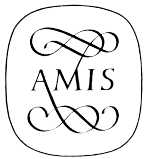
Journal of the American Musical Instrument Society

VOLUME XXVI • 2000



Progress, Adaptation, and the Evolution of Musical Instruments*

Laurence Libin

History, the written record of human events, has aptly been called selective fiction; intellectual fashions and social preoccupations inevitably bias the interpretation of data chosen from an already incomplete chronicle, making a wholly objective, comprehensive account of the past unattainable. Uncertainty particularly clouds the history of music in performance, for which little direct evidence predates audio recordings. Antique musical instruments, however, offer tangible clues to how music sounded to our forebears.

Investigation of old instruments in terms of their past usage gained scientific footing (within the field now called organology) in the late nineteenth century, when public museums began systematically to collect musical instruments on a large scale. Since that time, the relationship between instrument design and musical style has received increasing attention. As scholarly perspectives change and research brings more information to light, organologists adjust or discredit their predecessors' theories. Still, obsolete histories, like old instruments, have much to teach us, not least to beware of apparent verities.

\+ + +

The approach to the history of musical instruments espoused today by many musicians as well as the general public owes much to late nineteenth-century antiquarians and museum curators whose views of how instruments evolve were rooted in then-current biological models, notably Charles Darwin's. The concept of biological and technological evolution implicit in typical late nineteenth-century classification systems and museum displays can be represented schematically by a tree whose branches ascend slowly through time toward increasing diversity,

*An earlier version of this essay was originally presented as a lecture at the Museum of Art, Brigham Young University, on 21 April 1995, and subsequently at the sixty-first annual meeting of the American Musicological Society, New York City, on 4 November 1995. I am grateful to the College of Fine Arts and Communications, the School of Music, and the Museum of Art of Brigham Young University for partial financial subvention of the research.

complexity, and sophistication.[1] The primary force nurturing this growth, so far as instruments are concerned, was commonly thought to be the rise of music as an art form, culminating in the masterworks of Beethoven, Wagner, and the rest of the Romantic pantheon. Where such inspired geniuses led, many believed, instrument makers naturally followed.[2]

1. "The tree is the type of all evolution: all trees are seedlings, but they differ in their mode of growth. Some, like the beech and oak, throw their branches upwards, and these are typical of the development of the material arts. . . . The vegetable kingdom thus furnishes us with the grand type of progress; continuity and bifurcation are principles of universal application, uniting the lowest with the highest created thing" (Lt.-Gen. Augustus Lane-Fox Pitt-Rivers, *The Evolution of Culture and Other Essays* [Oxford: Clarendon Press, 1906], 44, 49). However, in an evolutionary tree of artifacts, branches routinely merge; see Alfred L. Kroeber, *Anthropology* (New York: Harcourt Brace Jovanovich, 1948), 260. For a hypothetical tree of a particular instrument family, see Henry Balfour, *The Natural History of the Musical Bow: A Chapter in the Developmental History of Stringed Instruments of Music* (Oxford: Clarendon Press, 1899; reprint 1976), especially 2–3. On the evolution of evolutionary theory, see Niles Eldredge, *Reinventing Darwin: The Great Debate at the High Table of Evolutionary Theory* (New York: John Wiley & Sons, 1995).

2. Arguments in support of the composer's primacy often cite the so-called Wagner tubas, first scored in *Das Rheingold* in 1854. Richard Wagner himself, however, attributed their conception to the instrument maker Adolphe Sax. Already in 1852 Sax had built a set of especially powerful "saxtubas" that were introduced in Fromental Halévy's opera *Le juif errant*. Wagner's preference for their sound over that of trombones (for which the Valhalla motif was originally sketched) thus represents a response to instrument innovation, not a cause. (Halévy reportedly also employed another novelty, the free-reed mélophone, in an opera score. Opera, like dance music and other popular genres, offered especially fertile ground for novel instrumentation.) Sax's invention of the saxophone, patented in 1846, evidently owed nothing to compositional demands but rather was inspired by practical circumstances: Outdoor bands required louder, more durable woodwinds to bridge the gap between clarinets and tenor brasses. Although long ignored in Germany, saxophones gained some acceptance as an alternative tone color in French, Belgian, and British orchestration during the mid-nineteenth century; however, a truly distinctive saxophone idiom awaited the jazz age and the attention of jazz-influenced composers such as Darius Milhaud.

Comparison of treatment of brass instruments in earlier (1837 and 1839) and later (1844) editions of instrumentation treatises by Georges Kastner illustrates the responsiveness of musical practice to instrument innovation, notably Sax's. According to Stewart Carter in his lecture, "Georges Kastner on Brass Instruments: The Influence of Technology on the Theory of Orchestration" (International Historic Brass Symposium, Amherst College, 27 July 1995), "Never before had compositional theory maintained such an immediate relationship to technological change." Carter observes that Kastner's work was "an important model for Berlioz's *Grand traité d'instrumentation et d'orchestration* (1843)." The homogeneous sound and standardized fingering of Sax's saxhorns were important to the popularity of brass bands especially in the United States, where in 1849 the influential bandleader Allen Dodworth recom-

This view of craft subservient to art found apparent support in accounts of dissatisfied musicians' efforts to improve inadequate instruments; Johann Sebastian Bach's practical criticism of various church organs was especially pertinent. However, the significance of such reports could be exaggerated. Philipp Spitta, writing in the 1870s about the "ideal instrument which floated in the mind of Bach," proclaimed that "no instrument but one which should combine the volume of tone of the organ with the expressive quality of the clavichord, in due proportion, could be capable of reproducing the image which dwelt in the master's imagination when he composed for the clavier. Every one sees at once that the modern pianoforte is in fact just such an instrument."[3] In implicitly denigrating the claviers (stringed keyboard instruments) of Bach's day (1685–1750), Spitta was swayed by ideas of progress current in his own era of unprecedented technological and imperial expansion.

Attitudes like Spitta's went largely unchallenged by later writers on music. For example, with reference to the adventurous orchestral scoring of Hector Berlioz (1803–69), the prominent German organologist and museum curator Curt Sachs (1881–1959) maintained that, "Under the influence of modern orchestration all instruments were developed to the greatest possible technical efficiency and musical effectiveness."[4] Like many observers of his generation and earlier, Sachs vested modernity with positive value and gave imaginative composers the upper, even decisive, hand in shaping the development of orchestral instruments.[5]

---

mended saxhorns in at least six pitches (*The Message Bird,* August 1, 1849, quoted in Charles Hamm, *Music in the New World* [New York: W. W. Norton & Co., 1983], 283–84).

3. Philipp Spitta, *Johann Sebastian Bach,* trans. Clara Bell and J. A. Fuller-Maitland (London: Novello & Co., 1889), 2:44.

4. Curt Sachs, *The History of Musical Instruments* (New York: W. W. Norton & Co., 1940), 389. Out of context, Sachs's sweeping assertion seems to imply that pre-Romantic instruments were less efficient and effective than later ones, an opinion at variance with contemporary accounts and with many modern listeners' experience. How pre-Romantic music sounded to Sachs can be ascertained from his important series of recordings, *L'Anthologie Sonore,* initiated in 1934. As an advisor to museums in Germany and New York, Sachs had first-hand experience with antique instruments, which he believed should be restored to playing condition whenever feasible. Unfortunately, such restorations and the irreversible effects of age often distort original qualities.

