VIII

THE

KEYBOARDS

GENERAL CONSIDERATIONS

Except for a handful of percussion, all the instruments we have discussed so far fall neatly into groups related both by acoustics and by playing technique. The various keyboard instruments, however, are related to each other only by playing technique; numbered among them are idiophones (celesta), stringed instruments (piano), woodwinds (organ), and electronic instruments (ondes martenot). The keyboard mechanism so dominates this acoustic miscellany that, with certain exceptions, all keyboard music looks much alike on the page, and music written for one instrument can be played on another with surprisingly little distortion of the musical content*—indeed, prior to the eighteenth century composers made little or no distinction among the keyboard instruments.

TECHNICAL DISTINCTIONS

The major acoustic distinctions to be made among keyboard instruments are that between sustaining and non-sustaining instruments and that between those which are **touch-sensitive**—i.e., those in which the loudness of the notes is governed by the force with which the

* This is not to condone such substitutions, however. The practice of playing harpsichord music on the piano or of treating virtually *all* music as legitimate grist for organ or piano transcriptions is in questionable musical taste at best.

	sustaining	*touch-sensitive*
celesta	no	yes
keyboard glockenspiel	no	yes
toy piano	no	yes
piano	no	yes
electric piano	no	yes
clavinet	no	yes
accordion (etc.)	yes	no
organ	yes	no
electric organ	yes	no
melotron	yes	no
performance synthesizer	yes	no
ondes martenot	yes	yes
harpsichord	no	no
clavichord	no	yes
hurdy-gurdy	yes	no

FIGURE 171. *Keyboard instruments classified by sustaining power and touch sensitivity.*

keys are struck—and those which are not. The above table (which for the sake of convenience includes three "early" keyboard instruments discussed in Chapter XIII) shows how these features are distributed among the keyboards.

It will be noted that almost all keyboards that are touch-sensitive are non-sustaining, and vice versa. As might be imagined, there are substantial differences in playing technique between these two groups of instruments, differences that can be generalized as "piano technique" versus "organ technique" and are discussed below under the headings for those two most important of all keyboards.

Non–touch-sensitive instruments are typically supplied with a variety of **stops** by means of which the instrument can take on a variety of different timbres. Each stop usually affects the whole keyboard and has not only its own timbre but also a specific loudness and even pitch: many stops sound not at written pitch but in some other octave. In the organ, where the idea of stops first originated and where it is most highly developed, stops are found giving pitches as much as three octaves above or below the keyboard pitch, and there are non-octave stops whose function is to add a strong third, fifth, or even seventh partial to the tone of an ordinary stop used simultaneously. The terminology for the various octaves is based on the fact that the note C_0 on the organ (its lowest keyboard pitch) requires an open pipe about eight feet (two and a half meters) long; thus any stop that sounds at actual pitch is said to be an "eight-foot" (8′) stop. If the stop sounds an octave above keyboard pitch, it is a 4′ stop, if two octaves higher a 2′ stop, etc.; if it is an octave *below* keyboard pitch it is a 16′ stop, and so on. The organ's non-octave stops get fractional numbers: a twelfth above keyboard pitch (third partial) is 2⅔′; two octaves plus a major third above keyboard pitch (fifth partial) is 1⅗′; two octaves plus a flat minor seventh above keyboard pitch (seventh partial) is 1⅐′.

The various stop pitches are called **registers**; one speaks of, for instance, "the 8′ register" or "the 4′ register." There may be many stops in each register, and the name of each stop says something about its timbre—for example, "flute stop" or "harp stop." The art of combining and contrasting stops is called **registration**.

Keyboard instruments are enough alike in technique that doubling is fairly easy, particularly where similar conditions of sustention and touch-sensitivity prevail. The organ, accordion, and ondes martenot require performance techniques that players of other instruments cannot be assumed to have mastered,* but players of these three instruments are often, though by no means always, able to double on piano and other "ordinary" keyboards. Any pair of non-sustaining keyboards, as well as electric organ, performance synthesizer, and melotron, may be set next to each other at right angles, the lowest note of one instrument adjacent to the highest of the other, so that the player can rapidly and easily shift from one to the other or even play them simultaneously.

With the exception of a few specialized electronic instruments, keyboard instruments are **polyphonic**; that is, many different notes can be played simultaneously, enabling the production of chord progressions and counterpoint on a single instrument. This is achieved by providing each note with its own separate string, pipe, bar, or what-have-you, so that when the key governing that note is depressed, the note will sound no matter what other notes may be needed simultaneously. One consequence of this is that, all else being equal, the greater the number of notes sounded simultaneously the louder the sound will be. Acoustic interference takes its toll and the effect is much more subtle than might be imagined, but the varying of texture to obtain nuances of volume is a vital part of sensitive keyboard writing, particularly for instruments that are not touch-sensitive. Basically, a chord of eight notes will sound a little less than one dynamic level louder than a single note played with the same force.

FINGERINGS

The only limits on polyphonic playing are the number, spacing, and dexterity of the player's fingers. Since the arrangement and width of the individual keys are standard for all keyboards, the following chart, which shows the average maximum stretch between the various fingers of one hand, is valid for keyboard instruments of all sorts. Note that left-hand configurations are mirror images of right-hand ones, so that the thumb normally plays the lowest note of any right-hand grouping and the highest in a left-hand one.

In addition to the ordinary stretches charted above, the thumb can be turned under the other fingers, reaching as much as a fifth beyond the second finger. While this turning-under of the thumb is awkward and seldom used in chords, it is absolutely essential to the smooth and rapid playing of scales and scale-like patterns, where the thumb reaches under and beyond two, three, or four other fingers to continue the scale beyond the range of five notes. Observe that (1) the left-hand fingerings are essentially a mirror image of the right-hand ones; (2) the fifth finger is seldom used in such passages (it is employed much more frequently in chords and leaping passages, such as broken octaves); and (3) the thumb is turned under—or, what amounts to the same thing, the rest of the hand is rotated over the thumb—only when the

* This is also true of the harmonica, which does not even have a keyboard and is in this chapter only for want of any more appropriate location.

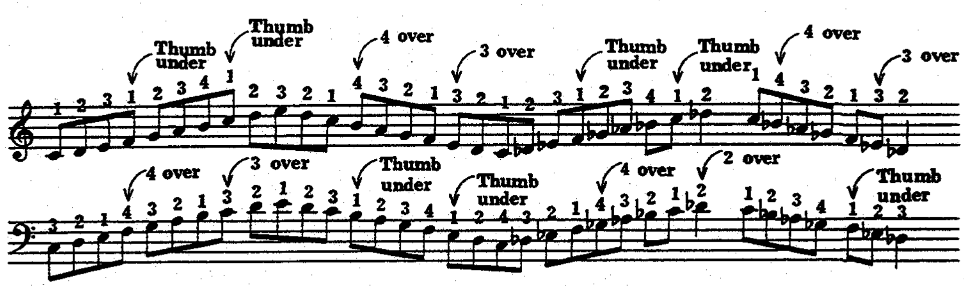
To Finger	Stretch From Finger 1	2	3	4
5	M 10th	M 7th	M 6th	aug. 4th
4	M 9th	m 6th	perf. 4th	
3	m 9th	aug. 4th		
2	M 7th			

FIGURE 172. *Limits on spacing of intervals and chords on a keyboard instrument: average maximum stretch between pairs of fingers on one hand, where all fingers are positioned over the keys.*

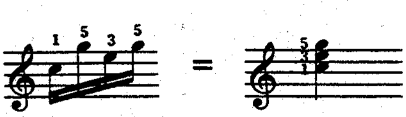
thumb strikes a white key, and preferably the note F or C (right hand), E or B (left hand). Indeed, the whole fingering pattern is arranged around the favorable positioning of the thumb, which is almost never used to strike a black key in scalewise passagework (since it is shorter than the other fingers, in order for it to strike a black key the hand must be either rotated outward or placed far back on the keyboard). In chords and leaping figures, however, the thumb plays black keys as often as any other finger.

Right hand

Left hand



Broken chords and leaping passages are generally fingered as if the notes they contained were to be played simultaneously as a chord:



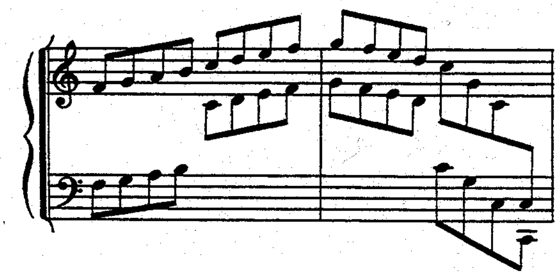
Among instruments of the piano type there is some flexibility in this regard; see the discussion of the piano, below.

There is almost no limit to the agility of keyboard music. Passages requiring large or awkward movements of the hands must of course be written with some caution, and rapid repeated notes (usually played with alternate fingers of one hand) are difficult, though possible; but performance standards for pianists at least are currently so high that feats of incredible virtuosity have become almost commonplace.

NOTATION

Music for a keyboard instrument is generally notated on two staves, braced together at the left of each line of music, and with the bar lines, if any, running through the complete double staff.

Notes played by the right hand are generally written on the upper staff, those played by the left hand on the lower staff; however, the two staves are usually also assigned different clefs, and where the assignment of hands is simple and obvious it is entirely normal to assign high notes to the upper staff and low notes to the lower one, regardless of how they are to be played:



Indeed, notes of more than three ledger-lines are to be avoided between the staves. In complex passages, nonetheless, and especially when the hands must overlap or even cross, composers should keep the two hands on strictly separate staves, even though, for instance, a bass clef may be required for the upper staff and a treble clef for the lower. Despite these precautions it will *occasionally* be necessary to specify verbally which hand is to play, particularly when one hand enters before the other and in an uncharacteristic range. This is done by simply writing the letters "L.H." or "R.H." at the beginning of the passage in question.

Crossed-hand passages are usually so obvious from the notation that no special instruction is necessary, but when the two hands overlap in the same range great care must be taken to see that they don't get tangled up. Basically, in such a situation one hand must lie above and behind the other, and that hand should generally be the one that has to use more fingers and to play more black keys. Often it does not matter which hand is on top; and all other things being equal, if one hand is "on the scene" before the other, that hand will take the lower position. On occasions where the relative position of the hands is important to the playability of the passage, the notes to be played by the top hand should be marked "sopra" (Italian: "above"), or those for the lower hand marked "sotto" ("below"). It may also be wise to indicate the fingering of one or both parts if the passage is particularly sticky—determination of the best fingerings requires access to a keyboard but no particular ability as a keyboardist.

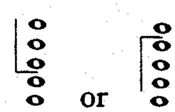
Tricky and deceptive-looking passages in general, as well as dense counterpoint and oddly spaced chords, will benefit from an *occasional* indication of fingering. This should be kept to the absolute minimum, and it should be remembered that in indicating the fingering of a single note, that of a great many succeeding notes may well be implied by simple logic. Fingering is indicated with the Arabic numerals 1–5 for the five fingers of the hand, placed immediately above the notes indicated. If a change of fingers is required while a key is kept depressed, this is indicated with a curved line, thus: 

, indicating in this case that the note is to be struck with the second finger, and the third finger then substituted while the key is held down. All the notes of a chord should be fingered, not just one or two. The figures are usually stacked above the chord in the same order as the notes they affect, but they may be placed to the left of those notes instead. When the thumb is to play two notes at once (see below), a bracket is used to show that the single figure 1 is to be applied to two notes: 

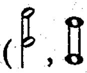
A number of special notations applied to chords should be mentioned here. The **arpeggio**, in which the notes of the chord are struck one after another in a rapid sweep, is indicated with a vertical wavy line to the left of the chord affected. Normally the notes are played from lowest to highest, but with arrowheads it is possible to differentiate downward (↓) from upward (↑) arpeggios. Some composers use a straight vertical arrow (↑) to indicate a rapid arpeggio, reserving the wiggly line for a more leisurely, romantic effect. A vexed question of keyboard notation is what to do about arpeggios in which the notes are struck in a less traditional sequence, the usual solution being to indicate the order as a series of grace notes individually tied to the chord itself:

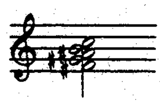
Sometimes the word "arpeggio" is added to make sure the effect is properly played (grace notes are usually played more slowly than the notes in an arpeggio). One defect of this notation is that it requires a sharp-eyed and slightly paranoid player to discover the last note in the sequence—in this case, d^2—since that note is usually simply written into the chord and its presence may not be at all obvious.

The distribution of the notes of a chord between the two hands is usually made clear by their assignment to one or the other of the two staves or by their grouping on two note-stems. Where this is not feasible (generally in chords consisting of whole notes or other stemless note-forms) the distribution of the notes may if necessary be indicated with a half-bracket:



Harmonically, a **tone cluster** is any chord consisting entirely of seconds, but on keyboard instruments the term implies not so much a harmony as a playing technique in which notes are struck in some way other than with the tips of the fingers. The smallest "tone cluster"—usually not considered as such—is that produced by using the side of the thumb to play two adjacent white or black keys; this technique is so traditional that one simply writes the required notes and lets the player deduce the fingering. Only for such unusual configurations as

will it be necessary to provide a fingering. Larger tone clusters, performed with the flat or side of the hand or with the whole forearm, have a special notation of their own, consisting of a heavy black line linking the two outermost notes of the cluster ( ) or, for open note-heads, the "open" equivalent of this notation (). If the cluster consists entirely of white keys, a natural sign is placed *above* the cluster, and if it consists entirely of black keys, a sharp is placed there. All-white or all-black clusters of less than a sixth in width are played with the side of the hand, loosely curled into a fist for the smaller intervals. This is usually called "playing with the fist," but the image called up of a pugilistic attack on the defenseless keyboard is of couse totally inaccurate. "Mixed" tone clusters such as



with the heel of the hand playing white keys while the side of the fifth finger plays black ones, are also possible, but these should be written out in full, as here, and the direction "with fist" added. Fully chromatic tone-clusters a sixth or less in width are played with the flat of the hand (or of the fingers, held together) held normally. The thumb is not really needed for this, and may play its own note outside the cluster:

Tone clusters of all sorts a seventh or an octave in width are played with the flat of the hand held sideways. All sorts of "mixed" tone clusters are possible in this mode, but it must be remembered that all the black keys must form a single coherent group, as must all the white keys; a cluster with, for instance, white keys at top and bottom and black keys in the middle cannot be played this way. Some possible "mixed" clusters—and suggested notations for them—are shown below.

Tone clusters greater than one octave in width are performed with a combination of the side of the hand and forearm. Those between a ninth and two octaves wide are somewhat awkward, and chromatic clusters (performed by jamming the arm and hand into the angle at the front of the black keys) may miss a few black keys at the elbow end of the cluster. Double-octave clusters are performed with the hand turned aside, and since the hand is not used, the fingers can pick out single notes (*not* chords) as much as an octave beyond the wrist end of the cluster. Clusters of more than two octaves require the hand again; the maximum width of cluster is three octaves (larger ones are performed with both arms, up to six octaves). "Mixed" clusters are possible, as described above, and by bending the wrist various complex combinations can be achieved—the composer should derive these by direct experimentation. In general, though, white keys should be grouped at the elbow end of the cluster. It might be thought that a large, double-arm cluster must be very loud, but in fact it is usually only a little more than one dynamic level louder than a single note played with equal force. Nonetheless, the loudest sounds possible on any keyboard instrument are these double-arm clusters.

The keyboard **glissando**, performed with thumb or index finger, is really a key rip, as with the mallet instruments, and should be notated as such. It can only be done on the white keys, though the glissando may begin and/or end with a black key.

The position of keyboard instruments in a score is not quite standardized. In orchestral or other large scores they are usually found between percussion and strings, though keyboard idiophones are often buried among the percussion, and members of the organ, accordion, and ondes martenot families may appear almost anywhere, including top or bottom. In chamber music, keyboard instruments almost invariably appear at the bottom of the score, though, again, "light" instruments such as the celesta or accordion may appear elsewhere.

KEYBOARD IDIOPHONES

KEYBOARD GLOCKENSPIEL AND CELESTA

The term "keyboard percussion" is normally used to refer not to the instruments here at issue but rather to those which in this book are called "mallet instruments": the xylophone, vibraphone, and so on. The celesta and keyboard glockenspiel have traditionally been numbered among the percussion, however, and are often included in percussionists' arrays, though there is nothing in percussionists' training that would enable them to play these instruments, both of which are virtually identical in technique to the piano, described below.

The sound-producing elements in the celesta and keyboard glockenspiel are rectangular metal bars like those of the vibraphone and glockenspiel. These are struck by small hammers that work like the hammers of a piano but in appearance resemble small, light, rubber-series mallets.

The keyboard glockenspiel sounds almost exactly like the ordinary glockenspiel, and its main value lies in its ability to play polyphonically. In light of this it is somewhat surprising to find that most parts for the instrument are largely monophonic—indeed, many parts are written on a single staff. The celesta differs from the vibraphone in having a considerably more delicate tone but it is just as cold and impersonal, and of course it lacks the vibraphone's vibrato. As with other idiophones, the lack of harmonic upper partials in the sound of these instruments makes chords into single sonorities rather than identifiable collections of pitches, and the ear often has great difficulty in determining the octave in which a given note lies; this is particularly true in rapid, disjunct passages.

Both celesta and keyboard glockenspiel are, of course, touch-sensitive and non-sustaining. The sound, particularly in the lowest notes, dies away rather more rapidly than that of a piano. Both instruments are provided with a system of dampers and a damper pedal, just like the piano;* because of the massiveness of the bars, however, the dampers are only partially effective, and a truly sharp staccato is impossible. The massiveness of the bars also precludes piano techniques that depend on sympathetic resonance. There is no equivalent to the piano's other two pedals, and no easy access to the interior.

* Some keyboard glockenspiels do not have these features.

