as "scrivelloes" and "bagatelles," by form as "hollows," "cores," and "defectives."[28] The different parts of the tusk varied in value: the most expensive being the solid body; next, the enamel-covered tips used for the production of billiard balls; and finally, the hollow part at the bases of the shaft known as cheap "bamboo ivory" were suitable only for cutting bangles sold *en masse* in India.[29] Banyan and Khoja merchants had their own terms for tusk classification that often incorporated Swahili words. The foremost distinction was between *pembe* (soft) and *gendi* (hard) ivory, but they also identified a hybrid class called *chotara*. This term was also applied to the Indian merchants' offspring with Swahili women because they believed that "the ivory alluded to, consisting of a mixture of the two qualities, is produced by elephants which are the outcome of a cross between the two species of soft-tusked and hard-tusked animals."[30] This double meaning of *chotara* illustrates one of the ways in which racial categories were co-constructed along with an animal-derived material that became a global commodity.

The mechanization of ivory-cutting in Europe and the United States in the second half of the nineteenth century accelerated production and extracted maximum value from the material. Kunz noted that "ivory always commands full value; for there is little or no material wasted, even the dust being available for polishing, for making India ink, or for the making of 'ivory jelly' [for

27. Ernst D. Moore, *The Great "Kilimanjaro" Tusks Outside Arnold, Cheney & Company's Ivory House in Zanzibar*, 22 Dec, 1908, The National Museum of American History, Archives Center. Series 3, Box 61, Folder 4.

28. Robert P. Skinner, "Ivory and Walrus Tusks in Europe," Daily Consular and Trade Reports (Hamburg: Department of Commerce and Labor, Bureau of Manufactures, 1913), 1390.

29. "Ivory," *Zanzibar Gazette*, 5 Dec 1894, 73266J-00, British Online Archives.

30. Ibid., 4.

eating]."[31] The idea of precious waste was indicative of both the value of ivory material and the scale of production that consumed thousands of tusks every year. Ivory dust was a sign of the Industrial Age, a byproduct of mass manufacture, obtained in much larger quantities than from the chisel-and-file technique used in a traditional workshop. Maximizing the use of the material showcased industrial progress and served as a point of comparison with non-Western craftspeople who were presented as slow and inefficient in their labor: "This waste of time and material constitutes a heavy handicap on the Indian workman, more than offsetting his advantage over European workers in the matter of cheap living, so that he is unable to withstand the European competition."[32] Thus, colonial histories of labor and slavery intertwined in the process of determining the value of ivory.

TRUE AND GENUINE: IVORY IDENTIFICATION WITH SCHREGER LINES

Due to the high value of genuine ivory, the market was flooded with forgeries and imitations. The search for a reliable method of verifying the authenticity of such a valuable material made businesses turn to science. The result was commercial applications based on anatomical studies. These techniques of verification paved the way for producing ivory substitutes that would match its unique properties. The anatomists and commodity scientists trying to understand these properties were the precursors of materials science engineers.

On December 17, 1865, Richard Owen gave a speech on ivory in front of the Royal Society of Arts in London. The aim was to present the current state of knowledge on the structure and growth of this valuable material with the explicit goal of drawing conclusions for commercial applications of ivory. Owen admitted that, until this point, scientific research had not contributed substantially toward this goal, in particular in the matter that seemed to be the audience's main concern: improving ivory's qualities, while diminishing its price.[33] This lecture by one of the most prominent British naturalists of the

31. Kunz, *Ivory and the Elephant* (n.24), 437.

32. Ibid., 260.

33. Owen's research was facilitated by access to fossil ivory from mastodons and mammoths, fresh tusks from elephant specimens in the London Zoological Gardens, and a large collection of tusks from the ivory trading company of Robert Fauntleroy & Co. Thus, commerce had aided science, and now it was time for science to return the favor. For his

period received wide attention from ivory trade representatives and the inventors who sought to substitute ivory with a cheaper material.