5. A British authority on orchestration, Adam Carse, expressed a seemingly contradictory view: "Of the various elements which together go to make up the technique of writing and presenting music, none can show a more remarkable expansion than can orchestration, yet the development of none appears to have been so largely dependent

The schemes of gradual, purposeful evolutionary progress posited by Victorian museums promoted a vital political agenda. Just as one of the main aims of compulsory public education was—and still is—to enforce social controls, so public museums sought to impress civil attitudes on their visitors, especially those of the laboring class, which included many illiterate rustics and disaffected immigrants who seemingly posed a threat to social order in cities where major museums were located. Anxiously recalling the revolutions that swept Europe in 1848–49, government officials, prominent educators and clergy, and capitalists who financed cultural institutions felt that museums, like churches and schools, should promote an ideal of slow, incremental progress as opposed to sudden, disruptive change. Augustus Henry Pitt-Rivers, the founder of Oxford's Pitt-Rivers Museum, made this socializing aim explicit when he wrote, "the facts of evolution and the process of gradual development is the great knowledge that we have to inculcate, and this knowledge can be taught by museums provided they are arranged in such a manner that those who run may read—the working classes have but little time."[6]

Reflecting this paternalistic attitude, exhibits of artifacts as well as of organisms reinforced a doctrine of continual improvement aimed at

---

on the mechanical improvement of instruments" (*The History of Orchestration* [London: Kegan Paul, Trench, Trubner & Co., 1925], 335). But Carse, too, ultimately gave priority to musical demands: "However much the growth of the orchestra has been the toy of circumstances, conditions, or the mechanical or technical development of instruments, the real driving force behind such evolution is after all the insistently growing demand of musical art for fit means of expression. The impelling power of a constantly advancing art has always carried with it the realization of better and more worthy means of expressing itself, and with the demand, the man, the instrument, and the opportunity have always been forthcoming" (ibid., 7).

The musicologist Rita Benton clearly observed both sides of the coin: "the history of instrument making . . . is interwoven throughout musical history with the fabric of the art itself. This remains true whether one believes that new designs in instruments inspire composers to feats of originality, or whether one believes, as many do, that it is more often the composer who makes demands on the ingenuity of the instrument maker, who must then find a way to satisfy those demands" (introduction to the reprint edition of Daniel Spillane, *History of the American Pianoforte, its Technical Development, and the Trade* [New York: D. Spillane, 1890; reprint New York: Da Capo, 1969], v). The mutually opposed views of Gerald R. Hayes and Edward J. Dent are summarized in Cyril Ehrlich, *The Piano: A History* (London: J. M. Dent & Sons, 1976), 22.

6. Pitt-Rivers is quoted by Barry Cunliffe, "British Archaeology: What Can We Learn about Our Past?" *Royal Society of Arts Journal* 134, no. 5386 (September 1988): 696. On the similarly civilizing influence of Victorian civic parks see Simon Schama, *Landscape and Memory* (New York: Alfred A. Knopf, 1995), 565–70.

eventual perfection, a goal regarded as perhaps achievable with musical instruments in the near future if not reached already.[7] In assembling an encyclopedic repository of musical instruments at The Metropolitan Museum of Art in New York City, the enthusiastic collector Mrs. John Crosby Brown (1842–1918) explicitly sought "to trace the development of the several distinct types of musical instruments from the first rude beginning to the finished forms now in use, and, secondly, to illustrate the varying forms assumed by these types under the influence of the different civilizations. The first [goal] explains the presence of the large number of savage specimens in the collection. Through these it is possible to recover many of the primitive forms which are otherwise inaccessible, and to discover many obscure links in the chain of development."[8] In language echoing sentiments about the course of human evolution, Mrs. Brown thus acknowledged evidentiary gaps in an essentially mechanistic pattern of progress toward modern "finished forms." Like many Victorians, she apparently considered the "savage specimens" as little more than relics lacking contemporary musical relevance.

Mrs. Brown allowed that music's progress was irregular, but she believed that the evolutionary trend led inevitably to its apex in her own day and culture; thus, Mrs. Brown anticipated Curt Sachs in her ethnocentric opinion (widely shared in an era of complacent Western imperialism) that "With Europe we reach the most highly developed forms [of instruments] which musical history presents."[9] Measured solely by conventional standards of beauty and engineering complexity, Mrs. Brown's pronouncement was mostly correct (either she ignored American developments or subsumed America within Europe), if short-sighted. Today,

7. World War I annihilated such naiveté, but earlier it had been proposed that the United States Patent Office be abolished because everything useful had already been invented, or was soon about to be.

8. *Catalogue of the Crosby Brown Collection of Musical Instruments of All Nations,* vol. 1, *Europe* (New York: The Metropolitan Museum of Art, 1904), xv. See also vol. 4, *Historical Groups* (1905): e.g., "From the natural tube the advance has been gradual and by slow degrees" (p. 63); "Gradually the single string was supplemented by others . . ." (p. 128). The cataloguer, Frances Morris, constantly reiterated the concept of gradualism: "In fact, the student of this instrument [the piano] may follow its gradual development from the primitive dulcimer to the modern instrument" ("New Installation of the Musical Instruments," *Bulletin of The Metropolitan Museum of Art* 9 [1914]: 206).

9. *Catalogue of the Crosby Brown Collection* . . . 1: xviii–xix. An account of the Crosby Brown Collection, citing the influence of Henry Balfour, the Pitt-Rivers Museum's curator, appears in Laurence Libin, *Our Tuneful Heritage: American Musical Instruments from The Metropolitan Museum of Art* (Provo, Utah: Brigham Young University Museum of Art, 1994), 1–12.

some would maintain that, say, a classical Hindustani sārangī is as sophisticated in its way as a violin.

Not surprisingly, successful instrument manufacturers such as Boston's prestigious piano firm of Chickering & Sons celebrated this turn-of-the-century culmination in self-congratulatory terms: "In viewing a great work accomplished, it is always interesting to trace the process of evolution which has been the means of arrival at the successful outcome. The achievement of the great pianoforte makers in bringing that instrument to its present popular and general use is a great work."[10] Not fearing unfavorable comparison of new products with outmoded ones but proud of their patented improvements, Chickering & Sons and other leading manufacturers donated instruments or construction models to museums and supported trade fairs and exhibitions that advertised their prowess.

The idea that instruments develop primarily in response to advances in musical style appealed strongly to Mrs. Brown's like-minded contemporaries in view of Herbert Spencer's often quoted remark, "Music must take rank as the highest of the fine arts—as the one which, more than any other, ministers to human welfare."[11] If, as the aesthete Walter Pater pronounced in 1877, "All art continually aspires towards the condition of music," then elite Western instruments, notably such advanced industrial products as pianos and organs, should, like the Eiffel Tower (1889), proclaim the triumph of modern Western civilization. This optimistic reasoning underlay the acquisition and comparative display of musical instruments of all cultures and times by museums of art, anthropology, and technology.[12]

10. Chickering & Sons, *Catalogue of the Exhibition, Horticultural Hall, Boston, January 11 to 26, 1902* (Boston: Barta Press, 1902), 3. Paradoxically, under the direction of the charismatic, French-born musician and instrument maker Arnold Dolmetsch (1858–1940), Chickering's craftsmen also pioneered the commercial production of new instruments of antique type.

11. "On the Origin and Function of Music," *Fraser's Magazine* 56, no. 334 (October 1857): 408. Like his contemporary Thomas Huxley, the English philosopher Herbert Spencer (1820–1903) promoted Darwin's theory of biological evolution and extended its principles to social behavior. For fuller discussion of nineteenth-century evolutionary thinking, see Jacques Barzun, *Darwin, Marx, Wagner: Critique of a Heritage*, rev. 2nd ed. (Garden City: Doubleday & Co., 1958).

12. Pater's epigram (from "The School of Giorgione," *Fortnightly Review*, n.s. 22, no. 130 [October 1877]: 528) recalls words of the organologist and collector Carl Engel (1818–82): "Music, in however primitive a stage of development it may be with some nations, is the most universally appreciated of the Fine Arts" (*Descriptive Catalogue of the Musical Instruments in the South Kensington Museum* [London: George E. Eyre

In the powerful wake of Charles Darwin's *On the Origin of Species by Means of Natural Selection* . . . (1859), elucidating the evolutionary history of instrument types—reconstructing their chronology and identifying missing links—became a central concern of organology. As Albert A. Stanley stressed in his 1918 catalogue of the University of Michigan's instrument collection, "it is . . . evident that some theory as to the priority of type must be accepted as a starting point in the evolution of instruments, and, also, that no classification is possible that does not rest on a definite evolutionary sequence."[13] In view of the many philosophical and heuristic implications of evolutionism, this emphasis must be understood in contemporary terms.

