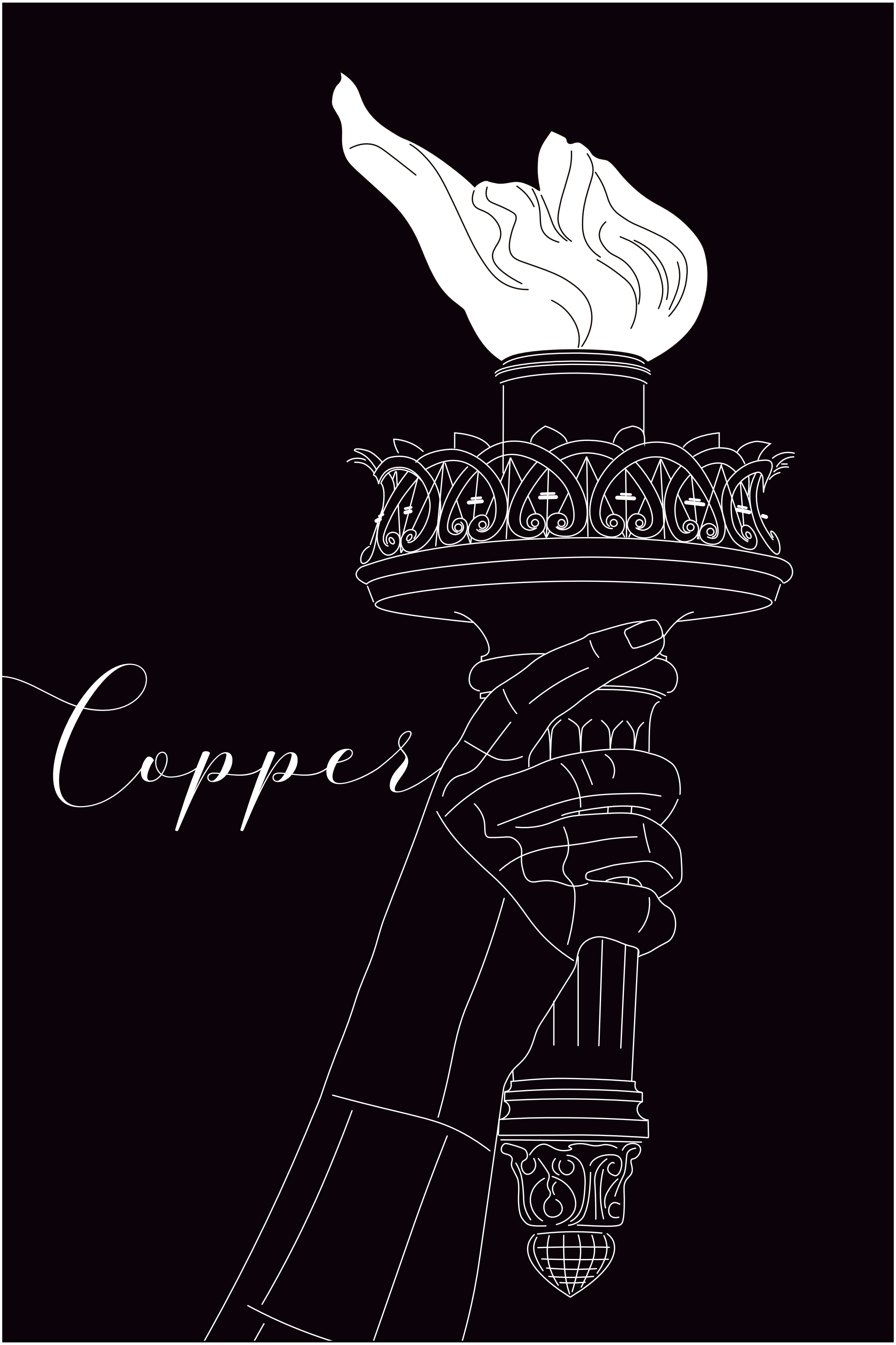
Copper

Material Intelligence

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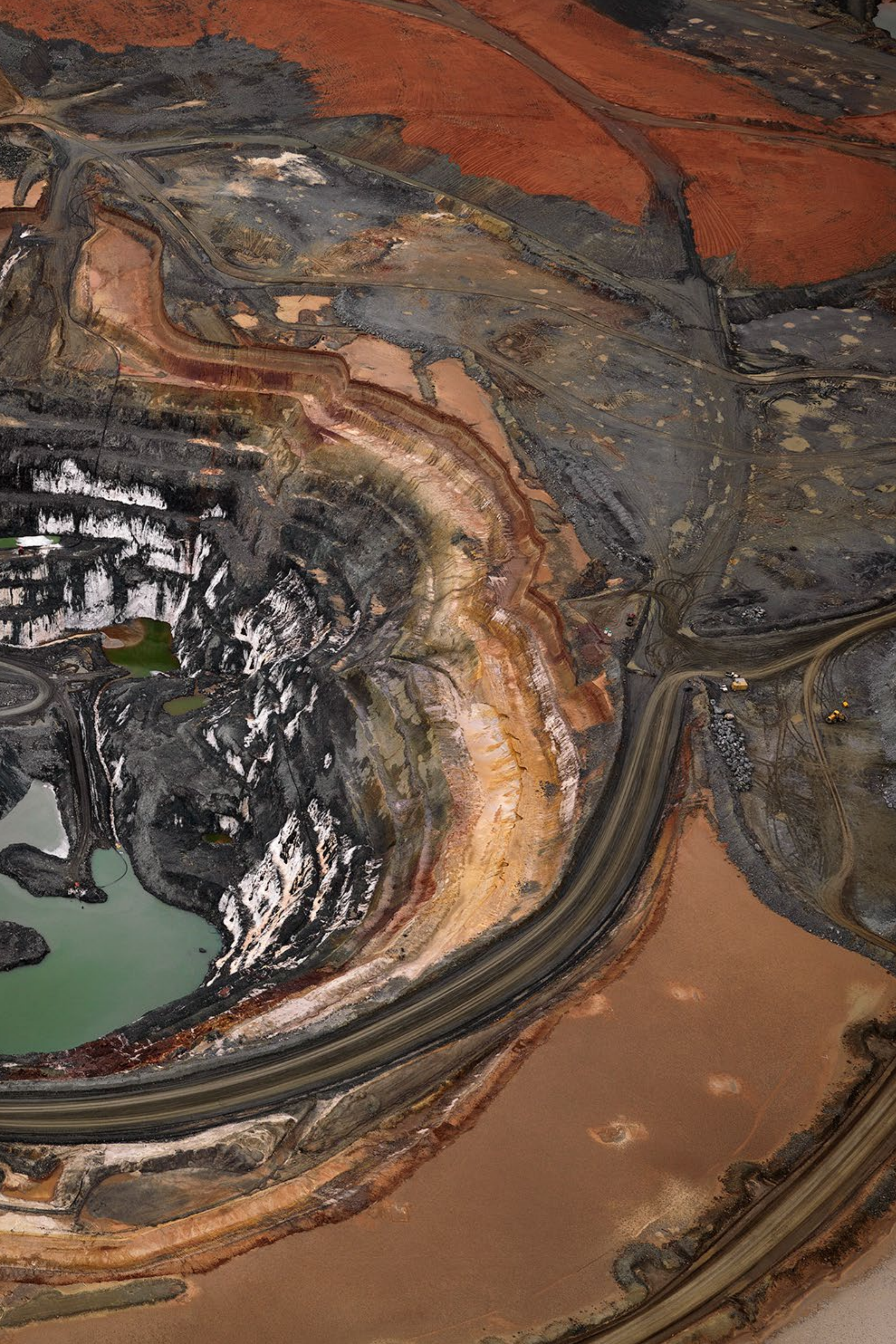
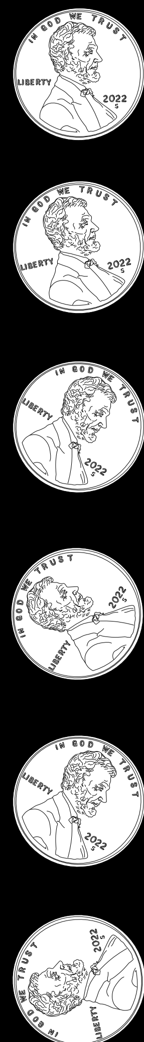
Contents




LIBERTY
1964

When you came, you said to me:
“I will give fine quality copper ingots.”
You left, but you did not do what you promised me.
You put ingots which were not good
before my messenger and said:
“If you want to take them, take them;
if you do not want to take them, go away!”
What do you take me for
that you treat me with such contempt?

From the Babylonian ‘complaint tablet to Ea-Nasir,’ written in cuneiform, ca. 1750 BCE. It has been called the oldest customer service complaint in history.