According to Owen, "the utility of teeth in commerce and the arts depends chiefly on a peculiar modification in their laws of growth."[34] He considered tusks as an adaptation, and thus explored physical properties of these elongated incisor teeth focusing on the geometry of microscopic dentinal tubules in relation to animal ontogeny and behavior.[35] This approach illustrates Owen's homology principle in organ development: drawing from comparative anatomy and paleontology, he examined the form and function of teeth in different species. Owen described elephant tusks as "the largest of all teeth in proportion to the size of the body"[36] and studied their structure under the microscope. He defined elephantine ivory through one distinctive feature: the lines visible in the traverse sections that radiate from the center of the tusk:

> By this character, which is presented by even the smallest portion of an elephant's tusk in transverse section or fracture, true ivory may be distinguished from every other kind of tooth-substance, and from every counterfeit, whether derived from tooth or bone. It is a character—the engine-turned decussating appearance—which is as characteristic of fossil as of recent ivory.[37]

These lines, unique to elephantine ivory, became its trademark and the main marker of its difference from other materials and imitations. For example, many of the milk-tusks available on the market came from hippopotami.[38] To verify the authenticity of genuine ivory, odontologists recommended "sawing through one of them; the cross-section reveals the unmistakable characteristics of ivory."[39]

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discussion of fossil tusks, see Richard Owen, *A History of British Fossil Mammals and Birds* (London: John Van Voorst, 1846), 244.

34. Richard Owen, "The Ivory and Teeth of Commerce," *The Journal of the Society of Arts* 5, no. 213 (1856): 65–76, on 66.

35. Ibid., 69.

36. Ibid., 67. As the first president of the Microscopical Society of London, Owen had a genuine interest in promoting microscopy as a tool for advancing science and industry.

37. Ibid., 65.

38. Elephant calves shed their first pair of tusks before reaching one year of age and replace them with teeth that grow throughout their lifetime. For mammals these deciduous teeth are often called "milk teeth."

39. Willoughby D. Miller, "Studies on the Anatomy and Pathology of the Tusks of the Elephant," *Dental Cosmos* 32, nos. 5, 6, 7, 9 (1890): 337–48, 421–29, 505–26, 673–79, on 339.

Scientific understanding of this optical phenomenon at the time unequivocally pointed to tusk morphology: specifically, to dentinal tubes that carry nutrients along the tusk's growth. A dense network of minute canals allows successive calcification of layers of the soft pulp inside the tooth cavity. Anatomists like Owen believed that the lines matched the microscopic structure of the tusk. However, he did not use the term "Schreger lines" to describe this phenomenon, as this was mostly limited to German-language publications, especially in Viennese scientific circles.

Named after Bernhard Schreger (1766–1825), a German surgeon and anatomist who first described bright and dark lines in mammalian teeth, the Schreger pattern is typical of both elephantine and mammoth ivory.[40] In his contribution to the natural history of teeth in 1800, Schreger reported on "the noticeable differences in the direction of the stripes" in *Knochensubstanz* (bone substance), which "form a simple arch with a concavity towards the cavity."[41] At the time, the origin of these lines was unknown, but scientists suspected they derived from the fibrous structure in the tooth's bone-like substance. Although Schreger lines came to be associated primarily with tusks of Proboscideans, Schreger mentioned none of these species in his publication. He based his analysis on a comparison between human teeth and those from several domestic animals, including horses, sheep, and cows. His method testified to the predominance of comparative anatomy in early nineteenth-century medical science and its importance for the development of odontology. For example, Georges Cuvier's study of fossil and extant pachydermatous teeth informed the methodology of many anatomical taxonomists and dental anatomists, including that of Owen.[42] Odontologists studied the morphology, pathology, and anomalies in elephant tusks attempting "to establish theories of dental diseases on the ground of analogy with assumed inflammatory processes in ivory."[43]

German-speaking commodity scientists who studied Schreger lines often used the technical terminology of decorative arts that later used this feature for authenticating ivory objects. Physician Fritz Obermayer described an engine

40. Cornelia Marlen Schmidt, "Bernhard Nathanael Gottlob Schreger (1766–1825). Leben und Werk" (Dr. med./PhD diss., Friedrich-Alexander-Universität, Erlangen-Nünberg, 2014).

41. Bernhard Nathanael Gottlob Schreger, "Beitrag zur Geschichte der Zähne," *Beiträge für die Zergliederungskunst* 1 (1800): 1–7, on 2.