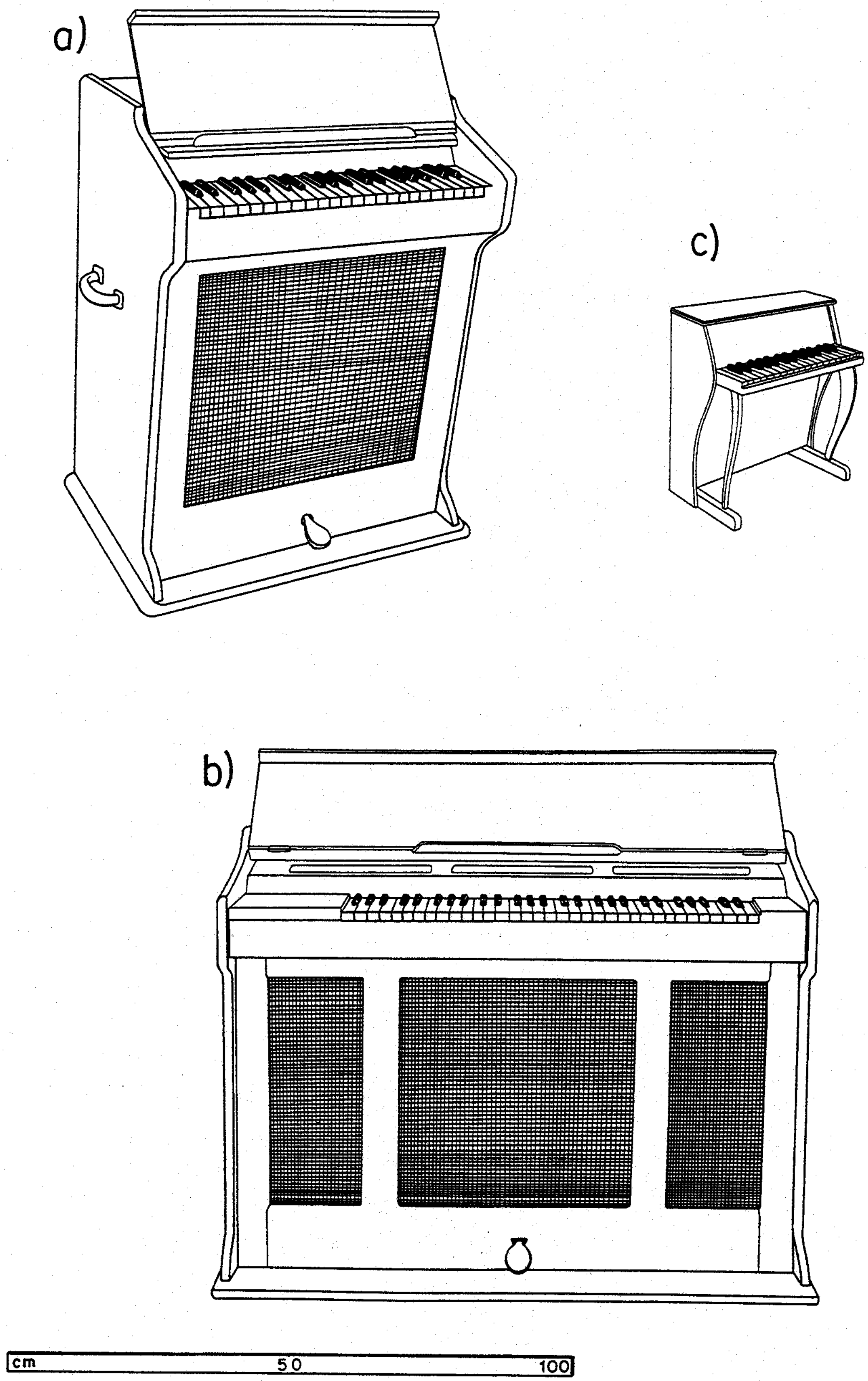


FIGURE 173. *Keyboard idiophones: (a) keyboard glockenspiel; (b) celesta; (c) toy piano.*

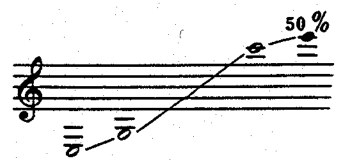
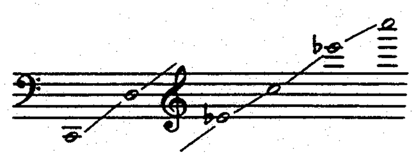
name of instrument	abbreviations	written range	sounds	availability
keyboard glockenspiel	kbd. glock. keygl.	 single notes { loudest: *ff*; softest: *mp*–*mf*	2 octaves higher	very rare
celesta	cel.	 single notes { loudest: *pp*–*p* — *mp*–*mf* — *f*; softest: *ppp*–*pp*	1 octave higher	usually available

FIGURE 174. *Keyboard glockenspiel and celesta—vital statistics.*

name of instrument	abbreviations	written range	sounds	availability
toy piano	T.P.	 single notes { loudest: *f*; softest: *p*	as written	rare full-size

FIGURE 175. *The toy piano—vital statistics.*

The touch on these instruments is somewhat lighter than on the piano but is almost unbearably sluggish, so that dynamics, particularly at the soft end, are hard to control. It will be observed that both have very narrow dynamic ranges, a consideration of which composers are all too often forgetful. If the keyboard glockenspiel were not so rare, the two instruments would ideally be used as a pair, the celesta for soft passages and the keyboard glockenspiel for loud ones; in fact, a duplex instrument, with both actions in one case and a double keyboard, could easily be made—but no one so far has done so.

THE TOY PIANO

The toy piano is not really a piano at all. Its sound is produced from thin metal rods clamped to a frame and thinned at the clamped end to improve their tone, a gentle, bell-like chiming with a very prominent partial a major thirteenth above the fundamental. The rods are struck with hammers resembling those of the piano, and the **action** (the mechanism connecting the keys to the hammers) is a simplified version of piano action. Unlike the piano, the entire action—keys, hammers, and all—is made of "sturdy molded plastic," and because of this and various other corners cut in the manufacture of what is after all a toy, the action is loose (making dynamics hard to control) and very noisy. The typewriter-like clatter of the keys must be counted part of the instrument's sound—and no unpleasant sound it is.

The toy piano has no dampers and no damper pedal, so each note dies away naturally as it is struck. Fortunately for the clarity of the sound, decay is initially very rapid, and the tone dies away completely in only about four seconds. The pitch is actually more focused than that of the celesta, but the inharmonic partials make it hard to decide in which octave a note lies.

Jaymar, the most serious maker of toy pianos, manufactures eight sizes ranging from a single-octave diatonic model to one with 49 keys covering four full chromatic octaves—quite impressive for a toy. Figure 175 gives the ranges of the three largest sizes: c^1–f^3, f^0–f^3, and c^0–c^4, all completely chromatic. Notes above f^3 are somewhat flabby and "dead." The instruments are frequently out of tune—usually sharp—when purchased, but can be brought to pitch by filing down or building up the offending rods.

Toy pianos are, of course, built to be played by small children. Though the keys are of regulation width, the instrument itself is very low and must be set on a riser if an adult is to play it.

The dynamic range is, if anything, even narrower than here given.

Musical Examples

KEYBOARD GLOCKENSPIEL:

Messiaen, *Chronochromie*

CELESTA:

Webern, *Five Pieces for Orchestra*, Op. 10
Messiaen, *Turangalîla symphonie* (6th mvt.)
Stockhausen, *Refrain*

TOY PIANO:

Cage, *Suite for Toy Piano*
Crumb, *Ancient Voices of Children* ("Todas las Tardes en Granada")

THE PIANO

BASIC FEATURES OF THE INSTRUMENT

The piano (now called "pianoforte" only in the most stiffly formal contexts) is, in its modern form, a product of the late nineteenth century—a genuinely *industrial* product built around a heavy metal frame cast in a foundry and designed to withstand for years some twenty tons of pull placed on it by the strings running across it. In no other instrument is this amount of

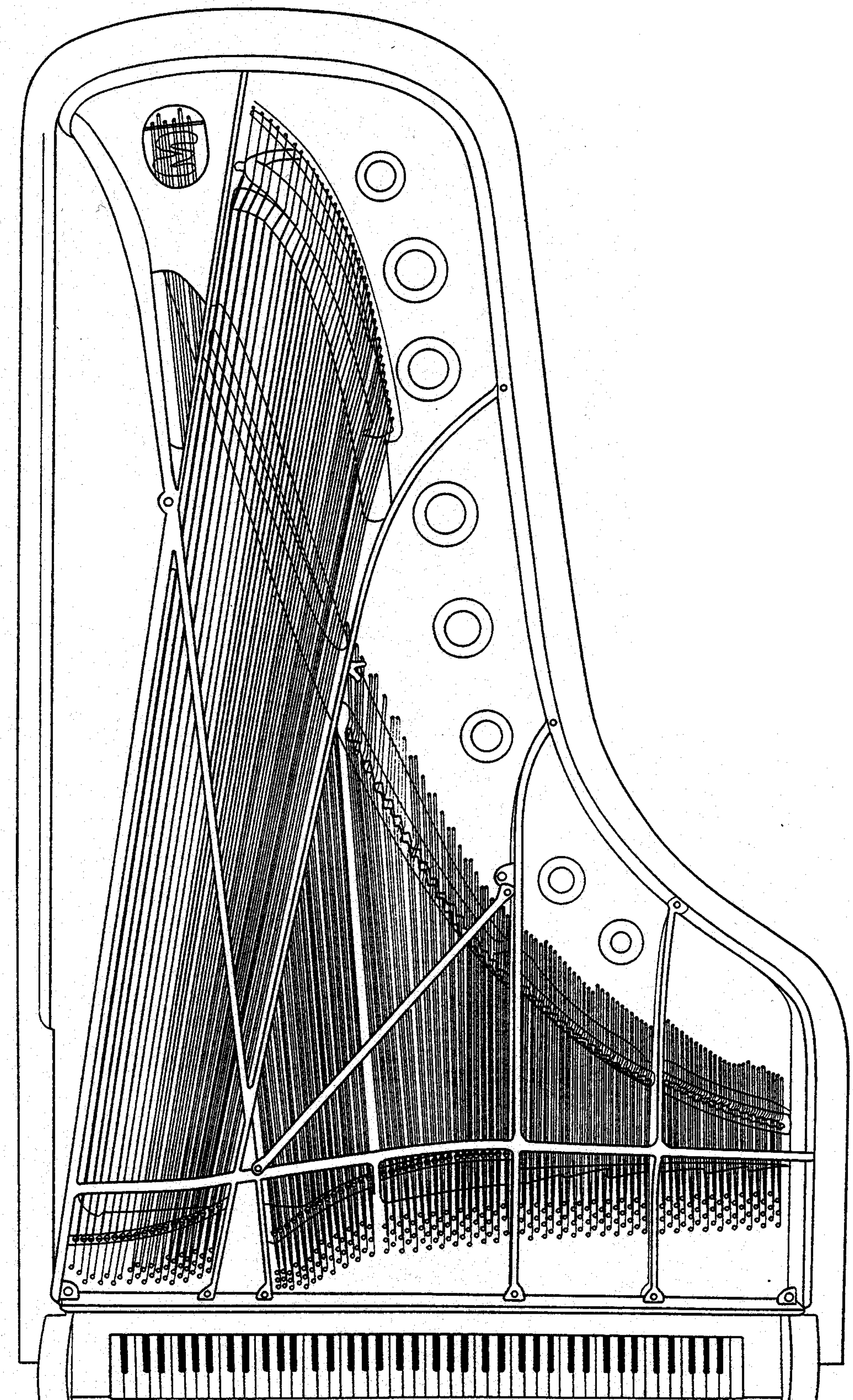


FIGURE 176. *Full-size grand piano with cover removed, seen from above.*

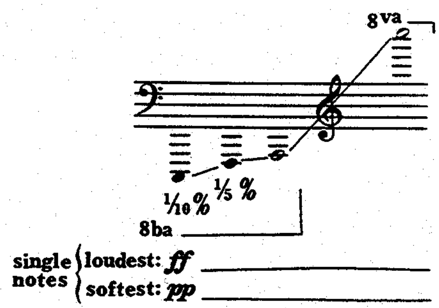
name of instrument	*abbreviations*	*written range*	*sounds*	*availability*
pianoforte	pfte. pno.		as written	ubiquitous

FIGURE 177. *The piano—vital statistics.*

internal tension even approached. In addition, the action is immensely complex, and the combination of great weight, dangerously high tension, and complexity means that merely to tune the instrument, let alone the kind of minor repairs other instrumentalists are used to doing on their own, requires the services of a specially trained technician.

Pianos are built in two formats: the **grand piano**, in which the strings, frame, and soundboard lie in the horizontal plane, oriented from front to back; and the **upright piano** (further subdivided—in order of decreasing height and tone quality—into the **full upright**, **studio upright**, **console upright**, and **spinet**), whose strings, frame, and soundboard are aligned vertically. Grand pianos are far superior to uprights, and only grands are used in concerts. Upright pianos are generally used only for study, practice, and home entertainment.

The range of the piano is among the most standardized of all instruments. The extension tones shown in Figure 177 are extremely rare, and would not even be worthy of mention were it not for the fact that they appear in pianos by Bösendorfer, generally considered to be the finest in the world. When played by themselves these extra low tones have an indescribably weird sound reminiscent of ring-modulation. Even when not used, the sympathetic resonance they provide helps to give the Bösendorfer its extraordinarily full, rich tone in the low bass. (Needless to say, composers should write these notes only as optional extras, if at all.)

Everybody knows that the sound of a piano comes from strings and that the strings are struck by hard felt hammers; the details are less widely known. In order to keep the dynamic range as high and as uniform as possible throughout the compass of the instrument, notes in the upper part of the range (usually from $B\flat_1$, F_0, or $B\flat_0$ up) are triple-strung, i.e., there are three unison strings, struck by the same hammer, for each note. Notes below this down to about F_1 or $F\sharp_1$ are double-strung, and only the lowest notes are single-strung. Pianos of the highest quality tend to have more strings than average, with a greater number of triple-strung notes than usual.

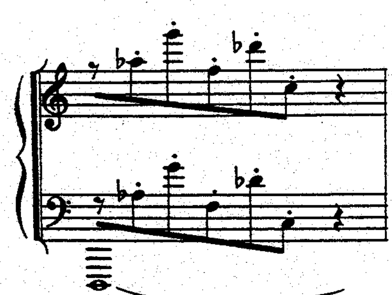
The action of the piano is designed so that there is never any direct mechanical connection between the player's fingers and the strings; the hammer is not pressed against the string, but is simply launched toward it, so that it bounces off the string and immediately falls back, allowing the string to vibrate freely. If a piano key is depressed very slowly and carefully, its hammer will not come in contact with the string at all.

Each note is provided with a felt **damper** that is automatically raised off the string when the key governing that note is depressed and falls back in place when the key is released, thus stopping the sound. The piano's highest notes have no dampers, for they are relatively weak in volume and die away quickly. The highest dampered note typically may be anywhere from $e\flat^3$ to g^3, generally falling higher on good pianos than on mediocre ones.

The piano is equipped with three pedals used as aids in expression. Of these, the right-hand pedal is by far the most important. It is called the **damper pedal**, and when depressed it raises all the dampers from all the strings, thus allowing notes to ring on after the keys are released, either for their complete natural duration (some twelve seconds, on the average), or until the pedal is released. The use of this pedal, a fundamental part of piano technique, is described in detail below.

The left-hand pedal is called the **soft pedal**, and when depressed it shifts the whole action—including the keyboard—to the right (rarely, left), so that the hammers strike only two of each set of three strings, and only one of each set of two. Single-strung notes are unaffected. This does make the sound softer, but only very slightly; more important is the effect on the tone, which becomes subtly more gentle and rounded. This pedal is not usually used for distinct contrasts of volume and timbre but, rather, as an aid to expression at low dynamic levels. This is described below in more detail. On most upright pianos the soft pedal is provided with an altogether different mechanism, whereby the rail against which the hammers lie when at rest is pushed closer to the strings, thus decreasing the distance between hammers and strings. The main effect of this is to diminish the dynamic range.

The middle or **sostenuto pedal** is relatively seldom used. When it is depressed, any dampers already raised will not fall back. It thus acts like a selective damper pedal, letting individual notes or chords chosen by the player ring on for as long as the pedal is depressed but allowing other notes to be played staccato. A passage such as the one below



is impossible without the middle pedal. This passage would be played by first striking the D_1, then depressing the middle pedal while the key was still held down, then releasing the key and playing the high notes. The middle pedal was only introduced toward the end of the nineteenth century and is still not a completely standard feature. Very fine pianos are still to be seen—mostly in Europe—with only two pedals, but as more and more pieces requiring its use are written, the middle pedal is bound to become universal—at least on grands—in the near future. Only a handful of uprights have a genuine sostenuto pedal of the sort just described. Many have only two pedals, and on others the third pedal is a functionless dummy; most common is a middle pedal that works exactly like the damper pedal save that it affects only the bass part of the range, usually from c^0 down.

In the normal course of play the damper pedal is depressed for each chordal or harmonic entity, that is to say, in accordance with the harmonic rhythm of the piece. Only soft and detached or intricately contrapuntal passages are generally played without pedal. The pedal is usually depressed *after* the keys are struck; the added sympathetic resonance from the unplayed strings causes the sound to bloom and is in large measure responsible for the flexibility and expressiveness of the piano despite its percussive means of tone production. In moving from chord to chord (or sonority to sonority, texture to texture) the pedal is released just as the new chord is being struck and then immediately depressed again. In detached playing the pedal is of course released much sooner. If a chord is preceded by a rest the pedal can theoretically be depressed before the chord is struck, but this is in fact only done where a particularly broad and resonant tenuto or sforzando is desired.

