

An Acoustical History of Theaters and Concert Halls: An Investigation of Parallel Developments in Music, Performance Spaces, and the Orchestra

CHRISTOPHER R. HERR and
GARY W. SIEBEIN
University of Florida

MUSIC AND ARCHITECTURE THROUGH THE AGES

Throughout much of the history of the Western world, there exists a clearly discernible connection between the development of music, the development of musical ensembles, and the development of spaces for music performance. One of the earliest examples of this connection rises out of the Early Christian and Byzantine religious practices. During the politically and socially unstable Medieval times, the church became the primary vestige for the continuation and advancement of scholarly knowledge and the creative arts. As a result, sacred music centered on the liturgy of the church was a very prominent musical style at the time. Such music took the form of chant, which was codified during the reign of Pope Gregory I (AD 590-604), and was performed by monks and other clergy as an integral part of the Mass (Randel, 199 and Raeburn and Kendall, 26).

The slow-moving, monophonic nature of these chants is directly attributable to church architecture at that time. Most often, large spaces constructed of stone were the norm, and they correspondingly possessed extraordinarily long reverberation times (Barron, 65). Exemplary churches in this tradition include San Vitale in Ravenna, Italy and the Hagia Sophia in Istanbul, Turkey among numerous others; and in general, they are much too reverberant making speech difficult to understand. Consequently, chant was the ultimate vehicle for the monastic choirs to convey the text of the Mass in a manner which took full advantage of the effect of these ethereal and spiritual sounds resounding in these large spaces.

Musicologist Thurston Dart, in his book *The Interpretation of Music*, cites several more examples of the relationship between music and architecture which span from the Early Gothic period in the 13th century to the Renaissance and the 16th century.

Perotin's music, in fact, is perfectly adapted to the acoustics of the highly resonant cathedral (Notre Dame, Paris) for which it was written. The intricate sophisticated rhythms and harmonies of the fourteenth-century *ars nova* are room-music; pieces written in the broader

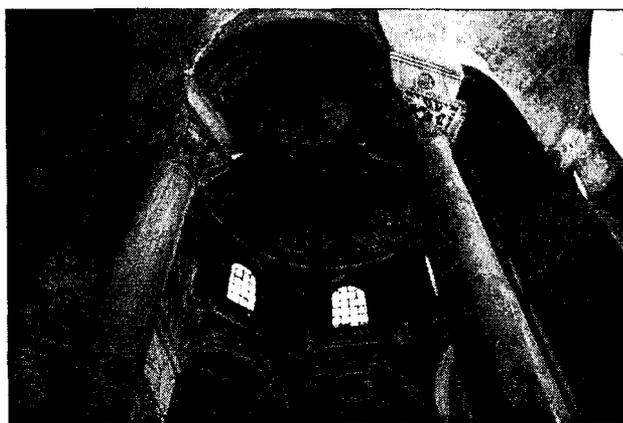


Fig. 1. Interior view of San Vitale in Ravenna, Italy.

style of the fifteenth century are resonant music. No instrument is specified, as a rule, in the manuscripts of keyboard music by Elizabethan and Jacobean composers, but some of it is clearly resonant music and therefore most suited to the organ, while another part is as clearly room-music for the harpsichord, virginals, or clavichord. Gabrieli's music for brass consort is resonant, written for the Cathedral of St. Mark's; music for brass consort by Hassler or Matthew Locke is open-air music, using quite a different style from the same composer's music for stringed instruments, designed to be played indoors (Dart, 1963).

With the examination of subsequent centuries, the observations of musicologists are augmented by surviving records of musicians' observations on the subject. Johann Joachim Quantz (1697-1773), author of an influential treatise on flute playing and contemporary performance practice, admonishes the performer on the importance of acoustics.

In the choice of the pieces in which he wishes to be heard in public, the flautist, like every other soloist, must adjust not only to himself, to his powers and capacity, but also to the place where he plays, to his accompaniment, to the circumstances in which he plays,

and to the listeners before whom he wishes to be heard.