In 1894, *Webster's International Dictionary* defined evolution in a metaphysical sense as "that series of changes under natural law which involves continuous progress from the homogeneous to the heterogeneous in structure, and from the single and simple to the diverse and manifold

---

and William Spottiswoode, 1870], 1). At the same time, the Rev. H. R. Haweis expressed a variant view: "Music, as distinguished from the various rude attempts of the past, is only about four hundred years old. Modern music, which is alone worthy of the name, is in fact, the youngest of the arts, and stands at present in a correspondingly unfavorable position; for while it has been brought to the highest perfection, the secret of its power is almost wholly unexplored; and as long as this is the case, music must continue to be ranked last among the fine arts . . ." (*Music and Morals* [New York: Harper & Brothers, n.d. (appendix dated 1871)], 20).

In explaining the practical purpose of the South Kensington (later the Victoria and Albert) Museum's collection, Engel expressed the conviction "that useful information may be gathered by investigating the productions of art even of uncivilized nations, and by thus tracing the gradual progress of an art from its most primitive infancy to its highest degree of development" (*Descriptive Catalogue,* 4).

13. Albert A. Stanley, *Catalogue of the Stearns Collection of Musical Instruments* (Ann Arbor: The University of Michigan, 1918), 5. Nicholas Bessaraboff, a Russian-born mechanical engineer, initiated a new phase of scholarship with his *Ancient European Musical Instruments: An Organological Study of the Musical Instruments in the Leslie Lindsey Mason Collection at the Museum of Fine Arts, Boston* (Cambridge: Harvard University Press for the Museum of Fine Arts, 1941; preface dated 1939). In analyzing this collection, mainly assembled in England before 1916 by the music antiquarian Francis W. Galpin, Bessaraboff adopted an egalitarian tone (he dedicated his catalogue "to the makers of musical instruments of all times and all countries without distinction of race, religion, or class"). Eschewing the rhetoric of progress from a state of savagery but instead considering all instruments to stand on equal footing, Bessaraboff invoked Immanuel Kant's metaphysical definition of "things-in-themselves as entities existing independently of our perceptions of space and time." According to Bessaraboff, the concept of "the musical instrument as a thing-in-itself will include in one unity all instruments built in the past, all instruments existing at the present time, and all instruments yet to be built" (p. 3).

in quality or function"—a meaning that recalls Pitt-Rivers's branching tree formulation (see note 1, above). Herbert Spencer encapsulated the natural evolutionary process in his catchphrase "survival of the fittest," often invoked to support arguments that fitness demonstrates progress.[14] Although Charles Darwin, no less, eventually distanced himself radically from the impression that natural selection is inherently progressive, saying, "I cannot avoid the conviction that no innate tendency to progressive development exists,"[15] a belief in continuous betterment, fostered by advertising ("New! Improved!"), persisted in popular thinking. *Webster's Third New International Dictionary* (1961) recognized the attachment of positive value to evolution, taking it to comprehend "a process of continuous change from a lower, simpler, or worse to a higher, more complex, or better state: progressive development."

Unfortunately, the assumption that progress means improvement fostered the mistaken impression that modern instruments are "better" than seemingly obsolete ones. For example, application of automated wind supply and electrically assisted mechanisms to pipe organs, allowing their growth to monstrous size by the 1930s, led to a view of older mechanical-action organs as inferior. (In reaction, Albert Schweitzer advocated the virtues of historical organ designs—among them, greater touch sensitivity and tonal coherence—and prompted their ongoing revival; see note 17 below.) Similarly, during the nineteenth and early twentieth centuries the violin and its relatives were popularly if wrongly judged superior to the viola da gamba (viol) family because viols (distinguished from violins by shape, tuning, number of strings, having fretted fingerboards, etc.) had become outmoded and hence appeared to have represented a less advanced, ancestral type.[16]

14. "This survival of the fittest, which I have here sought to express in mechanical terms, is that which Mr. Darwin has called 'natural selection, or the preservation of favored races in the struggle for life' " (*Principles of Biology* [New York: D. Appleton, 1866 (orig. 1864)], 444).

15. Letter to Alpheus Hyatt of 4 December 1872, quoted by Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History* (New York: W. W. Norton & Co., 1989), 257.

16. Representative statements include the following three: "In the Viol, which appeared in Europe during the 16th Century and became obsolete with the 18th Century, is shown the first step in the direction of the violin of to-day" (Mary Elizabeth Brown, *Catalogue of the Crosby Brown Collection,* vol. 4, *Historical Groups* [1905], 50). "As music grew, so did the rage for viols, and it is owing partly to the quantities made and partly to the caprice of makers, partly to the waste and ruin of time, that it becomes difficult to trace in detail the steps from the rough viol to the violin, until we suddenly find the latter, about the middle of the sixteenth century, occupying a modest position in the midst of that host of viols which it was destined to supersede forever" (H. R.

Likewise, under concert conditions, powerful and durable iron-framed pianos like Chickering's seemed a great improvement over smaller, quieter, wood-framed pianos, not to mention over the still more delicate and dynamically less flexible harpsichords of the eighteenth century; and complicated, many-keyed woodwinds such as the remarkable flutes devised by the German mechanic and metallurgist Theobald Boehm (1794–1881) came to be regarded more highly than "old fashioned" woodwinds such as single-keyed wooden flutes, which, while relatively inexpensive, were judged less effective by many players of modern music. The factual inaccuracy and unsound judgment that thus equated modernity *ipso facto* with superiority begged the question, better for what purpose?

Happily, the twentieth-century "Early Music" movement, dedicated to historically informed performance on antique instruments or accurate replicas, has successfully challenged such prejudices by demonstrating to open ears the proposition that the *Klangideal* (literally, "sound-ideal": a constellation of aural factors including tone color, dynamics, and articulation) of a given time and place is intimately bound up with contemporary aesthetic ideals and goals that remain relevant today.[17]

Granted, a past *Klangideal* probably cannot be fully known or practically replicated (what parent would allow a son to become a castrato?) and might not now elicit the same responses as formerly. Nevertheless, performance on historically inappropriate instruments, or on appropriate instruments played with anachronistic technique and style, can seriously distort a composer's intent. Whether such distortion is acceptable or even preferable is of course a matter of taste, not ethics, but one should not take "survival of the fittest" to mean that modern instruments

---

Haweis, *Music and Morals* [1871], 319). "The birth of the orchestra is thus connascent with . . . the beginning of the gradual obsolescence of the viol type rendered inevitable by the greater suitability and practical superiority of the newly invented violins; also with the beginning of the gradual rejection of plucked string instruments as a medium for the expression of serious music" (Adam Carse, *The History of Orchestration* [1925], 1).

17. Authenticity, like historical objectivity, forever eludes our grasp; how could we even recognize it? Still, as early as 1909, seeking adequate vehicles for performing Bach's organ works, Albert Schweitzer championed restoration of old organs and construction of new ones according to time-tested principles; see his "Die Reform unseres Orgelbaues auf Grund einer allgemeinen Umfrage bei Orgelspielern und Orgelbauern in deutschen und romanischen Ländern," *International Musicological Society Conference Report* 3 (Vienna: Artaria & Co., 1909), 581. Simultaneously, Wanda Landowska was reviving listeners' and composers' interest in the harpsichord, albeit in a new incarnation, while Arnold Dolmetsch was supervising Chickering & Sons' production of harpsichords, clavichords, lutes, and viols based on historical prototypes.

necessarily work or sound better than older types; they simply suit different purposes.

