war: "The thunder of the guns swells to a single heavy roar and then breaks up again into separate explosions. The dry bursts of the machine-guns rattle. Above us the air teems with invisible swift movement, with howls, pipings, and hisses. They are smaller shells; and amongst them, booming through the night like an organ, go the great coal-boxes and the heavies. They have a hoarse, distant bellow like a rutting stag and make their way high above the howl and whistle of the smaller shells." Erich Maria Remarque, *All Quiet on the Western Front* (New York: Random House, 1958), 59.

9. Ludwig Scholtz, *Seelenleben der Soldaten an der Front: Hinterlassene Aufzeichnungen des im Kriege gefallenen Nervenarztes* (Tübingen: JCB Mohr, 1920), 109.
10. Remarque captures this contrast between new recruits and seasoned soldiers, particularly with regard to their reactions to sound: "Every man is aware of the heavy shells tearing down the parapet, rooting up the embankment and demolishing the upper layers of concrete. When a shell lands in the trench we note how the hollow, furious blast is like a blow from the paw of a raging beast of prey. Already by morning a few of the recruits are green and vomiting. They are too inexperienced." *All Quiet on the Western Front*, 106.
11. D. Bachrach, "Über die Hörschärfe zu verschiedenen Tageszeiten," *Zeitschrift für Sinnesphysiologie* XLIX: 2 (1915): 99, quoted in *Archiv für Ohrenheilkunde* 97 (1915): 262–263.
12. A. Güttich, "Das Ohrlabyrinth als Kompass," *Deutsche Medizinische Wochenschrift* 38 (1916), quoted in *Berliner Klinische Wochenschrift* 43 (May 15, 1916): 528.
13. Michael Salewski, *Von der Wirklichkeit des Krieges: Analysen und Kontroversen zu Buchheims* Boot (Munich: Deutscher Taschenbuch Verlag, 1976), 31.
14. The rumble sounds of combustion engines colored the urban experience in Germany even prior to the outbreak of the First World War and were considered by many, such as the German-Jewish philosopher Theodor Lessing (1872–1933), to be sonic symptoms for cultural decline. During the war, these sounds changed into sonic markers of safety. For the seminal contribution of Lessing to the cultural identification of noise in the context of late imperial Germany, see the chapter by John Goodyear in this book.
15. "Wir machen eine gute Fahrt, und die Diesel machen ihr eintöniges Lied." Quoted in Edgar Spiegel von und zu Peckelsheim, *U-202: Ein Kriegstagebuch* (Berlin: August Scherl, 1916), 11.
16. Peter Fritzsche, *A Nation of Fliers: German Aviation and the Popular Imagination* (Cambridge, MA: Harvard University Press, 1992).
17. Ernst Udet, *Mein Fliegerleben* (Berlin: Ullstein, 1935), 57.
18. Letter from January 14, 1916 quoted in Johannes Werner, ed., *Briefe eines deutschen Kampffliegers an ein junges Mädchen* (Leipzig: K.F. Koehler, 1930), 15–18.
19. J. Henry Watt, *The Psychology of Sound* (Cambridge: Cambridge University Press, 1917), 1.
20. Werner T. Scott, "Airplane Deafness and Its Preventation," *Military Surgeon* 52: 3 (1923): 300-301. Quoted in *Zentralblatt für Hals- Nasen- und Ohrenheilkunde* 3: 4 (1923): 470.
21. F. Herath, "Funktelegraphie und Flugzeug" in *Der deutsche Rundfunk* 3: 44 (October 31, 1925): 2825–27; Hans Schlee, "Erlebnisse aus dem Anfängen der Funktelegraphie in Luftfahrtzeugen" in *Der deutsche Rundfunk* 3: 46 (November 15, 1925): 2986–87.
22. Ernst Udet, *Kreuz wider Kokarde*, (Berlin: Braunbeck, 1918), 61, 91. This chapter is based on the first chapter of my doctoral dissertation "Hearing Maps: Noise Technology and Auditory Perception in Germany 1914–1945," submitted to the Hebrew University in Jerusalem in 2005. I would like to thank Till van Rahden for his careful reading of previous versions of this chapter and Florence Feiereisen, Alexandra Merley Hill, and the anonymous readers for their helpful comments and insights. Finally, I owe special thanks (in alphabetical order) to Dan Diner, Joel Miller, Wolfgang Schieder, and Moshe Zimmermann for their intellectual contribution to my dissertation project. Unless otherwise indicated, all translations are mine.

In: Germany in the Loud Twentieth Century. Eds. Florence Feiereisen and Alexandra Merley Hill. Oxford, UK, New York, NY: Oxford University Press, 2012. 63–77.