42. Georges Cuvier, *Recherches sur les ossemens fossiles de quadrupèdes* . . . , vol. 2 (Paris: Deterville, 1812).

43. Miller, "Studies on the Anatomy" (n.39), 511.

turning pattern "characteristic of genuine ivory."[44] Engine turning or guilloché is a decorative technique for fine ornamental pieces that engraves surfaces with a rose engine lathe. A decade later, Austrian botanist Franz Ritter von Höhnel explained the occurrence of "true guilloching" (*echte Guillochierung*) in ivory through tooth morphology: the undulating dentine canals reflected light in the form of crossing darker and lighter bands depending on the angle of illumination.[45] The use of such terms demonstrates how knowledge about ivory interwove science, commerce, and craftsmanship. In the German-speaking context, this interdisciplinary synergy was facilitated by commodity science, or *Warenkunde*, a discipline that often focused on colonial goods.[46]

Commodity scientists developed empirical methods for verifying the quality and authenticity of colonial raw materials. The microscope became the primary tool for studying animal materials and their chemistry in the early nineteenth century, as shown by Podgorny and García in this volume. By the end of the century, Höhnel had devised new methods of microscopic analysis and introduced technical microscopy as an official subject at Austrian technical universities. His observation on the waves of adjoining canals in ivory structure was cited at length in the section on teeth of the technical microscopy textbook by another Viennese commodity scientist, Thomas Franz Hanausek, who specialized in studying raw materials.[47] Published in German in 1901, with an English translation in 1907, this manual is the last scientific publication to mention Schreger lines until their reappearance in the late twentieth century.

In the 1990s, wildlife conservationists and forensic scientists applied the Schreger pattern to differentiate between elephantine and mammoth ivory. As the latter is excluded from import restriction and constitutes a considerable source of commercial material, customs officers use a method based on measuring apparent angles in the crossing of the Schreger lines to distinguish between legal and illegal ivory. This technique works because these angles are

44. Fritz Obermayer, "Beitrag zur Kenntnis des Zahnbeines vom Elephanten, Nilpferd, Walross und Narwal," *Neunter Jahresbericht der Wiener Handels-Akademie*, 1881, 102–12, on 106.

45. Franz Ritter von Höhnel, "Beitrag zur Kenntniss der technisch verwendeten Elfenbeinarten," *Zeitschrift für Nahrungsmittel-Untersuchung, Hygiene und Waarenkunde* 6, no. 7 (1892): 141–44, 183–88, 205–11, on 144, quoted in Thomas Franz Hanausek, *The Microscopy of Technical Products*, trans. Andrew Lincoln Winton and Kate Grace Barber Winton (New York: John Wiley and Sons, 1907), 425.

46. Johann Beckmann, *Vorbereitung zur Waarenkunde, oder zur Kentniß der vornehmsten ausländischen Waaren* (Göttingen: Vandenhöck und Ruprecht, 1793).

47. Hanausek, *Microscopy of Technical Products* (n.45), 422–24.

obtuse in elephantine ivory, while the material from longer tusks of mammoths shows acute angles.[48] Today, materials science engineers analyze ivory as a model biocomposite that combines organic matter (collagen of the dentinal tubules) with minerals to explain the origin of Schreger lines.[49] They consider micromorphology of the tusk manifested in the Schreger pattern critical for the tusk's mechanical integrity.

This unique pattern did more than simply *reflect* the inner structure of the tusk. Apart from being a product of the biological development of the tusks, the Schreger pattern gained another meaning beyond anatomy—as a marker of ivory's authenticity. Producers of the first synthetic plastics that imitated this precious material mimicked the characteristic lines.[50] The Schreger pattern is visible to the human eye thanks to light refraction. When light hits a lens, optical prisms, or lenses in microscopes and photographic cameras, the light is redirected. The perceived visual effect is that objects may change appearance when refracted; for example, an object partially submerged in a glass of water appears bent when seen from a certain angle. When Höhnel used his improved microscope to examine the Schreger pattern, he noticed that "if with the same illumination the mount is turned about 180° on the microscope stage, what were crests in the former position are now valleys, and therefore the former dark streaks are now light."[51] This optical illusion shows how refraction produces shifts in perception and is capable of deception. According to historian of science Jutta Schickore, debates about optical illusions in microscopy were catalysts for reflexive methodological critiques of the limits of observation and the validity of knowledge.[52] Schreger lines used in the work of verification are themselves the product of an optical illusion. This paradox highlights the limits of scientific work in verification and claims to truth. Whereas *reflection*, as an

48. Edgard O. Espinoza, Mary-Jacque Mann, James P. LeMay, and Kent A. Oakes, "A Method for Differentiating Modern from Ancient Proboscidean Ivory in Worked Objects," *Current Research in the Pleistocene*, no. 7 (1990): 81–83; Edgard O. Espinoza and Mary-Jacque Mann, "The History and Significance of the Schreger Pattern in Proboscidean Ivory Characterization," *Journal of the American Institute for Conservation* 32, no. 3 (1993): 241–48, on 244.