+ + +

In place of slow but inevitable progress toward perfection, modern evolutionary theory proposes the idea that evolution in biology and technology means adaptation to randomly changing circumstances. This view recognizes the role of chance in directing change and admits of no ultimate finished state, and so imputes no value to later placement in time. Undermining earlier allegiance to teleology and gradualism, evidence from many fields now indicates that evolution's direction is aimless and unpredictable, and that adaptation (and extinction or obsolescence) can occur not only gradually but also with surprising rapidity after long periods of relative stability—a concept termed "punctuated equilibrium."[18]

Biologists and historians of technology have observed that increasing complexity is not a necessary concomitant of adaptation; simplification can also confer advantages by improving efficiency. They also note that diversification does not proceed unchecked; the burst of variation commonly fired by new conditions soon gives way to selective winnowing of less successful types, leaving fewer variants in the long run; these survivors in turn furnish the limited basis for future diversification. The paleontologist Stephen Jay Gould pictures the evolutionary process as like a Christmas tree in shape, broadest at the bottom where diversification has been most rapid, and narrowing toward the top rather than branching farther out through time. This paradigm, drawn from analysis of precambrian fossil animals, clarifies the development of technology and other systems as well.[19]

18. The paleontologists Niles Eldredge and Stephen Jay Gould introduced this concept in their article, "Punctuated Equilibria: An Alternative to Phyletic Gradualism," *Models in Paleobiology,* ed. T. J. M. Schopf (San Francisco: Freeman, Cooper, 1972), 82–115. For a more comprehensive if controversial discussion of concepts of modern evolutionary theory, see Gould's *Wonderful Life.* The political philosophers Karl Marx and Friedrich Engels observed that social organization and ideology are adaptive responses to economic and technological conditions. The extent to which music, as an aspect of social behavior, is likewise an adaptive response, and to what conditions, are primary concerns of ethnomusicology. For a discussion of dialectical materialism focusing on Marx and Engels as cultural evolutionists, see Marvin Harris, *The Rise of Anthropological Theory: A History of Theories of Culture* (New York: Harper & Row, 1968), 217–45.

19. On the evolutionary import of increasing complexity or simplification of artifacts, see Brian Cotterell and Johan Kamminga, *Mechanics of Pre-industrial Technology*

The distinguished organologist Herbert Heyde has maintained that instruments and music evolve in tandem mainly as a consequence of unbalance, or disequilibrium, between the capabilities of existing instruments and the expressive goals of musicians.[20] Certainly, performers faced with extreme demands on their techniques often look to instrument makers for help in surmounting these challenges; this point will be more fully discussed below. However, the nineteenth-century view that compositional "advances" such as increasing chromaticism, longer phrases, or greater pitch range and dynamic contrast, necessarily and *primarily* dictate the development and proliferation of instrument types is unwarranted; such changes (sometimes undeniably significant, as in the development of the Tourte bow[21]) only partly explain the phenomenon of evolution.

Instead, an instrument's development or obsolescence depends on a multitude of unstable forces—economic, political, social, technological, as well as compositional and performance-related ones—that interact

---

(Cambridge: Cambridge University Press, 1990), 9–11. For an accessible account of contingency in biological evolution, see Gould, *Wonderful Life,* where on p. 232 he credits Stuart Kauffman for demonstrating that a "pattern of rapid, maximal disparity followed by later decimation is a general property of systems"; see S. A. Kauffman, *The Origins of Order: Self-Organization and Selection in Evolution* (New York: Oxford University Press, 1993). On the appropriateness and limitations of biology as a model for technological evolution, and a summary of forces affecting technological change, see George Basalla, *The Evolution of Technology* (Cambridge: Cambridge University Press, 1988). On diversification and decimation among garden tools since the mid-nineteenth century, see Brent Elliott, "A History of Garden Tools," *The Garden* (Journal of the Royal Horticultural Society) 120, part 1 (January 1995): 40–43. Victorian eating utensils exhibit the same pattern of rapid diversification followed by reduced specialization. In both cases loss of artifactual variety was due to economic factors, not to changes in how plants grow and how people eat.

20. Herbert Heyde, "An Explicatory Approach to the Sound Qualities of Brass Instruments," unpublished paper presented at the twenty-eighth annual meeting of the American Musical Instrument Society, Vassar College, Poughkeepsie, New York, 18 June 1999.

21. In explaining the Tourte bow as the evolutionary outcome of "musical demands" that surfaced about 1770, David D. Boyden quotes the Belgian musicologist François-Joseph Fétis: "At this period . . . the distinguished artists resident in Paris were making progress towards the art of singing on their instruments . . . and they all desired bows which should answer better to the effects which they wished to produce, and which should possess at the same time greater lightness, spring and elasticity" (article "Tourte," in *The New Grove Dictionary of Music and Musicians,* ed. Stanley Sadie [London: Macmillan, 1980], 19:102). Fétis could have been better informed: earlier eighteenth-century bows are in fact typically lighter, more springy, and more elastic than later, Tourte-model bows, which however are better suited to executing long phrases.

with varying intensity and unpredictable consequences, sometimes abruptly and quite independently of composers' and performers' objectives. As a trivial example, sheer accident—in 1953 someone reportedly fell on his trumpet—led Dizzy Gillespie to adopt his distinctive, upwardly angled trumpet bell; the mishap favorably altered Gillespie's perception of his trumpet's sound, and its unconventional appearance set him apart from other trumpeters in the public's eye.[22] While this result evidently accorded with Gillespie's desires, it was not a consequence of intentional, musically directed activity.

More importantly, one consequence of the industrial revolution and related social upheavals was the dissolution of secretive, exclusive craft guilds that since the Middle Ages had sought to protect members from excessive competition; by restricting commerce in instruments and transmission of knowledge among instrument makers, guilds often inhibited change even as they generally upheld high prices and high standards of quality. Not coincidentally, the nineteenth century saw a greatly accelerated pace of invention and mass sales of relatively inexpensive, often novel instruments. Music publishing also expanded greatly during this period, not because composers were writing better music but because the appetite of middle-class consumers for new, entertaining pieces was insatiable.

Even instruments designed in the first place to cater to visual fashion, squelch competition, or demonstrate wider commercial application of a device or process—purposes well exemplified over the past 200 years by various forms of guitars such as lyre-shaped guitars, patented hybrid harp-guitars, and electric guitars—can sometimes unwittingly open opportunities for idiom and style to develop, since inventors' objectives can be irrelevant to users who accept or reject novel instruments for their own reasons.

In any case it is self-evident that an instrument's invention and adoption must precede cultivation of its distinctive idiom, not vice versa. Obviously, for example, idiomatic keyboard music could not have existed before the keyboard's invention. Performers must gain experience with unfamiliar instruments before composers can fully exploit their potential; for instance, Mozart's unprecedented writing for clarinets depended on the previously honed talent of his clarinetists, and Mozart's

22. See Thomas Owens, "Gillespie, Dizzy," *The New Grove Dictionary of American Music,* ed. H. Wiley Hitchcock and Stanley Sadie (London: Macmillan, 1986), 2:221.

contribution to a distinctive pianistic idiom, notably in slow movements of his mature clavier concertos, grew largely out of his own experience as a professional performer.

Many instrument innovations, for example those involving the employment of unusual materials or fabrication processes, aim at lowering cost, improving durability, or raising factory output; in such cases any audible result might be incidental. Even when sound is the focus of change, the impulse need not arise from compositional necessity. For example, theater organs such as "Mighty Wurlitzers" (called "Wurlitzer Hope-Jones Unit Orchestras" when introduced in 1911) were not introduced at the behest of composers—theater organ repertoire consists mainly of arrangements and transcriptions, not original works—but to provide a more economical, more versatile alternative to instrumental ensembles.[23] To take another example, in 1900 the electrical engineer Augustus Stroh patented oddly shaped, mechanically amplified violins (called Stroh violins) and other stringed instruments for use in acoustic recording studios; these loud and highly directional instruments were neither specified by composers nor, as a rule, greatly admired by studio musicians.[24] When microphones replaced recording horns, Stroh violins became obsolete except in novelty shows and occasional outdoor performances.

