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If you have a packet of sugar handy, take a look at it. Chances are good that you will find on it the words "pure cane sugar." As a commodity, sugar is defined in relation to its purity in a way that would make little sense for grain, beef, or oil. The anthropologist Sidney Mintz observed that sugar is the only staple food to be consumed in a pure chemical form, as crystals of the sucrose molecule: $C_{12}H_{22}O_{11}$.[1]

Historians, anthropologists, and other scholars of sugar—one of the most globally consequential commodities of the past five centuries—have taken this chemical notion of purity for granted. Thus, in his groundbreaking 1985 work *Sweetness and Power: The Place of Sugar in Modern History*, Mintz begins the chapter on "Production" with the statement that "Sucrose—what we call 'sugar'—is an organic chemical of the carbohydrate family.'"[2] If that's true, though, then why advertise "pure cane sugar?" Why should consumers care what plant their sugar comes from? "The mother beet and the mother cane are forgotten in the equal whiteness of their offspring," wrote the Cuban sociologist Fernando Ortiz in his lyrical *Cuban Counterpoint* of 1940, "because of the equal chemical and economic standing of all the sugars of the world, which, if they are pure, sweeten, nourish, and are worth the same."[3] If what's in the packet, and in your coffee, is pure and is sucrose, why should it matter what crop first produced it?

More so than any other commodity, sugar's status has always depended on a perception of its uniformity. But only recently could that uniformity appear as "sucrose," a concept built on the world-view of nineteenth-century organic chemistry. Furthermore, in the

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David Singerman is a research associate at Harvard Business School. In 2014–15 he was a postdoctoral fellow at the Rutgers Center for Historical Analysis. E-mail: david.singerman@gmail.com.

1. Mintz, *Sweetness and Power*, 22.
2. Ibid., 19.
3. Ortiz, *Cuban Counterpoint*, 24–25.

market for sugar in industrial countries, the economic value of sugar has been directly tied to its sucrose content only since the middle of the 1870s.

Until that point—and beyond it—sugar was understood through different forms of tacit knowledge and bodily expertise by those who made it, traded it, and consumed it. The objective of sugar production has not always been the extraction of something called "sucrose," nor is the history of the "ancient, complex, and difficult process" of sugar-making just the triumphant story of the ever-more-efficient application of chemical knowledge.[4] However, historians have anachronistically read this contemporary category backward. In doing so—in taking the equivalence of pure sugar and sucrose to be a natural rather than social fact—they have missed that this identity is itself the product of a specific set of historical forces and interests. The notion that "all the sugars of the world, if they are pure ... are worth the same" is the outcome of conflicts about whose knowledge about sugar counted as valid.

Inventing Purity in the Atlantic Sugar World, 1860–1930 asks how sucrose was made the sole standard of value, how scientific knowledge and practice were deployed in an attempt to control a global commodity, and how those attempts were resisted. The choice of sucrose as a measure, it argues, reflects configurations of power, influence, and interest in the long nineteenth century. It traces these configurations at scales ranging from buildings in Brooklyn to the whole of the Atlantic, and in spaces from Caribbean factory floors to Glasgow machinery workshops and New York refinery docks. Sugar has not just been sucrose all along. Rather, it had to be made that way.

Sugar's power as a commodity has always been linked to the uniformity of its substance. For sixteenth- and seventeenth-century Europeans, that substance's mass production constituted a modern marvel.[5] In his *Essay Concerning Human Understanding*, John Locke used sugar as an exemplar of a material that had a nearly universal effect on human beings. "If sugar produce in us the ideas which we call whiteness and sweetness," he wrote, "we are sure there is a power in sugar to produce those ideas in our mind."[6] Locke saw the slave colony of Barbados, across the Atlantic, become the wealthiest and most productive sugar-growing region on earth.