CHAPTER 4

From Seat Cushions to Formulae

Understanding Spatial Acoustics in Physics and Architecture

SABINE VON FISCHER

Spaces for musical performances are sites of extended debates about whether the natural sciences can measure and predict sonic and sensual experience. A film score can underline and heighten the drama of a story. Similarly, in a concert hall, a symphony's crescendo can evoke sensations that are no less intense. What happens in space that makes emotions fly? Sound waves are reflected and absorbed by the enclosing surfaces of a room, pitch and timbre change, reverberations last longer or shorter. While physicists are capable of quantitatively measuring these parameters, the question remains how their effects on our emotions can be evaluated. When is something "music to our ears"? Can good acoustics be defined solely with reference to physical properties, or must one appeal to subjective impressions, such as the reactions of musicians and audience?

ARCHITECTURE BETWEEN TECHNICAL AND SOCIAL SCIENCES

In the course of the current "sensual turn," as claimed by anthropologists and historians,[1] the sonic dimension of space has become a focus of interdisciplinary research, beyond the physical measurement of sound waves. At the core of these controversies lies the question of how the quantitative values of the science of acoustics are related to qualitative understanding in the social sciences and the arts. Architecture has always been connected with the technical and the social sciences, and spatial configurations are central to the sounds we perceive. When considering sounds in architecture, we are challenged by a variety of scenarios, such as the ocean of resonances of a grand orchestra in a concert hall, the echoes of our steps in a hallway, the hum of ventilators in an office space, and the background music in department stores. While the profession of the sound designer in the film industry is just a few decades old—with acoustic consultants for shopping and transit spaces being an even younger line of work—architects have always, intentionally or not, created sonic environments. A musical performance brings the aural to the foreground; even if the visual remains part of the scenario, it is the quality of the sound that is critical. In designing an architectural space, the aural space confronts us with all possible ambiguities of spatial boundaries, for the tactile, visual, and auditory components each perform according to their own rules. These ambiguities and the complexity of the task, along with budgetary constraints, often result in the exclusion of auditory considerations in the architectural design process.

In its initial stage, the science of architectural acoustics, which is not much older than one hundred years, was applied exclusively to theaters, operas, and concert halls. Over the decades, it entered and regulated the construction of apartment blocks, office buildings, hotels, and shopping malls. Today, it is not only the physical construction of a building that affects the sound, but also electro-acoustic technology, which inserts another level of ambient sound into the space. While independent from the physical location, sound technology can enhance existing qualities of a space, or even shape a space. However, when sound first became a scientific discipline and one connected with space, architects confronted it with great skepticism.

Recent investigations imply that the "sensual" and the "sonic" turns have indeed arrived in architecture; the era of the uncontested primacy of the visual seems to have come to an end. The number of publications dedicated to the other senses attests to this. In their *Spaces Speak, Are You Listening?* for example, Barry Blesser, a digital audio engineer, and Linda-Ruth Salter, a social scientist, explore how one experiences space by attentive listening, which they extend into the broader notion of "auditory spatial awareness."[2] The book does not investigate a specific culture or time period, but regards the presence, impact, and aura of sound as a general phenomenon. While much of Blesser and Salter's writing is based on the notion that most aural architecture is not intentionally designed but results from a combination of natural, incidental, and unwitting factors,[3] it is all based on the belief that there is a physical explanation for the acoustic experience. According to Blesser and Salter, the challenges in creating sound environments are to bring together the many specialized disciplines that shape our surroundings, as well as to find appropriate applications of sound technologies—which, in their estimation, are at hand. Such trust in the capacities of scientific calculation is the result of developments in the twentieth century, when architectural acoustics and electro-acoustics entered the scene. What remains to be resolved are the social and philosophical questions, which these technologies trigger.

In this chapter, I focus on German and Austrian examples of concert halls, which successfully created aural environments and can be read as benchmarks in the erratic development of the acoustic dimension of architecture. In this development, a tension existed between the traditional understanding of a coincidental, even superstitious or mystical quality of an architectural space on the one hand, and the modern approach of a scientific, measurable relationship between sound waves and the materials with which they must interact, on the other.

THE DEPTH OF THE MATERIAL

When the Viennese architect Adolf Loos (1870–1933) published "Das Mysterium der Akustik" ("The Mystery of Acoustics") as a newspaper article in January 1912,[4] he pleaded

for the preservation of Vienna's Bösendorfer Hall from the standpoint that a reconstruction elsewhere would never reproduce the acoustic qualities of this concert hall on Herrengasse 6 in Vienna's city center.