49. Fritz Vollrath, Ruixin Mi, and Darshil U. Shah, "Ivory as an Important Model Bio-Composite," *Curator: The Museum Journal* 61, no. 1 (2018): 95–110, on 98.

50. Julie A. Reilly, "Celluloid Objects: Their Chemistry and Preservation," *Journal of the American Institute for Conservation* 30, no. 2 (1 Jan 1991): 153.

51. Höhnel, "Beitrag zur Kenntniss" (n.45), 425.

52. Jutta Schickore, *The Microscope and the Eye: A History of Reflections, 1740–1870* (Chicago: University of Chicago Press, 2007), 248.

optical metaphor for objective knowledge making, promises an unmediated view of reality, *refraction* accounts for the materiality of a medium that changes depending on the perspective from which it is viewed. A refractive analysis of ivory allows us to return to the Victorian makers and consumers of ivory objects for whom knowing the material entailed knowing the animal and its environment.

GREEN, PINK, OR MILK: THE "TRUE" COLORS OF IVORY

Merchants and specialized craftspeople co-created knowledge about ivory at the turn of the twentieth century: carvers and matchers selected tusks suitable for making specific objects after processing by grailers, junkers, blockers, and sawyers. Apart from characteristics such as straightness and roundness of the tusk, the most prominent feature of ivory was its color. While consumers desired the signature warm-toned whiteness, "an expert can tell at a glance where a tusk, or even a small piece of ivory, came from"[53] based on slight variations in tint and transparency. Ranging from milky-white, through pink-hued, to green, the color of ivory was closely tied to the origin and composite structure of this biomaterial.

By inspecting the outer rind, commercial experts and naturalists distinguished between African and Asian elephantine ivory. The inner part of African ivory has a higher transparency attributed to a greater concentration of oils and a closer grain, in contrast to the denser and more "glassy," or brittle, Asiatic ivory, which was more prone to discoloration.[54] Microscopic observation of ivory's fine composition explained why "we have in African tusks light and deep orange, hazel and brown, and even brownish black, while the rind of Asiatic tusks is lighter hued, rather fawn colour or stone colour."[55] Specialists also recorded differences between African ivories sourced from different regions: "The West African product is hard, transparent and is known as living or glass ivory, while the East African is soft, opaque, white and is therefore

53. Charles Frederick Holder, *The Ivory King: A Popular History of the Elephant and Its Allies* (New York: Charles Scribner's Sons, 1886), 221.

54. Corse, "Observations on the Different Species of Asiatic Elephants, and Their Mode of Dentition," *Philosophical Transactions of the Royal Society of London* 89 (1799): 212. Elephant tusks are mostly composed of dentin, with an outer layer of cementum and enamel layer on the tip.

55. Kunz, *Ivory and the Elephant* (n.24), 233.

designated milk ivory."[56] Some suggested that it is possible to determine the source of African ivory with relatively high geographical accuracy based on visual inspection: "while some Congo ivory is hard, brittle, white, and translucent, other material from the same region will be opaque, and soft in texture as that from Zanzibar; it may also be greenish tinted at the nerve-centres."[57] In 1890, American dentist and microbiologist Willoughby D. Miller attributed the coloration of ivory material to the elephant's diet:

> One cross-section in my possession shows a deep green layer or ring 1.5 mm. in thickness, which, I conceive, must have been occasioned by some peculiarity in the food taken by the animal at the time this layer was forming. A closer investigation into the causes which bring about these differences in the properties of ivory from different districts would be of great interest.[58]

These variations in color suggest that external environment, or the site of harvest, affects the material described as the "pearl of the forest."[59]

The categorization of ivory into types according to source is based on the difference in physical qualities relevant to the process of production, such as the tusk size, symmetry, hardness, and color. This classification binds the material to the specific environment it is extracted from. Despite ivory being an animal-derived material, the technical language for its processing often employed vocabulary typically used to describe plant life: tusks were harvested from elephants like crops from fields; the outer layer of the tusk was often called bark; the material showed geographical variety, as if different soils yielded different types of ivory;[60] and it was sun-bleached in glass constructions resembling greenhouses.[61] Following this bizarre botanical nomenclature, Victorian consumers of ivory products imagined that massive elephants grow their tusks like trees do branches. It has even been suggested that concentric lines observed in tusks cross-sections indicate the age of the animal,

56. Hanausek, *Microscopy of Technical Products* (n.45), 422.

57. Kunz, *Ivory and the Elephant* (n.24), 443.

58. Miller, "Studies on the Anatomy" (n.39), 347.

59. Ernst D. Moore, "Ivory, the Pearl of the Forest," *Scientific American* 144, no. 1 (1931): 9–12.

60. Some attributed the variety in ivory material qualities to "the constitution of the soil, especially its proportion of calcareous salts and the amount of mineral matter present in the water." Skinner, "Ivory" (n.28), 4.

