

Instrumental modifications and extended performance techniques.

The instrumentarium of Western music throughout its history has been in a state of continuous change, and every type and period of music has given rise to its own modifications of existing instruments and playing techniques. The desire for instruments capable of greater range, volume and dynamic control has led not only to the use of new materials and improvements in design but also to the invention of new instruments, many of which have achieved small success and are now regarded as little more than curiosities. These developments, naturally, form the matter of other articles in this dictionary, in which the evolution of individual instruments to their present state is fully described. The 20th century saw an unprecedented expansion in the instrumentarium and a host of new approaches by composers and performers to the use of existing instruments; because these experiments often took place outside the mainstream of musical life it seems appropriate to discuss them as a group.

1. Introduction.

In the second half of the 20th century the problem of creating a repertory for a new or modified instrument became less significant than in the past, when even instruments for which major composers wrote important works (such as Schubert's Sonata for arpeggione and piano, d821) were not thereby guaranteed survival; indeterminate and graphic scores and compositions with unspecified instrumentation, together with various areas of free improvisation, have supplemented the compositions of those who often combine the three distinct functions of instrument inventor and/or builder, performer and composer in a single person. Some of these have come from different artistic disciplines, although often with a musical grounding, finding their way into the new field of invented instruments for a variety of creative reasons.

Since 1950 only a small proportion of Western music for ensembles in any style or area, including symphony orchestra, jazz and dance band, rock and folk group, has been played entirely on instruments that existed in, for example, 1900. At least half of the total output of three of the leading avant-garde composers who first came to prominence in the 1950s, John Cage, Mauricio Kagel and Karlheinz Stockhausen, includes new resources; they include unusual percussion, Renaissance, folk and non-Western instruments to newly invented acoustic, electro-acoustic and electronic instruments, as well as [Toy instruments](#), musical costumes, [Sound effects](#), environmental sounds, live electronics and electronic music on tape. Contemporary rock music relies heavily on instruments that were unknown before the 1930s, such as the electric guitar, electronic organ, electric piano and synthesizer. This flood of new instruments has been supplemented by many modifications, both temporary and permanent, of standard instruments in ways that go far beyond the intentions of the manufacturer or original designer; a number of composers have also called for extended performance techniques on traditional instruments.

2. Keyboard instruments.

(i) The piano.

The instrument that has been modified in the greatest variety of ways is the piano. A comparative newcomer, it was still in the early stages of its evolution in the 19th century, and many versions of both upright and grand forms were constructed. An early modification, which survives today in pianos manufactured by Steinway and many American companies, is the third or 'sostenuto' pedal, first introduced in 1844 by Boisselot in Marseilles, but not established until the American branch of Steinway adopted it in 1874. Some Bösendorfer grand pianos have an extension of a minor 6th to the normal range in the bass for reinforcing the left hand with octaves; a hinged flap covers these keys when they are not required, to prevent confusion in the player's visual orientation. Since the 1840s several modifications to the shape and lay-out of the keyboard, intended to simplify fingering, have been tried out (for example, the two manuals of the [Emanuel moór pianoforte](#), c1920, are tuned one octave apart – with provision for coupling them together – to simplify the execution of octaves and other large intervals; *see also* [Janko, paul von](#); [Keyboard](#), §3), and many inventors have built microtonal pianos (*see* [Microtonal instruments](#), §2). Even mirror-image left-handed pianos have been constructed; in 1876 Mangeot in Paris built several grands and uprights that combined a left-handed and a right-handed keyboard (as proposed by the pianist Józef Wieniawski), and a reversed copy of a Graf piano from 1826 was built for the left-handed pianist Christopher Seed by Poletti & Tuinman in the Netherlands in 1998. The largest piano ever built is probably the vertically strung Klavins piano in Bonn, in which the keyboard is some 4 metres above floor level on a special balcony for the performer.