In a large place, where there is much resonance, and where the accompanying body is numerous, great speed produces more confusion than pleasure. Thus on such occasions he must choose concertos that are written in a majestic style, and in which passages in unison are interspersed, concertos in which the harmonic parts change only at whole or half bars. The echo that constantly arises in large places does not fade too quickly, and only confuses the notes if they succeed one another too quickly, making both harmony and melody unintelligible.

In a small room, on the other hand, where few instruments are at hand for the accompaniment, the player may use concertos that have gay and galant melodies, and in which the harmony changes more quickly than at half and whole bars. These may be played more quickly than the former type (Quantz, 1966).

Moving into the 19th century, composers and conductors began to make recommendations on the acoustics of performance spaces and how to compose for them. I.F.K. Arnold, a music director active in the early 19th century, advised that composers and conductors should understand physics and acoustics (Koury, 181). Prominent composers Hector Berlioz and Richard Strauss both treat the subject in *Instrumentation*, written by Berlioz and later translated and augmented by Strauss. Their statements cover topics such as the layout of the orchestra, the placement of acoustical reflectors in the room, and scoring for dramatic music in the theater acoustic versus orchestral music and the concert hall acoustic (Koury, 187).

Clearly, then, throughout the ages, performers, composers, and conductors have been aware of the inherent link between music and architecture. While the plethora of musical and architectural periods makes an exhaustive treatment of their interrelationship a formidable task, the relatively recent development and prominence of the orchestra in Western music delineates a clear frame through which to examine the parallel development of the orchestra, orchestral music, and the concert hall.

THE RISE OF THE ORCHESTRA AND THE BAROQUE PERIOD

As the stirrings of the Reformation and the Counter-Reformation gradually died away near the end of the 16th century, the stage was set for the sweeping influences which were to dominate the next one hundred years. As the world turned its attention toward new thinkers, artists and scientists such as Milton, Cervantes, Borromini, Bacon, Descartes, Galileo and Newton, so also the musical world gradually turned away from the formal and stylistic traditions of the 16th century in

favor of new developments in operatic and instrumental composition. The work of Claudio Monteverdi (1567-1643) in the development opera and Arcangelo Corelli (1653-1713) in the development of the Trio Sonata and the Concerto Grosso contributed greatly to the beginning of the modern orchestra.

Musicians and composers at the time were most often employed as private servants by the wealthy nobility. As a result, performances were almost exclusively given in private and courtly circles "in any suitable ballroom, drawing room, salon, or hall." (Forsyth, 21) Due to the generally intimate nature of such rooms, the musical ensembles that performed there were often small. Yet in these modest beginnings, the instrumentation of the orchestra began to establish itself. Composers turned away from composing music intended for any combination of instruments and voices and began instead to write for specific combinations which frequently included stringed, woodwind, and brass instruments.

Composers throughout the Baroque and into the Classical period were generally place-bound, not only because of the boundaries of their courtly or church employment situations, but also because of the dangers and inadequacies of available transit. Thus, composers were very familiar with both the abilities and limitations of the performing forces at hand and the acoustics of the room in which they played. Indeed, the same observations made by Dart, Quantz, Berlioz, and Strauss can be made when investigating the relationships between the early orchestral music of the Baroque, the size and instrumentation of the orchestra, and the acoustical nature of the room which hosted the performance.

Johann Sebastian Bach, as one of the primary composers of the Baroque Era, provides an excellent study of this link with his famous Brandenburg Concertos. All six of the works draw heavily on the Italian concerto style established by Corelli and owe homage in particular to the later work of Antonio Vivaldi (1678-1741). Bach wrote the concertos between 1718 and 1721 while in the patronage of Prince Leopold of Cöthen, and they were likely premiered in Prince Leopold's court. The instrumentation of the works fits precisely the small orchestra Bach commanded in there. In addition, the limited numbers of the orchestra and the relatively florid counterpoint of the concertos are well suited to the small dimensions and low reverberation time of the room in which the concertos were performed.