61. David H. Shayt, "Elephant under Glass: The Piano Key Bleach House of Deep River, Connecticut," *IA. The Journal of the Society for Industrial Archeology* 19, no. 1 (1993): 37–59.

much like counting the rings of the tree trunk reveals the age of the tree.[62] This vegetal vision of ivory fits well into the plantocrocy logic of extractivism, where tusks functioned as a natural resource bound to the habitats of elephants that supplied Western demand for ivory.

Apart from environmental factors, tusk fractures obtained during fights or foraging affect the quality and properties of ivory material, making this commercialized matter intimately tied to the individual animal's life trajectory. Elephants use their tusks extensively to clear vegetation, move trees, scrape soil, and fight—all activities that over time wear the giant teeth down. Securing a symmetrical pair of tusks was difficult because as English explorer and hunter Samuel White Baker observed in 1867, "elephants invariably use one tusk in preference, as we use the right hand," and thus, "the *Hadam* (or servant), as the Arabs call the working tusk, is generally much worn."[63] The physical properties of ivory so valued by the industry stem from multiple functions the animals perform with the tusks. As adaptations, tusks provide "seized affordances" to ivory objects, to draw from Gilbert in this issue. Each tusk bears the signs of the elephant's life history. Sometimes a seemingly flawless tusk only revealed imperfections, such as cavities or growth deformities, during processing. This made ivory a difficult material to standardize for the purposes of mass production.

Some industries insisted on a wholesome approach to pairs of tusks belonging to the same animal to seek consistency in the variable properties of their products. A set of piano keytops should ideally come from a single tusk to match color, pattern, and texture.[64] The whiteness of ivory is neither a given nor a uniform category, considering that "gradations of white from mottled yellows and grays to faint reddish browns can occur naturally, depending on the elephant's diet, genetic inheritance, and state of health."[65] Achieving a standardized color scheme in ivory required work through bleaching with

62. Corse, "Observations" (n.54), 213. Later, Miller debunked this theory, yet he concluded that from the number of "strata interlamellaria" it is possible to determine that "the deposition of dentine by the pulp is not continuous, but takes place in periods." Miller, "Studies on the Anatomy" (n.39), 427.

63. Samuel White Baker, *Nile Tributaries of Abyssinia, and the Sword Hunters of the Hamran Arabs* (London: Macmillan, 1867), 533–34.

64. "Key Production Record Book, 1916–1930," The National Museum of American History, Archives Center, Series 3, Box 11, Folder 2.

65. Shayt, "Elephant under Glass" (n.61), 44.

chemical agents or sunlight, as well as regimes of care for ivory objects whose varied color was tied to the origin of the raw material.[66]

This color standardization in serial production of ivory objects at the turn of the twentieth century is yet another aspect of sustaining *classed whiteness* as a composite category anchored in animal materiality. Consider the cover of a New York ivory goods catalogue from the mid–nineteenth century: the central image depicts a black man holding a spear in one hand and an elephant tusk in the other, while another image shows an elegant white lady embroidering in the comfort of her home (figure 2).[67] The juxtaposition of the figures, caught in tropical exterior and temperate interior surroundings, respectively, refers consumers to the "white and black ivory" trope.[68] Animals appear at the top of the cover: on one side an exotic elephant with a howdah, on the other a domesticated farm bull. The materiality of ivory—symbolized by the elephant, the tusk held by the African, and the piano with ivory keys in the lady's room—become points of reference for white bourgeois privilege. *Classed whiteness* emerged in relation to the materiality of ivory, revealing what Jackson calls the plasticity of antiblackness, or "an antiblack mode of the human concerned with appropriating vitality and pathologization."[69] This sense of vitality appropriated refers to coopting animal materials to define the human subject along racial, classed, and gendered lines, rather than celebrating infinite mutability of matter. This composite image exposes the production of difference in animal materials through repetition: just as Schreger lines create a pattern that repeats itself, the formation and calcification of identity categories such as race and class require repetitive rituals of everyday practices. Such a refractive reading of this cover leads us to bring to light the composition of *classed whiteness*. But refraction is a tricky concept: watch out, appearances may be deceiving! Schreger lines are described as a naturally occurring phenomenon, and *classed whiteness* mimics this naturalness. It hitches on to the material properties of mammalian ivory to lend it an illusion of naturalness. Thus, a refractive

66. Hiltrud Jehle, "'Das beste kommt aus Zeylon und muß recht schön glatt und weiß seyn.' Eine Literatur- und Objektstudie zu Farbveränderungen an Elfenbein," *Beiträge zur Erhaltung von Kunst- und Kulturgut* (ed. Verband der Restauratoren e.V.), no. 2 (2019): 62–76.