In the 20th century many temporary modifications were made to the piano and new playing techniques applied to it. Isolated effects were required by Schoenberg in *Drei Klavierstücke* op.11 (1909), in which certain keys are silently depressed to raise the dampers and allow the strings to vibrate sympathetically, and Charles Ives, who in the 'Hawthorne' movement (1911) of his *Concord Sonata* called for the use of a piece of wood 14¾" (37.47 cm) long for the playing of diatonic clusters, while an 88-note 'plank' plays repeated clusters in the section 'Fabrika' of Aleksey Semyonovich Zhivotov and Mikhail Yudin's oratorio *Lenin* (c1930), and an 'octave bar' for clusters (eight white and six black keys) is specified in Lou Harrison's *Piano Concerto with Selected Orchestra* (1985). String glissandos, played by the fingers, are specified in Rued Langgaard's *Sfaerernes Musik* (1916–18).

The first composer systematically to explore unusual piano sounds and techniques was Henry Cowell. His innovations included the playing of chromatic and diatonic clusters (in *Adventures in Harmony*, 1913, and *The Tides of Manaunaun*, ?1917) and glissandos across several strings or along single strings, executed with the fingers while the dampers are raised (*The Banshee*, 1925), plucking the strings (*Aeolian Harp*, c1923, and *Piece for piano with strings*, 1924), damping the strings with the fingers and small mutes, and playing them with hammers and plectra, to create what he termed the 'percussion piano' (*The Leprechaun*, 1928–9) and stopping the strings to alter the pitch or produce harmonics (*Sinister Resonance*, 1930). Sheets of paper are threaded between the strings in Satie's *Le piège de Méduse* (1913) and an upright piano modified in the same way is proposed as an alternative to Georges Cloetens's [Luthéal](#) specified by Ravel in his *Tzigane* (1924) and *L'enfant et les sortilèges* (1920–25), which adds two treble and two bass stops to a normal grand piano; these provide, separately and in combination, additional timbres resembling cimbalom, harpsichord and lute or harp, created by placing suspended metal bolts and additional felt dampers in contact with the strings. A similar system, in which thin brass tongues folded round strips of felt are placed between the hammers and the strings, was devised by Pleyel to make the sound of the piano resemble that of a harpsichord; it was used in Reynaldo Hahn's opera *Mozart* (1925) and by Gabriel Pierné in 1926. In the early 1930s in works for percussion ensemble William Russell specified simple preparations such as a cluster board, string glissandos, and strings plucked and struck by beaters.

Unusual effects can also be obtained by playing the keyboard. Gordon Monahan's *Piano Mechanics* (1981–6) is 'a catalogue of actions and activities which approach the production of isolated acoustical resonances at the piano', including hand-swept strings, rapidly repeated single notes and clusters, trills and tremolos, partial damping with pedal and hand on strings; as with the repetitive 'strumming' technique adopted from the late 1960s by Charlemagne Palestine in performances of his own solo piano compositions, these techniques are intended to build up and vary substantial resonances and overtone structures in the instrument.