ARTICULATION AND PEDALING

Articulation on the piano is differentiated with both fingers and pedal. The continuum between staccato and legato can be expressed with the fingers alone, as can the various types of accent, simply by varying the touch; but the pedal is also involved in these differentiations: staccato notes are usually played without pedal, for instance, and accented notes, unless they are quite fast, are usually pedaled separately for each accent, even if the harmony does not change. Portato () on the piano means specifically that the notes are to be played with staccato touch but legato pedaling, and the staccato-tenuto () is often similarly interpreted to imply staccato touch combined with tenuto pedaling. Similar considerations lie behind such apparently contradictory notations as

The indication "fp" is usually realized by pedaling the indicated note or chord but then releasing the pedal while continuing to hold the key(s) down; the sudden removal of sympathetic resonances gives the effect of a sudden drop in volume, though the actual change in loudness is quite small.

A basic feature of piano writing is the production of varied textures through the use of broken and arpeggiated chords in all manner of patterns. These patterns are seldom of direct melodic interest, being used almost solely as a textural device. The underlying harmonic or melodic information buried within the pattern is articulated with the pedal and by bringing out specific notes with the fingers. Anyone interested in transcribing for piano music written in other media, or vice versa, must remember this aspect of piano style, which makes note-for-note transcription undesirable and often impossible. Even those who feel above such activities (and it should be borne in mind that music-theater works require piano-vocal scores as a matter of practical necessity) would do well to compare, for instance, Mussorgsky's original *Pictures* *at an Exhibition* with Ravel's orchestral transcription of it, or the Chaconne from Bach's D-minor violin partita with Busoni's piano transcription. Much can be learned about the nature of piano style from such study.

The constant use of the damper pedal gives pianists a certain flexibility in the fingering of broken and arpeggiated chords, for with the pedal down it is possible to put together groups of notes that could not be struck simultaneously. Chords such as

for instance, which do not quite lie under the hand, can be played simply by moving the hand across the keys while arpeggiating the chord with the pedal down. Careful composers provide such combinations with an arpeggio sign, as above, but this is frequently omitted, the implication being "play the notes as close to simultaneously as possible." It is also possible by this means to play arpeggiated chords containing many more notes than there are fingers to play them. Sometimes large chords that cannot be taken in one swipe are divided into a single practicable chord with an immediately preceding grace-note chord containing the notes left over at top and/or bottom. With such grace notes (unlike the arpeggio) pianists often take their time, even introducing *tempo rubato* to accommodate them.

For an unusual phrasing or to create an extended blur of sound the composer will occasionally need to specify exactly how the damper pedal is to be used. The symbol for the use of this pedal is " 𝆮 " written beneath the staff, with " ✱ " indicating its release. These ornate notations are increasingly being replaced with the simpler and more modern-looking "ped." and "______|," as used on the vibraphone. If the pedal is to be held down for more than one line of music, the expression "ped. (sempre)" should be used. If several notes or chords are to be pedaled separately one after another, it is traditional to mark each one "ped." without the closing asterisk or half-bracket.

A subtle technique used by pianists in certain styles and occasionally specified by composers is **half-pedaling** (symbol: "½ ped."). With the pedal thus half-depressed, neighboring sonorities blur lightly into each other but, because the dampers are slightly in contact with the strings, the notes die away just a second or two after the keys are released. Half-pedaling only works perfectly on a first-rate piano in excellent condition whose action has recently been regulated. In most cases some notes will ring on much longer than others, and half-pedaling should thus only be used in thick or dense passages where a great many notes sound at once and where there are frequent changes of harmony. A special effect related to half-pedaling and sometimes given the same name involves releasing the keys and then immediately depressing the pedal before the sound has been completely damped. The remaining sound continues as a filtered echo of the original notes, *pp* or *ppp*. A suggested notation for this effect is:

The damper pedal is useful even for the damperless notes in the upper part of the range, for the sympathetic resonance from the unplayed lower strings adds considerable body to these generally weak and ephemeral tones. Indeed, the only way to get a convincingly long-lived tone from the top octave is to strike the notes (preferably *forte* or louder) with the damper pedal down; after the loud attack (mostly attack noise) the note's main pitch will whistle on inside the piano, *p* or softer.

The soft pedal is used by pianists in conjunction with the damper pedal mostly as a way of varying the attack in soft or gentle passages. Composers should specify this effect (with the words "una corda" written above or below the staff) only when the soft pedal is to be held down for at least a few notes in a row.

The sostenuto pedal (also called "third," "middle," or "Steinway" pedal) should be specified wherever it is needed, for, as we have seen, a passage such as the one given on page 268 might be played with the damper pedal depressed throughout. Unfortunately, there is no standard notation for the sostenuto pedal; the term "sostenuto" in a piano score has only its ordinary meaning. Notations that have been used include "sos. ped.," "ped. III," "ped. II," and a variety of specially designed symbols.

When a single key or group of keys is depressed silently or is held down after the sound has completely died away, the sympathetic resonance of those strings will continue to be brought out by the playing of other notes. To be specific, notes above the pitch in question that double an upper partial of the silent note will ring on in a ghostly *ppp* of sympathetic resonance; conversely, notes below the silent pitch that have the pitch for one of their upper partials will cause the silent note itself to ring in a similar ghostly fashion. The sostenuto pedal is very useful for this effect because it can be used to sustain the silent pitch(es), leaving the player with both hands free. If a note is to be depressed silently the player must be allowed time to do so slowly and with care. On some pianos (e.g., Baldwins) it is virtually impossible to depress the keys silently.

SPECIAL EFFECTS

The sympathetic resonance of the piano strings can also be used in conjunction with other instruments. By singing or by playing any hand-held instrument directly into the piano, *forte* or louder, a distant *pp* or *ppp* echo will be elicited, giving back not only the pitch of the note played but to a certain extent its timbre as well. Of course, the damper pedal must be depressed to achieve this effect, and the piano's lid must be removed or completely raised.

The piano is a fairly powerful instrument, and for chamber music the lid is "put on the short stick," which holds it only a few centimeters open. The instrument is not ordinarily played with the lid completely closed, but that is certainly an option: the tone becomes somewhat muffled and "dead" and significantly softer than usual, so that with the additional aid of the soft pedal a true *ppp* can be produced.

A significant aspect of twentieth-century piano technique is the direct manipulation of the instrument's interior. The highly diverse techniques involved are categorized below. The reader is advised to refer periodically to Figure 176 for a better understanding of this material. The figure shows a full-size Steinway grand, seen from above; smaller instruments and those by other makers have a slightly different arrangement of metal bars and different numbers of strings and dampers. These differences are reflected in the variability of the playing restrictions imposed on the techniques here discussed. Many of these techniques require the player to stand, making pedaling and normal (on the keys) playing awkward, and many require the piano lid to be completely open or, preferably, removed altogether. The instrument's music rack must also often be removed, creating the problem of where to put the music. All of this, of course, and almost all of what follows apply only to grands. Interior work is very limited and difficult on uprights.

Sounds Made by Plucking, Striking, or Sweeping with the Hands

1. *Plucking the strings.* In the lower part of the range (at least up to d^1, and up to $c\sharp^2$ or higher on full-sized grands) the strings can be plucked in the space between the dampers and the tuning pins. The chief advantage of this is that the player need not stand up in order to pluck the strings. For all higher notes the player must stand up and pluck the strings beyond the dampers or (for damperless strings) beyond the crosswise metal bar. The sound of the plucked string, a brilliant ping reminiscent of the harpsichord, cannot exceed *forte* in loudness. Below the $c\sharp^2$–d^1 limit a gentler, richer sound can be obtained by plucking near the middle of the string. The player must stand up to do this.

In order to get a normal sound the dampers of all strings to be plucked must be raised. If they are not, a dry, dull "plunk" results.

It is difficult for the eye to pick out one note from another among the piano's many strings, so plucked notes must almost always be marked with bits of masking tape or the like in advance of performance, and even then plucking should be restricted to isolated single notes or groups of only a few notes, preferably close together in pitch. If the pitch is left indeterminate the strings can of course be plucked with much more freedom.

2. *Muting the strings.* This is done by pressing a fingertip against the string at one end. Notes below b^1, c^2, or $c\sharp^2$ (depending on the piano) are muted at the end of the string nearest the player; this can be done sitting down. Above this limit notes with dampers must be muted at the far end, and those without are muted just beyond the crosswise metal bar (capotasto bar) that forms a bridge for them—all this requires that the player stand.

To produce a sound, muting must be combined with plucking or (more usually) normal keyboard playing with the free hand. Muted notes decay in about half their normal time and sound dark and sombre compared to ordinary piano tone. Similar to muting is the complete **choking** of the sound by pressing a finger against the string(s) anywhere except at its extreme ends. When a choked note is struck by the hammer, a dull thunk, heavy in attack noise, results. Both muting and choking can be applied to a note that is already ringing.

3. *Harmonics* are produced exactly as on other stringed instruments (see Chapter IX) by lightly touching a node of the appropriate partial. Harmonics of any pitch up to about sounding e^3 can be produced on any string, and the second partial is obtainable up to somewhere between $c\sharp^4$ and f^4 inclusive (from strings pitched an octave lower) depending on the quality of the piano. The node for the second partial is too far away to reach from the keyboard below about D_0 (fundamental pitch).

Because the bass strings of the piano overlap the strings immediately above them, certain harmonics on the overlapped strings are not available. The bass and treble divisions of the piano are usually separated either at $B\flat_0/B_0$ or E_0/F_0; harmonics are not possible on the two notes immediately above the break. On the next two notes only the fifth and higher partials are available, on the next two after that the fourth partial is available but not the second or third, and on the next three to five all partials but the second can be played. Harmonics tend to sound cool, impersonal, and a bit mysterious—increasingly so for high partials. The higher the partial the more strongly the note's decay will be reduced and its dynamic level lowered. All harmonics must be played from a standing position, and all require that the damper pedal be depressed.

4. *Sweeping the fingers or fingernails across the strings* to make a glissando. This effect, which can be produced as loudly as *fortissimo* (particularly in the bass range), can be done with or without raised dampers; it sounds very dry if the dampers are not raised. If only selected dampers are raised (by depressing keys silently or with the sostenuto pedal) the notes in question will emerge strongly from the glissando and will ring on long after it has died. The extent of a swept glissando is limited by the lengthwise, crosswise, and diagonal metal bars inside the instrument. Any extensive glissando requires skillful alternation of the hands if it is not to sound discontinuous when crossing these bars. This is particularly true of the smooth, full-toned glissando produced by sweeping the strings on the far side of the dampers where, it will be noticed, the two notes immediately above the bass/treble break cannot be gotten at all. The more snarly glissando produced on the near side of the dampers is trouble-free in the bass, but since the dampers, crosswise bar, and pinblock crowd in on each other in the treble one must switch from the front to the back end of the strings somewhere between d^1 and $c\sharp^2$.

5. *Scraping the wound bass strings lengthwise.* The rasping sound produced (up to *fortissimo*) with the fingernails may be contrasted with a gentler, windy sound made by stroking with the fingertips, no louder than *piano*. The pitch of these scraped notes is exactly four octaves above the fundamental pitch of the note scraped. Most pianos have wound strings up to E_0 (small "baby grands" may have wound strings up to $B\flat_0$). The four notes immediately above the bass/treble break can be effectively scraped only in front of the dampers, so long notes (which require scraping a considerable length of string) should be avoided for those pitches.

Strings Struck, Swept, or Scraped with Percussion Sticks or Other Devices

Particularly common and effective is the use of a bass-drum beater to strike all the lowest strings at once, producing a deep, full boom as loud as *fortissimo*. These percussion techniques, as well as the finger techniques just discussed, can be performed by a non-pianist standing in the bend of the instrument, provided somebody or something presses down the damper pedal. A person standing in the bend of the piano cannot reach the part of the strings that lies between the dampers and the tuning pins but can produce the same effects at the opposite end of the strings, *except in the octave above the bass/treble division*, in which the far ends of the strings are covered by overlapping bass strings. Indeed, the four notes immediately above the break will be completely or virtually unavailable to a person beside the piano.

Bowing

C. Curtis-Smith has worked out a means of bowing the piano using multiple lengths of nylon fishing line threaded under or between groups of strings. This effect may be heard in virtually any of his recorded works with piano and can be studied in detail in the preface to his *Rhapsodies* (1973).

Striking or Knocking the Frame of the Piano

This is done with the knuckles or with percussion mallets. When the damper pedal is depressed, these sounds will ring on, *pp* or *ppp*, inside the instrument.

The Prepared Piano

This term denotes the insertion of various objects into the piano for the purpose of altering the tone when it is played either normally or with any of the techniques described above.

1. *Tack piano.* The hammers of a grand piano should be left strictly alone: they are vital to the tone quality of the instrument and can easily be damaged. The well-known device of sticking thumbtacks in the hammers to create a jangly, honky-tonk sound should be inflicted only on battered old uprights inured to such indignities.

2. *Light flat or round objects laid loosely on the strings;* for example, paper, aluminum foil, an aluminum pie plate, coins, marbles, rulers, or small sticks of wood. The sounds produced are rattling and indeterminate, since the object(s) are bounced around by the vibration of the strings and sooner or later fall off altogether onto the frame or soundboard.

3. *Objects inserted between the strings.* Held in place by the strings between which they are inserted, these objects do not move during play. The objects most suitable for such use are bolts of various sizes (with or without nuts), golf tees, small rubber erasers, coins, or strips of plastic such as collar tabs or a small, flexible ruler. Highly varied and interesting sounds can be produced by such means, ranging from a more or less muted version of ordinary piano tone to sounds resembling idiophones played with soft sticks: almglocken, cencerros, muted gongs, even temple blocks and slit drums. The exact effect produced must be determined by experimentation (bear in mind the variable positioning of the bass/treble break and the variable stringing layouts of different pianos), but certain general categories can be distinguished: (a) light objects serving only to mute or choke the piano tone; (b) heavier objects that add significantly to the mass of the strings, lowering their pitch and drastically altering their timbre; (c) objects inserted between strings of different pitches, linking them together as a single vibrating body of indefinite pitch; and (d) objects—such as a loose nut held in place with a bolt—inserted loosely enough to rattle when the string is played but not otherwise affecting the tone.

Several objects may be inserted at different points along the length of the same pair of strings, and for triple-strung notes the right + middle pair of strings may be prepared differently from the middle + left pair, or one string may be left completely unprepared. By using the soft pedal (eliminating the left-hand string) the timbre of such a note may be radically altered.

One final word about "piano interior": despite its rugged metal frame and heavy strings the piano is a delicate instrument—particularly the hammers, dampers, and strings—and great care must be taken not to damage it. The hammers and dampers should not be touched, and the strings, unlike those of a violin, guitar, or harp, are not designed to be touched and tend to corrode if handled frequently* or roughly. Preparations that require the strings to be forced visibly apart should be avoided, and it is a good idea to wipe the strings with a dry cloth after each performance, rehearsal, or experimental session in which they are touched.

* With half a century of "piano interior" masterpieces behind us it is high time something was done about this: it is ridiculous for piano makers to continue pretending that such considerations have nothing to do with their craft.

A handful of "quarter-tone pianos," with two keyboards pitched a quarter-step apart, were built in the early twentieth century. These experimental instruments were not successful, but quarter-tone piano parts continue to be written from time to time. These are invariably played on a pair of pianos set next to each other at right angles, one tuned a quarter-step lower than the other. The "detuned" piano must be tuned *down* the quarter-step, for tuning it up may cause the instrument to literally and very dangerously collapse or explode from the increased tension. Tuning a piano down a quarter-tone removes hundreds of kilograms of tension from the frame; this is hardly good for the instrument, but it is at least not dangerous to life and limb. Because of the deleterious effects of detuning, the quarter-tone instrument is always a cheap upright.

Musical Examples

PIANO:

Ives, Piano Sonata no. 2 ("Concord")
Stravinsky, *Les Noces*
Varèse, *Déserts*
Messiaen, *Turangalîla symphonie*
Stockhausen, *Klavierstück IX*
Cage, *Sonatas and Interludes*
Crumb, *Music for a Summer Evening*

ELECTRIC KEYBOARDS: NON-SUSTAINING

THE ELECTRIC PIANO

We now arrive at the first of many "electric" instruments to be discussed in this book, and it is necessary at this point to define some terms. "Electric" instruments are divided into two types: **electronic** instruments, in which the sound is the result of an oscillating voltage created by purely electronic means (more about this in Chapter X), and **electromechanical** instruments, in which a very soft sound created by non-electronic means is electronically amplified.

Electric pianos may fall into either of these categories. Generally the electromechanical ones are superior. The sound of these comes from small metal tines resembling the reeds of an accordion or harmonica and which are themselves called "reeds." These are struck with small hammers working like those of the piano, and the tiny sound produced is amplified electronically.

All electromechanical and some electronic pianos are touch-sensitive; those that are not are considered inferior instruments. With fingers alone the player can govern only about four dynamic levels—which four are determined by a volume control knob above the keyboard. This knob is sometimes replaced by a foot pedal that is not spring-loaded, so that a volume level once chosen will remain even if the player's foot is needed elsewhere. The volume control expands the instrument's overall dynamic range to the limits of human sensitivity and endurance, *ppp–ffff*; similar huge dynamic ranges are characteristic of all "electric" instruments.