Viewed through the instruments of the modern natural sciences, Locke's "power in sugar" would seem obviously to be the sucrose molecule. Until the nineteenth century, however, no one would or could have described sugar in those terms. Instead, they did so with

4. Mintz, *Sweetness and Power*, 21–22.
5. Otremba, "Inventing Ingenios," 120.
6. Locke, *Essay*, Book II, Chapter XXXI: "Of Adequate and Inadequate Ideas."

reference to its process of production, and especially with what Lissa Roberts called "sensuous" techniques of bodily experience.[7] Thus, Barbadian observers admired the remarkable sophistication of its plantations and the sugar they made, yet they did not speak of sugar that was "pure," but of sugar that was "white," or "well cur'd," or "of a bright colour, dry and sweet," and "of a kind of Sugar somewhat inferiour to the Muscavado; but yet will sweeten indifferently well, and some of it very well coloured."[8]

Nearly every history of Caribbean slavery describes the process by which sugar was made, and emphasizes the skills of the slaves who made it and the dangers they faced.[9] It was slaves who cut the cane, carted it to the mill, and fed the stalks between the rollers that released their juice. In the boiling house, it was slaves who controlled the heating and cooling of that juice in a sequence of kettles. This was the tricky procedure that produced crystalline sugar and leftover molasses, and planters anxiously recognized they did not possess the trick. The "art of boiling sugar [is] generally least understood either by overseers or their masters," wrote the Antiguan planter Samuel Martin in 1765, but "trusted wholly to the skill of negro-boilers, who indeed arrive by long habit to some degree of judgment by the eye only."[10] They stretched the scalding syrup between their fingers, tasted it, inhaled its odors, and waited for it to make a certain sound as it bubbled.

Knowing when to "strike" the syrup from the final kettle (or "pan") to produce the most crystals was the most prized ability of the sugarmaster. After the syrup was struck, it was cooled and drained of its molasses for weeks in conical molds. Finally, it was the sugarmaster's task to go down the loaf from light to dark, slicing as many as sixteen different levels of color and value.[11] Plantation sugar was tied to its place of origin and the skills of its makers. It was also tied to the biological properties of cane, which shaped the process that turned that cane into a transportable, salable commodity. Most famously, the size of plantations was limited by the fact that cane juice fermented relatively quickly after the plant was cut down.

The emergence of a chemical idea of purity was inseparable from the notion that "sugar" might be found in other plants. In 1747, the German apothecary Andreas Marggraf concluded, by microscopic observation and a "strong sweet taste," that what he had crystallized

7. Roberts, "Sensuous Chemist."
8. Ligon, *True & Exact History*, 84, 89–90.
9. See, e.g., Dunn, *Sugar and Slaves*.
10. Martin, *Essay on Plantership*, 23.
11. Moreno Fraginals, *Sugarmill*, 119.

from the roots of several European plants was "not merely a substance approaching sugar, but in fact a true and perfect sugar, which has a complete resemblance *with the familiar sugar extracted from the sugar cane*."[12] Marggraf's work, with later state sponsorship, brought into being an industry based on a new crop called the "sugar beet," which could produce masses of such sweet crystals, and do so in temperate climates. By late in the nineteenth century, however, chemists had come to claim exclusive access to sugar's essential nature. The chemist judging samples of beet, maple, palm, and sorghum sugar for the 1876 Philadelphia exposition wrote that "all of these are cane sugar in the chemical meaning of the term." It was a colloquial inconvenience, he complained, to "distinguish by different names the sucrose obtained from special plants."[13]

However, spreading a chemical notion of purity throughout the sugar economy was not simply a matter of chemists bringing the right instruments to measure it. As historians and sociologists of science have shown, the successful operation of scientific instruments is a local and contingent process, and the ability to propagate standards anywhere always depends on the ability to recreate particular techniques and material cultures. No scientific practice works in a new social and material context without a great deal of work to prepare the way. Far from stable knowledge about sugar inhering in instruments themselves, therefore, the fact that a chemical instrument "looked and behaved as it had on the other side of the world," and appeared to produce the same result, is the explanandum rather than an explanation.[14]

Nor is this a story of the metropolitan projection of scientific knowledge. Like empires, new ways of understanding the world are never extended by fiat. Many historians have emphasized the power of imperial institutions to project European forms of knowledge, but the "tyranny of distance," as Jim Endersby notes, extended both ways. If it was hard for a colonial scientist to draw attention to his work, it was very nearly as difficult for those in the "center" to make their authority felt far away.[15] A distributed Atlantic sugar economy, lacking even pretenders to inherent authority, was a field of negotiation rather than projection. American factory owners understood their property through distant chemists' numbers, Glasgow machine makers consulted with Caribbean machine users, and the Custom House in Manhattan struggled to supervise its own employees a few miles away on the Brooklyn riverfront.

12. Marggraf, "Experiénces chymiques."
13. Walker, ed., *International Exhibition*, 2.
14. Reeves, "Constructing an Instrument," 4.
15. Endersby, "Garden Enclosed."

