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The Right Stuff? Material Changes for New and Antique Musical Instruments

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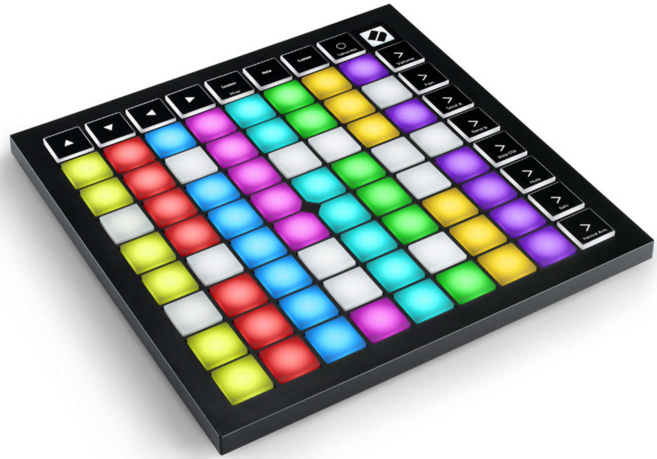
The last five decades have seen massive changes in how we think about the nature, the treatment of, and indeed the very stuff of musical instruments. Advances in technology, production, and materials affecting the design, analysis, construction, and conservation of musical instruments have been revolutionary. At the same time, a complementary backlash revisited historical materials and methods, and some traditional materials became linked to the endangerment of whole species. These advances, retreats, and concerns have affected and reflected how we think about what constitutes a musical instrument, how and of what they are made, and how we use, manage, and maintain both new and old.

As the human race continues its eternal search for a variously defined "better," synthetic and composite materials are explored to replace organic and metal components. After early, slow beginnings, the development of nylon, carbon fiber, plastic polymers, resins, acrylics, and their composites accelerated from the 1970s, their application in musical instruments driven by both performers and makers. Today, synthetic materials are commonly found throughout many instrument families. Nylon, fluorocarbon, and polymer "synthetic gut" strings proliferate in the guitar, ukulele, harp, and violin families. Fine bows are made from carbon fiber composites. Kevlar®, better known for bulletproof vests, is used to tie on tailpieces. Plastics have become essential for reaching wider, lower cost markets. Hordes of school children learn to play plastic resin recorders. Other budget-priced options introduced include acrylic oboes, ABS resin (acrylonitrile butadiene styrene) and rubber composite clarinets, and ABS or fiberglass-reinforced polycarbonate saxophones, while synthetic reeds tout improved consistency. Surprisingly, even the brass family was infiltrated in 2011 with brightly colored Pbone® plastic trombones with fiberglass slides, followed soon by plastic trumpets, cornets, and bugles. Though primarily intended (and often looked down upon) as student instruments, such are also used by professionals.

Various synthetic materials were tried as substitutes for leather, cork, textiles, and wood, with varying success. Kawai began adding ABS parts in piano actions in 1971, and by 2002 the firm was making complete actions from a composite of ABS and carbon fiber. Reportedly immune from humidity issues, they result in lighter, stiffer actions, great for loud playing. Adjustable carbon-fiber piano-action parts, developed by the historic piano-parts firm Wessel, Nickel & Gross after its 2005 revival, have been generally well received for replacing older actions. Since about 2000, Escaine®, a composite of microfibers and elastic polymers, has proven to be a consistent and durable leather substitute. The same period saw many of Steinway's Teflon® clicking action bushings replaced with traditional felt. Some synthetics incorporated into instruments in the 1970s and 1980s deteriorated badly within a few decades, crumbling or fracturing into uselessness. Pressed wood and MDF (medium density fiberboard) resin composite cases were cheap but not durable.

The Digital Age

The Digital Age, beginning in the late twentieth century, has challenged the very concept of the elements of musical instruments. In the 1970s and 1980s, advances with microprocessors, VLSI (very large-scale integration) chips, standardization of communication formats, and of course, increasingly better, faster, and cheaper memory fostered a revolution. Microchips, electrical signals, data, software, cables, wireless, and cellular signals became part of the fabric of novel musical instruments. MIDI's arrival (Musical Instrument Digital Interface) in 1983 as a standardized encoding for data communication across music-related hardware has proved an enduring component, whether through analog or digital synthesized sound, digital audio workstations, or even robotic drones activating percussion instruments. General-purpose digital signal processing (DSP) methods, developed in the 1980s and 1990s for sound sampling, generation, and transformation, were other critical enabling members of this new instrument fabric. Hardwired networks of microcomputers, acting in the 1980s as distributed musical instruments, evolved into wirelessly networked orchestras of individuals with mobile phones by 2007. Specialized programming languages such as Max/MSP, which originated in the 1980s, continue to be used in imaginative twenty-first-century instruments, and in digital controllers such as the Modular



The Novation Launchpad X, a 64-pad MIDI grid controller, also includes dynamic note and scale modes and mixer controls. Photo courtesy of Novation.