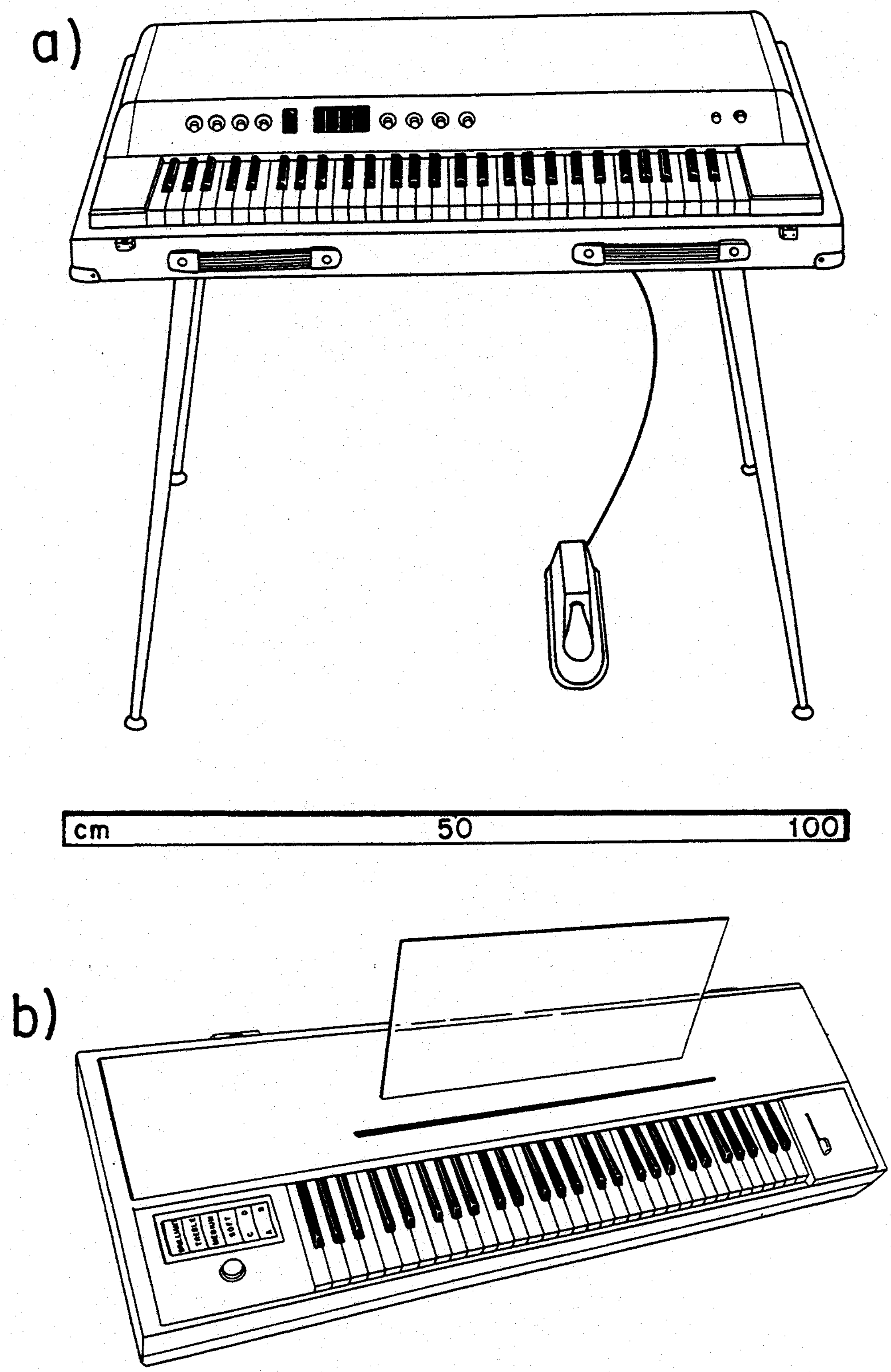


FIGURE 178. *Non-sustaining electric keyboards: (a) electric piano; (b) clavinet.*

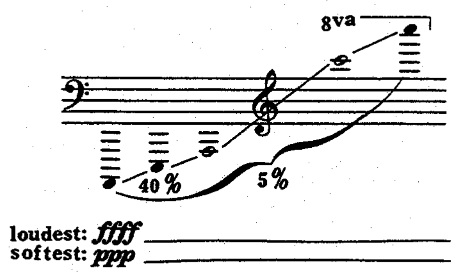
name of instrument	*abbreviations*	*written range*	*sounds*	*availability*
electric piano	elec. pno. el. pno.		as written	common

FIGURE 179. *The electric piano—vital statistics.*

Some electromechanical pianos have a damper pedal ("sustain pedal") like that of a real piano but others do not, and no electronic piano has one.

The most important thing to bear in mind about the electric piano is that it is *not* a debased form of pianoforte but an entirely separate instrument with its own distinctive timbre. Like most electrical instruments it has an extremely rich, rather coarse tone that is best served by thin harmonizations and widely spaced contrapuntal lines. The very full tone makes a damper pedal somewhat supererogatory, for the thick chords and stylized rhythmic patterns of traditional piano music would probably come across on the electric piano as impenetrable murk.

The notes of the electric piano sustain about as long as equivalent pitches on the ordinary piano. By adroit use of the volume control a note can be sustained rather longer than usual, be made to stay at full volume throughout most of the decay, or even be increased in volume after it has been struck.

Electric pianos are usually provided with one or two tone-control knobs, like the treble/bass knobs on an amplifier. Except for such impressionistic instructions as "bright tone" or "dark tone," manipulation of the timbre is best left to the player. As with other electrical instruments, the electric piano can be coupled to all kinds of tone-modifying devices such as vibrato, reverb, and fuzz-tone. These are discussed in Chapter X.

THE CLAVINET

There are a number of **electric harpsichords** on the market, some under fanciful trade names. Most have the normal harpsichord range of F_1–f^3, though some are missing a fifth or octave at the bottom of the range. The instrument may be electronic or electroacoustic and is a remarkably good imitation of real harpsichord timbre, though it is by no means close enough to fool a careful or sophisticated listener. Some electronic pianos, organs, and performance synthesizers have this sound available as a stop. The electric harpsichord is used in a number of Beatles songs ("Lucy in the Sky with Diamonds," "Because"), and can also be heard in Terry Riley's *A Rainbow in Curved Air.*

A more distinctive instrument is the **clavinet** (Hohner's trade name for its patented electric clavichord). The ordinary clavichord is an extremely soft instrument totally unsuited

name of instrument	*abbreviations*	*written range*	*sounds*	*availability*
clavinet	clvnt. clav.	 **loudest: *ffff*** **softest: *ppp***	as written	rare

FIGURE 180. *The clavinet—vital statistics.*

for ensemble work; the clavinet, on the other hand, has the enormous dynamic range of most electric intruments and a tone quality more reminiscent of the electric guitar than of its parent instrument.

The mechanism of the clavinet is virtually identical to that of the clavichord,* each key being a simple lever that presses a **tangent** against a string. The tangent remains in contact with the string as long as the note sounds, acting both to produce the sound and as a bridge determining the sounding length of the string. When the key is released the string is automatically damped by muting material resting against the unused portion of the string behind the tangent. This gives the sound an incredibly quick cutoff that gives the clavinet much of its air of crispness and precision—a feature it shares with the clavichord. An incredibly brittle staccato is available, and it is even possible to play a trill staccato, each note clearly separated from its neighbors.

Because the fingers are in direct mechanical connection with the strings throughout the duration of each note, the clavinet is the most expressive of the modern keyboards. By varying the pressure on the key *after* the note is struck, it is possible to produce a delicate vibrato, or bent tones up to a quarter-tone above the pitch initially sounded. The vibrato is ineffective in chords and is best applied to single melodic lines. It is not a standard technique, and since it can only be applied to slow-moving or static passages—preferably to individual notes—the instruction "vibr. ____⌋" should be written above the staff wherever vibrato is desired, the half-bracket indicating for how long the effect is to be applied.

Only three dynamic levels can be differentiated by touch alone (four, if full advantage is taken of the contrast in loudness between full chords and single notes), but a volume control knob like that of the electric piano gives the clavinet the tremendous overall dynamic range characteristic of "electric" instruments in general. The instrument is provided with six "stops" (really treble/bass filter pre-sets) and a "muting slide" to control its timbre; with these the tone can be inflected across a range bounded by an approximate "electric-piano" sound at one extreme and a "harpsichord" sound at the other. As with the electric piano, the details of their use are best left to the player.

* See Chapter XIII for details.

Musical Examples (from the popular literature)

ELECTRIC PIANO:

Paul Simon, "Congratulations"
Herbie Hancock, "Steppin' in It"

CLAVINET:

Stevie Wonder, "Keep on Running"

FREE-REED INSTRUMENTS

HARMONICAS

The harmonica is not a keyboard instrument, but its affinities and playing technique make it fit more comfortably into this chapter than elsewhere. It is closely related to the melodica and accordion, both unquestionably keyboard instruments; furthermore, it is a somewhat polyphonic instrument capable of playing chords, and its notes are lined up left-to-right in an essentially keyboard-like fashion.

The harmonica, melodica, and accordion constitute a family of **free-reed** instruments.* Unlike the **beating reeds** of woodwind instruments and most organ reed stops, a free reed lies in a slot through which it is free to vibrate (Fig. 183). Air passing through the slot sets the reed vibrating, and the resulting pitch is entirely a function of the reed's mass, length, and flexibility—there is no governing air column. A free reed thus constitutes a very compact acoustical system, and a great many can be fitted into a very small space. A harmonica may contain sixty-four reeds in an instrument only twenty cm long and four cm deep.

Without a controlling air column the pitch of a beating reed will rise as the air pressure is increased, while a free reed will remain stable. Free-reed instruments can thus produce a range of dynamics by varying the air pressure—unlike the organ, in which each reed stop has a single fixed dynamic level.

The mouthpiece of a harmonica is pierced by a row of holes each of which typically has access to at least two reeds of different pitch, one of which sounds on the exhale (**blow notes**) and the other on the inhale (**draw notes**). Harmonicas are made in an astounding variety of types, including "blow only" varieties, 8′ + 4′ octave-sounding models, and celesting ("tremolo") models, but all are variants on three basic patterns.

* The oldest and most respectable Western member of this group is the **harmonium** or reed organ. Though many old examples of this instrument are, at this writing, still to be encountered, only a handful of trivialized and decadent instruments continue to be manufactured, and the instrument seems to be slipping quietly into extinction. There are numerous important early twentieth-century parts for the harmonium, and should it despite appearances stage a comeback, the interested student may wish to consult Schoenberg's *Herzgewächse* for a notion of its capabilities.

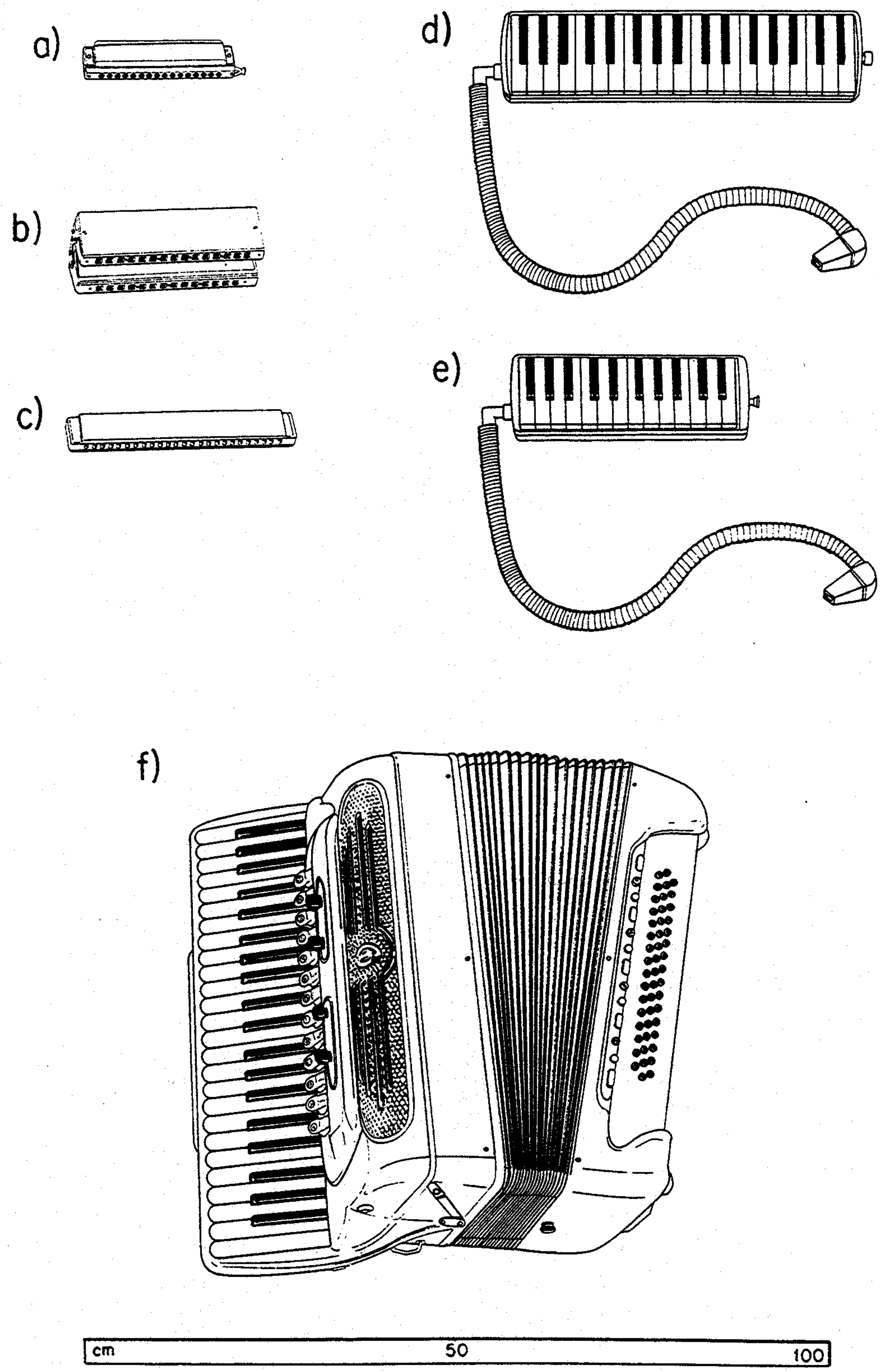
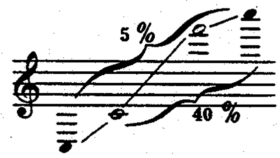
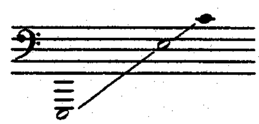


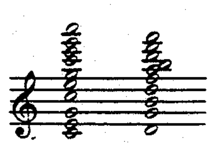
FIGURE 181. *Free-reed instruments: (a) chromatic harmonica; (b) double bass harmonica; (c) bass harmonica; (d) melodica; (e) melodica bass; (f) accordion.*

name of instrument	*abbreviations*	*written range*	*sounds*	*availability*
(chromatic) harmonica	harm.	 single notes { loudest: *f* / softest: *ppp*	as written (transposition not standardized)	rare*
bass harmonica	bs. harm.	 single notes { loudest: *f* / softest: *ppp*	as written	rare
double bass harmonica	d.b. harm.	 single notes { loudest: *f* / softest: *ppp*	as written	very rare

* It may be startling to see an instrument that can be found by the dozens in any music store described as "rare," but the reader must bear in mind that "availability" as defined here is not that of the instrument itself but of competent players with formal music training.

FIGURE 182. *Harmonicas—vital statistics.*

The **diatonic** (or "**marine band**") **harmonica** typically has ten holes giving the following notes:



Notice that f[1], a[1], and b[3] are missing. This pattern can be found transposed into every major and minor key.

Chromatic harmonicas are fitted with a slide mechanism that enables production of four tones from each hole instead of two. When the slide is pushed in it gives access to a different set of reeds, and when released automatically shifts back to the "out" position. In **Koch-type** chromatics the diatonic pattern is preserved, and pushing the slide in yields the same pattern transposed up a half-step. With this pattern the notes f♯[1], a[1], a♯[1], and b[3] remain

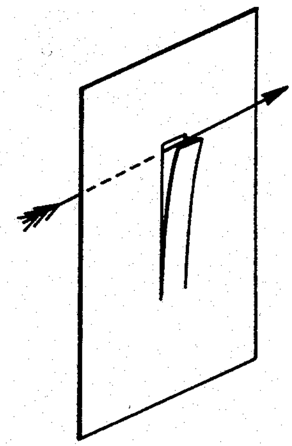
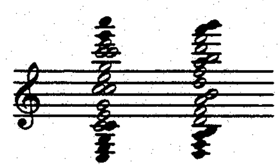


FIGURE 183. *A free reed; arrow shows direction of airflow.*

unavailable. **Fully chromatic** harmonicas use a different pattern, and will as likely as not have twelve holes rather than ten. Some even have sixteen holes (see Fig. 182). This



pattern is the most useful for all but the most invincibly tonal material. Both Koch-type and fully chromatic harmonicas exist in versions transposed down to a^0 or $b\flat^0$ and up to d^1, e^1, f^1, or g^1, but composers are advised to stick to the c^1 model, which is both the most common and most useful.

The harmonica is played with the mouth covering four adjacent holes at a time. When playing a monophonic line, the tongue covers the three left holes, so that air enters only the hole furthest to the right. For purposes of harmonization, the tongue may uncover any or all of the three blocked holes (provided all unblocked holes are adjacent) and may do so in an independent rhythm while note(s) from the right-hand hole(s) are being sustained:

(Note that in the above passage the second f^2 must be played as an $e\sharp^2$, i.e., a "blow" with the slide pushed in.)

Aside from this refinement, breathing and tonguing are much as they are on traditional woodwinds. For notes to be played legato they must be either all blow notes or all draw notes. The slide presents no obstacle to legato playing; in fact, it may be used to produce a trill. Large skips cannot be played completely legato but, as on the trombone, a very convincing "fake" is possible.

Blow and draw can be alternated very rapidly—as rapidly as one's diaphragm can alternate exhale and inhale—but notes so alternating must always be detached. Despite the use in play of both inhale and exhale, the player must occasionally take a breath.