Finally, and most importantly, in the production of sugar, scientific knowledge did not supplant craft know-how. As the editors of the recent volume *The Mindful Hand* argue, scholars should question a "historical map shaped by oppositional and hierarchically ordered pairs: scholar/artisan, science/technology, pure/applied and theory/practice." Those dichotomies themselves, they write, are products of political and social work during the scientific and industrial revolutions.[16] Instead, this project suggests, an important facet of the development of capitalism is the struggle over the terms by which to measure human labor and the products of nature.

The history of capitalism is, in other words, also a history of struggles over metrology. To scientists, "metrology" is the field concerned with investigating, creating, and disseminating standard values.[17] To historians and sociologists of science, however, "metrology" denotes the social work that turns certain values into apparently natural or self-evident ways of measuring the world.[18]

The metrological history of capitalism can be traced, for instance, from gold markets in the seventeenth century in West Africa and New Spain, to tobacco docks in Virginia and London in the eighteenth century, American cotton fields and Liverpool cotton exchanges in the early nineteenth, grain in Chicago in the 1860s, steel mills in Pittsburgh in the 1890s, and oil refineries in the 1940s.[19] In each of these places, under the banner of "reason," systems of measurement were progressively redefined in ways that tended to disadvantage groups like sugar factory workers, and to favor certain holders of political and economic power.

Labor historians such as David Montgomery and historians of technology such as David Noble have paid attention to the way that skilled workers resisted and exerted influence over standardized production methods.[20] More fundamentally, our usual hierarchy of scientifically rational production over ingenious craft work is the result of judgments about "standardization" and "efficiency," not their cause. Categories of privileged knowers have been redefined alongside categories of what was there to be known. The relationship between mind and hand in the sugar economy, historically complex, was in flux in the late nineteenth and early twentieth centuries. *Inventing Purity* exposes that fluidity before it solidified and came again to seem as natural in its new form as it previously had in its old.

16. Roberts et al., *Mindful Hand*, xiv.
17. Bureau International de Poids et Mesures, "What Is Metrology?"
18. Schaffer, "Late Victorian Metrology."
19. Schaffer, "Golden Means"; Lane, "Gone Platinum"; Linebaugh, *London Hanged*; Johnson, *River of Dark Dreams*; Beckert, *Empire of Cotton*; Cronon, *Nature's Metropolis*; Montgomery, *Fall of the House of Labor*; Noble, *Forces of Production*.
20. Montgomery, *Fall of the House of Labor*; Noble, *Forces of Production*.

In my first of three core chapters, I examine the nature of labor inside the industrializing sugar factories of the Caribbean—specifically in Puerto Rico and Cuba, which were increasingly attracted into the orbit of U.S. capital. Historians have recently demonstrated how, in contrast to earlier arguments that mechanization compelled the end of slavery because the two were inherently incompatible, slave sugar plantations were hotbeds of mechanical experimentation. In a related way, *Inventing Purity* shows how the subsequent automation of sugar production still depended on human craft.

An essential component of the operation of these factories was control and surveillance by chemists, who promised to guarantee the efficient production of chemically pure sugar. The introduction of chemical testing, I show, heightened tensions between owners' insistent demands for quantifiable work and their continuing reliance on workers' skill and senses for the process of quantification itself. Chemists and managers tried to design procedures and machines to eliminate the need for skilled labor in sugar-making—yet at crucial points, these factories continued to depend on artisans' knowledge.

Turning the factory into a laboratory-like space meant trying to isolate it from the agricultural hinterland. The environments where cane was grown were, in contrast to their previous integration with the plantation mill, now considered a source of uncleanliness, ambiguity, and even dishonesty on the part of farmers. That feeling was mutual. Growers and millworkers alike came to distrust chemists and their instruments, the supposedly objective arbiters of purity and value. The meanings of purity emerged as the terrain on which struggles over economic and social power were fought. When factories began, in the early twentieth century, to rewrite their contracts with cane farmers in terms of sucrose content rather than weight of cane, growers turned to the state to legislate proper scientific practice both inside the factory and in the cane field.

This chapter drew on a wide range of sources, including published handbooks for chemical practice in sugar factories, trade journals, and records of factories themselves in Puerto Rican archives. There, chemists documented their concerns about devious workers and exhorted one another to maintain strict discipline in sampling intermediate factory products. In doing so, their own words reveal how discrete points in the otherwise continuous production process for pure sugar allowed, and indeed required, the perseverance of multisensory knowledge and tactile intelligence, yet I show that chemists, too, had to work hard to make sugar into sucrose. The irony is that the more persuasively chemists described the factory as laboratory and as machine, and the more they established the chemical nature

of pure sugar, the more they rendered their own hard work invisible alongside that of the factory's artisans.