The best-known of all piano modifications is John Cage's [Prepared piano](#), devised in 1940 (not, as generally stated, 1938), in which a variety of objects are inserted between the strings, changing both timbre and pitch, to create a one-man percussion ensemble; a range of different, more muted sounds is heard when the soft pedal is depressed. The prepared piano was the culmination of Cage's explorations of some of Cowell's ideas – the muting of strings both manually (*Imaginary Landscape no.1*, 1939) and by sliding a metal cylinder along them (*Second Construction*, 1940), and sweeping them with a stick (*First Construction (in Metal)*, 1939). Up to 1954 he wrote nearly 30, mostly solo works for the prepared piano, some of them for dance performances. Over 120 composers have composed at least one work featuring the prepared piano. Closely associated with Cage around 1940 was Lou Harrison, who devised the 'tack piano', in which thumb tacks or drawing pins are inserted into the hammers to create a metallic sound quality. This idea (known in German as the 'Reissnagelklavier' or the 'Reisszweckenklavier') was arrived at independently and applied mainly to upright pianos by other musicians, including the composers Henry Brant, Paul Dessau, Kagel, Wilhelm Killmayer and György Ránki, as well as the honky-tonk pianist Winifred Atwell, and was used for producing louder piano sounds in early film music recordings; old and out-of-tune pianos, which produce a similar effect, have been called for (usually in theatrical contexts in connection with 1920s jazz or other popular musics), notably by Alban Berg, Max Brand, Peter Maxwell Davies (several works), Karl Aage Rasmussen, Zygmunt Krauze and Irwin Bazelon. The 'percussion piano' of Cowell was further developed by Lucia Dlugoszewski as the 'timbre piano' (1951), in which the strings are bowed with small 'bows' to produce sustained sounds; a similar approach has been adopted in several compositions since 1972 by Curtis Curtis-Smith, while since 1977 Stephen Scott has created a series of works in which the strings of a single instrument are bowed by an ensemble of about ten players with various flexible and rigid 'bows', as well as solo pieces in which silently depressed keys raise the dampers from the electromagnetically excited strings. Annea Lockwood and Hans-Karsten Raecke have developed their own, somewhat different approaches to preparing pianos. The piano strings are plucked in Tan Dun's *Concerto for Pizzicato Piano* (1995) and, as the 'Saitenklavier', in Stockhausen's *Klavierstück XVI* (1999). The piano has been the subject of many modifications besides that of preparation, and considerable use has been made of different methods of playing the strings, frame and case, both with fingers and various implements, in works by Kagel, Cage, Orff, Lukas Foss, Ben Johnston and others. Pianos with the action removed so that they must be played like a cimbalom have been specified by Peter Maxwell Davies and Denis ApIvor, and the strings are struck with T-shaped 'cluster-sticks' in works by David Bedford and Davide Mosconi. Foss, Bedford, George Crumb, Xenakis and others have called for undamped piano strings which vibrate sympathetically when other instruments are played nearby.

The most radical of all the modifications applied to the piano – electrification – was introduced in the 1920s and 1930s. Instruments such as the Elektrochord and the Neo-Bechstein-Flügel were adapted versions of the normal piano, electrically amplified to give variations in timbre and volume and a far longer sustain time than normal because they had no soundboards. Since the 1930s the sound-generating systems of electric pianos increasingly used reeds, rods or electronic oscillators instead of strings, while at the same time the outward appearance of the instruments has come to bear less and less resemblance to the acoustic original. The [Player piano](#) has provided a further means of surpassing the capabilities of the standard piano, and many composers, including Stravinsky, Hindemith, Grainger, Casella, Malipiero, Milhaud, Antheil and Toch wrote works for it, culminating in the series of astonishing virtuoso compositions by Conlon Nancarrow, which far exceed in speed and rhythmic complexity anything that a human pianist could play. Interest in the player piano among composers increased substantially from the 1980s.

(ii) Others.

A limited amount of modification has been carried out on other keyboard instruments. Clusters and plucking or striking the strings of the harpsichord (already explored by Friedrich Wilhelm Rust in the late 18th century for lute-like sounds) have been incorporated into some new repertory for the instrument, in particular works written for Elisabeth Chojnacka. The harpsichord has also been amplified, as in the Thienhaus-Cembalo and the electric harpsichords manufactured by Baldwin. As with the piano, a large number of experimental microtonal reed organs and pipe organs were built, chiefly between the mid-19th century and the 1930s, though a few, notably the 31-note organ of Adriaan Fokker and several electronic instruments, were devised later. The pipe organ has been modified for works commissioned by the organists Karl-Erik Welin and Gerd Zacher, who had built to his own specifications an organ with a touch-sensitive Great manual. Glissandos and timbre changes, produced by altering the wind pressure, have been obtained by switching an organ off during a sustained sound, and Zsigmond Szathmáry has removed individual pipes for controlled reduction in wind pressure. An unusual bamboo pipe organ was built in the Philippines by Diego Cera around 1816–24. The electronic organ is not (with very rare exceptions) an electronically amplified pipe organ (*see* [Electric organ](#)), though a number of hybrid pipe and electronic instruments, which may be regarded as modified pipe organs, have been built.