67. *Julius Pratt & Company Catalogue,* undated, The National Museum of American History, Archives Center, Series 1: Predecessor and Miscellaneous Companies, Box 1, Folder 1.

68. See, James Walvin, *Black Ivory: A History of British Slavery* (London: Harper Collins, 1992).

69. Jackson, *Becoming Human* (n.9), 11.

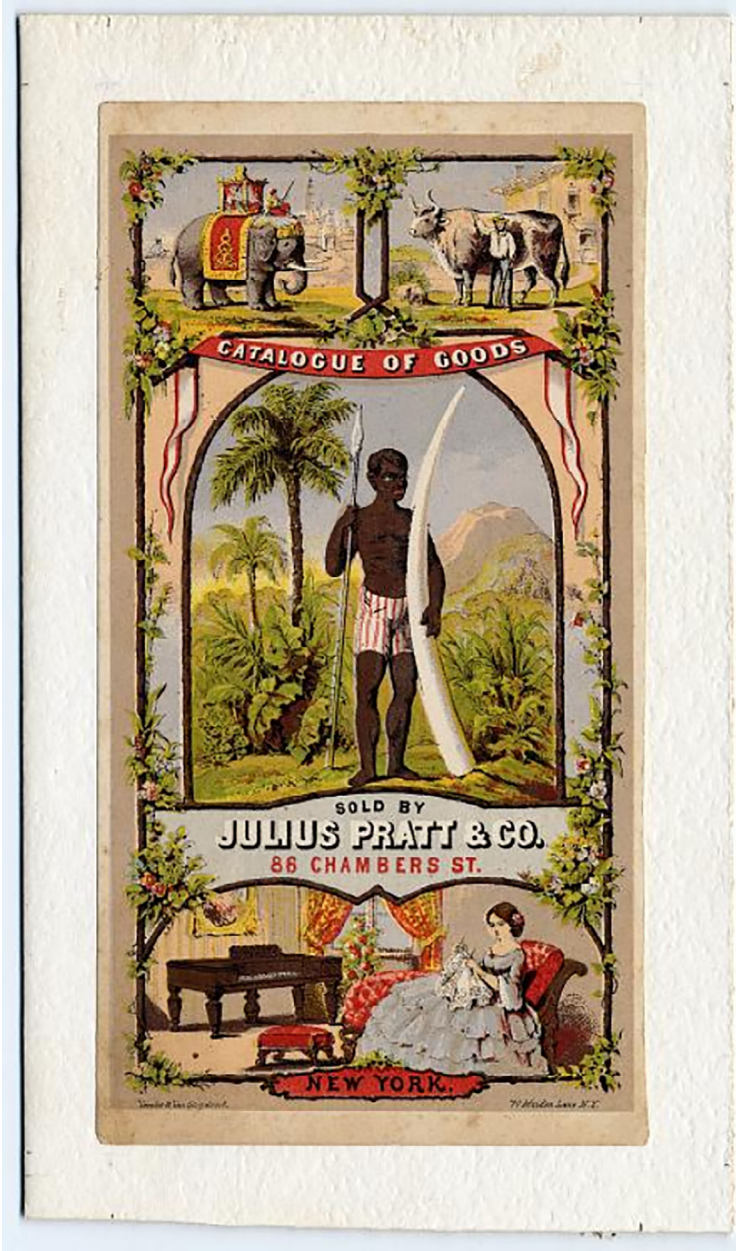

FIGURE 2. Cover of an ivory goods catalogue of Julius Pratt & Co. in New York from the mid–nineteenth century. The National Museum of American History, Archives Center, Series 1: Predecessor and Miscellaneous Companies, Box 1, Folder 1. Pratt, Read Corporation Records, Archives Center, National Museum of American History, Smithsonian Institution.

reading of ivory requires the engagement of the full range of our senses to further show how animal materiality produces difference.