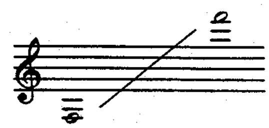
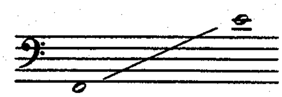
name of instrument	*abbreviations*	*written range*	*sounds*	*availability*
melodica	mel.	 single notes { loudest: *f* ; softest: *ppp*	as written	usually available
melodica bass	mel. bs.	 single notes { loudest: *f* ; softest: *ppp*	as written	very rare

FIGURE 184. *Melodicas—vital statistics.*

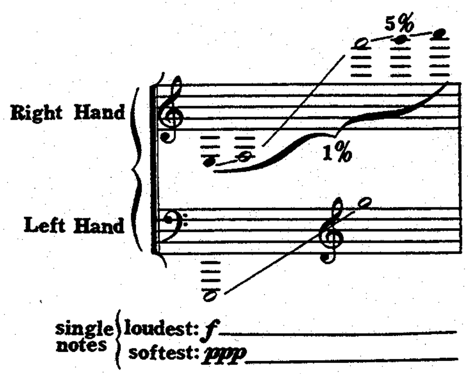
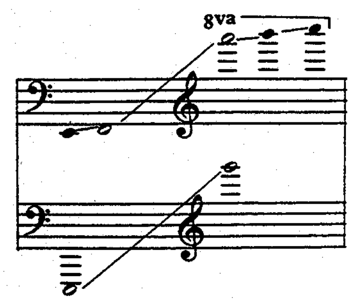
Vibrato on the harmonica, when desired, is made by fluttering the left hand back and forth at the bottom of the instrument (where the tone emerges), alternately obscuring and releasing the sound. A different kind of vibrato can be made by moving the tongue back and forth in the mouth.

Skilled players can bend the pitches of the notes by overblowing (or "overdrawing") beyond the reeds' capacity, and/or by partially blocking holes with the tongue. If done carefully this drives them slightly flat and *lowers* the volume; if forced too hard, however, the reeds will simply stop vibrating. Bent tones are easier and more idiomatic on diatonic harmonicas than on chromatic ones. Draw notes can be bent up to a whole step at the bottom of the range, but not at all at the top. On chromatic harmonicas, blow notes can be bent up to a half-step throughout the range (most easily in the middle), while on diatonic ones these notes can be bent up to a whole step at the high end, but only a quarter-step at the low end.

Among the various specialized harmonicas the most interesting and worthwhile are the **bass harmonica** and the **double bass harmonica**. Both have blow-only holes and no slide. On the bass harmonica the notes are simply arranged from left to right in chromatic order; the double bass harmonica is a duplex instrument (see Fig. 181) with the naturals on the lower half and the sharps on the upper, both in keyboard order. Obviously, both bass and double bass harmonicas are intended to be strictly monophonic, though they can if desired play small tone-clusters.

MELODICAS

The melodica is a breath-driven keyboard instrument. In order for a note to sound two conditions must be satisfied: air must be passing through the instrument, and a key must be depressed. The mouthpiece of a melodica lies at the left end of the keyboard, so that normally the instrument is held directly in line with the player's mouth, allowing only the right hand to play the keys. The left hand is used to hold the instrument. However, there are available a special

name of instrument	abbreviations	keyboard range	range of available pitches	availability
accordion	acc. accn. accord.			rare*

* See note to Figure 182.

FIGURE 185. *The accordion—vital statistics.*

stand and a long, flexible mouth tube, which together enable the instrument to be set crosswise in front of the player, like ordinary keyboard instruments, so that both hands can be used.

Unlike the harmonica, the melodica is completely polyphonic and is hence a somewhat more useful instrument. Its tone is virtually identical to that of the accordion, but the expressivity and capacity for rapidly repeated notes provided by breath as opposed to bellows makes the melodica worthwhile in its own right. Though David Bedford's *Music for Albion Moonlight* is so far virtually the only piece to specify a melodica, the instrument has been increasingly used in the performance of pieces with indeterminate instrumentation—most notably by Christian Wolff.

The melodica's keyboard technique is essentially that of the organ, but notes can be articulated by the tongue as well as with the fingers. The tongue is generally used only for rapid repetition (including fluttertongue), accents, and sforzandos.

The pitch range given in Figure 184 is that of the largest, "professional" melodica. The smaller sizes, which have tiny ranges, are of little use musically. There is a **melodica bass** (not "bass melodica"), but it is rarely seen.

THE ACCORDION

The accordion is unique in having completely different keyboards for the right and left hands. These are aligned vertically, with the highest pitch of each keyboard at the bottom and the lowest at the top.

Between the two keyboards is a large, flexible **bellows** that supplies the instrument with wind. Each note is provided with two identical sets of reeds, one speaking as the bellows collapses and the other speaking as it expands. Articulation with the bellows is very similar to that of bowed string instruments (see Chapter IX): a slur indicates that all notes beneath it are to be taken not only legato but, of necessity, in one motion of the bellows; portato () and related notations indicate articulation with the bellows rather than the fingers; and the symbols ⊓ and V above notes may be used to indicate the beginning of compression and expansion strokes, respectively.

Unlike bowing, however, motion of the bellows is never rapidly alternated. Normal detached articulation is provided by the keys, as on the melodica; the bellows is used to articulate only portato and accented notes and those that must emerge gradually from silence. An air valve operated by the left thumb enables the player to move the bellows silently from one extreme to the other in about half a second, if desired, so that, e.g., two long compression strokes may follow one another without an intervening expansion stroke.

A single stroke of the bellows can last about as long as a clarinet note played at comparable volume. Where necessary as an aid to proper phrasing, an apostrophe—analogous to the "breath mark" of winds—may be used to indicate the place in the music where the bellows are to be reversed. While it is impossible to continue a note completely smoothly while reversing the bellows, it is possible, as with bowing, to approach very close to such continuity.

The keyboard for the right hand is of the ordinary sort, and the right-hand technique is identical to that of the organ. The left hand, however, uses a **button keyboard**, a very compact diagonal grid of pushbuttons in which many more notes lie directly under the hand than on a traditional keyboard.

There are three competing types of arrangement for the left-hand buttons. The vast majority of accordions are still made in the **Stradella system**, outlined below, in which the left hand is tied to the playing of common chords and tonal bass lines. In the Stradella system four of the six buttons in each diagonal row give out chords, fully voiced across as many as five octaves. The last two buttons in the row look in the chart as if they produce single notes, but they do not; rather, they produce the entire pitch class over three to five octaves.

					C°
				C^7	
			Cm		F°
		CM		F^7	
	E		Fm		B♭°
C		FM		B♭^{7}	
	A		B♭m		E♭°
F		B♭M		E♭^{7}	
	D		E♭m		
B♭		E♭M			
	G				
E♭			etc.		

FIGURE 186. *The Stradella system of accordion basses and chord buttons. The pattern is given as seen from the front, i.e., with the bellows at the left. For the player this is reversed.*

It will be readily seen that the Stradella system is unsuited to any kind of sophisticated music-making. Its deficiencies are ameliorated somewhat in **free-bass** accordions, in which the two left-hand buttons in each row do give out single pitches, but for serious musical purposes a **chromatic free-bass** accordion is essential. Here the buttons are arranged in only three vertical rows and give out single pitches only, as shown below.

	E	
F		F#
	G	
G#		A
	A#	
B		C
	C#	
D		D#
	E	
F		F#
	G	
	etc.	

FIGURE 187. *Pattern of left-hand buttons on a chromatic accordion. The pattern is given as seen from the front, i.e., with the bellows at the left. For the player this is reversed.*

Note the economy of this pattern: minor seconds run diagonally downward to the (viewer's) left, major seconds right, and minor thirds straight up and down. Because there are three rows of pitches instead of two, the total pitch range covered is greater in this system than in others; it is this wide range that is given in Figure 185. The compact arrangement of buttons allows the fingers to stretch across much greater intervals than on a traditional keyboard, so that despite the fact that the thumb is not normally used and that the left hand, holding the instrument, cannot twist about with as much facility as, say, a organist's, almost any imaginable configuration of pitches within the range of two octaves can be played. The average maximum stretches are shown below. The thumb is included in these calculations because it *can* be used if the player unorthodoxly slips the hand forward around the side of the instrument. Chords requiring the thumb should be given some preparation time, since bringing the thumb forward is an awkward maneuver.

Stretch From Finger

To Finger	1	2	3	4
5	3 8ves	2 8ves	1 8ve	tritone
4	2 8ves + tritone	10th	tritone	
3	2 8ves + 3d	6th		
2	2 8ves			

A finger can push down two adjoining buttons simultaneously (the fingering should be given where this is needed), and tone clusters up to two octaves wide can be produced with the flat of the hand.

A tiny but growing minority of accordionists play chromatic free-bass instruments. These are the "classical" accordionists—often dedicated and highly trained professionals—interested in something more than the endless round of polkas and "Lady of Spain" that is the lot of the Stradella-system player. Composers should do these people a favor and stick to the chromatic instrument in their writing. In fairness it should be mentioned that **combination instruments** exist, in which there is either a chromatic free-bass system adjoined by the usual five rows of chord buttons, or else "stops" to switch the left hand from Stradella to chromatic and back again.

Most accordions have four **ranks** (complete sets)* of reeds available to the right hand. Two of these right-hand ranks are at 8′ pitch, one is at 4′, and one is at 16′. The two 8′ ranks are different in timbre and are called "flute" and "clarinet," respectively. The "flute" tone is not at all flute-like but is, rather, the normal reedy accordion sound; the "clarinet" is a more rich and fruity tone. Most of the possible combinations of the four ranks are provided by twelve stops (traditionally called **registers**), each of which is denoted by a symbol placed above the staff.

 flute = flute 8′

 clarinet = clarinet 8′

 = 2 × 8′

 = 4′

 = 8′ + 4′

 = 2 × 8′ + 4′

 = 16′

 = 8′ + 16′

 = 2 × 8′ + 16′

 = 8′ + 4′ + 16′

 = 4′ + 16′

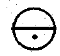
 = 2 × 8′ + 4′ + 16′

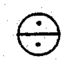
Those registers in which a single 8′ rank is combined with the 16′ and/or 4′ ranks use the flute in preference to the clarinet. Unlike the stops of an organ, only one accordion register can be engaged at a time, so combinations such as "clarinet 8′ + 4′ " are unavailable.  is called forth by a long pressure bar below the keyboard—like the space bar of a typewriter—worked

* In this case actually double sets, since each rank must be provided with both pressure and suction reeds.

by the heel of the hand. The other eleven registers appear as pushbuttons above the keyboard and require a free finger for their operation. The four solo registers, and those in which both 8′ ranks are present, are unambiguous in pitch,  giving a particularly full, sombre effect and  a particularly brilliant one. With , , , and especially  it will be somewhat unclear which octave is the main one and which the auxiliary. Whenever a true *fortissimo* is desired  should be used, since only with the aid of all four ranks can the instrument compete even with ordinary woodwinds in this respect.

Stradella-system accordions may have up to ten registers for the left hand, attempting to make up in sonority what is all too clearly missing in the way of pitch. Chromatic accordions have two left-hand ranks; these two ranks can be permutated in only three possible ways, symbolized as follows:

=8′ =4′ =8′ + 4′

These three registers are replicated up and down the left side of the instrument so that all can be easily reached at any point without moving the hand. Their timbre is calculated to fit in equally well with both right-hand timbres, and their volume is set so that a single left-hand rank will balance one or two right-hand ranks, while  will balance three or four right-hand ranks.

Whatever registers are used, the notation should stick to keyboard (i.e., 8′) pitch, any octave transposition being sufficiently indicated by the register symbol.

Musical Examples

HARMONICA (FROM THE POPULAR LITERATURE):
- Bob Dylan, "I Dreamed I Saw St. Augustine"
- Herbie Hancock, "Steppin' in It"

BASS HARMONICA (FROM THE POPULAR LITERATURE):
- Paul Simon, "Papa Hobo"

DOUBLE BASS HARMONICA:
- (no example)

MELODICA:
- Bedford, *Music for Albion Moonlight*

MELODICA BASS:
- (no example)

ACCORDION:
- Berg, *Wozzeck* (Act II, scene 4)
- Hindemith, *Kammermusik No. 1*
- Del Tredici, *Vintage Alice*
- Nordheim, *Osaka-Music Dinosauros*

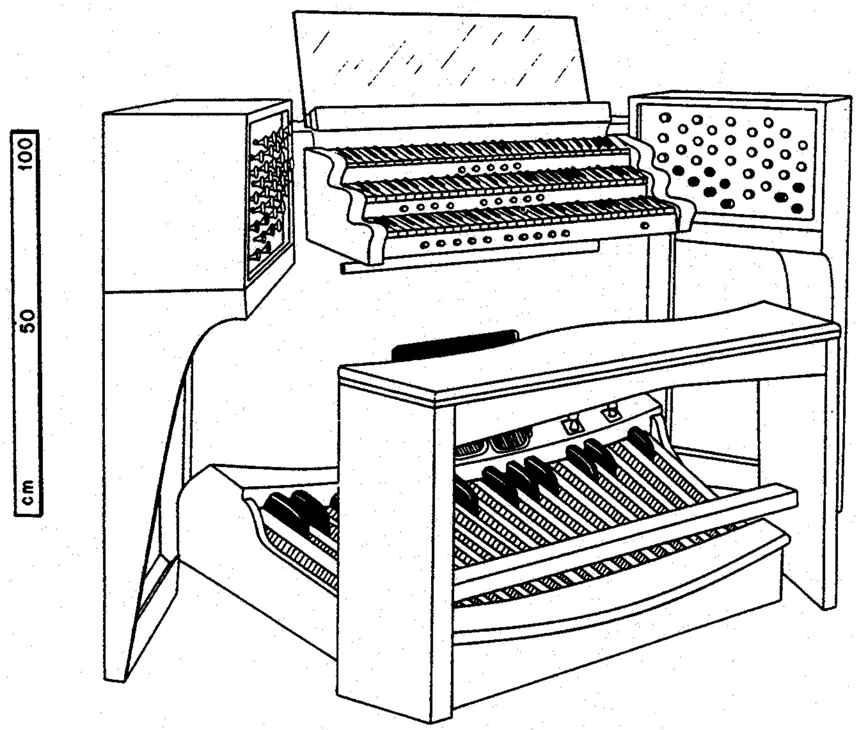


FIGURE 188. *A typical organ console.*

THE ORGAN

The organ is with justice called the king of instruments, for it is the largest, most complex, and arguably the most versatile of all. Its overall pitch range is a staggering nine octaves covering the entire gamut of musically useful frequencies; its dynamic range approaches that of an electronic instrument; and its variety of timbres is exceeded only by the studio synthesizer.

BASIC FEATURES OF THE INSTRUMENT

No two organs are alike, for each must be designed to fit, architecturally and acoustically, the room in which it is installed. Installing an organ in a building is comparable in effort and expense to adding a new wing; and moving an organ, like moving one's household, requires taking everything apart and putting it back together again in the new location, all arranged differently and perhaps completely redesigned.

The organ's great complexity and variability have proved daunting to many composers, and by far the greatest proportion of the organ literature has been written by people who were themselves organists. It is hoped that the following presentation will be of aid in dispelling some of this mystery and confusion.

The keys, stop-knobs, and other controls of an organ are located on a **console** (Fig. 188) which, unlike the rest of the instrument, is often movable and may even be stored in a closet when the organ is not in use. A typical organ console has three **manuals** (keyboards for the

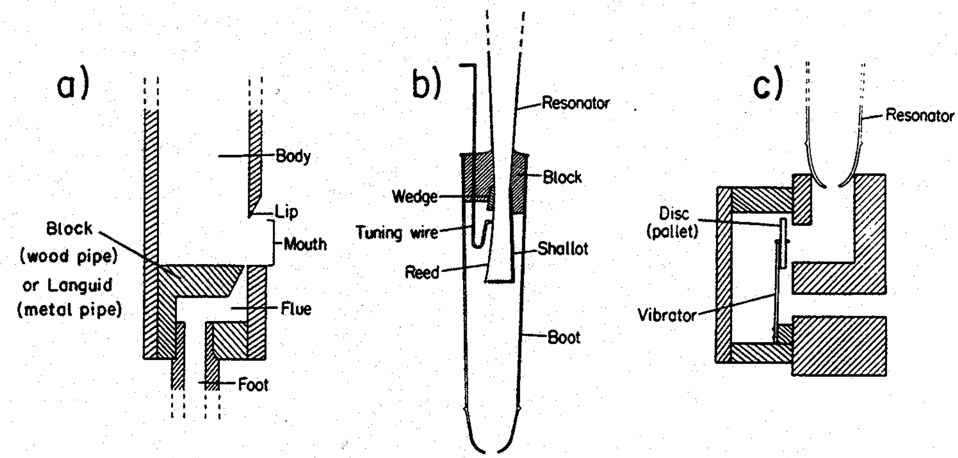


FIGURE 189. *Diagrammatic sagittal sections of organ pipes: (a) flue pipe; (b) reed pipe; (c) diaphone.*

hands), each with the five-octave range given in Figure 190, stacked one above the other. For the feet there is a **pedal** keyboard of two and a half octaves; this is just like any other keyboard, with black and white keys arranged in the usual pattern, but the keys are of course very large so that they can be played with the feet. No modern organ lacks a pedalboard and no organ has more than one, but the number of manuals varies. An organ with two manuals is considered small (single-manual instruments are almost always historical reconstructions and will not be further considered here), while large organs have four or even five.

Each of the manuals, and the pedal as well, controls its own distinct group of stops known as a **division** of the organ. The stops in a division are designed to complement and blend with each other, and each division is conceived with a particular musical purpose in mind. The divisions of a three-manual organ are called (starting with the top manual) **swell**, **great**, **choir**, and **pedal**. The great division (or **great organ**, as it is called) is the most important in any organ, containing the most commonly used, all-purpose stops.