3. Strings.

(i) The guitar.

After the piano the instrument that has probably undergone most modification is the guitar, especially in the form of its 20th-century offshoot, the [Electric guitar](#). Other long-established commercially manufactured versions of the guitar include the dobro, or [Resonator guitar](#), which has a metal disc mounted under the bridge to give increased volume, and the Hawaiian guitar, which evolved from the technique of laying a guitar across the lap and playing it with a slide. Since the 1960s, when the electric guitar first enjoyed great popularity, a number of new electro-acoustic and electronic variants have been devised. The Stick, developed by Emmett Chapman and marketed by Stick Enterprises in Los Angeles since 1973, consists of a long, wide, fretted neck with two sets of five strings; the left hand plays the treble ones (tuned in 4ths) and the right the bass ones (in 5ths), hammering them against the frets to set them vibrating. A guitar-like synthesizer controller, David Vorhaus's Kaleidophon, which also frees the right hand from its normal function, is only one of a number of such instruments developed since the late 1970s. Two devices intended to sustain the notes of the acoustic guitar are the Gizmotron and the Bass Gizmotron, devised by the rock musicians Kevin Godley and Lol Creme and improved by John McConnell around 1971; they each consist of a set of small revolving wheels that activate the strings. The E-bow ('energy bow'), which has a similar purpose, electromagnetically activates only one string at a time. A considerable range of electronic modification devices that process the signal produced by an electric guitar have been manufactured and have become part of the standard equipment used by pop and rock musicians.

Instrument inventors have made further and more unusual experiments with the guitar. Harry Partch refretted guitars in 1934 and 1945 to adapt them for the playing of music in his 43-note system, and many others have made similar adaptations to facilitate playing in various microtonal tunings. Hans Reichel has extended the frets on an acoustic guitar right up to the bridge, and has constructed a bodyless electric guitar which consists of two necks joined together at their lower ends to form a single straight length with pickups attached. Instruments based on the electric guitar have been made by Fred Frith, including an eight-string fretless version with a pickup at each end of the strings; Glenn Branca has done similar work. Strings about six metres long connect a string on each of two acoustic guitars to a low piano string for added resonance in Kagel's *Tactil* (1970).

Particularly in popular music, where the electric guitar has been most extensively adopted, new and often extravagant performing techniques have been evolved. Some country music performers on the electric Hawaiian guitar use models with four necks, one of which is prepared and reserved for sound effects such as train noises, much as guitarists in Hawaii previously specialized in producing animal and bird sounds. Jimi Hendrix's performances included passages in

which he played the instrument with his teeth, without interrupting the flow of the music. Temporary adaptations of the guitar, similar to those found in the prepared piano, have been devised, notably the attachment to the strings of small 'crocodile' clips and the insertion between them of threads of cotton or thin lamellae, and the use of bows and electric motors with the guitar laid on its back; among the exponents of electric and acoustic guitars prepared in such ways are the composer and guitarist William Hellermann, and the improvisers Keith Rowe, David Toop, Frith, Peter Cusack, Gerry Fitzgerald, Mike Cooper, Eugene Chadbourne (who also plays a modified dobro), Henry Kaiser and Kevin Drumm. Other new playing techniques involve additional microphones, movable bridges and hand-held slides (including the country music 'bottleneck'), scordatura of one or more strings, percussive playing on the body (as in flamenco), and acoustic feedback (pioneered by Hendrix and the improviser Derek Bailey in the late 1960s).