Musical Objects, which can be driven by motion or vibration. (For a sampling of audible results from this pocket-sized gesture controller, see and hear this video: https://www.youtube.com/watch?v=Uhps_U2E9OM.) Sample sound libraries, created from acoustic or electronic instruments, have become part of many tangible and virtual electronic instruments. By the 2000s, affordable software versions of digital audio workstations, sequencers, and virtual synthesizers became available on laptops, tablets, and mobile phones, along with digital sample library plug-ins.

While all musical instruments require some form of controller, i.e., an interface between player and sound production, these now can take nearly limitless forms. Thanks to new types of small, sensitive sensors as part of its "fabric," a controller can be a spherical ball with touchpads, fruit (with sensors attached), gloves, a light beam, giant or small touchscreens, sensors hung in public parks activated by wind or rain, or even based on a Slinky™. The fabric of a musical instrument can even be denim, with appropriate sensors embedded.

Hybrids cater to both traditional and new instrument forms. Hybrid pianos (2009) can function either as acoustic or electronic instruments through the traditional interface, while offering silent practice, recording, and playback. In contrast, truly chimerical "hyperinstruments," first developed in 1986, incorporate sensors into traditional musical instruments, process the signals, and generate sounds via computer programs and synthesized or sampled sounds.

Manufacturing Marvels

Over time, component manufacturing methods became better, faster, and cheaper, alongside electronic technology. CNC (Computer Numerical Control) progressed rapidly with the advent of the microprocessor in the 1970s. Many a musical instrument kit made in the 1970s onward benefitted from CNC parts production. The 1990s saw do-it-yourself and more affordable high-quality, commercial-grade CNC systems. By 2020, $1500 could buy a modest CNC machine with software, making even small runs of specialist parts profitable. 3D printing development is perhaps even more exciting. Debuted in 1984, the concept was not practical until the early 2000s when SLS (additive selective laser sintering) became commercially profitable. The printers were long limited to utilizing plastic or nylon, but by 2020, prices plummeted and dreams were fulfilled, as 3D printers could work with some metals, carbon fiber, wood fiber, or even concrete. Helper infrastructure kept pace, as "maker spaces" (workshops open to students or the public) and independent firms popped up to help create both data and product. These are exciting times for prototyping and making replacement parts!

Old is New Again

Yet, much as the late nineteenth-century Arts and Crafts movement rejected industrialization and mass production, the last quarter of the twentieth century saw a growing move to study, value, and reclaim traditional materials and methods for musical-instrument making and restoration. In part, this stemmed from dissatisfaction with how mass production methods caused substantive changes in materials, affecting an instrument's behavior and sounds. Early twentieth-century efforts at making "better" versions of historically based instruments had proved our forebears actually did know best. Those in search of accurate representation of past sounds increasingly felt they could not truly understand, restore, or duplicate the sound of older instruments unless they used materials as close as possible to the originals. Indeed, leathers tanned with modern mineral-based methods do not behave like those in eighteenth- and early nineteenth-century instruments. Microscopic analysis of piano hammer felt showed that modern, chemically based felt processing damaged wool fibers unlike historic methods, causing reduced resiliency and durability, and harsher sound. Natural gut strings "speak" differently from modern substitutes. Various efforts studying historic metal music wire, begun in the 1980s by Rémy Gug, continued into the 2010s, when Stephen Birkett began to produce authentic historic music wire. Thick modern felts do not control action noise or rebound like the layers of teaseled wools of earlier centuries. Old stuff can be good stuff.

Ironically, technological advances since the 1970s have greatly facilitated better study of traditional acoustic instrument components, benefiting and influencing organology, conservation, material analysis, restoration, and replica construction. The increasingly affordable toolset includes ever higher-resolution digital photography, high-speed photography, fiber optic cameras, 3D scanners, chromatography, dendrochronology, spectroscopy, and spectrometry. Computers, spreadsheets, and databases have made it possible to analyze, store, and share data in ways only dreamed of fifty years ago. By the 2000s, the limited-access Arpanet of the 1980s had become the Internet, a ubiquitous facilitator of instantaneous international communication, and the bare-bones World Wide Web became an essential tool for all fields. By 2020, quick access to far-flung colleagues, scanned documents, publications, photographs, audio and video recordings, and even once-fantasized video phone and meetings have come to pass.

Conservation Philosophy

Fifty years have also seen a shift in how collectors and curators regard the effect of use on the stuff of antique instruments. A growing realization of how playing causes wear and damage, and that invasive restorations and repairs had caused irretrievable loss of original information, had to be balanced with choosing to silence and protect instruments. By the 1990s, past trends to make virtually all instruments playable were generally replaced by making individual treatment decisions based upon rarity and originality of materials. Sadly, destructive and "updating" restorations are still common in the commercial instrument world. A remaining question in treating instruments that have experienced "modernizations," sometimes multiple, is: To what degree should that history itself be respected?