Throughout Europe, composers in similar employment situations were writing pieces for small instrumental groups, and, although orchestral instrumentation remained fluid due to varying circumstances, the essential wind and string components of the orchestra were increasingly present. Furthermore, the typical concert room could be described as small, seating 50 to 200 persons, and with a reverberation time at mid-frequencies of just over 1 second. These parameters gradually changed, however, as the developments of the 18th century came to fruition.

THE 18TH CENTURY AND THE CLASSICAL PERIOD

During the 18th century, improvements in orchestral instruments, the decline of musical patronage, and the rise of public concerts all contributed to a general growth in size of the orchestra, the audience, and the concert hall. In response, composers, continually aware of the effect of room acoustics on performances, began to write pieces which lent themselves to these larger spaces and ensembles.

The early 1700's witnessed the passing of several stringed instruments as they were replaced by newer and more powerful designs. The Viol family, specifically the Bass Viol, the Viola da gamba, and the Viola d'amore, all started to decline in popularity as the modern Violin family came to the fore. With the shoulders of the instruments perpendicular to the neck instead of sloping toward it, the back slightly rounded rather than flat, the ribs deeper than that of the Viols, and four strings instead of six, the Violin family was able to produce higher sound levels with a fuller tone than its predecessors (Randel, 542). Bow technology similarly developed, from the hunting bow style of the 15th century, to several different versions of a straighter bow in the 16th century, and finally to the modern bow invented by François Tourte (1747-1835) in the late 18th century. The modern bow, with its adjustable tension, allowed more pressure to be placed on the strings and therefore gave the player a much wider dynamic range than previously known (Randel, 61 and Koury, 7).

Improvements in the woodwind family consisted primarily of the introduction and standardization of new and rare instruments as opposed to the technological developments seen in the strings. The oboes and bassoons were sporadically augmented with their bass cousins, the English horn and the Contra-Bassoon. The recorder, the "flute" of the Baroque era, was replaced by the German transverse flute, the same design which prevails today, and, for the first time, clarinets were introduced into the orchestra (Koury, 8).

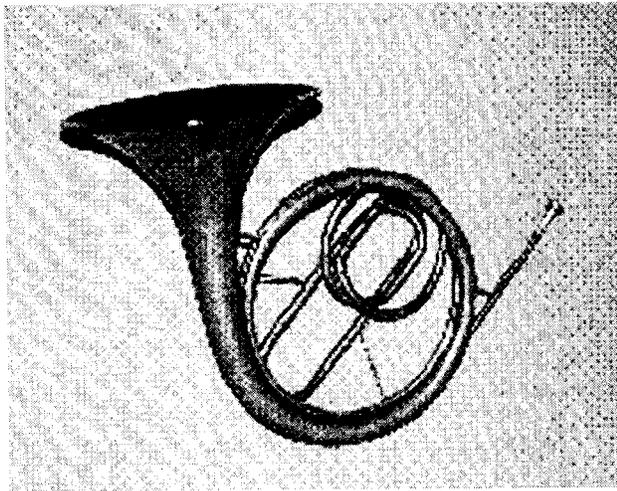


Fig. 2. An example of an early eighteenth century orchestral horn.

The Brasses were perhaps the least fortunate instruments of the time. Despite numerous experiments with keyed and slide trumpets, horns with detachable pieces of tubing, and trombones voiced from soprano to bass, no dramatic progress was made in brass instrument technology until the early 19th century and the invention of the valve. Due to the increasing size of performing venues, however, brass instruments became generally more accepted and were ever more frequently used as accompanimental instruments in the orchestra. Similarly, percussion instruments, particularly timpani, began to appear as an increasingly common feature of larger scores.

As instrumental improvements occurred, public concerts also slowly replaced the fading tradition of court musicians and private performances. The first recorded occurrence of public concerts was in 1672 in London, where the violinist John Banister advertised and charged admission for performances held every afternoon at four o'clock. Quickly catching on in England, music rooms became a common feature of taverns which advertised concerts as a popular attraction. Although the idea worked well there, Germany and France did not follow suit until 1722 and 1725 respectively. Rooms specifically for public concerts sprang up in the ensuing years, but not until mid-century were they firmly established as the dominant purveyor of the musical arts.