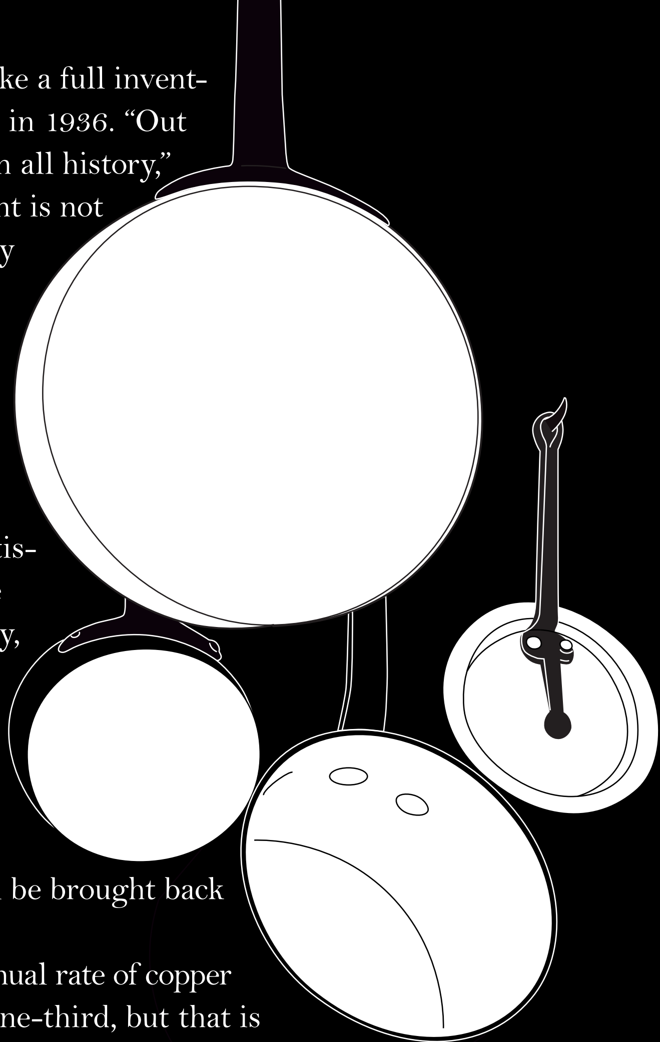
Find a penny, pick it up,
all the day you'll have good luck.

But what exactly will you have in your hand? The seemingly obvious answer is copper—simple, but almost entirely wrong. An American cent is only 2.5% copper, just a thin plating on the exterior. The core is made of zinc, because it's so much cheaper, about one-fifth the price. It's been like that since 1982. The coins were reformulated to reflect the rising cost of copper, driven by the demand in the electronics industry (it's the most electrically conductive metal, apart from silver, and nowadays about 70% of global copper use is for wiring). In 2023, the penny will be phased out entirely, with the last batch minted on April Fools' Day. Yes, these days, metal is just too valuable to make money out of it.

If it makes you feel any better, pennies were actually never made from pure copper. Mainly, they have been composed of a bronze alloy, which includes small quantities (about 5% total) of tin and zinc. Though it's not strictly legal to do so—this is government-backed currency, after all—you can actually take a fistful of these old coins and beat them into *mokume gane* ("woodgrain metal") with whorled, contrasting patterns. It won't be a very good version of the technique, mind you, because of the low percentage of copper. Better to use quarters—which are mostly copper, 8% nickel—or, much better still, do it the way that master Japanese smiths do it, meticulously stacking thin sheets of copper, silver, and gold into a billet, then heated as it's worked to create a new alloy between the various materials, binding them together.

In 1943, there was even a brief moment when pennies were made of zinc-coated steel with no copper at all. This was a bit of a disaster, materially speaking—the zinc oxidized to a dull grey, and when the plating wore away it exposed the underlying steel to rust. But it did save on copper, which was needed for the war effort: in radios and other equipment, and to make gun cartridges out of brass, an alloy mostly of copper blended with zinc. More recently, copper-based World War II metals have been in the news. With the ongoing increase in copper's value, Japanese vessels sunk in the Pacific have become targets for unlicensed salvagers who are intent on reclaiming copper pipes and brass propeller blades. Diving for 75-year-old metal scrap is just one, admittedly ambitious, example of the way that copper circulates. This is possible because, like aluminum and steel, it is infinitely recyclable. It suffers no loss of its ductility, conductivity of heat and electricity, resistance to corrosion, and other physical properties when it is melted or reshaped.

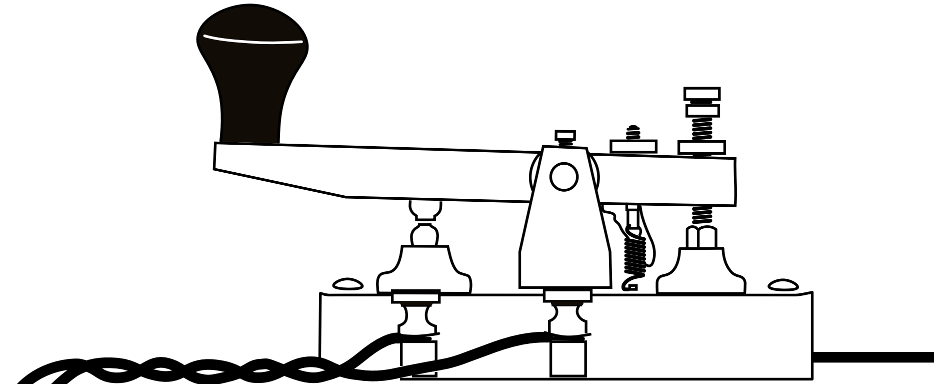
The visionary polymath Buckminster Fuller was fascinated by this universal exchangeability of copper, and went so far as to make a full inventory of the world's supply in 1936. "Out of all the copper mined in all history," he wrote, "only 14 percent is not at present in an averagely recirculating 22-year cycle of use … within decades, as much as 98% of all the copper that has been mined by all man will be in constant recirculation" Those statistics don't bear very close inspection, but amazingly, Fuller did predict the salvaging of "munitions ships at the bottom of the ocean. We know where all that copper is, and in due course, it will be brought back into use."

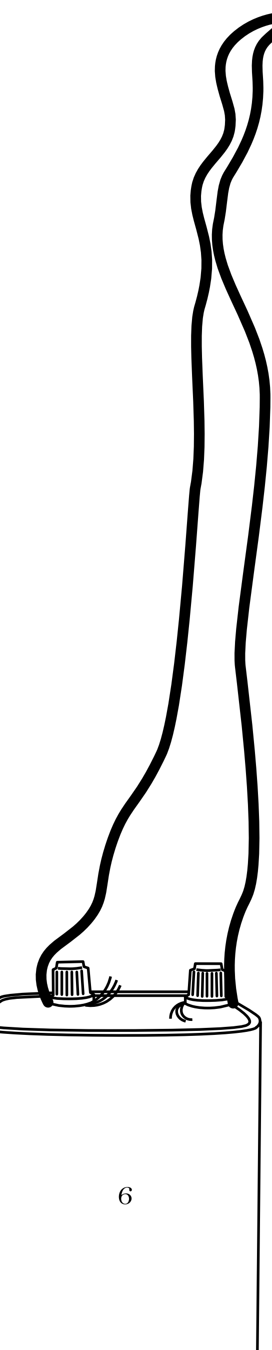


In fact, the current annual rate of copper recycling is only about one-third, but that is the highest rate for any metal. It would be even higher but for the difficulty of separating the metal from plastics, notably the PVC used to insulate wire. This gets us to the heart of the matter: copper is the ultimate chameleon, useful in its own right, but far more so when put into combination with other materials. Unless you happen to be an electrician, or own a lot of expensive copper pots and pans (highly responsive to changes in heat, thanks to the metal's high conductivity), you probably have very little experience with the metal in its pure form. It is almost always encountered in combination with other substances. This points to a key aspect of material intelligence: an appreciation for the inherently fluid and multivalent nature of substances, even

one as fundamental an element that appears as number 24 on the periodic table.

The story of copper's mutability is as old as technology itself. The nineteenth-century Danish curator Christian Jürgensen Thomsen coined the term "Bronze Age," the earliest copper alloy and a material that marked a critical shift in human development—supplanting rudimentary stone tools, but not yet arriving at the harder tools (and more destructive weapons) of the succeeding Iron Age. From that ancient time to the present day, copper alloys have remained at





the forefront of innovation. Bronze and brass between them dominate the artistic and technical history of metals, having been used for everything from astrolabes to zoomorphic sculptures.

Bronze medal winners at the Olympics do actually receive an object made of cast bronze (95% copper, 5% zinc), using modern techniques of casting and etching. For the Tokyo Olympics in 2020, all the metal needed (the silver, and gold, too) was reclaimed from used electronics donated by the public. Copper also plays a key role in the production of brass musical instruments. The timbre of the instruments in an orchestra's brass section depends on the alloy used, with more zinc resulting in a brighter but less expansive tone. ("Yellow brass" is a 70/30 blend of copper and zinc, while "Gold Brass" is 85/15.) Wynton Marsalis' trumpets are made by a company called Monette in Portland, Oregon, whose horns are considered the best in the business. Staffed entirely by trumpet players, they put together four feet of straight and flared brass tubing—about 150 parts total—into each of their handmade instruments. Marsalis gets a new one of these copper-based horns about once a year, each an incremental improvement on an ever-evolving design.

A little-known but crucial aspect of the metal's history has to do with the introduction of copper sheathing to oceangoing vessels in the 1780s. This marginally increased a vessel's speed and maneuverability, but more importantly, doubled its years of useful service by protecting against rot and infestation. Chillingly, this sheathing contributed substantially to the expansion of the Atlantic slave trade, as it meant greater returns on investment. Like the concurrent development of the cotton gin, this was a technical innovation that inadvertently led to untold human suffering.

Sometimes copper's role in an alloy is minimal, but nevertheless essential. Pewter, which is mainly tin with a small admixture of copper (typically 1–2%, to harden the alloy), was first developed in ancient Egypt. Due to its low melting point it could be readily cast in molds, and it was also cheap—the two factors together making it the only rival to ceramics and wood for inexpensive tableware throughout European history, all the way until the synthesis of plastics. An even less expensive option was "ley" or "lay" metal, a softer and cheaper alloy that had too high a lead content (15% or more) to eat or drink from. In 1844, the pioneering political economist Andrew Ure warned his readers that "the tendency of the covetous pewterer is always to put in as much of the cheap metal as is compatible with the appearance of his metal in the market"—so they had best watch out for lead-rich flasks of vinegar and wine!