A logical outcome was the evolution of a combination conservation/restoration philosophy, aided by technological advances. Digital documentation and online databases grow monthly. Acquiring accurate replacement materials and documenting changes became de rigueur by the 2010s, along with clearly delineating new vs. original material and preserving as much originality as possible. Advancement in conservation techniques is aiding in the stabilization of original elements. When funding permits, replicas of action parts or even whole instruments have been made, such as the 2019 replica of the Mount Vernon Longman & Broderip harpsichord, directed by John Watson.

The Elephant in the Room

Since AMIS's founding, laudable efforts by governments and international conventions to protect endangered species from humans, and all species from dangerous substances, have had multiple consequences affecting musical instruments. Since the passing by the United States of the 1973 Endangered Species Act, and since CITES (Convention for International Trade in Endangered Species) became an enforcing international regulatory body in 1975, ever-stricter regulations have affected the use and trade of some traditional musical instrument materials. In CITES's most restrictive category (Appendix I), we find elephant ivory, Brazilian rosewood, and tortoiseshell. Acquiring materials such as pernambuco and various ebony, mahogany, bubinga and rosewood species, or other species in Appendix II, requires considerable paperwork, documentation, fees, and lengthy processing times.

Until 2014, antique items could be bought and sold in the United States with official paperwork and permits. Massive lobbying and ads by conservation groups, featuring photos of orphaned baby elephants, resulted in a presidential directive enforcing draconian new restrictions on interstate and international ivory trade. While provably antique items containing ivory could still be exported from the United States, commercial import became strictly illegal. Outcries from collectors and lobbying by organizations such as the PTG (Piano Technicians Guild) and NAMM

(National Association of Music Merchants) managed to gain some relief for antique items with *de minimus* content. Administration changes in 2016 relaxed the policy on commercial imports of antique instruments, while still requiring permits and limiting ports of exit and entry. Unfortunately, musicians traveling internationally must still acquire time-limited “Musical Instrument Passports” to transport instruments containing any protected species, causing headlines and major headaches for touring ensembles. Within the United States, some individual states instituted various ivory trade bans, though enforcement appears to be minimal. By late 2019, the United Kingdom officially became the most restrictive country yet, expanding the ban on any trade for any items containing any ivory, including antiques.

Making matters more complicated, other government restrictions began to be enforced that affect international movement of various musical instrument materials. The Lacey Act, passed in 1900 to protect wildlife, was amended in 2008 to oversee the import of any species protected at any level by any country’s international or domestic law, affecting such common instrument materials as shell inlay and wood. Shipments now require additional paperwork detailing the species, quantity, value, and country of origin for each incorporated species and, of course, require a fee. Headlines featuring Lacey Act drama appeared in 2009 and 2011, as the U.S. Fish and Wildlife Service raided the Gibson guitar factory, confiscating ebony and rosewood components. In 2014, the banjo and mandolin maker Gold Tone was fined for not declaring mother of pearl or importing it through an authorized port. As of 2020, U.S. Customs began requesting that imports include a TSCA (Toxic Substance Control Act) document for the U. S. Environmental Protection Agency. Keep in mind that methylene chloride (used in some adhesives) and lead are controlled substances.

The Future

For millennia, musical instruments were made to sing using bone, wood, leather, and other natural materials. We are now challenged to acknowledge that other materials—including encodings, displays, miniature microphones, and speakers—are also part of the fabrics of musical instruments. I expect to see more 3D printing for duplicating old and creating new instrument parts, from all manner of materials. Seemingly ubiquitous computing and virtual instruments will become even more so. Tactile and other feedback efforts to simulate real instruments will continue. Still, acoustic instruments will not disappear while popular music acts, such as Alicia Keyes, use real pianos and a harpsichord, and Lizzo her concert flute on stage. Similarly, a high regard for "authentic materials" will likely persist.

Environmental concerns will undoubtedly continue. Since China's 2017 trade ban on ivory resulted in a significant drop in demand, prices, and poaching by 2019, we can hope that the remaining greatest-offending countries will follow suit, and elephant populations will rebound. Sadly, tree species will likely continue to suffer as tropical jungles are cleared for progress and profit. Ironically, many substitutes for natural materials are themselves plastic and epoxy resins, made from petroleum products, which are also under attack by environmental concerns.

Lastly, both concerns and hope for instrument preservation and conservation will doubtless remain. Many musical instrument collections have been suffering decreased funding and staffing. Destructive updating "restorations," pandering to an uncaring market, will likely continue. Data formats and programs inevitably become obsolete, and digital data is ultimately ephemeral. Will there be funding and personnel to proactively protect the data collected with these marvelous new methods? Can we find new caretakers and the space to inherit the cause of the old and new stuff of musical instruments? Salvation may ultimately spring from the often-trivial world of international social media, where passion and drive for even the most specialized areas, like each area of music making, should continue to thrive.