TICKLING THE IVORIES: ANIMAL INTIMACY WITH IVORY OBJECTS

Ivory was a preferred material for household objects because of its durability and uncanny beauty. Ivory is tough, yet easy to mold into desired shapes. It can be carved with intricate ornamentation, polished into brilliant shine, while its porosity allows it to be dyed vivid colors. Victorian consumers were attracted not only by its practicality and beauty but also by its exotic seduction—two characteristics that accentuate its animal origin. This entanglement seemed obvious to scientists of the nineteenth century. As Owen stated with confidence, "it is, of course, from our intimacy with the two existing species that our knowledge of the nature of ivory has been chiefly derived."[70] Nevertheless, while browsing historical records I have wondered whether people playing billiards, brushing their hair with an ivory comb, or simply holding cutlery during dinner ever realized they were actually handling an animal tooth. Were Victorian women clutching their umbrella handles, or men fondling their tobacco snuff boxes during strolls at the zoo, ever thinking of the connection between the elephant on display and their own ivory paraphernalia?[71] If elephant tusks were commodities, did processing further alienate them from the material properties of their rightful pachyderm bearers? The transformation of *things* into *objects* is a violent process, especially when applied to animal body parts.

The present capacity to articulate the transformation of ivory into a commodity, fully integrated in capital systems itself, has profited from the link to its animal origin. Part of the appeal held by true ivory lay in the charisma of the elephant: the largest terrestrial mammal that could be admired by the average nineteenth-century European or North American consumer only in zoos and traveling circuses. That this precious material was harvested from an enormous beast (dead or alive) lent the artifacts an element of exotic allure. In the age of colonialism, big-game hunting was a popular sport among noblemen and aristocracy. An expensive hobby, safari hunts generated a popular genre of

70. Owen, "The Ivory and Teeth of Commerce" (n.34), 66.

71. For a discussion on whiteness as a racial category in elephant exhibit and hygiene merchandise advertising, see Sarah Amato, "The White Elephant in London: An Episode of Trickery, Racism and Advertising," *Journal of Social History* 43, no. 1 (2009): 31–66.

travel writing in which the elephant was the top trophy. According to historian Nigel Rothfels, "killing an elephant thus became a requisite element in essentially every notable account of hunting in the second half of the nineteenth century."[72] In these spectacular narratives, tusks functioned as status symbols with large tuskers being the most prized game. Interpreting a record of an elephant hunt from 1863, philosopher Achille Mbembe draws "a connection between the *act of colonizing* and the *act of hunting*."[73] He argues that the "discourse on Africa is almost always deployed in the framework (or on the fringes) of a meta-text about the *animal*—to be exact, about the *beast*: its experience, its world, and its spectacle."[74] Ivory was intrinsically linked to colonial imaginations held by its consumers, which were further bolstered by trophy hunting narratives in which white hunters conquered African lands, wildlife, and peoples.

As an animal-derived substance, ivory retains liveliness even though as a material it usually implies elephant death. Despite being inanimate, ivory is often described as alive. Returning to the example of piano keys, the ability to absorb sweat makes ivory veneer a preferred surface. Pianists described ivory keys as "breathing" and bringing players haptic pleasure.[75] As another consumer recalled, "ivory is part of the anatomy of the elephant, an animal we all regard with interest and some affection, and we have an unconscious respect for the article itself." [76] Ivory maintains an animal intimacy, or "a specific kind of affective and material construct"[77] that blurs the binary divisions between life and death, and between human and animal. The animal intimacy imbued in ivory manifested through material properties such as porosity, elasticity, and plasticity.

The variety of objects manufactured from ivory at the turn of the twentieth century shows how ubiquitous this material was in a bourgeois household: from hair receivers, brushes, and whiskbrooms; to glove stretchers, cuticle knives, and shaving brushes.[78] What really stands out in an inspection of an

72. Nigel Rothfels, "Why Look at Elephants?," *Worldviews: Global Religions, Culture, and Ecology* 9, no. 2 (2005): 166–83, on 179.

73. Achille Mbembe, *On the Postcolony* (Berkeley: University of California Press, 2001), 196.

74. Ibid., 1.

75. Richard Conniff, "When Music in Our Parlors Brought Death to Darkest Africa," *Audubon Magazine*, Jul 1987, 85.

76. "Ivory Dust and Ivory Jelly," *The Marion Daily Star*, 15 Sep 1893, 3.

77. Mel Y. Chen, *Animacies: Biopolitics, Racial Mattering, and Queer Affect* (Durham, NC: Duke University Press, 2012), 5.