Copper even played a role historically in the production of the finer metals. For example, early modern consumers in Europe aspired to own objects and accoutrements made of sterling silver, which includes a small quantity of copper (7.5% or so) to harden the metal, or the slightly less expensive but visually alluring alloy known as *Paktong*, a Cantonese word that literally means "white copper." This traditional Chinese alloy was composed of about two-thirds copper and one-third nickel, sometimes also including zinc. Both durable and tarnish resistant, it found widespread use in household wares such as candlesticks, furniture hardware, and fireplace fenders. *Paktong* made a passable substitute for silver, and rather like true porcelain it remained something of a mystery material in Europe, as nickel itself was not identified as a distinct metal until 1751. That metal got its name from German miners, who believed that a mischievous sprite or *Nick* had interfered with what appeared to be copper ore, ruining its usual properties.

In 1905, the International Nickel Company smelted a natural ore in the Sudbury Basin in Canada that was the material inverse of *Paktong*, about 67% nickel and the rest mostly copper. Immodestly, the company president Ambrose Monell named it after himself, proclaiming the discovery of the wonder-metal Monel®, "Modern as Tomorrow." As design historian Ana Lopez comments, "it may have been just that, had it not been for the rising price of nickel," for it could be machined, forged, spun, cast, brazed, stamped, or welded, without losing its silvery appearance. After a brief heyday being used in architectural metalwork—including by the blacksmith luminary of the age, Samuel Yellin—price increases drove this short-lived alloy into obscurity.

While copper alloys like bronze, brass, and cupronickel are a complex and rich subject, they are only one aspect of this elemental metal's story. As hinted above, it is quite rare for copper to appear in nature in a pure form, a state known as "native copper." Instead, it is usually encountered in the form of compounds, most often as an oxide, that is, in combination with oxygen. This is chemically analogous to iron rust, though copper does not corrode physically to the same extent as it oxidizes, instead turning green in color. It may surprise you to know that the Statue of Liberty shone like a new penny when its installation was completed in 1886. Fifteen years later, its copper skin (31 tons of it, only 3/32" thick) was already acquiring the protective patina called "verdigris" that it bears today.

The role of copper in pigment production deserves attention as well. If not for naturally-occurring copper compounds, humans throughout most of our history would have had few options to introduce bright shades of blue and green to our material culture. A phosphate of copper and aluminum is present in turquoise, an important decorative stone in the ancient Americas, and a material also used as a pigment in paint. Azurite and malachite, both forms of copper carbonate, likewise were ground into pigments for painting. The blue skies and gowns in many Renaissance paintings, for example, were painted with azurite.

Copper oxide also is a critical colorant in glass—used to make a ruby red—and in pottery glazes. If fired in a standard environment, it produces a green color but amazingly, turns bright red when reduction-fired (that is, with oxygen choked out of the kiln atmosphere, traditionally by burning wet straw or some other organic material in the kiln). This is how the Chinese produced the legendary "oxblood" or *sang de boeuf* glaze—first achieved in the Ming dynasty for high-prestige ceremonial wares, and later perfected in the imperial kilns of Jingdezhen, under the supervision of Lang Tingji (hence its Chinese name *Langyao Hong* "Lang kiln red"). Western potters worked long and hard to duplicate this stunning copper-based red glaze; among them was Hugh Robertson, who has been called America's first art potter. Obsessed by his "struggle to master the Blood," Robertson ended up bankrupting his business for a time, but was successful in creating extraordinary red copper glazes, sometimes gorgeously streaked with green when the kiln was only partially in reduction.

Copper's beauty and serviceability comes at a cost. Like so many crucial materials, its extraction and processing takes a toll both on the environment and on people. Fatal accidents litter its history—the worst in the USA was the Speculator Mine disaster of 1917, when 168 Montana copper miners were killed while working at full tilt in response to war demand. More recently, in 2010, the world was riveted by the awful drama unfolding at Copiapó in Chile where thirty-three men at a copper and gold mine, were trapped 2,300 feet underground. In this case there was a happy ending, as the miners were brought up alive after sixty-nine days of being buried alive.

Such incidents parallel another troubling aspect of copper's story, the constantly ongoing ecological impact of its production. While the metal is not toxic in itself—our body actually needs small amounts of it to stay healthy—all stages of its production cycle are harmful to the ecosystem. The worst of these is the smelting process, which consumes fuel and produces sulfuric dioxide vapor, which downwind turns into acid rain. We've applied increasingly sophisticated scientific techniques to copper, at increasingly large scale, without fully reckoning with the consequences.

If our collective material intelligence over the millennia has gotten the human race into dire circumstances, material intelligence is also helping to get us out. Innovative research into copper alloys has become a growth industry in its own right. Inexpensive lead-free 'Ecobrass' has been developed for plumbing fixtures to safely deliver drinking water. Alloy C360, also known as "free-cutting brass," is now a common material used for machining, and it is both produced and recycled in a closed loop system without the admixture of other contaminating metals. Finally, the technique of bioleaching—using microorganisms to draw pure copper out of mined ore—has become increasingly common at the beginning of many forms of industrial copper production as a way to avoid smelting. A similar process is even being explored as an eco-friendly way to coax the metal out of used electronics.

In some ways, these new frontiers may have come as no surprise to a Bronze Age metallurgist. Copper has always been a shapeshifter, transforming itself constantly through interaction with other materials. A penny might not seem like much, especially when you learn that its coppery hue is only skin deep. But next time you hold one in your palm, perhaps before tossing it aside for another lucky soul to find, consider this: the metal on its surface was forged in the heart of a star, somewhere out in the universe. That copper has been circulating constantly ever since, though the cosmos, the earth's crust, and now our economy, and it will keep on moving for millennia to come. The 1936 song had it right. Pennies are, quite literally, from heaven.

Glenn Adamson

The conductor

Jaime Lopez
Cornelius Skeahan
Paul Vance
Co-edited by Barrie Cline

Imagine you are outside in a blizzard, trying to manipulate a piece of thick but very cold copper wire. It feels like shaping rock into a form other than that it was given. You struggle with the cable to get it to do what you want, trying your best to act with precision. One mistake in your splice can later lead to disastrous consequences.

Copper, at room temperature, has astounding malleability. The wire can be cut, bent, chopped, twisted and shaped, to run throughout a building wherever power is needed. But if it is too thin a gauge, or—in the case of high voltage work, has an air gap beneath the wrapped insulation—the heat will elevate, and an explosion may result. It must be visually inspected constantly throughout the process, and closely monitored for heat levels. If it is humming, the system may need proper grounding. You must listen carefully to how wire communicates to you.

Electricians are the neurologists of the construction industry. Our goal is to make the safest, most efficient, and precise network of connections possible. If done right, the building's occupants barely know what is happening. Akin to the human nervous system, symmetrical streams of conduit flow in and out of buildings, parks, running through streets and subways. Although silver is the best current conductor for this flow, precious metals are far too expensive. Copper, on the other hand, has an ideal combination of cost and conductivity, making it an excellent metal for moving both high and low voltages through a number of different raceways. It has a high heat threshold, and creates its own natural layers of protection from corrosion. Copper is durable, and with proper insulation, can survive extreme conditions of weather intact.

In the highly specialized and treacherous operation of high voltage splicing, teams of electricians must marshal all of their training with this material and deploy it with the utmost care. Were the general public to peek down into a manhole on the street, they would see an elaborate labyrinth of insulating cable outlining the perimeter of the vault. The arrangement might seem haphazard, but the union-trained professional can read the installation like a detective reading a crime scene. For this electrician, each layered cable stitches together a story of the past, suggesting clues as to how to retrofit and adapt them for future use. The safety and efficiency of the system depends on the excellence of its design and installation.

The unseen workmanship of high-voltage splicing entails many discrete maneuvers. First, the cables are wrestled into position, so that they rest smoothly on the shelves in the vault to protect the layers of insulation around the copper. The cable is cut precisely with powerful hydraulic tools. With the precision of a surgeon, the splicer uses a curved knife to score the outer layer, peeling back the insulation and the semiconductor layer. Then, the electrician cuts through the conductor itself—a compacted strand of copper. To make a joint, connecting tubes are slid over the cables to be connected, ensuring there is no space separating the two ends of the copper strand. A crimper, carefully deployed, connects the compacted copper wires together. If this is not done consistently, a buildup of heat will eventually break down the copper's insulation, leading to an explosion. Electricians therefore carefully inspect each crimp, both visually and by feel.

There are many more steps to the process, none of them performed without care, or indeed alone, as each splicer team requires at least two people. The communication between electricians working together—spoken and unspoken—can be the difference between life and death.

When the job is done, the current—the electrons in the copper wire moving in the same direction from the power source through the grid—can flow. This is the transmission of civilization itself, and we are union electricians, shepherding it safely to you.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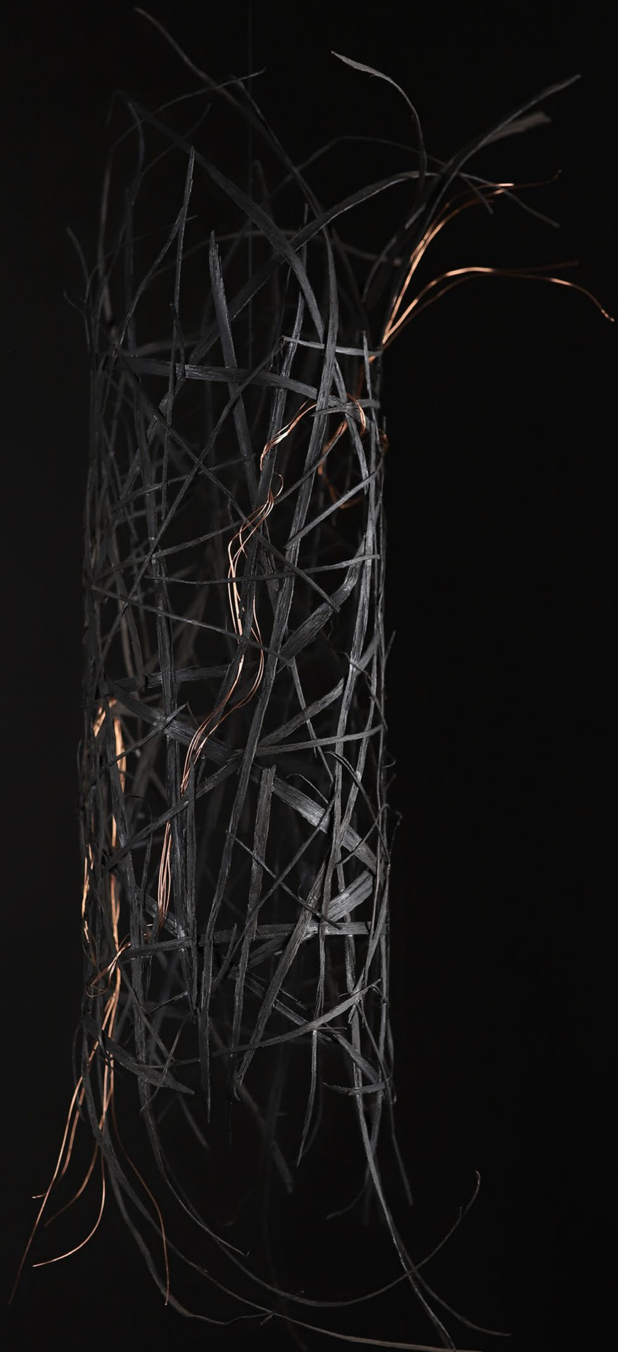

Copper culture

Edward S. Cooke, Jr.