(ii) Others.

Bowed strings are probably the group of instruments to which modifications were applied earliest, but paradoxically they received less attention in the 20th century. Adaptations to the instruments themselves, such as scordatura tunings and the use of the mute, and non-standard performance techniques – for example, playing *col legno*, making percussive effects on the body and producing harmonics – have long since been accepted. Luigi Russolo's *arco enarmonico* was a new form of bow designed to eliminate the need for fingering. Electrical amplification of bowed strings was introduced and quite extensively explored in the 1920s and 1930s and, especially since efficient contact pickups became available (including some that are built into special bridges), has become widespread in most types of music. A number of electric bowed string instruments have been devised with soundboards (bodies) of reduced size, or no soundboards at all (see also [Electronic instruments, §I, 2\(i\)\(c\)](#)); the similar [Stroh violin](#), though itself not electrified, was designed for use in the recording studio.

Other experiments in the adaptation of instruments of the violin family have included the mechanically operated modified string instruments (including two six-string violins with flat bridges for ease of executing three-note chords) constructed by Erich Doerlmann for Herbert Eimert's ballet score *Der weisse Schwan* (1926), and Harry Partch's 'adapted viola' (1928–30) with a cello fingerboard, designed for playing microtonal music. New instruments have been constructed with different compasses and size–compass relationships: shortly before 1920 Léo Sir built six such instruments to complement the standard four (they were used in Honegger's *Hymne pour dixtuor à cordes*, 1920); and Carleen Maley Hutchins and Frederick A. Saunders of the Catgut Acoustical Society of America have devised a set of eight instruments (see [New violin family](#)) which have had some success (Henry Brant featured them in *Concert for True Violins*, 1966); single instruments designed to extend the compass of the normal violin are the Violino grande and Gunnar Schonbeck's treble violin (tuned a 4th higher). Ken Parker has constructed a ten-string double electric violin for the Indian violinist Lakshminarayana Shankar, in which two separate bodies with five strings each are mounted on a convex support; the strings can be tuned to cover a range from that of the double bass up to the violin. Jon Rose has modified a number of bowed strings: his instruments, which have additional strings (including sympathetic strings), bridges and fingerboards, include a ten-string 'double violin' whose two bodies are placed end to end on an extended neck, and a violin and cello with 19 strings. Violins have been made from metal, transparent or coloured perspex (for rock musicians); experimental lopsided instruments have been built, and violins, mandolins and guitars have been constructed from two-ply sheets of wood that are assembled from used matchsticks (some 10,000–12,000 per instrument) with the burnt heads retained for decoration.

Around 1920 Carlos Salzedo devised many new techniques for the harp, including glissandos and the use of various kinds of plectra; Anne LeBaron has prepared her harp with sheets of paper and crocodile clips. Electric harps and specially-designed pickups are manufactured; Zeena Parkins has played an electric harp of her own design.

4. Wind.

(i) Brass.

Modifications to brass instruments in the 20th century largely fell into three categories: the use of newly invented mutes; the use of 'wrong' mouthpieces; and alterations to the structure of an instrument. A number of new types of mute were introduced in jazz and dance bands in the early years of the 20th century, including a tin-can mute for a cornet (1917), various home-made mutes (used, notably, by the Original Dixieland Jazz Band), the 'wa-wa', aluminium 'hat' (modelled on the Derby bowler hat worn by musicians) and the 'plunger' (which in its original form was a rubber sink plunger without the handle); the last gives a very vocal quality to the sound and was pioneered in the 1920s by, among others, the trumpeter Bubber Miley. John Silber has explored a variety of new mutes for the trombone, including flat discs, found objects and several that incorporate tuned organ reeds. Reeds have also been added to mouthpieces: Silber has used many types of single-reed mouthpiece and another trombonist, Vinko Globokar, has played on different

reeds and other mouthpieces; a bassoon reed has been fitted to the French horn by Gordon Mumma and in the Tromboon devised for 'P.D.Q. Bach' by Peter Schickele.