78. F. J. Kaldenberg, "Ivory Toilet Articles. Price List," circa 1880–1875, The National Museum of American History, Archives Center, Warshaw Collection, Box 1, Folder 5.

inventory of ivory objects is that so many were toiletries, handled on a daily basis in a personal hygiene regimen.[79] Users often praised the feel and heft of ivory items that furnished their pockets, closets, and vanity tables. Articles such as nail files or hair combs used for grooming sustained modern standards of beauty that constituted important ways in which classed whiteness was performed. Ivory rendered into hygiene tools afforded certain rituals to classed whiteness, especially those connected to leisure (as a material for musical instruments, games, and sports) and grooming, both types of activities increasingly available to the burgeoning middle-class. Thus, the animal intimacy brokered between humans and ivory lies in a palpable material quality—one activated in the most basic contact zone between the surfaces of human and nonhuman bodily parts.

Human intimacy with ivory is more than skin deep. Since the eighteenth century, Europeans ingested pulverized ivory as a medicine, absorbing it at the tissue level.[80] Victorians and Americans acquired a taste for jellies made from ivory dust boiled in water.[81] Ivory was an early biomaterial used by surgeons to make internal prostheses and grafts. Only later would these efforts gain recognition as precursors to endeavors in materials science and engineering to create new biocompatible substances. Jacques W. Maliniak, a pioneer of reconstructive surgery in the post-WWI era, recommended using ivory in rhinoplasty, praising its accessibility and malleability. He described the Schreger pattern as a feature that enabled the identification of the highest-quality material and warned against the use of celluloid and other forms of ersatz ivory, which according to him "should be avoided for implantation in the human tissues, since they are foreign bodies completely different in their composition from true ivory."[82] Maliniak considered prosthetics made of ivory to be compatible with the human body because they were biological materials that "possess a specific vitality."[83] The same publication reported on the remodeling of nasal "negroid wings" for a white patient together with ivory implantation, a reminder that the standards of beauty shaped and chiseled with the use of ivory remained deeply racialized.[84]

79. Alexandra Celia Kelly, *Consuming Ivory: Mercantile Legacies of East Africa and New England* (Seattle: University of Washington Press, 2021), 101–6.

80. "Analytical Records from the Lancet Laboratory," *The Lancet* 153, no. 3936 (1899): 312.

81. A recipe for ivory jelly can be found in Catharine Esther Beecher, *Miss Beecher's Domestic Receipt Book* (New York: Harper & Bros., 1862), 178.

82. Jacques Maliniak, "The Use of Ivory in Rhinoplasty," *Archives of Otolaryngology* 1, no. 6 (1925): 599–611, on 605.

83. Ibid., 603.

84. Ibid., 610.

CONCLUSION

The most widespread manual for ivory identification, published in 1991 shortly after the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), utilizes the Schreger pattern as the key feature to differentiate between legal and illegal ivories.[85] There are several other diagnostics, including isotope analysis and Zooarchaeology by Mass Spectrometry (ZooMS), X-ray tomography, spectroscopy, DNA analysis, and radiocarbon dating, but optical microscopy of a pattern first observed in the beginning of the nineteenth century remains the easiest and cheapest technique. The Schreger pattern serves not only as an entry point for a historical analysis of authenticating animal materials, but itself becomes an object of study unraveling knowledge practices as material engagements. Knowledge about ivory derives from the people who handled it: traders, craftspeople, carvers, anatomists, microscopists, and conservationists.

Ivory has largely disappeared from our daily lives. It still exists as an exotic material of the past era. Contemporary problematizations of the ivory trade focus on elephant conservation rather than on ivory's colonial past.[86] This article demonstrates that studying animal materials is intimately tied to their histories of extraction, production, and use. Reading ivory refractively exposes the naïve optimism of celebrating the vitality of matter without acknowledging its reductive tendencies in defining the human subject along racial, classed, and gendered lines. At the same time, losing sight of the animal in unraveling the fusion of meaning and matter would be another violent reduction that the refractive reading of animal materials helps to avoid.

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85. Edgard O. Espinoza and Mary-Jacque Mann, "Identification Guide for Ivory and Ivory Substitutes" (World Wildlife Fund and Conservation Foundation, 1991).

86. Racial categories continued to shape elephant management and conservation in South Africa, where diminished or missing tusks were key for proving elephants' degeneration or adaptation. Jules Skotnes-Brown, "Domestication, Degeneration and the Establishment of the Addo Elephant National Park in South Africa, 1910s–1930s," *The Historical Journal* 64, no. 2 (2021): 357–83, on 380.

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