Copper is the most common and extensively used nonferrous base metal, a reddish ore found in veins on the surface of the earth or in easily excavated deposits. Among its many strengths are its malleability—it does not need to be reheated constantly while shaping it—and its workability. It can be raised with a hammer, bent into shape and brazed along a seam, or spun on a lathe. And copper can be combined with a range of other metals to make a variety of alloys, metals blended in the molten state, that possesses different strengths and advantages for use.

Until recently, copper was also inexpensive, the least costly of the base metals. Its place in the hierarchy of metals is clearly seen in its use for the lowest denomination coins, like the American penny.

Despite its cheapness (in some ways, because of it), copper's versatility has made it a highly valued material. In South Asia, for example, metallurgical skill is deeply rooted. Craftspeople have worked copper and its alloys with great skill over thousands of years. We shouldn't assume that artisans there have preserved traditions and techniques from centuries ago, but watching them at work does give insight into the continued intensive use of tools and hand skills.

In Tambat Ali (Copper Alley) in the city of Pune, the constant din of hammering is heard. The objects made there are mostly spun on a lathe against a wooden chuck, an industrial process, rather than raised on a stake. But artisans will then provide a hammered surface or chase the metal to produce embossed designs.

This work is done seated, with very little equipment. The maker sits on a low platform or cushion, about five or six inches off the ground. Either a short vertical steel stake set into a low stump or a long horizontal stake running underneath the cushion provides a polished working surface between the artisan's legs. The maker moves the workpiece against the stake with one hand, hammers with the other, often using a foot to steady the work. In effect, the work is taking place right in the artisan's lap.

The advantages of this are several. The artisan can move metal with precision, resting elbow on hip bone, ensuring the weight of the hammer (not muscle power) provides the force. The maker's foot helps steady the work piece and, feeling vibration, can provide helpful biomechanical feedback. Sight, sound, and feel are interconnected. When British visitors to India in the 18th century saw people working on the ground in this way, they considered it inferior—these people were not "civilized" enough to stand at a bench. They did not understand that it's just a different, in some ways superior, set of efficiencies.

Copper's color and affordability also accounts for the metal's fashionability during the Anglo-American Arts and Crafts period of the late 19th and early 20th centuries. It fit perfectly into the vernacular aesthetics of the period, an era known for the predominance of brown and green. Its soft earthy tone, not shiny like silver, was right at home alongside fumed oak, natural dyes, and matte ceramic glazes.

With the period's focus on product and process, many people wanted to learn metalsmithing outside of a professional apprenticeship system, in amateur classes or in schools and colleges. Due to its expense, silver was not an option for instruction outside the trade. If a student made a mistake, the waste could be melted down, but there would still be considerable loss. Copper was far more affordable—it was exactly during this time that mines in Arizona and several other Western states began to produce great quantities of the metal. Copper also shared many physical properties with silver—it could be hammered, engraved, pierced, chased, sawn, and soldered. In 1906 Augustus Rose, an instructor at the Rhode Island School of Design, wrote an instructional book, *Copper Work*, which provided many exercises for sheet copper of various gauges with detailed lists of needed tools and clear steps for the processes.

In more recent decades the economy of copper has shifted. This may be surprising, given the speed and efficiency of copper production today, as compared to past centuries. The extraction of the pure metal from the ore, once done in coal- or wood-fired bloomeries, is now accomplished using chemicals and industrial rollers. This has meant a major transformation for makers, who once had to hammer out billet or ingot copper, and now have uniform sheets that they can lay out, use shears to cut, and then shape. Yet, market

forces have also undermined copper craftwork. The Arts and Crafts philosophy about vernacular metal has waned, replaced by a preference among individual smiths for shiny metals such as chrome-plated and stainless-steel wares.

Meanwhile, despite technological developments in processing, the cost of the metal has risen exorbitantly as copper has become increasingly in demand for the building industry (copper piping, wiring, electrical wiring, flashing, gutters, and downspouts), and for electronic equipment (wires, circuit boards, etc.). People are breaking into uninhabited homes to rip out copper pipes and wiring. Younger sons of South Asian artisans working with copper or copper alloys cannot purchase metal at a cost that ensures a profit and are leaving their familial traditions and pursuing different occupations. And in schools and craft workshops, there is little evidence of copper as an entry point into metalworking. Instead the focus has shifted to jewelry.

When we think about material intelligence, it's important to keep these matters of economy in mind, and consider fluctuations across time. Never think of a material—copper or anything else—only in the present tense.

Good copper

Kawther Alsaffar

In 2015 I was in the middle of my Master's studies at The Royal College of Art. Days before I was due to fly to Kuwait for the holidays I was given a prompt: to make products that revolved around musical resonance. The idea connected, for me, with the word Saffar—my ancestors' trade. The colloquial translation is "good copper." The Alsaffafeer were tinkerers who made and mended pots and pans, on a wage that relegated them to poverty.

I visited Souq Alsaffafeer in Kuwait to reinvest in this long-neglected craft. What I found was a shanty town mainly dedicated to tanak, simple objects from folded sheet metal. There were little reminders of the past everywhere: admiralty anchor replicas, badly wrought iron nails, a spray-painted date of 1957 on the chinko (folded sheet aluminum) ceilings. I went around the workshops, asking for someone from the Alsaffar family, and found only one man by that name, Ahmed Alsaffar, whose work was in tin plating Dallahs, brass coffee pots. But he and the other workers met me with hostility and suspicion. I was not welcome here.

Why did I care? And why should they? My interest didn't make sense to them. After a good deal of pleading, a craftsman named Ghandi and his assistant agreed to sink some circular brass and copper sheets to my design specifications. They quickly jury-rigged their own tools: metal pipes, blunt hammers, butane torches and car acid for the pickle. A few days later I came back to collect the small shallow plates they had made. They were nothing special, but we were inventing our own methodology, and they were certainly unique. When I asked how much money they wanted, they exchanged confused glances, then asked for 10KWD (about thirty US dollars) per piece. I gave them what they asked for, happily. The discomfort dropped from their faces. The exchange now made sense. I wasn't there to exploit them, as they must have assumed.

I set up my own makeshift workshop in my backyard and spent over a month, hammering and annealing, hammering and annealing. I recorded the sounds. The process was indeed deeply resonant; the material wanted to be heard. It told me when it was too brittle, when it was getting too thin, and how to hammer in rhythm to make my pattern concentric and even.

But I could only understand Kuwait's craft culture through the work of the Alsaffafeer. Beginning in 2016, I created new designs blending traditional and new technology, applying an engraved concentric grid on the sheets of copper, to aid

in the methodical hammering. I made improvised wooden molds, and spent months making copper and aluminum pieces with the craftsmen in Souq Alsaffafeer. The bottom line for them was profit, but I was showing up daily, and caring deeply. So they did too, in return. It instilled a sense of pride they were sorely due.

There is a stark difference between metalworking in Kuwait and that in neighboring countries, like Iran, where repoussé and inlay techniques are venerated traditions. Crafts in Kuwait are fundamentally utilitarian, and with the influx of oil wealth in the 1950s, came to be associated with poverty. Trades long held by Kuwaitis were now occupied by laborers of other nationalities, who were not treated as social equals. Their work was not considered as design or intellectual property. What permeates much of Kuwaiti society instead is what William Morris called the "false distinction of luxury"—imported commodities and superficial architecture in classical and orientalist styles.

As my relationship to the artisans of the Souq deepened, I explored sand-casting, too. Again I went door-to-door asking for the best craftsmen, and again I was met with resistance at first, then collaboration and understanding. In Kuwait, casting is done with recycled metals and "green" unprocessed sand from Egyt. Through economic necessity, the foundries operate within a circular economy: they use discarded remnant metals from other industries and building demolitions, ironically benefiting from Kuwait's lack of concern with sustainability.

Gradually I established myself at a foundry called Alwafi. I found that when there was too much decorative interference from me as a designer, the objects didn't express their material qualities. The best form of work was in-depth material exploration, with form taking a back seat. A couple of weeks into the experiments, I had a dream that two of the artisans, Mahir and Pentu, were using long ladles to pour two different metals into the mold simultaneously, via separate gates. When I told Mahir about the dream he laughed and said that was impossible, but then we took the risk, and the results were beautiful from the start. I was ecstatic. In my eyes we had just managed to metaphorically turn sand into gold. We spent the next couple of weeks making Dual Bowls, as I called them. The pieces were primitive yet completely exemplified the beauty of raw casting techniques.