Political considerations external to musicians' wishes can also influence an instrument's survival or desuetude. Certain instruments of high symbolic potency have been ruthlessly suppressed: for instance, after defeating the Jacobites in 1745 England's Hanoverian rulers outlawed Scottish Highland bagpipes as "instruments of war."[25] And sporadically in the American South, African slaves were disallowed drums, horns, and other loud instruments that could be used to convey signals.[26]

23. David L. Junchen, *Encyclopedia of the American Theater Organ* (Pasadena: Showcase Publications, 1985), 1:16.

24. See Julian Pilling, "Fiddles with Horns," *The Galpin Society Journal* 28 (1975): 86–92. According to Pilling, "[t]he idea of attaching a horn to amplify the sound produced by a bow on a string originated from the sound-box of the gramophone . . ." (p. 86). The model for Stroh's amplifying diaphragm likewise came from the gramophone, or phonograph.

25. Nancy London Crutcher, *An Organological Study of the Great Highland Bagpipe* (M.A. thesis, Wesleyan University, 1976), 18, quoting Frank Adam, *The Clans, Septs, and Regiments of the Scottish Highlands,* rev. by Innes of Learney, Lord Lyon King of Arms (Edinburgh: W. A. Johnston, n.d.), 424.

26. Eileen Southern, *The Music of Black Americans* (New York: W. W. Norton & Co., 2nd ed., 1983), 182.

Conversely, instruments of relatively minor importance have been artificially elevated to stimulate feelings of political solidarity, as occurred with the so-called *Martintrompete* (or *Martin-schalmei;* a brass free-reed instrument with multiple bells, patented in 1927 by Max Bernhardt Martin of Markneukirchen) adopted by working-class bands, the so-called *Schalmeien-Kapellen,* of the German Communist *Rotfront;* no musical benefits ensued.[27]

Economic imperatives, too, can direct change for better or worse from a musician's standpoint, as when Federal-era embargoes on British goods and high import tariffs spurred development of American instrument manufacture. Inept management, depressions and fiscal panics, and wartime reallocation of resources are among other non-musical, economic factors that have driven instrument makers out of business or forced them to readjust priorities; for instance, during the twentieth century, wartime shortages of copper wire required substitution of steel wire for winding piano bass strings. Toward the end of the century, restriction of international commerce in elephant ivory necessitated development of synthetic substitutes, not only for covering piano and organ keys but also for making woodwind instruments.

Similarly, during the nineteenth century the growing popularity of upright pianos and declining market share for "square" models was due not to any tonal or mechanical advantage of uprights but mainly to their economy of floor space and greater efficiency of manufacture, which allowed lower pricing. The late piano historian and technician Roland Loest pointed out (in conversation, August 1995) that the upright piano's rectilinear geometry—for example, making use of key levers of equal length, unlike those in square pianos—allowed for rapid, straight saw cuts rather than labor-intensive curved cuts; consequently, upright pianos cost less to produce. Loest also noted that the purpose behind Sébastien Erard's development of the double-escapement piano action, patented in 1821, was not so much to increase rapidity of repetition for the sake of virtuosity, as is usually stated, as it was to make the action more comfortable and reliable under the touch of amateurs having limited finger technique.

Economics also played a part in eroding interest in pipe and reed organs when compact electronic substitutes became generally affordable.

27. I am grateful to Herbert Heyde for this information; Heyde notes (personal communication, 10 November 1999) that the prominent East German politician Erich Honecker had played in one of these bands.

The best known of these, introduced in 1935, was named for its inventor, the American electrical engineer Laurens Hammond. Soon, Hammond and other electronic organs infiltrated homes, nightclubs, and other venues where pipe organs would have been impractical and reed organs insufficiently versatile. The pipe organ's indelible association with church music contributed to its marginalization in an increasingly secular society. Today, electronic organs are in turn being displaced by smaller, even less expensive but more versatile synthesizers. Though still in their infancy, synthesizers are not mere organ substitutes, but constitute a distinct, quickly proliferating "species" that offers vast scope for musical experiment among amateurs as well as professionals.[28] The fast pace of innovation in audio electronics has already made synthesizers like those developed by Robert Moog in the 1960s and 1970s appear quaint.

Travel and migration, too, exert strong evolutionary pressure on instruments, though musicians can be slow to realize the potential of an exotic import. The banjo, introduced to America by African slaves before 1700, did not become acculturated here until minstrel shows brought the plantation instrument to white urban audiences during the mid-nineteenth century; thereafter, banjos were quickly adapted to mainstream tastes and transformed in appearance and capability.[29] Coming from a different direction, the wave of orientalism that followed Japan's opening to foreign trade in 1854 yielded not only entertainments such as Giacomo Puccini's opera *Madama Butterfly* (1904), but also a spate of ephemeral instruments of vaguely oriental form, including the one-string "Jap fiddle" employed by American and British vaudevillians.[30]

More importantly, the freely vibrating metal reeds at the heart of harmonicas, accordions, mélophones, the *Martintrompete,* and reed organs supposedly stem from Asian precursors brought to Europe as early as

28. Electronic amplification itself can increase creative options; see J. Kenneth Moore, "The Mixing and Miking of Broadway: Changing Values of a Sound/Music Aesthetic," *To the Four Corners: A Festschrift in Honor of Rose Brandel,* ed. Ellen C. Leichtman (Warren, Michigan: Harmonie Park Press, 1994), 169–88.

29. Karen Linn, *That Half-Barbaric Twang: The Banjo in American Popular Culture* (Urbana: University of Illinois Press, 1991), passim.

30. Laurence Libin, *American Musical Instruments in The Metropolitan Museum of Art* (New York: W. W. Norton & Co. and The Metropolitan Museum of Art, 1985), 144–45. Also see Pilling, "Fiddles with Horns," 89–92.

the mid-seventeenth century.[31] At first generally ignored in the West except for limited applications, the free-reed principle finally came into its own in the nineteenth century, chiefly in domestic rather than concert instruments and for the same practical reasons that later promoted sales of electronic organs: tuning stability, easy maintenance, and economy of cost and size. Tonal beauty, while not irrelevant—and indeed touted in advertising—was often a secondary consideration in these instruments, which appealed mainly to amateurs.

During the second quarter of the nineteenth century the proliferation of free-reed types might well have been represented by an expanding tree; the subsequent drastic culling, fully evident only in retrospect, was partly the consequence, at least in the United States, of pretentious "improvements" that raised prices but yielded no real benefit, and a dearth of compelling repertoire. The reed organ's heyday had passed by the time small, quiet electric turbines became available to take over the chore of pumping wind.[32] Companionable harmonicas, however, found a secure niche in popular culture and continue to enjoy ample sales; and thanks to the promotional effort of aficionados, fine nineteenth-century harmoniums and melodeons, still occasionally to be found in good condition, seem poised for a rebirth of attention from historically-minded listeners and players.

Although as with free-reed types, instrument innovation operates to some extent independently of mainstream musical style, makers do normally intend their products to be useful and must attend to customers' reactions. Inventors typically propose new ideas and users accept, modify, or reject them, causing makers in turn to respond. Performers themselves seldom initiate radical changes; most professional players have their hands full mastering the familiar instruments upon which their livelihoods depend. (Most instrument manufacturers,

31. Sibyl Marcuse, *A Survey of Musical Instruments* (New York: Harper & Row, 1975), 734.

32. Electric air pumps were applied to pipe organs, orchestrions, and vacuum cleaners shortly after 1900. Quieter motors suitable for installation inside player pianos followed quickly; however, cost and weight limited their use in small reed organs. Interestingly, the Regina Music Box Company of Rahway, New Jersey, facing competition from Thomas Edison's (nearby) development of the phonograph, in 1909 became one of the earliest successful manufacturers of electric vacuum cleaners; then, using vacuum technology, in 1911 Regina began producing player pianos. See Earl Lifshey, *The Housewares Story* (Chicago: National Housewares Manufacturers Association, 1973), 292–98.

especially large-scale ones, similarly focus on perfecting the products they are accustomed to making and resist radical redesign and costly retooling; however, see note 32 above.)