The pipes of the **swell organ** are always **enclosed** in a **swell box** fronted by Venetian shutters which can be opened and closed by means of a **swell pedal** (also called **swell shoe**) located above the pedalboard and operated by the player's right (usually) foot. The swell box gives the organ its only real powers of crescendo and diminuendo, and that across only two dynamic levels: *mp–f*, say, or *pp–mp* or whatever, depending on the loudness of the stops being used at the time.*

Divisions other than the swell may be enclosed in whole or in part. On a few organs all divisions are enclosed, but this is almost universally frowned upon since enclosure, even with the shutters fully open, causes the sound to blend and resonate in a way that, while tonally attractive, tends to weaken the clarity of individual melodic lines. Generally, each enclosed division or partial division is provided with its own swell shoe. Swell shoes are not spring-loaded, and once set in a given position will stay put until a change is needed.

The **choir organ** mostly contains accompanimental stops designed more for smooth and well-blended harmony than for clear melody. It is often but not always enclosed. The **pedal organ** is specialized for the performance of bass lines and of *cantus firmus* in all registers. Its

* The difference in loudness seems greater than it really is, however, because when the pipes are obscured by closing the shutters the sound becomes not only soft but *distant*:

stops are centered around 16′ rather than 8′ pitch, so that, for instance, there will usually be a stop sounding at 5⅓′—i.e., the third partial of 16′. The pedal division usually also contains a few full-toned soloistic stops at 4′ and/or 2′ pitch, to play mid- and high-range *cantus firmus* lines.

If an organ has only two manuals they are swell and great. If there are more than three manuals, the "extras" are at the top, above the swell manual. The fourth manual is usually called **solo** and its division mostly contains rather loud, self-sufficient stops that are indeed intended to carry a single melodic line accompanied from another manual. The solo organ is usually enclosed. If there is a fifth manual its division may have any of a wide variety of names, depending on what specialized function has been assigned to it. Usually it will be some sort of **antiphonal division**, its pipes placed at a distance from the rest of the organ. If the fourth manual is not a solo, it too may control an antiphonal division whether or not a fifth manual is present. Antiphonal divisions are frequently the great, swell, and/or choir divisions of a preexisting small organ cannibalized to augment a larger successor. Among specially designed antiphonal divisions, perhaps the most common are the **celestial organ**, specializing in loud stops, and the **echo organ**, specializing in very soft ones (usually enclosed). Echo, celestial, solo, and numerous other specialized divisions, antiphonal or not, may also appear as **ancillary divisions** on a medium or large organ. Ancillary divisions, of which there are seldom more than two or three, are not attached to any particular manual but are available to all by means of **couplers**. Couplers—which look and act exactly like stop knobs or tiles—also link the various manuals to each other and to the pedal; when the coupler "pedal to great" is drawn, for instance, all the stops of the pedal organ become available for use on the great manual, but not vice versa. For the reverse effect, the "great to pedal" coupler is used. Couplers for most or all possible combinations of manuals (and pedal) are generally present; those linking the pedal and the other manuals to the great are *always* available. Couplers may be drawn together in any combination.

The stop controls of the organ are located to the right and left of the manuals (see Fig. 188) and take the form of draw-knobs or rocking tiles, each imprinted with the name and register of the stop it governs. The stop controls for each division are typically grouped together. Normally, drawing or releasing a stop requires that the appropriate hand be free for at

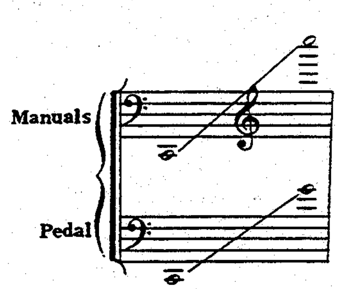
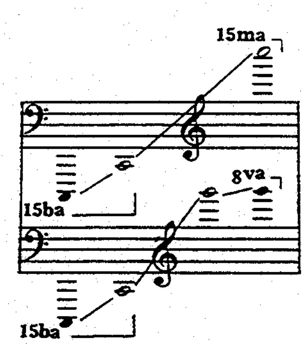
name of instrument	*abbreviations*	*keyboard range*	*range of available pitches*	*availability*
organ	org.	 single notes: loudest: *fff*; softest: *ppp*		common

FIGURE 190. *The organ—vital statistics.*

least half a second, and changing a complicated combination of stops may require the use of both hands for up to four seconds.

Fortunately, however, the process of adding, subtracting, or changing stops is made considerably easier by the use of **pistons**, which are present on all medium and large organs. A piston is a pushbutton which when pressed automatically draws any prearranged combination of stops (including couplers and/or tremulant, if desired) while releasing all stops not needed for that combination; the player can thus draw and release many stops at once by pressing a single button. To make things even easier, the pistons are scattered all over the console in handy places—above and/or below each manual, in the keyjambs, above the pedals—so that one will always be within easy reach (a quarter-second) of each hand and each foot.

Related to the pistons is the **crescendo pedal** (or **shoe**), a non–spring-loaded pedal resembling the swell pedal. When rocked forward it gradually brings on *all* the stops (with the exception of célestes, percussions, and tremulant—see below) in a smoothly graded series, with a crescendo effect that can cross the instrument's entire dynamic range. When rocked back it releases these stops in reverse order, leaving (at the extreme position) only the stops the player had drawn beforehand. If the loudest, fullest possible sound is desired ("full organ"), the crescendo pedal will be rocked all the way forward.

THE STOPS

There are hundreds of different kinds of organ stops; needless to say, no organ possesses all or even most of them. The stops are classified into eight or so groups based on their timbre and the way in which they are constructed, and examples of each of these groups are found on all but the very smallest organs.

All but a specialized handful of stops are either **flue stops** (Fig. 189a) or **reed stops** (Fig. 189b).

Flue pipes produce their sound exactly as a recorder does: a jet of air (supplied by a rotary electric blower) emerges from the flue, whence it is directed across the mouth of the pipe toward the sharp edge of the pipe's upper lip. The "air reed" thus produced is set into vibration just as in the flute, and sets up a standing wave in the pipe, the frequency of which is determined by the pipe's length and whether or not it is blocked off ("stopped") at the top. If the pipe is stopped it sounds an octave lower than otherwise and gives forth only odd-numbered partials. The tone of a flue pipe begins with a pronounced **chiff** of high-pitched inharmonic sounds as the standing wave builds up and stabilizes. In soft-sounding pipes of low pitch the chiff may be considerably louder than the steady tone.

A clear majority of organ stops are flue stops. These are further subdivided into **foundations**, **flutes**, and **strings**. This division is based on the degree of harmonic development of the stops, the strings having many and strong upper partials, the flutes having few and weak ones, and the foundations lying somewhere in the middle.

The foundations, as the name implies, are the most important stops in the organ, and at least some will be found in every division of the instrument. These are the stops with the typical "organ" sound, full, smooth, and rich, and they are often used by themselves. But they are also designed to blend with and support every other timbre on the organ without destroying the individuality of those timbres. This is particularly true of foundations at other than 8′ pitch. A basic point of organ registration is the varying of timbre and dynamics through the addition of stops that double upper partials of a stop already drawn, and most of this work is done with foundation stops. Generally, the higher the register of a given stop the softer it will be, so that it will blend with a stop of lower pitch rather than competing with it. When one or more high-pitched stops are added to an 8′ stop of any sort, they will, without destroying the basic timbre, *brighten* the tone quality, *increase* the loudness, and *clarify* the attack (because high pipes speak more quickly than low ones). Addition of 16′ and/or 32′ stops also increases the loudness but the tone then becomes ponderous and heavy. If such a stop is loud enough it will be heard as the fundamental, the 8′ stop then being heard as the second or fourth partial.

The most important foundations are the **diapason chorus**, found complete in the great and pedal organs and perhaps in other divisions as well. These stops are usually named as follows:

Name	*Pitch on the Manuals*	*Pitch on the Pedal*
contra (or double) diapason, or diapason	16′	32′
diapason or principal	8′	16′
principal or prestant	4′	8′
nasard	$2\frac{2}{3}'$	$5\frac{1}{3}'$
principal or superoctave	2′	4′
tierce	$1\frac{3}{5}'$	$3\frac{1}{5}'$
larigot	$1\frac{1}{3}'$	$2\frac{2}{3}'$
twenty-second	1′	2′

All these are standard features of almost any organ. Rarer stops in this series are:

Name	*Pitch on the Manuals*	*Pitch on the Pedal*
resultant	32′	64′
contra (or double) diapason	32′	—
subquint	$10\frac{2}{3}'$	$21\frac{1}{3}'$
terz or third	$6\frac{2}{5}'$	$12\frac{4}{5}'$
quint	$5\frac{1}{3}'$	$10\frac{2}{3}'$
tenth or gross tierce	$3\frac{1}{5}'$	$6\frac{2}{5}'$
septième	$1\frac{1}{7}'$	$2\frac{2}{7}'$
twenty-ninth*	$\frac{1}{2}'$	1′

*The $\frac{1}{2}'$ register is more likely to appear as a flute stop, under some such name as *campana* or *sifflöte*.

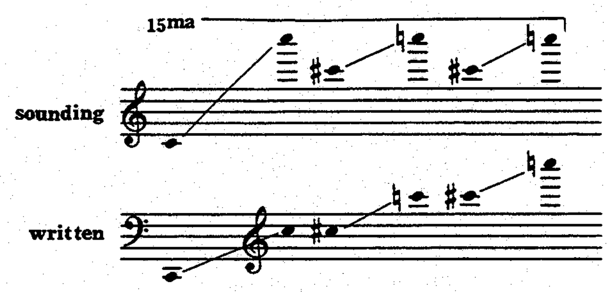
Of these, the quint and twenty-ninth (or its flute-stop equivalents) are not uncommon on medium-sized organs; the others are generally found only on large organs, and it is a rare instrument indeed that possesses them all.

Stops that sound at pitches other than 8′ or one of its octaves are called **mutations**. These stops reinforce various non-octave upper partials of 8′ stops and stops in other octaves, as the table below shows. Mutations are not in fact used for partials above the eighth. This is not to say that a 64′ and a 1 1/7′ stop would never be drawn simultaneously, but only that if they were (and this would require a coupler because it is unlikely to the point of impossibility that both would be in the same division) they would both—together with numerous other stops—be in the service of reinforcing 8′ or perhaps 16′ pitch. All this of course applies only to "normal" registration: if one wants each key to sound two discrete notes five octaves plus a flat minor seventh apart then there is nothing for it but to draw resultant 64′ + septième 1 1/7′ and damn the consequences.

Partial Number	*Fundamental Pitch*				
	64′	32′	16′	8′	4′
3	21 1/3′	10 2/3′	5 1/3′	2 2/3′	1 1/3′
5	12 4/5′	6 2/5′	3 1/5′	1 3/5′	
6	10 2/3′	5 1/3′	2 2/3′	1 1/3′	
7			2 2/7′	1 1/7′	
10	6 2/5′	3 1/5′	1 3/5′		
12	5 1/3′	2 2/3′	1 1/3′		
14		2 2/7′	1 1/7′		
20	3 1/5′	1 3/5′			
24	2 2/3′	1 1/3′			
28	2 2/7′	1 1/7′			
40	1 3/5′				
48	1 1/3′				
56	1 1/7′				

The pitch of a mutation stop is not tempered, but tuned perfectly to the appropriate harmonic of 8′ pitch. If, for instance, one were to draw the larigot 1 1/3′ on one manual and a soft 8′ stop on another, depressing the c^1 key on the first and the e^3 key on the second, one would expect a unison at e^3 to result; but in fact the two e^3's would beat strongly against each other because of the difference between the equal temperament of the keyboard itself (as reflected in the 8′ e^3) and the just intonation of the larigot rank as a whole relative to 8′ pitch. The unfortunately rather rare septième 1 1/7′ is particularly interesting, for if it were unorthodoxly to be used as a solo stop it would produce nothing but quarter-tones—otherwise unavailable on the organ without special tampering.

No stop ascends above sounding c^6, and those of less than 2′ pitch **break back** to a lower octave rather than pass this limit. A ½′ stop, for instance (see the example below), breaks back twice as the scale is ascended,



so that the stop actually sounds at 1′ pitch in the octave from (written) $c\sharp^2$ to c^3 and at 2′ pitch from $c\sharp^3$ to c^4. When a mutation breaks back it no longer doubles a partial but, rather, a privileged frequency one or two octaves lower; at these giddy altitudes it seems to make no difference.

At the other end of the scale, 64′ stops break back in their *lowest* octave, so no pitch below C_2 is ever produced. The one exception to this is the stop called *resultant*, which also happens to be the most commonly found 64′ stop. The resultant sounds simultaneously two ranks of diapason or flute pipes a fifth apart, the lower rank being at 32′ pitch. If the stop is well designed and the building acoustics are favorable, one hears a powerful difference tone (the "resultant") at 64′ from the interaction of the two ranks. From the pedal low C_0 this stop plays both C_2 and G_2 but is heard (or, rather, felt) simply as C_3—a frequency of only 8 Hz.

The resultant is an example of a **compound stop**, in which a single stop-knob gives simultaneous access to two or more ranks of pipes. The most important compound stops are the **mixtures**, which lie at the opposite end of the scale from the resultant, since the ranks of a mixture are tuned to produce a balanced cluster of high partials—up to the sixteenth in some examples.* A large mixture *may* contain an 8′ rank—or even a 16′ or 32′ one, as some pedal mixtures may contain up to eighteen ranks of pipes—but it is characteristic of all mixtures that they are intended to be drawn in combination with appropriate octave-sounding stops. If drawn alone a mixture stop produces an audible chord of independent pitches rather than a blend of unobtrusive harmonics. Individual mixture pipes, unlike those of ordinary stops, may ascend as high as c^7, but most or all of the ranks in a mixture break back one or more times in a staggered pattern. This feature is purposely designed to give notes in different parts of the keyboard slightly different timbres—the sort of thing we take for granted in ordinary string and wind instruments but which would be virtually absent from the organ without mixtures. These slight timbral differences allow each line of complicated polyphony to emerge with the utmost clarity.

* The thirteenth, fourteenth, and fifteenth partials are never present, and the seventh, ninth, and eleventh are rare.

Common stop-names for various types of mixture are *cymbal*, *fourniture*, *acuta*, *sesquialtera*, and *plein jeu*. A compound stop related to the mixture is the **cornet**, which differs, however, in that its partials are so balanced that it can—indeed, should—usually be used as a solo stop giving a unified, very rich sound. Cornet ranks break back only where absolutely necessary. The individual ranks of both mixtures and cornets always consist of flue pipes, usually of the foundation variety.

Moving on from the foundation stops we come to the **flute stops**. These are subdivided into **open**, **stopped**, and **half-stopped** flutes. Stopped flute pipes are covered at the top and sound rather hooty; acoustically they are **stopped pipes** (for a discussion of which see Chapter II). The cover of a half-stopped pipe is pierced by a smallish hole; these pipes are somewhat harsh and penetrating in timbre. Most open flutes produce a sound much like that of the recorder; the reader can experiment with the sounds of stopped, half-stopped, and open pipes by playing on a recorder mouthpiece while blocking off the bottom of it (partially, completely, or not at all) with one hand.

Open flutes are by far the most common (typical stop-names: *blockflöte*, *spitzflöte*, *hohlflöte*, *waldflöte*, *orchestral flute*, *tibia*), occurring across a wide range of both dynamics and pitch: open flutes may be pitched anywhere from 32′ to ½′—including all the common mutation pitches, though the ordinary foundation-type mutations work perfectly well with most flute stops. The softest of all organ stops, the *ppp vox angelica* 8′, may be either an open flute or a foundation. Unfortunately, this and the few other *ppp* stops are generally available only on large organs.

Stopped flutes (*gedeckt*, *bourdon*, *quintadena*, etc.) are generally quite soft—never louder than *forte*. They occur at all pitches from 64′ to 1′, including the most common mutation pitches.

Half-stopped flutes (*rohrflöte* and other names beginning with "rohr-") are the least common type, though almost any organ will have at least one such stop. They are found within a dynamic range of *p* to *mf* and at pitches between 16′ and 2′. The rare *rohrquint* 5⅓′ and *rohrnasat* 2⅔′ are the only half-stopped mutations.

Acoustically, flute stops differ from foundations in having a less well-developed harmonic spectrum. At the opposite extreme are the **string stops**, whose name derives—rather imaginatively—from their very bright, zingy tone. String stops are less common than either flutes or foundations; almost all are named after stringed instruments, the major exception being the *salicional*, the most useful and common of all string stops.* Strings are built at a wide variety of dynamic levels, and at pitches from 32′ to (rarely) 2′, including all the more common mutations—though, again, the ordinary foundation mutations serve string timbre perfectly well.

A specialized type of compound stop called **céleste** is usually made from string ranks. A céleste consists of two otherwise identical ranks tuned a few Hz apart so that they beat together, making a very pleasant, gentle vibrato. Célestes are usually soft (*mezzo-forte* or softer) and are almost invariably of 8′ pitch. Because the low difference tone that makes the vibrato effect is difficult to elicit at low pitches, célestes descend only to c^1, g^0, or c^0, breaking back below that pitch.

* On the other hand, the group of stops beginning with "geigen-" (German: "violin-") are not string stops at all, but foundations.

The most common céleste stop is the *voix céleste*, usually made from salicional pipes. Some specialized célestes have more than two ranks, the idea being to create not a vibrato but the slight turbulence characteristic of massed instruments playing in unison. Foundation and flute célestes also exist, usually with a slower vibrato than a string céleste: the most common foundation céleste is called *unda maris* (Latin: "wave of the sea"). There is no such thing as a reed céleste.

Each pipe of a **reed stop** (Fig. 189b) enlcoses in its base (or **boot**) a single metal reed that beats against the opening in a **shallot**, the whole system resembling a clarinet reed and mouthpiece. Unlike the clarinet, however, a reed pipe's pitch is governed entirely by the reed itself: the "pipe" ascending above the boot is actually a **resonator**, governing the timbre but not the pitch.