Modification of an instrument by rearranging the tubing or removing or adding sections has been explored by several virtuoso brass players. In *Tubassoon* (1979) Melvyn Poore features quadrophonic amplification of four open sections of the tuba, controlled by the valves and played with a bassoon reed; he has also played the tuba with a clarinet mouthpiece and an oboe reed. The tuba player Zdzisław Piernik has created an instrument with multiple bells, which somewhat resembles an experimental trombone invented by Adolphe Sax in the mid-19th century, having seven tubes with individual bells, and six valves. The improviser George Lewis has treated his trombone by removing sections while playing. In *Bolos* (1962) by Jan Bark and Folke Rabe special effects are produced by hitting the mouthpiece of a trombone with the palm of one hand, blowing through a separate mouthpiece and removing the slide so as to produce a 'vacuum smack'. The distinctive uptilted bell of Dizzy Gillespie's trumpet (originally the result of an accident) was adopted by the trumpet section of his orchestra to compensate for the downwards angle of the instrument when the players were reading from a score.

(ii) Woodwind.

Woodwind instruments have been less often subjected to dismantling and rearrangement than brass, though Globokar's *Discours IV* (1974) calls for three performers playing a single clarinet body with three mouthpieces, and Evan Parker devised a similar Communal Blown Instrument in which a selection of wind mouthpieces are fitted to a single large tube with a horn. Special effects are obtained by using mouthpieces separated from their instruments, such as a double reed or the top joint of a single-reed instrument, and wind instruments with the mouthpiece, reed or top joint removed have been played somewhat in the manner of brass instruments (the first occurrence of the latter technique is probably in the part for sarrusophone in the opening of Ravel's opera *L'heure espagnole*, 1907–9).

The saxophone was the basis of several new instruments of an experimental nature: the jazz saxophonist Roland Kirk specialized in playing two unusual variants – the Manzello (a curved soprano, similar to the Saxello) and a modified Stritch (a straight alto) – simultaneously with a normal instrument; slide saxophones were briefly popular in the 1920s and 1930s and several modern versions have been made, including Paul Lytton's Lyttonophone; and Jim Sauter and Don Dietrich have created a composite saxophone by playing on two instruments with the rims of the bells touching. New designs for woodwind instruments, intended to simplify or extend their playing techniques, include the 'logical bassoon' with electric action, the slide Vermeulen flute, several new systems of keywork devised by Robert Dick, wind instruments that control small synthesizers, such as the Lyricon, Electronic Valve Instrument (later marketed by Akai, together with the saxophone-like EWI) and Yamaha's WX series, and the fanciful variants, one of which can be assembled in different ways, invented by Hans-Karsten Raecke. Flutes and pipes have been made of materials such as plastic and (increasingly) bamboo, and David Toop devised a combination of the Mirliton and a duct flute, in which a live wasp, imprisoned in an enclosed compartment, provides a drone. Devices added to woodwind instruments to modify their sound include the occasional improvised mute, and electronic devices which process the signal the instrument produces (such devices are widely used with other instruments, particularly the electric guitar, but octave multiplier and divider circuits are primarily intended for use with wind instruments).

Extended performance techniques have been thoroughly explored by woodwind players. Flutter-tonguing has become common, and other techniques, such as unorthodox cross-fingerings, multiphonics, split notes, circular breathing, and humming, singing or growling while playing, are becoming increasingly so. Key noise is specified in a number of works, the earliest of which was probably Varèse's *Density 21.5* (1936).