Rather than envision fundamentally new instruments, dissatisfied or adventurous musicians generally press for refinement of existing types, to render them easier to play or to extend their expressive range—or in individual cases to grab attention with a unique gimmick. Although idealistic or hard-pressed performers occasionally collaborate with instrument makers to improve designs, more often than not their plans run aground. For instance, Percy W. Gatz, a former bassoonist of the New York Philharmonic Orchestra, worked with the German woodwind manufacturer Wilhelm Hermann Heckel in the early 1930s to develop a customized bassoon key mechanism combining features of Almenräder and Boehm systems; the resulting mechanism was so complicated and confusing that it never gained acceptance.[33]

Occasionally, inventor and performer are identical. One such person, the virtuoso pianist Josef Hofmann (1876–1957), who held more than 70 patents, helped Steinway & Sons refine grand piano string scalings and key actions.[34] Another musician-inventor who succeeded brilliantly is the American guitarist and electrical engineer Les Paul (b. 1915), father of the popular Gibson solid-body electric guitar and a major contributor to audio recording technology; Paul relates, however, that one of his most prized inventions, an especially sturdy contact microphone, was initially suppressed by the manufacturer who bought his design.[35] The Augsburg organ and piano maker Johann Andreas Stein (1728–92) was another inventive musician, of whom Mozart wrote that "He often

33. Gatz's bassoon is in The Metropolitan Museum of Art, accession number 64.276, together with its documentation.

34. Personal communication, Henry Z. Steinway, 30 November 1999. Other pianist-inventors were not so successful. For example, the double-keyboard mechanism invented by the Hungarian pianist Emanuel Moór (1863–1931) only briefly interested piano manufacturers; despite vigorous promotion, fewer than 70 instruments were built that incorporated his design. Another Hungarian pianist, Paul von Jankó (1856–1919), developed a radically new keyboard of which Edwin M. Good has written, "The failure of Jankó's invention is inexplicable to those who suppose that civilization and technology operate on the basis of reason. It was a very intelligent, rational solution to the problems of the ordinary keyboard, but like most utopian solutions, it ignored human factors, including musical ones. It failed in part, certainly, merely because it was different" (article "Jankó, Paul von," *Encyclopedia of Keyboard Instruments,* vol. 1, *The Piano,* ed. Robert Palmieri [New York: Garland Publishing, 1994], 186).

35. Verbal communications, 1998–99.

said, if I myself weren't such a passionate music lover and couldn't do some little things myself on the clavier, I'd surely have lost patience with my work long ago; only I really like instruments that don't disappoint the player, and that are durable."[36] Yet, despite his musical insight and mechanical ability, Stein introduced instruments—the *Melodica,* the *Saitenclavier*—that proved impractical and ephemeral.

On the other hand, throughout history important design principles and inventions applied successfully to instruments have originated outside musical practice. For example, before the nineteenth century proportional geometric schemes derived from cosmology, architecture, and other disciplines often governed instrument design in order to ensure harmonious results, visually and aurally. Drawn wire for string instruments, valves for brasses, the piano's hammer mechanism, the Theremin's vacuum tubes and loudspeaker, and computer chips for synthesizers all stem from technology first developed for nonmusical purposes. For example, the rebounding hammers central to Bartolomeo Cristofori's conception of the piano, about 1700, were long prefigured in hammer mills and striking clocks, and something very like J. A. Stein's celebrated piano hammer escapement device appears in a mechanical knitting frame said to have been invented about 1590 by the English clergyman Rev. William Lee.[37] The difficulty of proving causal links among devices like these does not negate George Basalla's rule, "novel artifacts can only arise from antecedent artifacts."[38]

It can therefore truly be said that *Klangideale* arise no less from mathematics and technology than from artistic decisions, and that tonal preferences inescapably reflect cultural attainments in many fields. Most probably, humankind's first sound-producing artifacts were multipur-

36. "Er sagt oft, wenn ich nicht selbst ein so Passionirter liebhaber der Musik wäre, und nicht selbst etwas weniges auf dem Clavier könnte, so hätte ich gewis schon längst die gedult bey meiner arbeit verloren; allein ich bin halt ein liebhaber vom instrumenten die den spieller nicht ansezen, und die dauerhaft sind" (my translation). *Mozart. Briefe und Aufzeichnungen. Gesamtausgabe,* ed. Wilhelm A. Bauer et al. (Kassel: Bärenreiter, 1962–75), 2:69. Interestingly, neither Mozart nor Stein focuses on tone quality, but reliability is a chief concern.

37. Lee's slender escapement-like devices are of metal and combine catch and spring in one unit; Stein's are wider, of wood, and returned by a separate wire spring. Lee's stocking loom also employed jacks passing through a comb or rack, and although these are not exactly analogous to a harpsichord's jacks and racks, the relationship is noteworthy. See William Felkin, *A History of Machine-Wrought Hosiery and Lace Manufactures* (London: Longmans, Green, and Co., 1867), plate II facing p. 42.

38. Basalla, *The Evolution of Technology,* vii–viii.

pose implements whose acoustic properties were incidental.[39] Once these properties were recognized and appreciated, prehistoric people exploited the potential of artificial sounds, and noisemakers thereupon became specialized—not because they were needed in the first place, but because increasingly sophisticated uses were found for sound-producing utensils in communication, hunting, fighting, ritual, entertainment, and aesthetic expression. Developments in technology expanded the range of available sounds and refined their control, requiring users themselves to specialize. Customs and taboos regulating the usage of different instruments and the power of musicians led to hierarchies of status, vestiges of which survive to the present. Instruments' status, involving gender associations and other attributes, further channeled technological innovation toward or away from particular types.

Obviously, then, what we call "musical" instruments have many functions in addition to making music. Ethnic instruments, for example, ensure social continuity through the incorporation of traditional materials, symbolism, craft, and folklore. Some, like the Irish harp, have become emblems of nationhood. Elite instruments such as fine violins can function, even silently, as objects of art or as vehicles for investment. In many societies instruments still play a role in magic and ritual: bells, for example, are widely believed to avert evil. Of course, bells, bugles, and the like have also served as signal devices. At all levels of society, instruments work symbolically to convey their owners' status and perhaps gender; in Western art, for example, flutes are a conventional phallic symbol, while harps usually represent grace and goodness. And whether they are played or not, instruments provide a livelihood for makers who sometimes could not care less what becomes of their products after sale. Any evolutionary theory has to take these extramusical functions into account because they help explain the pace and direction of instrument evolution.

It is necessary here to distinguish between innovation and invention. Invention, the originating process, typically involves only a single person, maybe working in isolation and most often unsuccessfully. Innovation concerns not the initial creative process but the success of an invention after its birth, that is, its widespread adoption. Most inventions, whether fostered by personal expressive needs or practical incentives or

39. For discussion of some prehistoric instrument-making techniques, see Laurence Libin, et al., "The Fire Watchers," *Bulletin of Primitive Technology* 9 (Spring 1995): 11–36.

other factors, lead nowhere: as great a genius as Leonardo da Vinci invented or envisioned bizarre instruments that served no useful purpose and failed of adoption.[40] But such experiments provide the necessary seeds for innovation. Those that prove useful—and this recognition can be long delayed—lead to a market-driven proliferation of varieties, of which only a few might enter what we call, in retrospect, the mainstream of musical practice.