It was impossible, however, to think about this Caribbean transformation without also thinking about the machines that made it possible. In the nineteenth century, 80 percent of the world's sugar-making machines were built in Glasgow, Scotland, by engineering workshops that specialized in this market. Thus, in my second core chapter, I turn to these engineers and machines, whose own labor histories have until now been totally ignored. Understanding Glasgow's place in the Atlantic sugar economy is important to seeing how long-distance networks of capital can structure the relationships among workers, technology, and expertise.

Glasgow firms faced novel challenges for both the design of their products and the transoceanic management of information over great distances of time and space. Special expertise was required to design and maintain mills, evaporators, and centrifuges that could survive many decades in taxing environments. As a result, these companies built decades-long relationships with sugar plantations and central factories abroad, sending specially trained draftsmen and engineers for consultations, inspections, and follow-up visits. The knowledge acquired from these journeys, and through communication by the transmission of plans and designs, helped Glasgow's firms track their creations for decades, through changes of owners, plantations, and islands.

In the Caribbean, these new machines and new techniques of sugar production let sugar factories attempt to apply an ideal of consistency, interchangeability, and chemical purity that was linked to efforts to de-skill craft labor. However, Glasgow firms continued to rely on customary and craft methods of design and construction, and on cooperative models of engineering work, well into the 1940s. As the market for sugar itself became standardized, in other words, the building of sugar machines remained a personal business.

This chapter drew primarily on the archives of these sugar engineering firms, held at the University of Glasgow Archives Centre, which include job books, order books, and other forms of accounting and recordkeeping, as well as thousands of plans and diagrams. In narrating the relationships between human users and machines that could last several lifetimes, forms of recordkeeping themselves play a crucial role. As this chapter shows, only the persistence of custom, craft, and ingenuity in Glasgow's machinery workshops allowed chemists to implement chemical discipline and standardization elsewhere within the sugar economy.

The third and final of the core chapters explores corruption in the sugar trade in New York City during the last quarter of the

nineteenth century, when the tariff on imported sugar was the single biggest source of the federal government's revenue. The largest issues of political economy—empire, corruption, and monopoly power—swung on material conflicts about what sugar was and how it should be measured. In particular, this chapter reframes the origins of the notoriously powerful cartel known as the Sugar Trust, which held sway over American tariff and foreign policy for decades.

With so much lucre at stake, refiners, chemists, officials, and irate members of the public contested the ways sugar would be valued in the nation's customs houses. Economic historians have long considered the formation of this monopoly to be a textbook case of consolidation in a highly competitive market for an interchangeable good. But here, as elsewhere, not all sugar was the same. This chapter shows that late-nineteenth-century Americans saw the trust's power as directly linked to its control over the material means of determining sugar's value.

Confronted with charges of widespread customs fraud in the late 1870s, the Treasury abandoned the evaluation of sugar based on color, and chose instead to rely on the chemical testing of imports. The largest refiners, in particular, argued that such tests would weaken the power of corrupt customs samplers and appraisers. However, the Treasury soon discovered that chemists themselves were just as easy to manipulate and harder to hold to account, and tens of millions of dollars were siphoned from federal coffers. Many observers recognized, though, that these manipulations mattered even more for the shape of the sugar market as a whole. By influencing customs chemists to raise their competitors' tariff burden, even by fractions of a cent per pound, the most powerful refiners could entirely wipe out their rivals' profits and compel them to join the cartel that became the Sugar Trust.

This chapter also sheds new light on the complexity of corruption itself in the Gilded Age. Corruption is easy to see when, for example, transcontinental railroads bribe legislators to write and rewrite laws on their behalf, as Richard White has recently documented.[21] However, Americans confronted a murkier situation when they tried to identify corruption in the allegedly scientific valuation of commodities, because it was impossible for non-experts to point to exactly how and where improper assessment had taken place.