Reed stops are divided into three groups: **chorus reeds, semichorus reeds**, and **imitative reeds.** All of the organ's *fff* stops are chorus reeds. Almost always loud—never softer than *mezzo-piano*—chorus reeds have a brilliant, blaring tone and are all named after brass instruments, with the important exception of the low-pitched *bombarde* stops. They are found at pitches from (rarely) 64′ to 4′. Reed mutations are very rare; those that do exist are chorus reeds designed to reinforce the upper partials of the loud 16′ or 32′ *contra bombarde* or *tuba* stop, usually as part of an ancillary **bombarde organ** division.

Semichorus reeds are characterized by short resonators that only slightly mitigate the naturally buzzy tone of the reed: in German these stops are collectively called the *Schnarrwerk.* They are mostly rather soft, never louder than *forte*; the *vox mystica* 8′ is a *ppp* semichorus reed found on some large organs. All octave-sounding pitches from 32′ to 1′ are represented among these stops, which are generally named after Renaissance and medieval instruments (the *gemshorn*, however, is a foundation stop and the *bombarde* is a chorus reed). An important exception is the common *vox humana* 8′, which sounds just barely enough like a human voice to be vaguely disquieting in effect.

The **imitative reeds** are mostly products of the nineteenth century, when the organ was conceived of as a sort of keyboard orchestra. These stops represent attempts to imitate the sounds of orchestral reed instruments, all of which are represented on one organ or another. The two basic timbres, oboe/bassoon and clarinet,* are each represented in a variety of pitches and timbres; clarinet imitations, for instance, include (*orchestral*) *clarinet* 8′ or 16′, *bell clarinet* 8′, *basset horn* 8′, and *major clarinet* 8′ or 16′. The oboe/bassoon group includes octave-sounding stops ranging from *contra bassoon* 32′ to *octave oboe* 4′. The most deliberately imitative stops generally have the word "orchestral" in their names. In addition to the imitative reeds there are imitative flutes, strings, and chorus reeds, but none of these sounds so distinctive as the imitative reeds.

A few miscellaneous stops do not fit into the scheme outlined above. The **diaphone** (Fig. 189c) is reed-like in its mechanism, but instead of a thin reed the vibrator is a solid block called a **pallet**. Diaphones are voiced to sound like foundation stops and are used to give a true *ff* or even *fff* foundation tone at 16′, 32′, or even 64′ pitch, where a flue stop could not play so loudly. Although the diaphone is acoustically unique, musically it is just another foundation stop.

* There exist *saxophone* and *contra saxophone* stops, but these are found only on rather decadent large organs.

Most organs contain one or more **percussions**, which are actual percussion instruments built into the organ and struck by pneumatically driven hammers when a key is depressed. The only percussion commonly found in new organs is the *chimes*, an ordinary two-and-a-half-octave set of tubular chimes built into the instrument and serving more of a ceremonial than a musical function. The old theater organs originally built to accompany silent movies contain a wide variety of percussions—everything from xylophone to piano to castanets—and in Europe even the most respectable Baroque organ is likely to feature a rotating, jingling *Cymbalstern* or twittering *nightingale*.

Finally, there is an important "stop" that makes no sound at all—the **tremulant**. This device produces a fluctuation in the air supply so that a vibrato is imparted to all the stops. Every organ has at least one tremulant, and many have several of different speeds and/or in different divisions. As might be imagined, the tremulant is not traditionally used in combination with a célesting stop. When this is done, the two conflicting vibrati produce an uneven, turbulent sound.

It will readily be seen from the foregoing that organ registration is an art as complex and demanding as all the rest of instrumentation put together. The extent to which composers ought to specify the registration of their organ music has been—deliberate indeterminacy aside—a vexed question for a long time.

Most of the literature runs to one or the other of two extremes. Some composers prefer to leave everything up to the organist—a procedure which, though admirably trusting, is an invitation to disaster, particularly if one is working in an unfamiliar idiom. Others, especially those who are themselves organists, specify everything in great detail; the disadvantages to this are, first, that one must have access to an organ in order to be certain of the sounds produced, and, second, that the great differences among individual organs make such detailed specification only partially applicable to any organ other than the one at which it was composed.

The reader is advised to avoid both these extremes and to register according to these principles: (1) specify only those stops and registers that are meant to be clearly heard, leaving the player to adjust the balance and blend with subsidiary stops of his or her own choice; and (2) avoid specifying any but the most common stops by name, using instead the general designations listed below. These, combined with the register in feet and the indicated dynamic level, will give the organist all the guidelines necessary to choose appropriate stops on any organ:

foundations
flutes
stopped flutes
rohrflöte
strings
chorus reeds
semichorus reeds
oboe (8′ or 4′) or bassoon (16′ or 32′)
clarinet
mixture(s)
céleste
tremulant

Surprisingly little has been done in the way of developing contemporary special effects for the organ. The only such effect that has been used is **switching off the electric blower** (this can be done from the console). The effect produced is one of combined diminuendo and downward glissando, with various little squeaks and toots as the flue pipes produce whistle tones (p. 30) just before dying away. The composite sound is rather like a bagpipe deflating, especially if reed stops are involved.

Two possible special effects that have so far remained unexploited are the **special tuning** of a stop and **rearranging pipes**. All organ pipes can be tuned, but only reed stops can be adjusted easily enough (with their tuning wires) to make it worth a composer's (or performer's) while to retune even one rank for a special effect (microtones, unconventional temperament, etc.). As mentioned above, the septième $1\frac{1}{7}'$ (if present) produces quarter-tones without retuning. An equally intriguing possibility is to mix the pipes from two or three different ranks (no lower than c^1—deep pipes are increasingly large and heavy) to produce a "stop" in which different notes have more or less radically different timbres and/or dynamic levels.

NOTATION

Organ music is written on three staves. The lowest staff bears the pedal part; notes played by the hands are written on the upper two staves in the usual fashion. These upper staves do *not* represent separate manuals. Of course, if the two hands play simultaneously on separate manuals, their parts will be segregated on the same two staves, but the situation must be clarified by specifying the manuals involved either by name or with Roman numerals, "I" representing the lowest manual. Changes of manual by both hands together should also be indicated in this way.

All registration instructions are written immediately above the staff or staves they affect, possibly with a brace or half-bracket if more than one staff is affected. All the stops in a new combination should be listed together in a vertical stack, with both name and register given for each.* If one or more stops are to be added or subtracted from an existing combination, the name of each stop is preceded by a + or −, respectively.

The organ and other sustaining, non–touch-sensitive keyboards have substantially different finger technique from that of the piano. The normal articulation of successive tones on the organ is legato, whether or not a slur is written, and in order for the necessary smooth connection to occur each finger must remain on its key to the very last possible instant. To aid in this process two techniques are used that would sound weak and awkward on a touch-sensitive instrument: first, a finger may slide off a black key directly onto an adjacent white key, and second, the thumb may "walk" off a white key onto any adjacent key, white or black, by bending and unbending the knuckle. In addition, organ fingering requires a great deal of substitution, as here:

(R.H.)

* The name comes first: "diapason 8′," not "8′ diapason." Of course, no register is given for mixtures, couplers, or tremulant, though in organ specifications the number of ranks in a mixture is given as a Roman numeral, e.g., "fourniture IV."

Composers must be careful not to exceed the fingering possibilities of the instrument; even

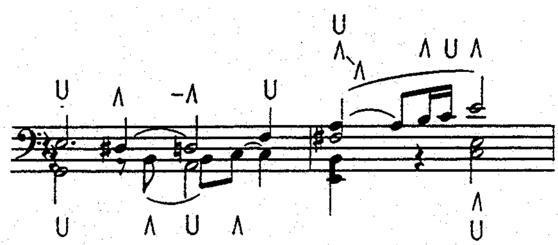
such an easy-looking passage as: 

is impossible to play legato.

In detached playing, of course, these limitations do not apply. Notes are detached in organ music only at the ends of phrases or where specifically marked by the end of a slur, a staccato-dot, a tenuto line, or an accent.

The pedals are played with heel and toe of both feet. Substitution (of heel for toe or vice versa, or of one foot for the other), sliding with the toe from a black key to any adjacent key (black or white) and "walking" one foot across the keys with alternating toe and heel are all integral parts of this technique. Black keys are always played with the toe. Trills and rapidly repeated notes must be taken with alternate feet.

When playing a single line the two feet working together can play with great rapidity if desired, and even when each foot handles a separate line surprisingly rapid motion is possible. Since each foot can play two-note chords of a second or third, or tone-clusters up to a minor sixth in width, slowly moving polyphony of up to four independent parts is possible, though difficult:



Most organists would regard such a passage as a bit perverse, and composers should write this sort of thing only where absolutely necessary.

The example above also illustrates the symbols used for designation of pedaling patterns. These are as follows:

Λ = toe

U = heel

Λ- U , U-Λ = substitution of heel for toe (toe for heel) in one foot

Λ↘Λ , Λ↘U , U↘Λ , U↘U = substitution of left toe or heel for right toe or heel (notated above staff)

Λ↗Λ , Λ↗U , U↗Λ , U↗U = substitution of right toe or heel for left toe or heel (notated below staff)

Λ – Λ = slide toe off first note directly onto second

Indications for the right foot are placed above the pedal staff; those for the left foot are placed below it. Pedaling, like fingering, should only be specified where absolutely necessary for the clarification of a tricky or deceptive passage.

Musical Examples

ORGAN:

Janáček, *Glagolitic Mass*
Hindemith, *Kammermusik* No. 7
Varèse, *Ecuatorial*
Messiaen, *Les Corps glorieux*
Kagel, *Improvisation ajoutée*

ELECTRIC RELATIVES OF THE ORGAN

THE ELECTRIC ORGAN

Like the electric piano, the electric organ is not simply a debased form of its parent instrument but an independent musical entity with its own characteristics.

The electric organ is an extremely variable and ill-defined instrument, and in order to comprehend its vagaries it is necessary to consider the hypothetical ideal—the "essence," if you will—around which are clustered its various real forms. This archetypal instrument is an electronic imitation, not of the ordinary organ as described above, but of the theater organ of the early twentieth century. These organs were short on mixtures and mutations, possessing instead a great variety of soloistic 8′ stops, running to extremes such as the *tibia clausa*—a *fortissimo* stopped flute with virtually no upper partials—and the *kinura*, a semichorus reed so buzzy it has been compared to "a bee in a bottle." There were also many imitative stops and numerous percussions, and almost everything was enclosed.

All these features are carried over into electric organs, even though pipe organs are no longer designed in this way. The basic appearance and operation of an electric organ are the same as those of a pipe organ, but all sounds are produced electronically.* In place of swell and/or crescendo pedals there is a **volume pedal** covering the entire dynamic range of the instrument. This gives the electric organ considerably more dynamic flexibility than a pipe organ.

It is an unfortunate fact that the vast majority of electric organs made today are unadulterated junk. Everyone has seen these tiny, gadget-ridden, musically useless plastic toys in the salesrooms of "piano" dealers, where they are sold in large numbers to the naïve—but one should not on this account write off the electric organ altogether, for fine instruments continue

* Some early electric organs—now highly prized—were electromechanical, but all currently made are electronic.

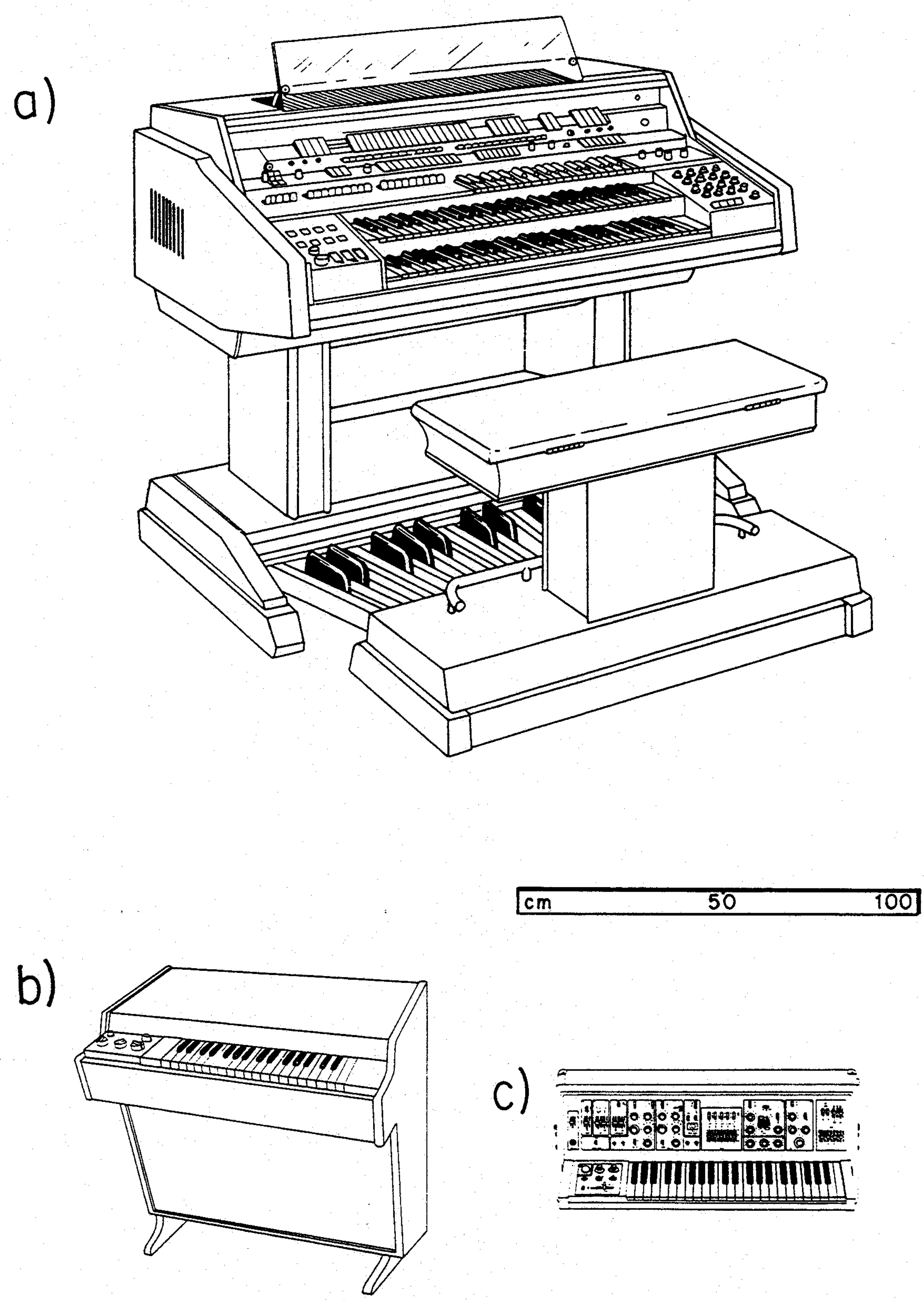


FIGURE 191. *Sustaining electric keyboards: (a) electric organ; (b) melotron; (c) performance synthesizer.*

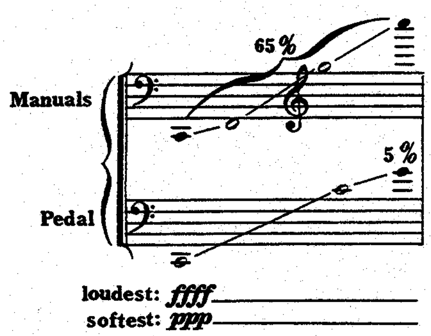
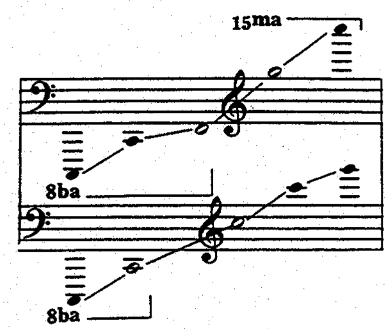
name of instrument	abbreviations	keyboard range	range of available pitches	availability
electric organ	elec. org.			common

FIGURE 192. *The electric organ—vital statistics.*

to be made. Some of these, intended for use where a pipe organ would be desirable but would not fit the space and/or budget allotted, have up to five manuals and a great many stops; it is interesting that even these "respectable" organs have numerous theater-organ–type stops.

The more typical electric organ—the sort used by jazz and rock groups—is a much smaller instrument, with only two manuals and a smaller keyboard range than the pipe organ, especially in the pedals, which seldom exceed two octaves. Some cheap models have no pedals at all. Most electric organs have no pistons, though there may be "presets" giving the more common combinations. All have couplers, but few have any ancillary divisions.* Only the 8′ series of mutations are likely to be present, and they perhaps only on one manual. There is always a tremulant—often of variable speed—and there may be a **reverb** and/or a **sforzando** tab as well. Many older electric organs were built with a **Leslie** attachment—a raised, rotating loudspeaker that sprayed the sound around the room, causing subtle shifts of phase in the echoes. Recent instruments have a purely electronic **phaser** instead. The schlockier varieties of electric organ are provided with **repetitions** that give a repeated attack (at variable tempo) for as long as each key is held down. Some repetitions apply only to the percussions, but some will affect any stop. Some of the percussion repetitions give specific dance rhythms (tango, polka, etc.). For many years the repetitions had no use except among the musically illiterate, but they are now to be heard quite frequently in popular music.

There are at least two percussions in any electric organ. These most frequently include snare drum, castanets, bass drum, tambourine, wood block, marimba, vibraphone, chimes, piano (i.e., *electric* piano), and/or harpsichord, though almost any imaginable percussion instrument or plucked string can be found in one organ or another. These non-sustaining sounds are made electronically, and if indefinitely pitched will produce the same sound from every key, just as on a theater organ. A "snare drum" stop, for instance, produces a little "biff" of white noise of exactly the same pitch and timbre from each key.

* When there is one, it is for the purpose of keeping traditional and theater stops out of each other's way.

name of instrument	*abbreviations*	*keyboard range*	*range of available pitches*	*availability*
melotron	meln.	 loudest: *ffff* softest: *ppp*		rare

FIGURE 193. *The melotron—vital statistics.*

The tone of the electric organ, as of the theater organ before it, tends toward the extremes of a mysterious, detached coolness on the one hand and an overbearing lushness on the other—usually both in the same instrument.