The advent of valves for brass instruments is a case in point. Brasses underwent only subtle changes during the century before keys were added in Haydn's day, but in the early nineteenth century valves (previously used in water pumps, among other applications) transformed brasses, changing their technique and increasing their flexibility. This development led by the 1830s to a rapid florescence of brass instrument types suitable for purposes ranging from virtuosic solo use (occasionally featuring novel echo attachments), to increasingly melodic employment in orchestras, to all-brass bands. By the last quarter of the century selection had taken its toll—here composers played a major role—and by, say, the 1930s fewer types of valved brasses remained in ordinary use than had arisen in that first rush of diversification. Some varieties that fell by the wayside had distinctive characteristics that modern brasses lack, and audiences are poorer for their loss. Fortunately, obsolescence is not the same as extinction, and Vienna-valve horns and rotary-valve trumpets, not to mention typically American bell-over-shoulder horns, have been revived in special circumstances.

The piano furnishes another example of rapid diversification followed by decimation. Within a generation of its invention Bartolomeo Cristofori's "hammer harpsichord" had spread from Italy to Iberia and Germany, where builders experimented freely with its mechanism and structure. By 1800 pianos of extremely varied design, many from small, isolated workshops, were ubiquitous; but despite continuing innovation in important structural and mechanical aspects, standardization during the later nineteenth century greatly reduced the number of essentially different designs in commercial production. By 1900 fewer distinctive types (such as square pianos and harp-pianos) were being manufactured than had been in use even fifty years earlier. Today, some early piano models have been cautiously revived to afford participants in the

40. For descriptions of Leonardo's viola organista, mechanized kettledrums, tunable bells, glissando flute, and other instruments see Emanuel Winternitz, *Leonardo da Vinci as a Musician* (New Haven: Yale University Press, 1982), part III, 137–203.

historically-informed performance movement more options; however, only a handful of factories worldwide still produce grand pianos on a substantial scale, and for most practical purposes their designs are interchangeable—the outcome, some would argue, of industrial overstandardization, which inhibits innovation and reduces variety. Consistent with their having achieved near-iconic status by 1900, concert grand pianos changed very little during the twentieth century compared to the nineteenth (excepting the recent addition of digital recording and playback capability and MIDI interfacing), a stasis reflected in their nearly uniform, formal black appearance.

It is significant that the United States became a world leader in piano design and manufacture before the nation had much to show in the way of professional composers or concert pianists; but it did have a burgeoning amateur market, protective import tariffs, manufacturing know-how, and ample raw materials. The striking number of American piano patents especially in the period 1830–47, a period of rapid market expansion even before Steinway & Sons entered the field in 1853, suggests that the immediate impulse for many such inventions arose more from profit motives or delight in mechanics for its own sake than from well-perceived musical concerns, advertising claims notwithstanding. The complaint of one anonymous writer in regard to competitive practices in the boiler industry could as well have applied to nineteenth-century piano manufacture:

> . . . it is an almost every day occurrence that a device or construction which has been tried and found wanting if not worthless, is again brought up as a great improvement upon other things which have been proven by their survival to have been the "fittest." This is particularly the case when a person or firm, have, by long experience, succeeded in supplying a felt want, and developed a business which promises to pay them in the end for their trouble and outlay; immediately a class of persons, who desire to reap where they have not sown, rush into the market with something similar, and, generally, with some idea which the successful party had tried and discarded, claiming it as an "improvement," seek to entice customers, who in the end find they have spent their money for that which satisfieth not.[41]

41. *Steam, Its Generation and Use with Catalogue of the Manufactures of The Babcock & Wilcox Co.* (New York and London: Babcock & Wilcox, 27th ed., 1893), 33. Because diversification leads so often to early obsolescence, patent statistics are not a reliable index of innovation (as opposed to invention), although they can indicate the vector of change. Before 1836 United States patents were issued without rigorous tests of novelty. In principle, United States patents are awarded to the inventor, but some governments award patents to the first applicant, who might not be the inventor.

A lesson from paleontology can help explain "natural selection" among instruments. Most scientists now assert that dinosaurs disappeared not gradually in the face of increasing competition from mammals, as was previously thought, but quickly, due to an environmental catastrophe that overwhelmed their adaptive capability. Luckily for us, mammals were physiologically preadapted for survival in the strange new situation. By the same token, saxophones, with their colorful tonal palette, wide expressive range, and great agility, were fortuitously preadapted to twentieth-century functions and tastes (particularly expressed by jazz and related popular music) and so flourished in musical environments where types such as the double-reed sarrusophone family could not compete. The Belgian inventor Adolphe Sax (1814–94) did not knowingly anticipate the extraordinary demands that American jazzmen such as John Coltrane would place on saxophones; it just turned out, by chance, that Sax's invention proved compatible with American popular music idioms and so helped shape their course.

While dinosaurs died out, many simpler organisms apparently survived unscathed; this suggests that sometimes simplicity confers advantages over complexity. Many percussion instruments have preserved their morphology virtually unchanged for centuries. Such conservation of form obviously does not depend on stability of repertoire or even of playing technique (in his 1960 work *Dimensions of Time and Silence,* the Polish composer Krzysztof Penderecki calls for a gong to be bowed). The slide trombone, too, has not changed fundamentally since the Renaissance; it retains an elegant system of telescoping tubing that allows great freedom of pitch, for example allowing a *portamento* (sliding) effect. This agility, lacking in most other brasses, provided a measure of expressive potential that, like the saxophone's, lay latent until liberated by experiments notably in the realm of 1930s and 1940s popular music, by artists such as Tommy Dorsey and Jack Teagarden.

Similarly, the newfangled piano, while overshadowed by the well-established harpsichord at least until the 1760s, was preadapted to accommodate the rise of naturalistic dynamic expression in the later eighteenth century, and in fact had a voice in promoting that trend. Musical naturalism arose within a wider intellectual movement that, in Oliver Sacks's words, "sought to replace the Newtonian world of masses and atoms by a world of dynamics and forces."[42] Once interpreting the world

42. Oliver Sacks, "The Poet of Chemistry," *The New York Review of Books* 40/18 (4 November 1993): 56; see also Jacques Barzun, *Darwin, Marx, Wagner,* 47.

in dynamic terms took hold, the piano underwent explosive technical development in directions that could not have been extrapolated from musical trends alone; progress in industrial metallurgy and mechanical engineering might have been a more accurate predictor. But, as noted above, many developments, including ones aimed at correcting perceived shortcomings such as the piano's inability to sustain a tone indefinitely or increase its loudness, or to remain in tune for long periods, led to dead ends.

Musicians of a Romantic frame of mind naturally believe that, for all its inherent flaws, the piano represents an improvement over the harpsichord and clavichord. So far as Spitta's unprovable notion (quoted above) of the "ideal instrument" is concerned, it is obvious that practical composers necessarily work within the limits of actual existing instruments, just as armies operate within the range of their guns, however much generals long for more powerful ones. Even visionaries like the American composer Harry Partch (1901–76) cannot write for instruments that have not yet been invented; Partch made his own instruments to suit his exotic scales, but few composers are so resourceful.[43] The point is that "invention begins not so much in need as in want."[44]

Out of the great diversity of all instruments ever invented, many types fail to engender significant music. Even some that do so—the baryton beloved of Haydn's patron Nikolaus Esterhazy, or the arpeggione employed memorably by Schubert—fall out of use if their specialization, cost, or difficulty of playing inhibits wider adoption. To take a more familiar example, the highly mechanized pedal harp became more or less sidelined during the twentieth century partly because it does not cope easily with chromaticism and because (like the harpsichord) its plucked strings cannot generate much volume, a limitation the guitar overcame through amplification. The pedal harp's cost and inconvenient bulk also pose obstacles to wider use; smaller, simpler "folk" harps are more widely available than ever before. Best suited to intimate chamber music, a genre that declined in popularity during the twentieth century, the elegant, elite pedal harp could, in the twenty-first century, become an endangered species unless championed by a charismatic performer.