The past seven years of my professional life have been predominantly dedicated to sand-casting with the Alwafi foundry. Our methods have been refined by myself and Mahir over the years, with the addition of techniques like cold cutting and halo plating, but the fundamental motivation remains the same.

In May 2020 Mahir passed away while he was with his family in Egypt. I don't think I, or any of the craftsmen in the foundry, have truly recovered. As they say in Kuwait, مكانة خالي. "His place is empty." While we continue to produce to the same high level of production, it is certainly not the same. His level of mastery preceded pure experience, and his charisma, kindness and love for craft meant he was known in every pocket of industrial Kuwait.

Sand-casting, as they practice it in Alwafi, is an art of subtlety. The shift in a gate, the level of moisture, the use of


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recycled or virgin sand can make all the difference to a successful casting, which takes hours to set up. The loss of just one skilled individual in an ever-shrinking industry brings it a significant step closer to demise. These skills are not being passed on to future generations. I can only hope to understand and cherish them fully before they are replaced by more automated methods.

Every year the government threatens to demolish Souq Alsaffafeer, and parts of the surrounding neighborhood. The future potential of this real estate, it seems, is more valuable than its history. I believe that the best way to view craft is through the experiences of artisans of every nationality. This is the true uniqueness of the place, a more authentic form of cultural identity, which acknowledges the ubiquitous cross-pollination of the modern world. Only by shifting this narrative can we allow craft to be adequately supported, and ultimately, to thrive.

Frank Rebajes: The copper king

Christina L. De León

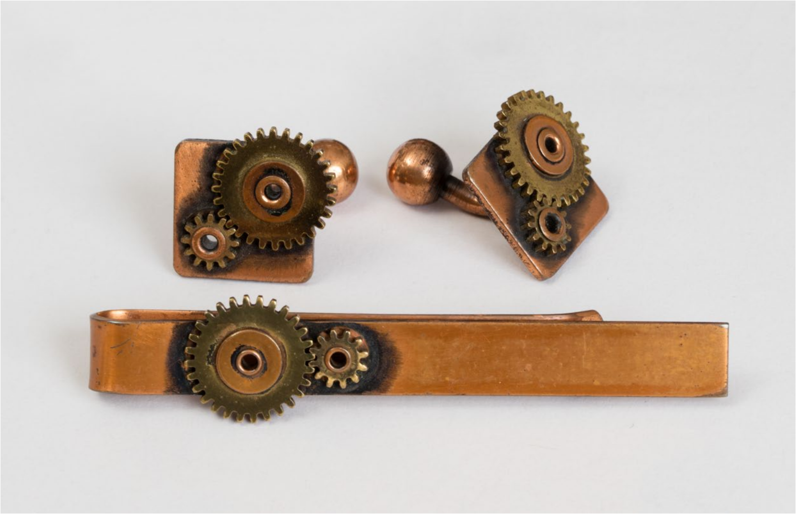
In the mid-twentieth century, Rebajes was one of the most sought-after costume jewelry brands in the United States. The story of its founder is a quintessential rags-to-riches tale. A young immigrant achieved the "American dream" by redefining a humble material, copper, into a coveted fashion accessory.

Francisco Torres set sail for New York from the Dominican Republic as a sixteen-year-old boy, in 1922. In his newly adopted city, he transformed himself into Frank Rebajes, taking his mother's last name, which he believed possessed a unique flair. While clever and quick-witted, money and fame eluded him for years as he worked a variety of jobs to make ends meet.

In 1932 Rebajes married Pauline Schwartz, and in an effort to become financially stable, he began transforming cans and scrap metal into animal-shaped sculptures that he sold at the Washington Square Park Outdoor Festival. His work caught the eye of Juliana Force, the first director of the Whitney Museum of American Art, who purchased his entire inventory for $30. Rebajes used the capital to open a

modest shop in Greenwich Village, and it was there that he started experimenting with copper, often lining it with aluminum to protect the skin from staining.

Rebajes' pieces had a bold sculptural quality that showed his adeptness with the material. This is particularly evident in his brooches representing animals like bulls, lobsters,



rams, and antelopes. In these designs, he manipulated the copper in a variety of ways, hammering, twisting, and folding the metal to create three-dimensional objects, and selectively oxidizing the surface to produce depth and shadows.

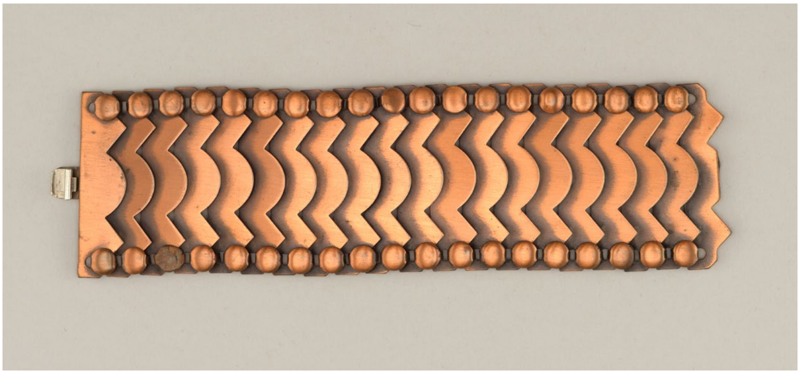
Rebajes was determined to elevate the value of copper. He believed the public should have access to well-designed and affordable objects: earrings, brooches, rings, bracelets, cuff links, necklaces, tie clasps, and eventually decorative home goods. Everything he made sold for less than $10 (about $100 in today's money), a price point calculated to fill a gap in the market. In a 1953 interview, Rebajes said, "There is no other jewelry in Europe like mine. It is either very costly, or ten-cent-store stuff."

It is not difficult to imagine how an articulated bracelet made of highly polished copper would have given its wearer a sense of pizzazz—a fashionable pop of color, without

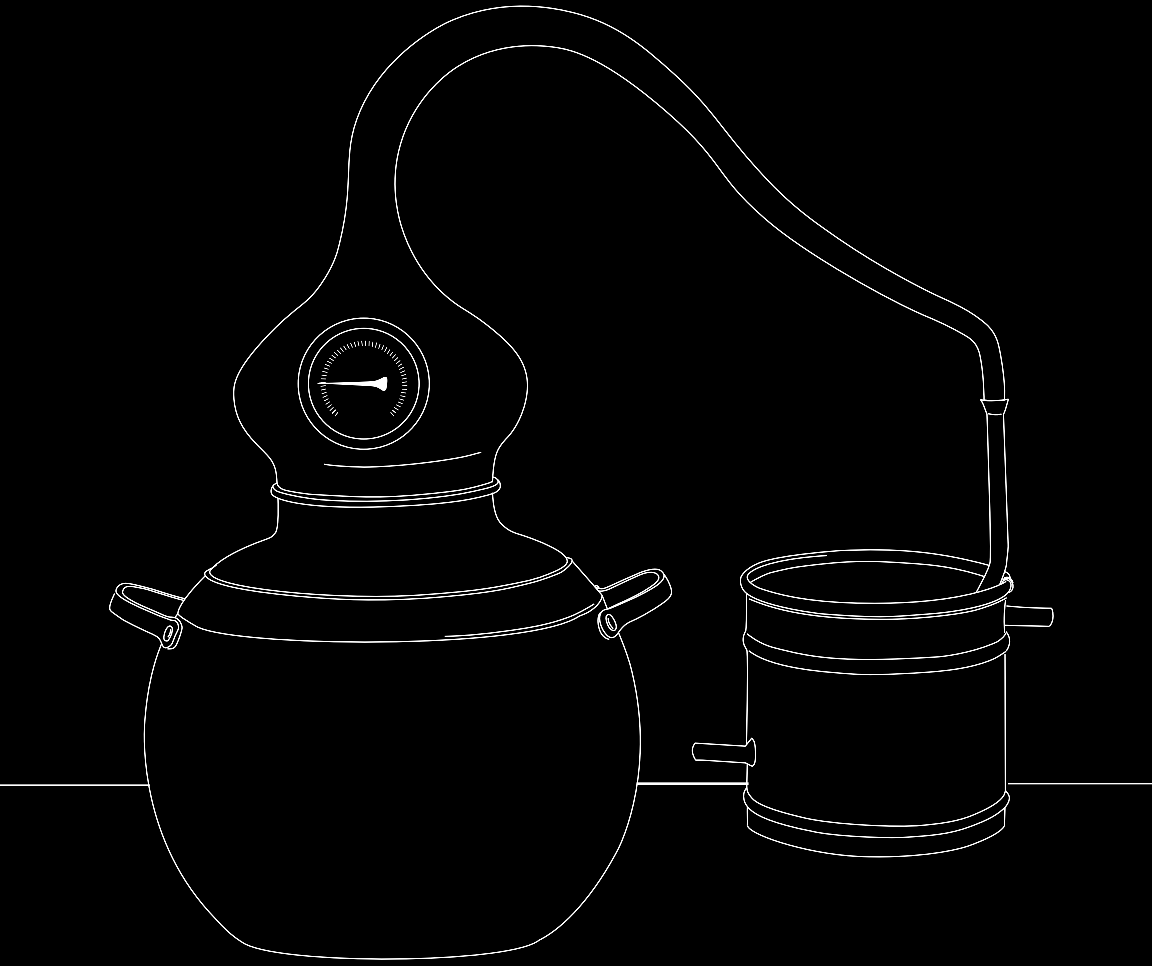
breaking the bank. Even his kitschiest designs, like a cowboy-shaped pin with legs that swing from side to side, were charming and whimsical accessories.

A curious aspect of Rebajes' work, rarely commented on, is the way he used copper to render skin tone. He often employed stereotypes of Asian, Indigenous, and Black people in his designs, such as African women with exaggerated facial features, wearing oversized earrings and stacks of necklaces. His use of copper in this context is reminiscent of the way onyx and other dark stones were used to depict Black women and men in the eighteenth and nineteenth century (oftentimes these figures, too, were meant to be worn as personal adornment). Although Rebajes was from a coastal town in the Dominican Republic, his parents originally hailed from the Spanish island of Mallorca in the Mediterranean. He is known to have had a racially mixed social circle; yet, what do these pieces say about Rebajes' viewpoint on race? Perhaps more importantly, what did it say about the people who purchased them?