As a consequence of the increased popularity of public concerts, concerts strictly for the nobility slowly died out. By the late 1700's, royal patronage of musicians was largely extinguished. The architecture of concert halls, owing to the increase in the size of the audience and the corresponding increase in the number of players in the orchestra, had to respond to these new demands. The construction of the Hicksford's Rooms (1738) and the Holywell Music Room (1748) in England allowed seating for 300 persons and, at Holywell, an increase in reverberation time to 1.5 seconds. This trend of increased seating and longer reverberation times continued with the 1775 Hanover Square Rooms in London which seated 800 persons and had a reverberation time of approximately 1 second, as well as with the 1781 Leipzig Altes Gewandhaus for 400 persons with a 1.3 second reverberation time.

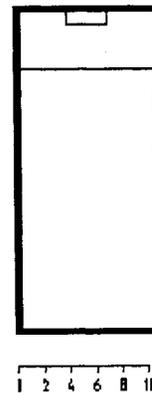


Fig. 3. Floor plan of the Hanover Square Room.

Franz Joseph Haydn (1732-1809) is one of the most interesting examples of this era, for he was one of the last composers to be employed by a patron -the Esterhàzy family of Austria -yet he also entered several public ventures in London with the help of concert impresario Johann Peter Salomon. The differences between the orchestral forces and compositional techniques Haydn used at the Esterhàza castle versus those of the last set of Salomon Symphonies premiered at London's King's Theatre Concert Room are notable. Of particular interest are the prestissimo *perpetuum mobile* of Symphony no. 57 and the avoidance of sudden dynamic changes in Symphonies 102-104. In the case of no. 57, premiered in the Esterhàza Music Room, the "dry" acoustic was essential to the success of the passage. Had it been performed in a larger room with a longer reverberation time, it would have sounded not only muddled and blurred, but also too soft, for the orchestral forces for the performance numbered only 18 (Forsyth, 40). In contrast, the London Symphony no. 103 employed an orchestra of 59 and was premiered in the King's Theatre Concert Hall. Forsyth writes, "The large orchestra Haydn used for these works "...combined with the comparatively reverberant acoustics for the size of the hall, would have produced a full, powerful tone, with audible sound reflections from the enclosing surfaces even when the orchestra played no more than *meuoforte*. In these works Haydn avoids sudden leaps between *piano* and *forte*, the effect of which would be lost with the longer reverberation time." (40)

TONE COLOR, ROMANTICISM, AND THE 19TH CENTURY

Changes in the 19th century followed the trends established

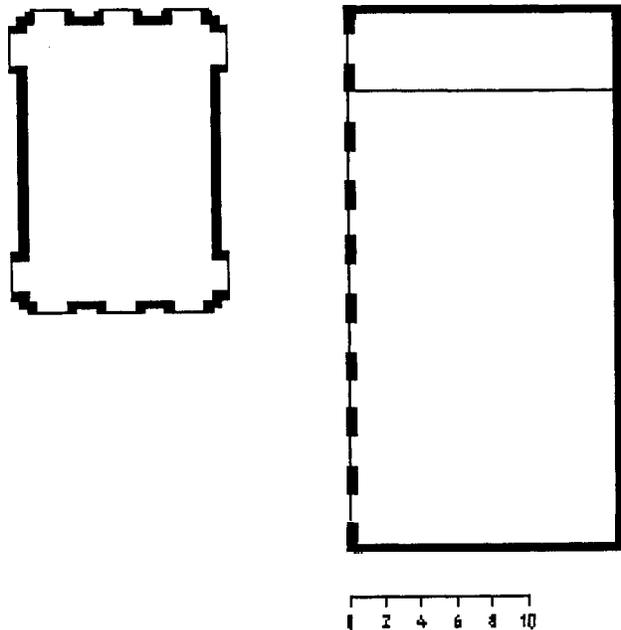


Fig. 4. Floor plans of the Esterhaza Music Room (left) and the King's Theater Concert Hall (right).

earlier - orchestral expansion, instrumental improvements, and audience growth - with two significant additions, the emergence of the modern conductor and a compositional shift of emphasis away from melody and toward tone color.