43. Harry Partch, *Genesis of a Music: An Account of a Creative Work, its Roots and its Fulfillments* (2nd ed., New York: Da Capo Press, 1974). The "ether-organ" cited by Charles Ives in connection with his Fourth Symphony, second movement, and occasionally said to be imaginary, is of course a theremin, as Ives's own conductor's note makes clear.

44. Henry Petroski, *The Evolution of Useful Things* (New York: Alfred A. Knopf, 1992), 40.

The question why some instruments thrive while others fail bears heavily on attitudes toward performance practice. If, as was commonly supposed in Spitta's day, composers' conceptions are the main impulse behind instrument innovation, this would support a contention that Beethoven's late sonatas transcend his pianos' limited capabilities, hence his works goaded piano makers forward, and playing these sonatas on the kinds of "imperfect" pianos known to Beethoven falsifies his intent.[45] If, on the other hand, instrument innovation is largely the outcome of other forces, then we might allow that such innovation generates or propels style change by providing composers with previously unimagined or at least unexplored expressive means. According to this view, Beethoven, an expert pianist and an eminently practical if demanding composer, calculated his sonatas to exploit fully but not to exceed the capabilities of contemporary pianos—as would have happened if, for instance, he had demanded a crescendo on a held note or pitches outside the piano's range. Hence, Beethoven's intent, so far as his notation conveys it, precisely suits the limits of contemporary pianos, and he would not have written what he did if such pianos had not already been deployed.[46]

To reiterate a point raised above regarding saxophones and trombones, devices that arise in response to particular sets of circumstances can, if sufficiently adaptable, perform functions quite unintended by their inventors. Adventurous twentieth-century composers such as Henry Cowell, Charles Ives, and John Cage found fresh ways to attack the piano long after its structure had reached a developmental plateau by 1900. Similarly, although the vocal mechanism of *Homo sapiens* has not changed at all in historical time, modern composers frequently call for novel or unconventional vocal techniques; one of the simplest, called *Sprechstimme* ("speech song," halfway between singing and talking) was introduced as late as 1897 by Engelbert Humperdinck in his melodrama *Königskinder,* and a century later David Hykes and his Harmonic Choir

45. "Beethoven said . . . that he felt constricted by the limitations of the piano, although there is no reason for the claim (now happily out of fashion) that he ever calculated without those limits when writing for the keyboard" (Charles Rosen, *The Classical Style: Haydn, Mozart, Beethoven* [New York: W. W. Norton & Co., 1972], 404). Similarly, although Pierre Boulez has complained of his dissatisfaction with the modern piano, his piano music, while exceptionally difficult, is entirely playable.

46. Konrad Wolff has noted that "Schubert's piano music uses higher registers more consistently than even Beethoven's late works, but that trait is simply a result of the many improvements in the instrument" (*Masters of the Keyboard,* enlarged ed. [Bloomington: Indiana University Press, 1990], 185).

were exploring Tibetan vocal harmonics. Leaving aside the difference between technique and idiom, this constant revealing of fresh expressive potential even in the most intimately familiar "instrument" shows that extreme or unprecedented demands on performers need not compel any changes in their instruments; in other words, new messages need not compel a change in the medium.

This is not to say that successful instruments are by definition perfect; improvement does in fact occur in design and construction. Bells cast of tough alloys that do not crack, synthetic strings and drum heads that resist breaking, woodwinds that remain stable under varying humidity, all represent technological progress. Instruments with moving parts are especially open to improvement because the ease of operation and reliability of mechanisms can be objectively tested and their problems diagnosed. Electronic instruments, too, are being made measurably more efficient, versatile, and reliable.

However, players who have mastered a particular type of instrument are often reluctant to modify their technique to accommodate a different mechanism. Hence, for instance, many nineteenth-century orchestral players hesitated to adopt the Boehm key system for woodwinds or new types of valves for brasses even when these could, with practice, enhance facility and evenness of tone. Similarly, nineteenth- and twentieth-century efforts to introduce more comfortable, ergonomic violas have met with mixed success.

Tonal goodness and expressivity, however, are subjective matters that cannot be quantified, much less universally defined or even readily considered apart from players' abilities. The vast tonal spectrum of ethnic musics and *musique concrète* (a mid-twentieth-century compositional development involving manipulation of recorded sounds and noise) demonstrates that listeners can learn to appreciate almost any kind of sound in a musical context; but no performer willingly tolerates a clumsy, unresponsive instrument.

It is striking that one recent development in piano design, while embraced enthusiastically by leading performers, has been obstructed by concert hall administrators. A front-page article in *The New York Times* described Daniell [*sic*] Revenaugh's addition of a second lid hinged to the bottom of a grand piano in order to project more sound.[47] Although endorsed by concert pianists including Martha Argerich, Peter Serkin,

47. Anthony Tommasini, "Not Even Practice Gets a 2-Lid Piano Into Carnegie," *The New York Times,* 8 December 1997, A1, B5.

and André Watts, use of the patented lower lid was reportedly not permitted in Carnegie Hall, apparently only because it looks odd. Exclusion from a prestigious hall clouds the future of Revenaugh's invention and demonstrates the impact of nonmusical forces on instrument evolution.

+ + +

To summarize, musical style change alone offers an insufficient explanation for the evolution of instruments; other forces, particularly economic and technological but also social and political ones, as well as visual aesthetics, also influence the course of innovation and obsolescence, sometimes more strongly than the wishes of musicians do. Particularly during the past two centuries in Europe and America, and more recently in the developing Third World, change has been driven by enthusiasm for new products regardless of their utility, as inventors pursued profits or tinkered with instrument designs for the fun of it.[48] How else to explain the brief vogues of the arpeggione, keyed cittern, harp guitar, harpo-lyre, and ukulele, to name only a few? Once novelties become popular, people begin to believe that they were developed for important purposes; but, to invert a well-known saying, "Often, invention is the mother of necessity."[49]

As implied above, performers generally exert a more compelling influence on instrument design than composers, if only because far more instruments are bought and used by performers, especially amateurs. This is not to say that composers lack concern for instruments' (and voices') limitations; on the contrary, their music must fit within these limits if it is to be heard. Examples of composers adjusting notes or writing in one key rather than another to stay "within range" are legion; it simply makes no practical sense to write notes that cannot be performed.[50] The main point here is that while musical style depends upon

48. It has been said of saxophones, for example, that "as with motor cars, most of the larger makers have year by year brought out new models differing only in minor points which might form the basis of a commercial campaign" (Philip Bate and J. Bradford Robinson, "Saxophone," *The New Grove Dictionary of Musical Instruments,* 3:317).

49. Robert Post, curator of technology, National Museum of American History (Smithsonian Institution), quoted in Steve Lohr, "Reluctant Conscripts in the March of Technology," *The New York Times,* 17 September 1995, E16.

50. When a note exceeds normal parameters, the answer must lie either in the availability of an exceptional instrument or in a performer's unusual ability. Either that, or the composer is ignorant or joking, or trying to convey some obscure message.

the capabilities of existing media, style change is only one selective factor affecting the evolution of instruments and a less powerful force than is commonly believed.

Although it is commonly said that composers require (not just desire) new instruments to accommodate their conceptions, such claims usually cannot be substantiated. To take one example, Beethoven's often-quoted complaints about inadequate pianos express his frustrations as a performer, not as a composer. Instances of composers inventing or modifying instruments in order to achieve desired effects are rare and usually fruitless, since the results are usually too specialized for wider adoption. Harry Partch's microtonal instruments, for example, beautiful as they are, remain outside the mainstream. Instruments that flourish over long periods are either quite simple or readily adaptable to unpredictably varying conditions; successful accommodation in turn fosters new idioms.[51]

51. Further discussion of innovation and the impact of technology on music appears in Leonard B. Meyer, *Style and Music: Theory, History, and Ideology* (Philadelphia: University of Pennsylvania Press, 1989), chapter 4, especially 119–20.