Unlike contemporaries such as Sam Kramer, Art Smith, and Margaret de Patta, Rebajes was not an adventurous or experimental designer. He directly catered to the masses. He once said, "The original piece has to be made. What's the difference if we make a million copies? Real artists are interested in money." Despite the success he garnered throughout his lifetime, however Rebajes today remains in the shadows of design history. Could it be that the populist approach that led to his success is what has caused him to be disregarded since? Maybe so, but this misses the most interesting thing



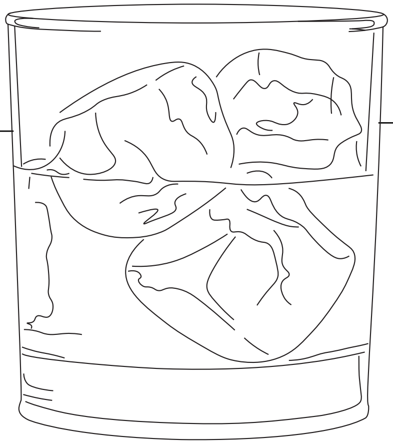
about Rebajes: the way he managed to reflect the social, economic, and cultural milieu of his time using little more than a humble piece of metal. His story yields insights into the everyday reception of mid-century modernism, rather than its elite consumers. With copper, Rebajes proved excellence is not limited to the exclusive.



I looked at the ornaments on the desk.
Everything standard and all copper.
A copper lamp, pen set and pencil tray,
a glass and copper ashtray with a copper
elephant rim, a copper letter opener,
a copper thermos bottle on a copper
tray, copper corners on the blotter holder.
There was a spray of almost copper-
colored sweet peas in a copper vase.

It seemed like a lot of copper.

—Raymond Chandler
The High Window (1942)




The Ortho I.U.D. Collection
FROM
The History Of Contraception Museum
Legend has it that the first such devices were smooth pebbles inserted in the uteri of camels to prevent pregnancy during long desert crossings. The I.U.D's shown above are representative of the various shapes and sizes used around the world since the early 1900's.
AT ORTHO PHARMACEUTICAL (CANADA) LTD. TORONTO ONTARIO
RUBBER

The copper IUD

Carolyn Herrera-Perez

It's a little T-shaped plastic device, with copper collars and wire wrapping around its frame. That added metal may look like an element for electric conduction, but actually it makes the object one of the most potent contraceptive devices ever developed. Medically known as the CuT380A, this intrauterine device (IUD) has been marketed as the Paragard in the United States since its release in 1988. The official name derives from the element (Cu), its overall shape (resembling a letter "T"), and the total area of the device's exposed copper surface (380 square millimeters). Many people with uteruses choose the Paragard for its unique qualities: it is immediately effective upon insertion, lasts as long as ten years, and is entirely hormone-free. Unlike IUDs that use hormones, the CuT380A's active component is the copper itself, which makes it over 99% effective at preventing pregnancy.

For over a century, IUD design haphazardly followed the arc of prevailing material science. In 1909, the first IUD was made of dried silkworm gut, wound into a ring shape. The silk ring caused a reaction that could prevent pregnancy: when any foreign object is inserted into the uterus, the local area counters by causing inflammation. This response makes the uterine environment hostile to sperm and more difficult for an embryo to implant itself in the uterus lining. All IUDs, then and now, create these effects, but local inflammatory reactions alone are not reliable in preventing pregnancy.

In the 1960s, a significant boom in birth control technology brought "the pill" and second-generation IUDs to the market. True to the spirit of the '60s, these devices were often made of innovative, flexible plastics in an array of shapes and sizes: rings, spirals, loops, bowties, triangles, and much more. The new plastics allowed for bulkier forms that were designed to fill the uterine cavity, bringing a lower pregnancy rate and many unwanted side effects like cramping, heavy bleeding, and abdominal pain. Like the silk design from 1909, these IUDs had no "active ingredient," and because they were considered drug-free the plastic IUDs of the 60s and early 70s did not go through extensive testing by the US Food and Drug Administration (FDA).

One of these second-generation devices came to negatively impact perceptions of IUDs for decades. Introduced in 1971, the Dalkon Shield was fraught with flaws, beginning with its basic design. The crab-shaped plastic device was challenging to insert; worse, the string used to extract it from the uterus was porous, with multiple strands. Like a wick, it pulled bacteria from the vaginal canal into its user's uterus, which could lead to inflammatory disease, septic infections, miscarriage, and sterilizing injuries. Fifteen women died using the Dalkon Shield, and over 300,000 lawsuits were filed against its makers, the A. H. Robins Company. The company sold discounted shields to developing countries even after the FDA took it off the US market in 1974. As a result of the incident, IUD design is now highly regulated by the FDA. Still, overall IUD usage dropped dramatically, and to this day the use of this technology in the United States lags that of other countries.

While the Dalkon tragedy unfolded, new scientific research suggested the effectiveness of copper for contraception. To better fit the contours of the uterus, American doctor Howard Tatum made a device in the form of a plastic T.

At the same time in Chile, Jaimie Zipper, MD, discovered that placing a copper wire in one horn of a rabbit's uterus prevented that portion from pregnancy. Tatum's T-shaped design still had a pregnancy rate of 18%. But when copper was added, the combination produced a remarkable effect: "a pregnancy rate of just 1 percent after a twelve-month trial ending in 1970." A year later, the FDA reclassified copper IUDs as a drug, warranting extensive testing before the CuT200's release in 1976. In 1984 an updated version with more copper—the CuT380A—was approved and brand-named the Paragard for the US market. Still available today, its introduction gradually changed opinion regarding the technology, making way for the hormone-releasing IUDs of the 2000s.

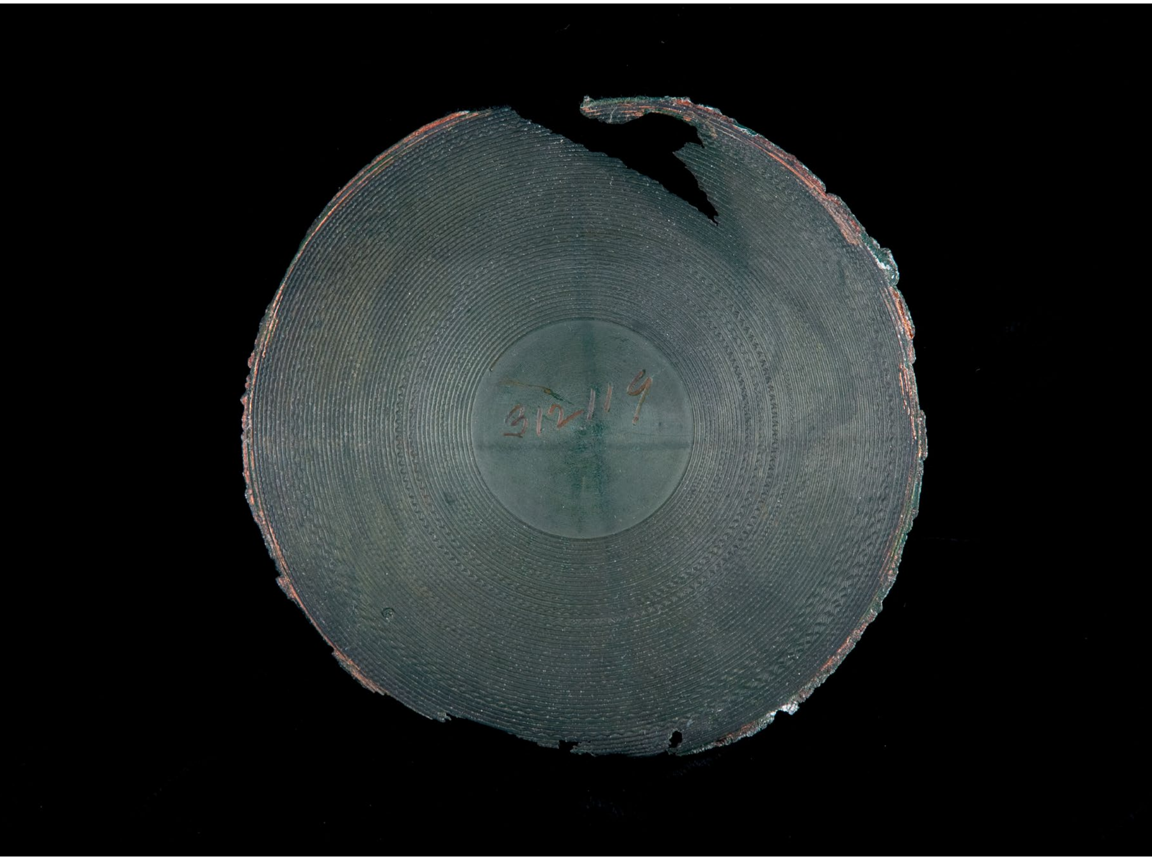
Curiously, there is no widespread agreement on why the metal works in copper-bearing devices. Through a simple but notoriously painful insertion process, the IUD is placed in the uterus. Copper ions make the area spermicidal by impacting sperm motility, or "movability." When the United Nations studied the first Copper T, the CuT200, they offered a surprising explanation—the detachment of sperm heads from their tails. In other words, the metal is toxic to sperm but it remains unclear exactly why this is the case. Over time, as the metal slowly dissolves, the device gradually becomes less effective. Unique to copper contraceptives, typical side effects include mild to unbearable cramping and a heavier, more painful menstrual period.