In terms of expansion, the addition of players in all sections of the orchestra as well as the common appearance of previously unusual instruments such as the English horn, the Contra-Bassoon, and the Ophicleide all aided the further standardization of the modern orchestra. The woodwinds, through the work of German flautist Theobald Boehm, augmented and standardized a system of keys which alleviated many of the problems of the old finger-hole system. Furthermore, Heinrich Stöltzel's invention of the valve in 1818 freed the brass family from the limits of the harmonic series, thus enabling the use of these instruments in much more melodic and soloistic ways than previously possible (Morley-Pegge, 30). These improvements combined with the success of public concerts, encouraged entrepreneurs, musical societies, and architects to accommodate still larger audiences and orchestras.

While the growth of the audience demanded larger rooms, the expansion of the orchestra came with inherent problems in ensemble because, simply, more players are more difficult to keep together. Thus, as the orchestra grew, so also did the popularity of the baton conductor. Until the 19th century, conducting in the modern sense did not exist. The small orchestras were led by a musician in the group, generally the keyboard continuo player in the late 17th and early 18th century, and the first violist or concertmaster after that. Whether the emergence of a baton conductor separate from the ensemble enabled the further enlargement of the orchestra or was a result of it, is a speculative question. Regardless, orchestras grew, conductors became both necessary and fashionable, and the arrival of the modern orchestra was imminent.

As the halls, audiences, and orchestras changed and grew, so also did composers adapt their works and create new styles to fit the times. Larger halls meant longer reverberation

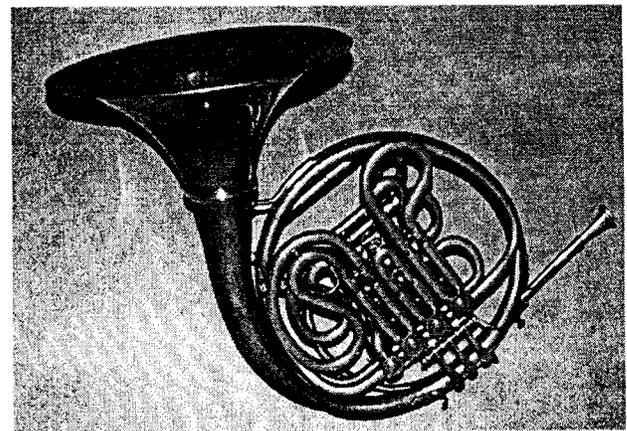


Fig. 5. Example of a modern valved horn.

times. Larger orchestras meant more varied instrumentation and thus a new array of possible sound combinations at the disposal of the composer. These factors, when combined with the long-held focus on melodic and contrapuntal music and contemporary movements in the other creative arts, set the stage for composers of the Romantic period to turn toward the expressionism and the use of tone color as a primary compositional tools. Tone color, inextricably tied to the art of orchestration, is the purposeful combination of different instruments to create specific effects. It relies heavily on the reverberant acoustic of the contemporary concert halls, for without such a "live" sound, the instruments would have lacked the blend and ring which made tone color a convincing effect.

Concert hall architecture, becoming ever more scientific, evolved to meet the acoustic goals of the musical establishment in addition to the space requirements of a larger audience and orchestra. Some examples of the time include the 1870 Vienna Grosser Musikvereinsaal which seated 1,680 persons and had a reverberation time of 2.2 seconds, and New York's Carnegie Hall which seated 2,760 persons and had a reverberation time of 1.7 seconds (Forsyth, 330).