There are on the market many electric-organ hybrids—with the electric piano, with the performance synthesizer, with the accordion (the "bellows" acting as a volume control), and so on. None of these instruments is very worthwhile. Competition with the performance synthesizer has led to the introduction of all sorts of unusual and even bizarre timbres. Many of these are quite attractive, but in the constant succession of new brands and models an experimental stop can easily become obsolete before it has even reached the awareness of the musical public.

THE MELOTRON

The melotron takes the principle of the imitative stop to its logical conclusion. Each note on this instrument is produced by a short piece of tape with the sound of a flute (4′), violin (4′), and cello (16′) recorded on it on three separate tracks which the player can select by means of a three-position switch. Notes below the range of the instruments recorded are produced through electronic manipulation of notes an octave higher. There is only one manual and no pedals. Only one timbre can be played at a time, though it is possible to switch from one to another in mid-note. Because of the limited length of the tapes, no single note can exceed eight seconds in duration (but the **orchestron**, a recently invented variant, can sustain tones indefinitely). Loudness is controlled by a knob above the keyboard.

Despite its almost obscenely imitative nature, melotron music still has an odd, electronic flavor to it both because the dynamics are unrelated to the original loudness of the instruments recorded and because the attacks are missing from the tapes, so that while a realistic legato is possible, detached notes have a purely electrical onset.

In addition to the three standard "stops," tapes can be purchased giving brass (8′) or choral (8′, on the sound [ɑ]) timbres, and various others are available from time to time.

THE PERFORMANCE SYNTHESIZER

Performance synthesizers differ from the studio-type synthesizer in that they are seldom modular, have all circuitry governed by switches and potentiometers rather than patch cords, are

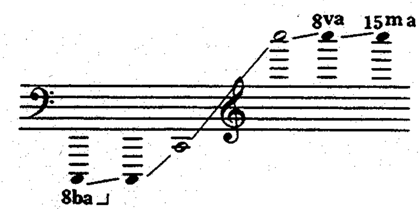
name of instrument	*abbreviations*	*keyboard range*	*range of available pitches*	*availability*
perfor-mance synthesizer	synth.	 loudest: *ffff* softest: *ppp*		usually available

FIGURE 194. *The performance synthesizer—vital statistics.*

small enough to be portable, and are much more limited in the number and variety of sounds they can produce. Certain digital performance synthesizers rely so completely on stored "live" sounds that they are in effect digital melotrons. The superiority of such an instrument to the conventional melotron is obvious, and indeed "analog" melotrons seem to be on the way out. (Detailed information on synthesizer functions and terminology is given in Chapter X.)

A "typical" performance synthesizer (hard to define because this instrument is extremely variable) produces most of its sounds from a single oscillator and is thus monophonic: if two keys are depressed simultaneously only the lower will sound. There will be only one manual and no pedals.

The timbre of the oscillator is governed by a number of "stops" usually resembling electric-organ stops in both name and tone quality. It is important to remember that even at this far remove the model for, say, a "string" or "brass" stop is usually the equivalent *organ* timbre, not the orchestral one. There may be an "organ" stop giving a diapason-like tone. There will always be at least one 16′ and one 4′ stop; many synthesizers have 32′ and/or 2′ capacity, and on some the pitch of the whole instrument can be independently adjusted up or down by any amount.

In addition to these electric-organ–like features there are distinctive "synthesizer" characteristics:

1. One or more high- or low-pass filters with variable band-width.

2. Separate controls governing attack and decay times. The attack may be varied between near-instantaneity and a long, slow crescendo of some ten seconds; the decay starts immediately upon completion of the attack and is similarly variable. The decay may be switched off altogether, leaving a continuous tone like that of the organ. Any decay pattern will be cut off instantly by release of the key.

3. On some synthesizers it is possible to link the filter to the attack/decay mechanism, giving the rather silly "bwee" attack popularly associated with synthesizers.

4. Many have an auxiliary oscillator, with independent pitch and volume controls, used to create complex sounds or two-part parallel harmony. There may also be a ring-modulator.

5. There is usually a portamento control by means of which the speed of the oscillator's shift from one keyboard pitch to the next can be varied, enabling the production not only of portamento *per se* but also glissandos of any length and speed.

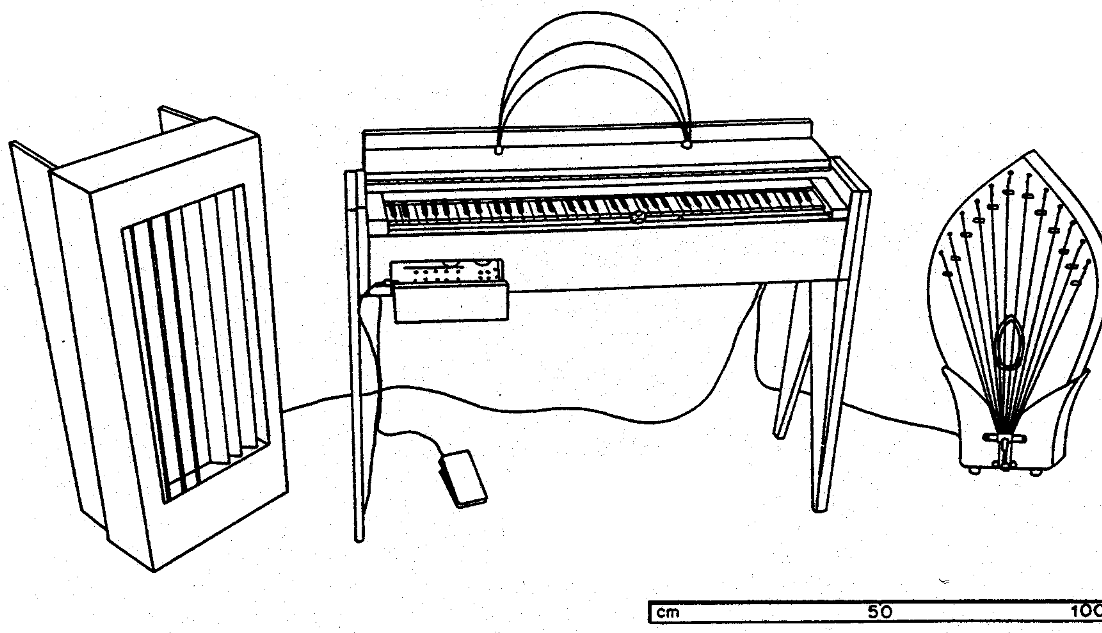


FIGURE 195. *Ondes martenot.*

6. Sequencers, often multistage and sometimes involving a digital memory, are increasingly to be seen.

Finally, a variety of additional devices may be present, most frequently including reverb, phaser, and/or vibrato units.

Increasing numbers of **polyphonic** synthesizers are now being made, capable of playing two, four, eight, ten, sixteen or more parts, depending on how many oscillators there are. Some have a separate oscillator for each key. Polyphonic synthesizers seldom have pitch variability (except, of course, that provided by the keyboard itself and by the octave transpositions of some of the stops) and have a limited range of preset timbres. In fact, were it not for the separate attack and decay controls most of these instruments would be indistinguishable from electric organs, since all the other "synthesizer" features are suppressed or severely restricted. Some instruments have both a single monophonic "stop" of independently variable pitch and timbre and several polyphonic ones that are more restricted.

The performance synthesizer is really a hybrid between the studio synthesizer and the electric organ. All degrees of hybridization exist, ranging from near-studio models to electric organs with added "synthesizer stop." There are also specialized performance synthesizers such as bass-range **pedal synthesizers** and **drum** and **guitar synthesizers** designed to be played by percussionists or guitarists rather than keyboard players. The **lyricon** is a newly invented woodwind synthesizer designed to be played by a clarinet or sax player, and the even newer **EVI** ("electronic valve instrument") is designed for brass players.

The digital synthesizer, still on the drawing board when the first draft of these pages was written, is now very much with us. The microelectronics revolution has thrown the electronic keyboard industry into a state of chaotic experiment and innovation from which it is unlikely to emerge as long as the size and cost of component circuits continue to decrease by—as

Scientific American puts it—"a factor of two every eighteen months." Not only performance synthesizers but electronic organs, pianos, and harpsichords (to say nothing of combination forms that may be as bizarrely hybrid as griffins) are constantly appearing with new sounds, new gadgets, new capabilities—and in more and more cheap and compact forms.

The new performance synthesizers may be wholly or partly digital (see Chapter X). Software for these instruments (meaning, in most cases, nothing more than a variety of pre-packaged timbres) relies on floppy discs, or tape cassettes like those used in home video games. Most have no interface capability at all. The main effect in any event has been to make available uncannily accurate imitations of massed strings, brass, etc., as well as sound effects such as surf, helicopters, and so on. Digital drum synthesizers come full circle in that realistic drum and cymbal (traps) sounds are obtainable from them.

The problem with all this attractive technology is that new models grow obsolete and die as fast as they are born. When work on this book was begun in 1976, one of the most popular polyphonic synthesizers was the Arp String Ensemble; but by the time we started production in 1983 Arp had gone out of business. Anyone unwise enough to have written idiomatically for that particular synthesizer five years ago has now got a problem—and this example could be multiplied endlessly. Performers may well revel in wave upon wave of new toys, but composers will just have to sit back and wait until the waters subside.

Musical Examples

ELECTRIC ORGAN:

Stockhausen, *Momente*
T. Riley, *A Rainbow in Curved Air*
Reich, *Four Organs*

MELOTRON (FROM THE POPULAR LITERATURE):

The Beatles, "Strawberry Fields Forever"

PERFORMANCE SYNTHESIZER (FROM THE POPULAR LITERATURE):

Herbie Hancock, "The Traitor"

THE ONDES MARTENOT

The ondes martenot is an electronic keyboard instrument of tremendous artistic sophistication and expressivity. In this respect it is light-years ahead of the other electronic keyboards, which whatever their other merits are utterly incapable of subtlety. The sound of the ondes—produced by the (electronic) heterodyning of two ultrasonic oscillators—is extremely rich and attractive, reminiscent of the violin or the voice and as expressive as either.

The instrument is monophonic (if several keys are depressed simultaneously only the lowest will sound), and the keyboard is normally played by the *right hand only*. The left hand works a set of controls (Fig. 196) governing timbre, dynamics, and articulation. The latter two functions are controlled by a large rectangular button that gives increased loudness in

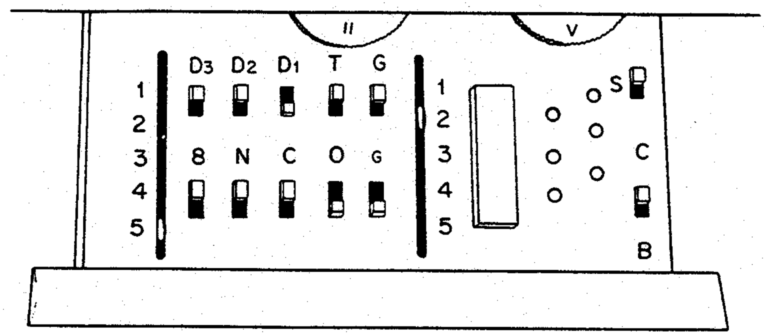


FIGURE 196. *Ondes martenot—controls for the left hand.*

response to increased pressure—thus, the ondes is touch-sensitive. In order for a sound to be produced a key must be depressed and at least minimal pressure applied to this expression button. While maintaining steady pressure on the button it is of course possible to differentiate everything between staccato and legato by means of the keys alone, but for accents, swells, and the numerous unnotated subtleties of dynamic expression this does not suffice, and normally the **expression button** will be struck separately for each detached note, acting in this regard rather like the tongue of a wind player. For the rare passage so disjunct that both hands are required on the keyboard, the ondes is equipped with a volume pedal like that of other electronic keyboards.

In order to keep such passages to a minimum, the left hand is provided with six **transposition buttons** immediately to the right of the expression button. From front to back these six buttons shift the pitch of each key by a quarter-step down, a quarter-step up, a half-step up, a whole step up, a major third up, and a perfect fifth up. They are additive in combination—like the valves of a brass instrument—so that the fifth and sixth buttons, for example, raise the keyboard pitch by a major seventh when used together.

The front two transposition buttons are of course used for the production of quarter-tones. The remaining buttons serve to extend the effective stretch of the right hand, enabling it to negotiate leaps of up to two-and-a-half octaves without shifting position. Since a single motion of the hand can be used in striking both the expression button and the transposition buttons, the latter are particularly suited to the production of grace notes, and that is indeed their main function in most musical contexts.

The microtonal resources of the ondes martenot are not restricted to the transposition buttons. Each right-hand key can be moved slightly to the left or right to produce vibrato and bent tones up to a quarter-tone above or below normal pitch; the keys are spring-loaded to return to their normal position when released. In addition there is a movable **ring** used for glissandos. The ring is attached to a thin rope running in front of the keyboard; moving the ring (into which the right index finger is inserted) winds and unwinds the rope inside the instrument, producing variations in pitch corresponding to the position of the ring. The notes of the equal-tempered scale are labeled just beneath the rope, so specific pitches can be accurately pinpointed with this mechanism. The transposition buttons can be used in conjunction with the ring.

A switch at the right front of the control drawer governs the choice of keyboard (position C, standing for the French "clavier") or ring (position B—French "bague"). Since the right

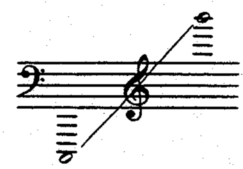
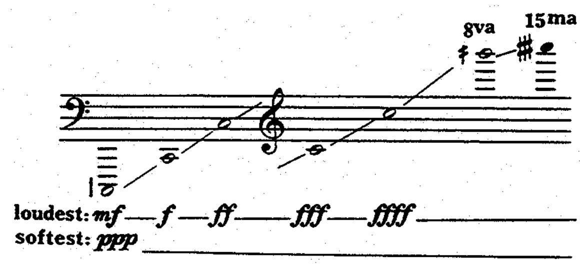
name of instrument	*abbreviations*	*keyboard range*	*range of available pitches*	*availability*
ondes martenot	ondes O.M.			in France and Quebec usually available; elsewhere very rare

FIGURE 197. *The ondes martenot—vital statistics.*

hand is perfectly capable of playing the keyboard while the index finger is in the ring, the switch from keyboard to ring and back can be quite fluid, limited only by the left-hand excursion necessary to shift the B/C switch.

On the front of the instrument is a switch governing the register of the keyboard (and ring). The ondes' two registers, an octave apart, are simply called "high" and "low," and cannot be designated in feet because the two are considered equal in importance. All notes are written *at actual pitch* no matter which register is used. The "keyboard range" given in Figure 197 is that of the low register, chosen for notational convenience, though the high register is if anything more often used. There is no timbral difference between the registers. The transposition buttons can be used to extend the range upward beyond the top of the upper register to a surprising c ♯^{6} (Fig. 197). This top note requires the simultaneous use of five of the six buttons, making the manipulation of the expression button somewhat awkward. Many older ondes martenots still in use have only the two quarter-tone transposition buttons, and accordingly cannot ascend beyond b ‡^{4} (they can produce indeterminate pitches up to about e^5, however). On the other hand, these same old instruments have a very coarse tuning knob that can *lower* the range of the keyboard as a whole by any amount down to the subsonic range. This low-note capability has been abandoned because those notes are weak and unconvincing—they are not even very clearly pitched.

The ten switches to the left of the expression button control the timbre and distribution of the sound. Those marked "D_1," "D_2," and "D_3" ("diffuseur"—French for "loudspeaker") are speaker outputs. **D_1** is the ordinary timbre of the instrument. **D_2** engages a spring-based reverb unit built into the speaker. **D_3** is an auxiliary output which may feed to a separate speaker placed at a distance (for antiphonal effects), or can be used to interface the ondes martenot with other electronic devices (see Chapter X). D_3 can also be used with either of two older speakers whose production has recently been discontinued. One is a plate-type reverb unit (former D_2), and the other (former D_3, illustrated) encloses the speaker cone in a complete sound-box with sympathetic strings running across it, front and back. Neither of these speakers can match D_1 (or the new D_2) in power, and the old D_3 is reportedly cranky and difficult to maintain. Its beautiful and distinctive timbre, resembling D_1 played into a piano interior, is well worth preserving, however, and old "palms" are likely to remain available for many years.

The remaining seven switches control the timbre of the output signal. They are designated as follows:

T = tutti
G, g = gambé ("stringy")
O = ondes (basic timbre)
C = creux ("hollow")
N = nasillard ("nasal")
8 = octaviant (prominent second partial)

The strength of the second partial in "8" is governed by a slider to the left of the switches. The other slider (on the right) controls the prominence of the "gambé" sound, but only when "g" (not "G") is engaged. In combination these seven "stops" interact in complex and subtle ways, so their detailed use is best left to the player; nonetheless the primary designations "hollow," "nasal," etc., can be given just as they might be on any other instrument.

On the far right side of the control drawer, just above the C/B switch, is one final switch, marked **S** (for "souffle"—breath). When engaged, this switch adds a component of white noise to the tone. The intensity of the white noise relative to the main pitch is governed (on a scale of I to V) by a dial placed just behind the switch. When S alone is engaged, without any of the other timbre switches, white noise alone is produced.

The other dial (behind T and G) controls the blend of speaker outputs when D_1 is used simultaneously with D_2 and/or D_3. The scale of this dial is marked 0 to V; in position 0 only D_1 will sound, while in position V only D_2 (and/or D_3) will be heard.

A final refinement is a **knee lever** below the keyboard, which when pushed to the side gives progressive removal of the sound's harmonic train. On the most recent model this has been replaced by a foot pedal of equivalent function.

Musical Examples

ONDES MARTENOT:

Messiaen, *Turangalîla symphonie*
Varèse, *Ecuatorial*