5. Percussion.

A percussionist typically does not specialize in a single instrument, but learns more neutral finger and stick techniques that can be applied to any resonant object, which can just as easily be a found object or a newly invented instrument. During the 20th century the greatest expansion of resources was in the area of percussion; many of the instruments and performance techniques that are now standard in the symphony orchestra were first introduced up to the 1930s in jazz, variety performances, the music hall, accompaniments to 'silent' films and so on. This expansion can be divided into several areas: in addition to the modifications to be considered here, there are the enormous range of noise-makers and 'found' instruments required in some experimental works (for examples of which see [Sound effects](#)), the adoption and integration into the orchestra of many non-Western instruments (a process that has gone on for several centuries), the development of new instruments such as the flexatone, musical saw and vibraphone, and the recent evolution of [Electronic percussion](#) used primarily in rock music.

Familiar instruments have been used in many contexts as the source of new sounds, ranging from the 'rimshot' on drums, which first became popular in the 1920s, and the 'water gong' devised in 1937 by John Cage, to bowed cymbals and vibraphone keys, cymbals inverted on drum skins and the great variety of sounds obtained from a large Paiste tam-tam (160 cm diameter) activated by a battery of different objects in Stockhausen's *Mikrophonie I* (1964) (the sounds are also modified and amplified electronically). Substantial amplification of smaller percussion was employed in several works performed by the solo percussionist Max Neuhaus in the mid-1960s.

New variants of existing percussion instruments may be considered in corresponding groups. Several new drums have been devised, such as the Geophone, a rotating drum containing sand, used by Messiaen and others; the Boobams developed by William Loughborough which Henze has featured; and the Rototoms invented by Michael Colgrass in the 1960s, which offer the resources of a set of tuned drums that have been employed by Peter Maxwell Davies and other composers, as well as rock musicians. The sizzle cymbal and hi-hat, found chiefly in popular music and jazz, have been supplemented in improvisational contexts by cymbals made of scrap and found materials; Paul Burwell has cut small cymbals to square, elliptical and flower-like shapes, altering the ratio between the circumference and the size and therefore modifying the overtones they produce. Chimes and gongs have been made of unusual materials such as marble (Robert Erickson and Gunnar Schonbeck), stone (Carl Orff), glass (Anne Lockwood and the members of the Glass Orchestra), and bamboo, aluminium and steel (David Sawyer's *Handchime*). Modern versions of the musical glasses, as well as the struck Bouteillophone, are required in a number of 20th-century scores. Early in the century John Taylor & Co. of Loughborough constructed a set of cup bells (two and a half octaves) for the Dutch composer Daniel Ruyneman: Ruyneman's own Electrophone electric bells date from around the mid-1930s. Keyed percussion instruments are well-represented in the work of Harry Partch and other makers of microtonal instruments; in addition Ron George has built extended vibraphones, Schonbeck has made marimbas out of marble, and Christopher Charles Banta has specialized in building bass and contrabass marimbas with individual resonators. Various types of Lamellophone have been adopted or constructed, including the Marimbula specified by Cage in *Imaginary Landscape no.3* (1942) and more recently in works by Henze.

Whole families of percussion instruments have been devised and used by Lucia Dlugoszewski and large numbers individually by Mauricio Kagel for his theatrical works. Several new ergonomically efficient systems for mounting percussion kits have been constructed, including the Loops console of Ron George.

The enormously expanded battery of instruments with which contemporary percussionists are often surrounded is accompanied by an equally large selection of beaters and sticks, and this has often led to the 'wrong' sticks being used, either from choice or because there is no time for the player to change to the appropriate ones. Two types of stick devised in the 20th century are the jazz 'wire brush' of the 1920s (adapted from an outdoor fly swatter) and the 'superball mallet' (based on the eponymous ultra-resilient rubber toy ball) originally constructed in the early 1970s, which is ideal for unusual friction effects. Multi-stick techniques, the player using two or more sticks in each hand, have become quite common; a similar approach is adopted in the part for the tapered kidney-shaped Deri drum in Stockhausen's *Momente*, where a fast tremolo is executed by two sticks (held in one hand) pivoting round a third stick that is drawn across the skin of the drum to create a glissando.