Every user's experience of the Copper T is unique. Some people I have interviewed had ideal experiences, including Karie (she/her), who has used the copper contraceptive for years and says it's "a great choice . . . It just works for me." Others needed to remove the device, describing the pain of their menstruation or, in the case of Elizabeth (she/they), a discomfort that occurred years after device placement. After receiving their CuT380A in 2015, they started experiencing uterine pain in 2020. A sonogram revealed that the device had malfunctioned. "It was broken and mangled . . . they said it looked like it had been like that for years." After a painful process that was close to requiring surgery, Elizabeth's device was finally removed by physicians. Now, over 1,000 lawsuits claim that the Paragard has fractured upon removal, causing further complications.

Despite these widely publicized risks, benefits, and histories, many people remain unfamiliar with the CuT380A. Perhaps it is the inherently private nature of this technology, or the troubling history of IUDs in general, that has obscured this use of copper from public view. Nevertheless, the CuT380A IUD has become one of the most consequential copper objects in society, especially significant in the lives and bodies of its users.

The earliest weapons were hands, nails and teeth.
Next came stones and branches wrenched from trees,
and fire and flame as soon as these were discovered.
Then men learnt to use tough iron and copper.
With copper they tilled the soil.
With copper they whipped up the clashing waves of war.

—*Lucretius*



Material intelligence in orbit

Jennifer L. Roberts

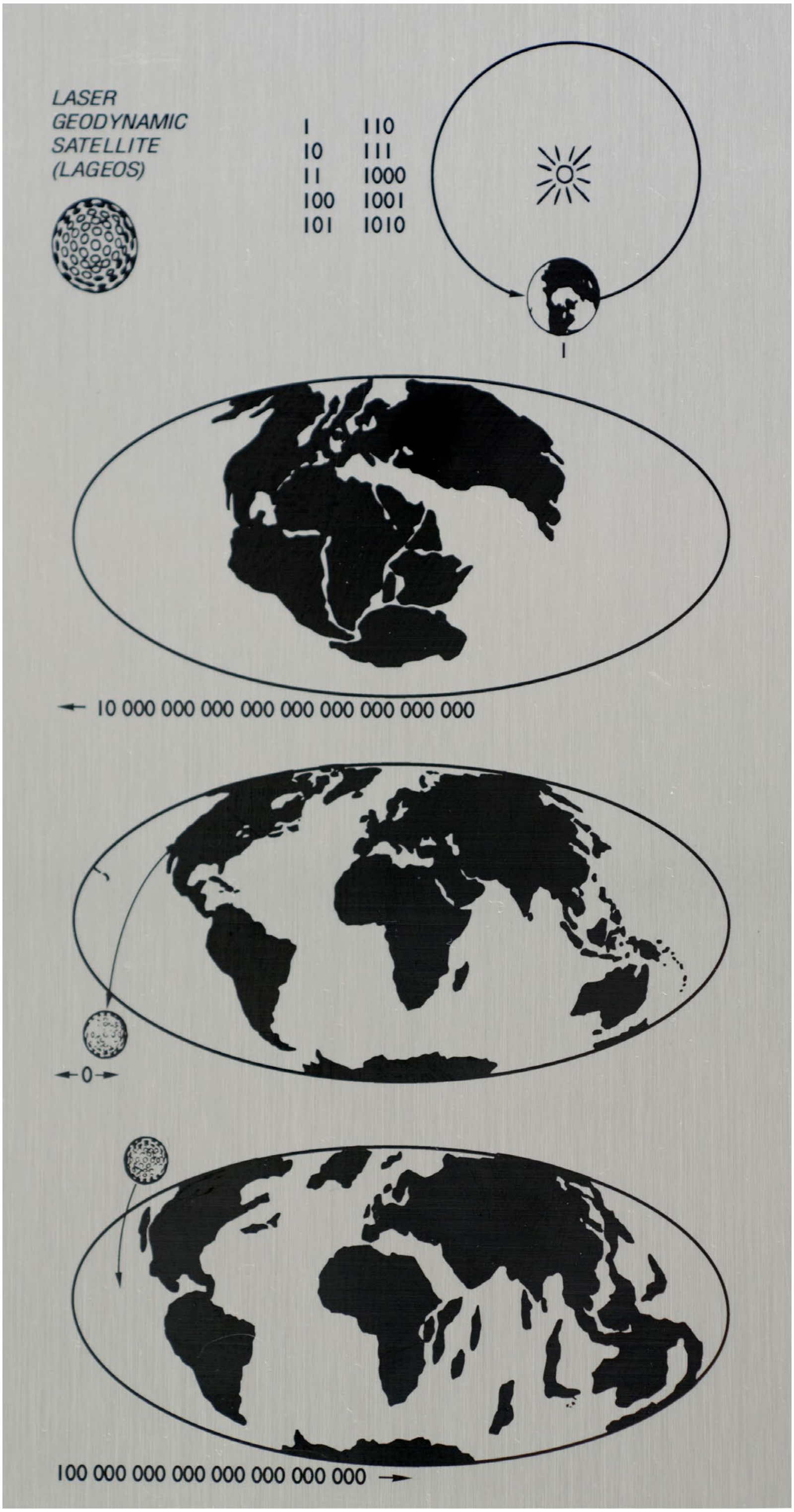
The LAGEOS satellite was launched by NASA into an extremely stable Earth orbit on May 4, 1976. It still circles quietly 3,700 miles above us—and it will continue to do so for something resembling eternity. Its orbit is so secure that, barring some unforeseen catastrophe, it will not fall back to Earth for another 8.4 million years.

It's pretty spectacular as satellites go, looking like some sort of cosmic disco golf ball. The outer shell is aluminum, studded with 426 retroreflectors made of fused silica and germanium. It looks vaguely menacing, but in fact it is a completely passive object. It has no sensors or electronics on board, no power or propulsion. It is designed for a single purpose: to reflect laser beams in the service of geodetic measurement (LAGEOS is an acronym for Laser Geodynamic Satellite). Ground stations transmit pulsed laser signals to the satellite, which the retroreflectors then return directly back to their source. The round-trip travel time of the laser provides an extremely precise measurement (within 2 cm) of the distance of the satellite from the ground. When combined with readings taken from other stations, this information allows the distances between various points on the Earth's surface to be determined with exacting precision. It also allows us to take fine measurements of changes in these values, indicating the Earth's rotation rate and polar wobble, tides and tidal loading, the exact rate of continental drift, and much more.

If LAGEOS allows us to perceive the otherwise imperceptible dynamism of the planet, it can only do so because of the extreme stability of its own orbit: it provides something like a still point against which these intricate shifts can be measured. And this is where the copper comes in. Inside the aluminum shell is a very heavy cylinder of solid brass, a copper-zinc alloy, which gives the satellite a high mass-to-area ratio. LAGEOS is only 24 inches in diameter, but it weighs 900 pounds. Along with its spherical shape, its high mass keeps it stable by resisting the atmospheric and radiation drag that cause other satellite orbits to decay.

This heavy chunk of metal may seem like an odd topic for a journal about material intelligence: after all, the copper here seems pretty dumb. It's an inert, inarticulate lump; dead weight. It's just brass for mass, holding steady. But steadiness is not easy, especially in space, which is anything but constant. Every object "in" it is moving at unfathomable speeds in a flurry of relative and absolute motion. In space, it means a great deal to establish a constant point of reference.

In achieving this, the satellite calls back to the long history of brass in astronomical instrumentation. Think of all those beautiful, finely crafted, early modern armillary spheres, indicating the movement of planets and stars around the earth. In these instruments, as in LAGEOS, brass holds orbits in place. And in the longevity that it bequeaths to the satellite, the brass cylinder also recalls all the great copper and copper-alloy monuments on Earth: massive bronze statues meant to last for generations; copperplate engravings that preserve information through centuries. If humans have recruited copper in the past to hold still against the flow of time, LAGEOS brings this memorial impulse to new orders of magnitude. When it finally drops into the Earth's atmosphere, the Earth itself will be hardly recognizable, and any remaining members of the human species might as well be aliens. Recognizing this, NASA asked Carl Sagan to design an engraved plaque for the satellite that would serve as "a kind of greeting card" for any future beings who might find it. The plaque is curled around the inner cylinder, and it dates the satellite by indicating its time of origin against a sequence of maps of continental drift. The plaque is made


LASER
GEODYNAMIC
SATELLITE
(LAGEOS)
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of stainless steel, but it's the eternity of the adjoining brass that gives it meaning and purpose.

And strangely, it is precisely in its inertness that LAGEOS inherits all the ancient powers of intricacy, workability, and connectivity that have been associated with copper on Earth. When combined with its support network of lasers and tracking stations, this blunt chunk of alloy produces the most exacting and meticulous observational arrays; the most exquisite traceries of global positioning; the finest geodetic filigrees. It helps us draw maps of the earth to centimeter scale, and to detect slow, minuscule changes in sea levels, coastlines, and the elasticity of the earth's crust. And because it is impervious to most forms of drag, LAGEOS is also hypersensitive to minute changes in the forces that do affect its orbit. Surfing through the Earth's gravitational field, it detects minute variations in that field. It is even able to detect phenomena at relativistic levels of subtlety. The Earth, as it spins, pulls spacetime along with it. This is known as the Lense-Thirring Effect, a form of "frame-dragging" that was predicted by general relativity and has now been confirmed by the LAGEOS satellite, which measured a tiny shift in its own orbit in the direction of the Earth's rotation over the space of a year.

The paradoxically brilliant dumb brass of the LAGEOS satellite suggests that we have much to learn about material intelligence by dragging it into other frames of reference. Material culture studies have tended to be geocentric: it has yet to imagine what astonishments might arise from studying the way material intelligence works off planet. And if it seems somehow irrelevant to study copper in space, we should remember that, after all, metals do not come from the Earth. Every atom of copper in the objects in this issue of Material Intelligence was synthesized in the core of a supergiant star, then blasted by a supernova over some ungodly distance through space and time to get here. In thinking about copper in orbit, we are simply taking the first step toward returning material intelligence to its frame of origin.