Initially, this dissertation proposed to question one crucial element of the process of standardization and distancing that we call "commodification": namely, the erasure of information about the place and people of a commodity's origin. Such an erasure seemed an important component of canonical accounts, such as that in William Cronon's

21. White, *Railroaded*.

Nature's Metropolis, of how nature is transformed into market goods. What I planned to show was that sugar became a commodity by its subjection to the standardizing power of laboratory science and the reduction of its economic value to the measurement of a chemical property. In this way, sugar seemed more paradigmatic than peculiar; in other words, oil, ore, natural gas, rare earths, and other twentieth- and twenty-first-century commodities are more like sugar in 1930 than like wheat in 1850. However, as I researched and wrote, *Inventing Purity* came to pose a more fundamental critique. The enormous diversity of products lumped under the name "sugar," circulating within something called the "sugar market," should make us wonder in what sense we can ever say that sugar has been standardized, or that nature has been commodified.

The question that needs answering is thus not "How was nature commodified?" but rather "How do people come to accept the claim that billions of distinct natural objects are the same?" This similitude is rarely an analytic fact, retrospectively arrived at by scholarship. Instead, it is at least as much a product of the economic, political, and social powers of modern capitalism as is the allegedly material fact of commodification itself. The claim of commodification is always an interested one, laden with motive. As historians, therefore, we should look to critically assess its origins, who advocated for it, and who benefited from it. In addition, we should be careful not to accept it as both the start and end points of our analyses, from which we work backward to explain how it came to be. Social, cultural, and environmental histories of capitalism that wonder "how nature was turned into commodities" presuppose the existence of the order they attempt to explain.

Foodstuffs spoil; metals are heavy and expensive to move; people resist. Such objects are valuable precisely because they deviate from the ideal of a perfect commodity, abstracted from the means of its production. Those deviations give shape to markets. The ways in which units of a commodity differ are what structure the world built around that commodity, whether cotton, tobacco, wool, iron, coal, tea, grain, meat, sugar, or human labor.

From Marx to Cronon, scholars have shown how commodification of all kinds depends on systems for turning a "first nature" of plants, animals, minerals, and human beings—enslaved through much of the nineteenth century, then legally free—into a "second nature" that traffics in market abstractions. In each case, the question confronting states or economic institutions like Chicago's Board of Trade was, as Cronon put it, "how to impose artificial boundaries on the world of 'natural'" substances.[22] This conversion not only requires

22. Cronon, *Nature's Metropolis*, 133–134.

the deployment of heavy machinery, but also depends on distant individuals achieving working consensus on what the valuable properties of those pieces of nature should be, and how they should be measured. That consensus, however, was achieved neither by fiat nor by the victory of rationality, but rather by the conquest of certain ways of thinking by others more closely tied to political power.

Although they emphasize the artifice of grades or qualities, historians have rarely questioned contemporaries' claims that the boundaries between them could, eventually, be found and policed. When writing of "fraud," "adulteration," or "honest grading," we must beware whose metrology we inhabit. Patrolling such borders is never merely a matter of finding sufficiently upstanding policemen, nor is it enough for historians merely to note that qualities used to value commodities, such as plumpness or fuzziness, are inherently subjective. As science studies has long shown, there is no "objective" way to subdivide and measure nature.

Factory chemists promised their employers that instruments could guarantee purity and quality, freeing them from the tyranny of artisan knowledge, which they denigrated and discredited yet tried desperately to capture. The same instruments gave hope to revenue officials that they could circumvent frauds in the collection of sugar tariff, yet equally opened further opportunities for mischievous merchants to plunder the Treasury. By writing histories of commodification that emphasize how systems transform nature into goods, historians neglect the pivotal role of intermediaries who made empires of commodities seem possible. Thus, even as their narratives help decompose the process of commodification, they nonetheless ensure that structures and institutions of commodification appear stable and automatic.

There is never a point at which harvests or herds sublimate into interchangeable commodities, however, because commodification is not a transformation that can be mechanized or automated. Rather, it is a continuous and continual process, in which privileged valuers must constantly reaffirm that idiosyncratic natural specimens are fundamentally the same. The fact that modern systems for creating and transporting commodities seem to operate so smoothly is not a cause, but rather a consequence, of economic, social, and ultimately political choices about how to value nature. The efficiency of those systems does not indicate that human judgment has been either automated or obviated. Instead, it should invite us to look ever more closely for how such consensus was won.

In the sociologist Harry Collins's famous analogy, standards are like ships in bottles. They are obviously human creations whose power comes from seeming to have always existed. *Inventing Purity*

suggests that we think of commodities in the same way, especially those as apparently natural as pure sugar.

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