Notable compositions which took advantage of these new developments are Hector Berlioz's (1803-1869) *Symphonic Fantastique*, a tour-de-force in orchestration and orchestral effects, the symphonies of Gustav Mahler (1860-1911), the works of Richard Wagner (1813-1883), and many others. Of particular interest are the orchestral segments of Wagner's opera music. Wagner, a man of very strong opinions and convictions, also had very clear sonic conceptions of his compositions. He employed orchestral effect and tone color manipulation with great success throughout his career, and the Bayreuth Festspielhaus which he conceived and built served him well. As an opera house, the orchestra played from the deep pit underneath and just in front of the stage. This pit, in combination with a house planned to serve only artistic needs, was "designed to be comparatively reverberant to blend the expressive tonal colors in Wagner's operas," according to Forsyth (8).

THE 20TH CENTURY, EXPERIMENT AND RETROGRADE

Quick to follow the traditions of the Romantics were the experiments of the 20th century composers. While the size and instrumentation of the orchestra settled into its most stable state yet, orchestral music and concert hall design changed dramatically.

In the musical realm, Arnold Schonberg (1874-1951) led the twelve-tone (often called the second Viennese) school of composition which liberated Western music from the previously set boundaries of tonality. In an environment of almost "anything goes," composers of the 20th century are doing everything from writing for orchestras with electronic accompaniment to writing for orchestras which once again employ the instruments of the 16th and 17th centuries.

While composers tried and tested new musical ideas,

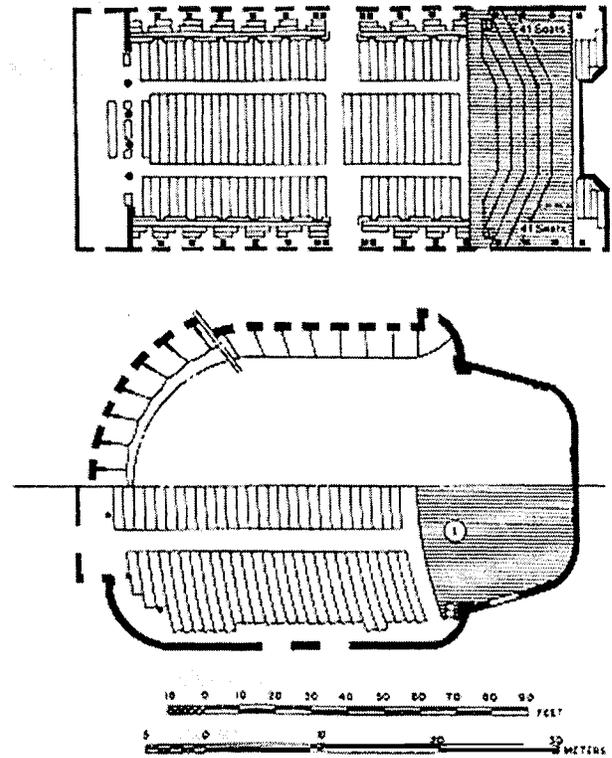


Fig. 6. Plan of the Vienna Grosser Musikvereinsaal (top) and Carnegie Hall in New York (bottom).

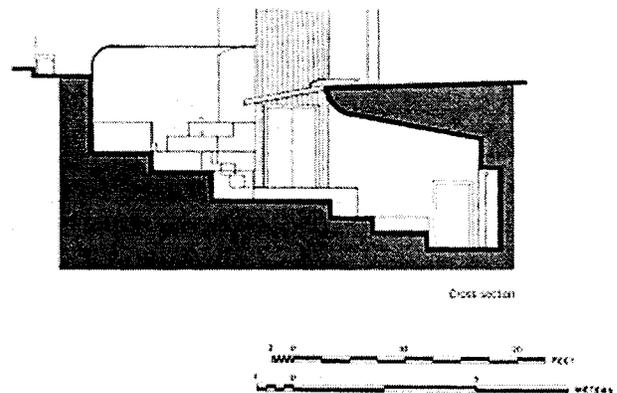


Fig. 7. Section through the orchestra pit at Wagner's Festspielhaus in Bayreuth.

concert hall design, based on the observations of Wallace Clement Sabine and subsequent students of acoustics, developed into its own science. The newfound technical basis for the acoustical behavior of rooms allowed architects and designers to apply their findings to new building types rather than relying on the empirical successes of the past. While this new freedom allowed fresh ideas to blossom, throughout the century there have been numerous failures, the most prominent of which is Avery Fisher Hall in New York. Much has been learned from these mistakes, however, and concert halls today are in general successful in achieving the design goals set for them.