The Finn walking out of the mine,
When the dark hills have crawled over the sun,
Has the shade of copper;
The red dust is ground in him.
He quits the mine,
But it comes along with him—
Red dust ground under his nails,
Red dust in his brain.

— Excerpt from, *Copper Dust*, by Milton Burgh.

Contributors

Barrie Cline is art faculty of the Harry Van Arsdale School of Labor Studies (HVASLS) and co-editor of "The conductor".

From Corona, Queens, *Jaime Lopez* is an IBEW Local 3 A-Journeyman Electrician and has over 20 years of electrical experience and service to the union. He graduated from Empire State College, HVASLS, and was awarded the SUNY Chancellor's Award for student excellence.

Cornelius Skeahan is part of a long history of NYC rank-and-file organized labor family members. He is a first-generation Local 3 electrician and graduated from HVASLS in 1989. He has worked as a Journeyperson in different capacities of supervision and became a Shop Steward in 2007 and Safety Director in September 2019.

Paul Vance is an artist and has been a Local 3 union electrician for the past 9 years. Paul is a graduate of Pratt Institute as well as from HVASLS. He recently began a ceramic practice.

Edward S. Cooke, Jr. is a scholar specializing in American material culture. With a focus on furniture, his practice explores the narrative capacity of objects. He is a founding co-editor of the *Journal of Modern Craft*, and at Yale, Cooke serves as the Charles F. Montgomery professor of American decorative arts. His most recent book, *Global Objects: Toward a Connected Art History* (2022), looks at the production, consumption, and circulation of functional aesthetic objects made from clay, fiber, wood, and metal.

Kuwait-based product designer, *Kawther Alsaffar* uses metal-casting to merge traditional craft with cultural critique and modern technology. Through many lenses including human connection and material integrity, she focuses on promoting craftsmen's lived experiences and their work. In 2014, she founded Studio Saffar—a product design studio that creates homewares rooted in local craft tradition.

Christina L. De León is Acting Deputy Director of Curatorial and Associate Curator of Latino Design at Cooper Hewitt, Smithsonian Design Museum. In her position she has worked to build the museum's collection of US Latinx and Latin American design, while also organizing exhibitions and public programs that highlight designers from across the Americas.

Carolyn Herrera-Perez is a writer, a maker, and Contributing Editor of *Material Intelligence.* Her research focuses on crafts, designs, and materials of the Americas. She has worked with various art non-profits, most recently Curatorial Fellow at Cooper Hewitt and Guest Curator of *Peters Valley: Present at Peters Valley School of Craft.*

Jennifer L. Roberts is Elizabeth Cary Agassiz Professor of the Humanities at Harvard University, where she teaches courses in material studies, print studies, and the visual and artisanal history of science in the Department of History of Art and Architecture. She is the author of numerous books and essays on American art and science from the eighteenth century to the present, and is currently working on two new books: *Contact: Art and the Pull of Print*, based on her 2021 Mellon Lectures, and *Life Signs: The Tender Science of the Pulsewave*, co-authored with artist Dario Robleto.

Credits

ii. Mines #22, Kennecott Copper Mine, Bingham Valley, Utah, 1983. Photograph by Edward Burtynsky.

iv. Penny Loafers by Sonya Clark, 2010, Copper and pennies. Courtesy of artist.

7. "What hath God wrought? Samuel F. B. Morse, May 24, 1844"

12. Deck job by Paul Vance (February 2012) from the Paul Vance interview conducted by Setare S. Arashloo and Barrie Cline and Jaime Lopez, 2016-11-17. Illuminating History: Union Electricians in New York City, Archie Green Fellows Project, 2016-2017 (AFC 2016/035), American Folklife Center, Library of Congress.

15. Wire cart (December 2012) from the Paul Vance interview conducted by Setare S. Arashloo and Barrie Cline and Jaime Lopez, 2016-11-17. Illuminating History: Union Electricians in New York City, Archie Green Fellows Project, 2016-2017 (AFC 2016/035), American Folklife Center, Library of Congress.

16. Suspended by Egeværk, 2020, boiled oak and copper thread. Private Collection. Images courtesy of Egeværk.

17. The Great Bartholdi Statue, Liberty Enlightening the World: The Gift of France to the American People. Published by Currier & Ives., ca. 1885, chromolithograph print. Library of Congress Prints and Photographs Division.

19. Charger by Laurin Hovey Martin, ca.1900, copper. Gift of Matthew Robinson, Yale University Art Gallery, 1998.56.1.

21. Tambat (coppersmith) hammering the top of a bumba (hot water heater), Pune, India, 2016. Photo by author.

22, 24, 28, 31. Craftsmen and the metal sinking process in Souq Alsaffafeer. Photographer, Mathais Deaprdon.

25. Dual Bowls in process in Alwafi Foundry. Photographer, Mohamad Chehimi.

27. Pentu and Haneef pouring brass and zinc. Photographer, Mohamad Chehimi.

30. Dual Bowls, 9 materials and methods. Photographer, Mohamad Chehimi.

33. Bull Brooch by Francisco Rebajes, ca. 1940s. Hammer and cut copper. Gift of Linda Lichtenberg Kaplan; Cooper Hewitt, Smithsonian Design Museum, 2017-59-3.

34. Gears Tie Clip and Cufflinks by Francisco Rebajes, ca. 1940s. Copper plate and gears. Gift of Linda Lichtenberg Kaplan; Cooper Hewitt, Smithsonian Design Museum, 2017-59-22-a/c.

35. Brooch by Francisco Rebajes, ca. 1945. Copper. Gift of Eitel and Frances Groeschke in memory of Pauline and Frank Rebajes; Cooper Hewitt, Smithsonian Design Museum, 1990-108-8.

36. Bracelet by Francisco Rebajes, ca. 1940-1950. Copper. Gift of Dorothy Hoberman; Cooper Hewitt, Smithsonian Design Museum, 1992-138-1.

37. Brooch by Frank Rebajes, ca. 1950. Copper. Gift of Eitel and Frances Groeschke in memory of Pauline and Frank Rebajes; Cooper Hewitt, Smithsonian Design Museum, 1990-108-7.

40. Poster, The Ortho I.U.D. Collection. Dittrick Medical History Center, Case Western Reserve University. 20004.020-PosterD.

43. A midwife talks about an intrauterine device with a patient at a reproductive health clinic in Yaounde, Cameroon, West Africa. Jake Lyell, Alamy Stock Photo.

46. Copper and brass processing, Photographed by Alfred T. Palmer, February 1942. Chase Brass and Copper Company, Euclid, Ohio. Farm Security Administration/Office of War Information Photograph Collection, Library of Congress Prints and Photographs Division.

47. Elecrotyped copper negative disc of a sound recording deposited at SI in October 1881 in sealed tin box. Content: Tone; voice saying. “One, two, three, four, five, six”. Photograph: Rich Strauss, Smithsonian.

48. Laser Geodynamics Satellite (LAGEOS). NASA Image and Video Library, 7667283.

50. Still from "Laser Geodynamics Satellite (LAGEOS)," NASA's Marshall Space Flight Center, YouTube.

51. Armillary Sphere by Carlo Plato, 1588. © History of Science Museum, University of Oxford, inv. 45453.

52. Detail of stainless steel plaque designed by Carl Sagan for LAGEOS. NASA's Goddard Space Flight Center.

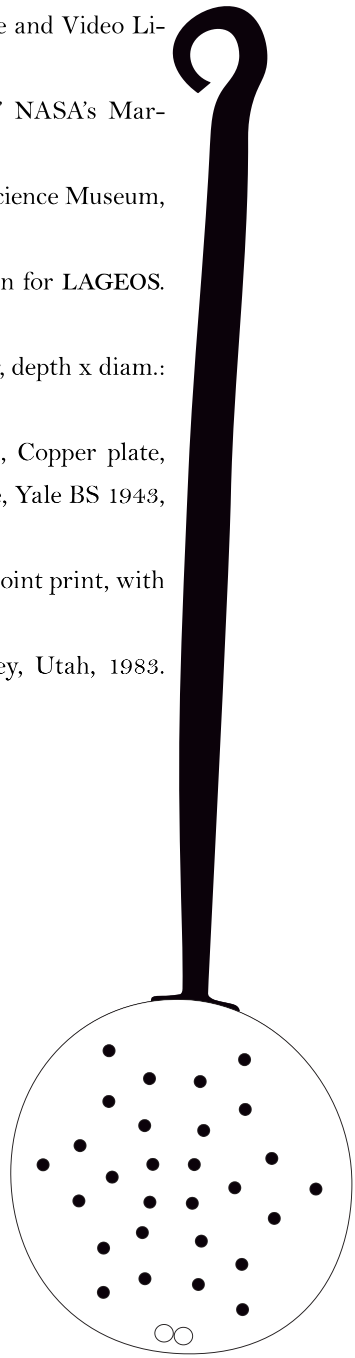
55. *Food Plinth* by Myra Mimlitsch-Gray, ca. 2000, copper, depth x diam.: 3 x 22 in. Courtesy of the artist.

56. *Jo* (canceled plate) by James McNeill Whistler, 1861, Copper plate, Yale Center for British Art, Gift of Robert N. Whittemore, Yale BS 1943, B2014.22.21

57. *Jo* by James McNeill Whistler, 1861. Etching and drypoint print, with drypoint cancellation. LMA / AW / Alamy Stock Photo.

64. Mines #22, Kennecott Copper Mine, Bingham Valley, Utah, 1983. Photograph by Edward Burtynsky.

Illustrations by Wynne Patterson.



I used a kind of gray-green
early on in my practice for painting steel,
to make it look more like it had a kind of patina to it,
like copper and bronze and so on.

The color I used was a Benjamin Moore color called 2012.
My then-young daughter started calling me 2012—it was
my nickname.

—*Michael Graves*