Variety in 20th century hall design is not strictly attributable to the freedoms of this new science, for popular ideas on the acoustical attributes a hall ought to possess have changed as well. While the Romantic composers desired halls with long reverberation times to accommodate their lavish compositions and extensive use of tone color effects, at the dawn of the 20th century, composers such as Igor Stravinsky (1882-1971) and Schoenberg began writing music which relied heavily on rhythm and the distinctness of tones as compositional devices. Such works were better suited to halls with lower reverberation times of approximately 1.5 seconds than to the halls which the Romantic composers favored (Beranek, 58).

Contemporary orchestras are not performing only contemporary works, however, and as a result, modern concert halls must respond to the demands of music from the Baroque to the 20th century. Designers and architects have responded with halls which possess everything from retractable absorption to completely movable and variable ceiling and wall planes as found in Paris' IRCAM center.

Composers are also being stretched, for no longer is the concert hall the only venue for the performance of orchestral music. Now the advents of technology must also be accommodated. Despite the tremendous variety in orchestral composition and performance spaces, the maxim remains — composers write music which responds to the acoustics of the space in which it will be performed. The prominent American composer Daniel Pinkham (1923-) stated his ideas as follows.

Music that I have composed for King's Chapel in Boston is in a style which might sound muddy when performed in a reverberant concert hall but which sounds at its best in this rather dry environment, which transmits the details of each line with crystalline clarity while still providing a useful blend for the various lines.

In writing scores for moving pictures and TV, which are to be performed in acoustically dead recording studios, this approach must be carried even further, since any persistence of sound must be deliberately written into the music. When I was preparing my *Easter Cantata for Chorus, Brass, and Percussion*, the rehearsals were held in Jordan Hall, Boston, which is fairly live. For the actual performance in a TV studio, I found that the only way to cope with the dead acoustics was to permit the percussion instruments to ring as long as they would, and this gave to the *whole sound* the impression of adequate reverberation. As a result of this experience, I have written my latest *Concertante No., 3 for Organ and Percussion Orchestra* so that the after-ring of the percussion following each phrase is deliberately carried over into the beginning of the next phrase; in a dead hall this will compensate for the lack of reverberation, while in a live hall it may either enhance the reverberant sound of the room or the percussion ring may be curtailed at the will of the performers to minimize confusion. On the other hand, I have found great

difficulty, even with highly experienced musicians, in performing in a live hall some music which had originally been written for the dead acoustics of the TV studio.

Stravinsky's *Rite of Spring*, premiered in Paris in 1913, is one of the more notable examples of the 20th century relationship between music, performance space, and the orchestra. Commissioned by Sergei Diaghilev, the work was to be premiered in Paris' Théâtre National de l'Opera, a space with a seating for 2131 persons and a reverberation time of 1.1 seconds. This was ideally suited to Stravinsky's driving, pulsing music, for in a highly reverberant hall, the detail and pulse of the work would have been lost in the subsequent decay of the sound.

BEYOND THE 20TH CENTURY

What lies ahead in the realm of acoustics, music, and the orchestra is difficult to predict, for the wide variety of compositional styles and acoustical environments define no clear trend. Perhaps electronic music, so prominent in the popular, new age, and jazz works of the present will further infiltrate the orchestral medium. Possible unforeseen technological developments will enable instrumental improvements which could radically alter the limitations of the modern orchestra. In the realm of the concert hall, will variable acoustical features gain popularity so music from all periods can be faithfully reproduced? Or will halls develop which cater to only one of the periods begin to gain prominence? Again, perhaps unforeseen developments shall offer new possibilities in concert hall design which depart entirely from the other scenarios. What seems certain is the constant desire to improve, progress, and change. With such change the survival of music, acoustics, and architecture and their relationship to one another is assured.

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