> I was asked whether the Bösendorfer Saal should be preserved. I presume what prompted the question was the idea that reverence for the past demands we should not demolish a hall that has played such an important role in the musical history of Vienna. But it is not a question of reverence for the past, it is a question of acoustics.[5]

In 1872, Ludwig Bösendorfer, piano maker, patron of the arts, and one of the most colorful and original of Viennese personalities at the time, had taken over the equestrian stables of the Palais Liechtenstein and had converted the riding hall into a concert hall of nearly six hundred seats.[6] The discipline of architectural acoustics did not yet exist as such and was more of a trial-and-error approach at first: Bösendorfer himself—wearing his inimitable top hat while riding a pony and listening to his friend shout from the other end of the hall—decided on the position of new interior walls and during construction moved the rear wall three times until the acoustics satisfied his ear.[7] The large windows that remained over the newly added wooden siding in the hall were reminiscent of the previous life of the building; while the hall itself was not spectacular, its dimensions and surfaces were chosen with care. The concert hall in the converted riding stable gained a reputation as an outstanding venue and, at the time, even became Vienna's most popular concert hall. It was praised for "its beautiful simplicity, which made a 'very intimate yet noble impression' and contributed to the 'inner collection of listeners.'"[8] Accounts of the time pleaded that the hall was of the same significance as Vienna's Großer Musikvereinssaal, yet exceeded its acoustics.[9] The success of this daring challenge to one of Europe's prime concert halls might have been the result of subjective judgment; however, the list of musicians who performed in the Bösendorfer Hall reads like the *Who's Who* of the European music scene of the time, among them pianists Anton Rubinstein, Franz Liszt, Moriz Rosenthal, Eugen d'Albert, Johannes Brahms, Ignaz Paderewsky, Bruno Walter, Teresa Carreño, Emil von Sauer, Arthur Schnabel, Ernst von Dohnányi, Béla Bartók, and Edvard Grieg; violinists Pablo Sarasate and Georg Hellmesberger; composers Johannes Brahms, Anton Bruckner, Hugo Wolf, Max Reger, Gustav Mahler, and Richard Strauss; and many more.[10]

In "The Mystery of Acoustics," an enthusiastic plea for the conservation of the concert hall, Loos expressed his skepticism over the new science of architectural acoustics. It was a widespread belief at the time that the acoustic performance of a space could not be calculated or predicted, because music was not a technical discipline but rather an art form. At the turn of the century, physical acoustics were not integrated into architectural practice—if at all, acoustics were determined empirically. The idea that reverberation time could be calculated with a formula, based on dimensions and surfaces of a space, must have seemed to many a modern fashion rather than a law of nature.

> Until now *every* new hall has had poor acoustics. . . . Have our ears changed? No, it is the material the hall is made from that has changed. For forty years the material has absorbed good music and has been impregnated with the sound of the Philharmonic and the voices of

our singers. There are mysterious changes in molecular structure which until now have only been observed in the wood violins are made of.[11]

According to Loos, the building material and its tuning over time are essential to the acoustic performance of any space—therefore mere copies of the geometry of famous concerts halls must be doomed to fail.

In Loos' reasoning, the high quality of music to which those walls were exposed over the course of time was responsible for the outstanding acoustic performance. He believed that, like the wooden body of a string instrument, a concert hall can never sound perfect from day one; the depth of the walls of a concert hall "soak up" (or "absorb") the music being played and are "impregnated" by the singing voices over time. He suggested "mysterious changes in molecular structure" that defied scientific explanations (until today). In the case of Vienna's Bösendorfer Hall, music resounded on masonry walls under the heavily loaded floor slab of the library above, with no need of adjustments by sound absorbers. When Loos praised the acoustic performance from the depth of the bare walls, he overlooked the fact that the Bösendorfer Hall was said to perform at its best when two-thirds occupied,[12] which equals the absorbing body surface of four hundred people in the audience.

FROM MYSTERY TO MEASUREMENT

The key turning point from "mysterious processes" to measurements in architectural acoustics had already come about in 1900 when American physicist Wallace C. Sabine (1868–1919) had published his formula of reverberation time, and it is very likely that these papers had traveled across the Atlantic Ocean to Vienna long before Loos published his polemic newspaper article in 1912. Already in May 1911, at the latest, the physicist Gustav Jäger had presented his experiments of reverberation measurements at the Imperial Academy of Sciences in Vienna.[13] It is not documented but it is likely that Loos had learned of the recent scientific developments, which were to impact architecture thoroughly in the decades to come.

Reverberation is the sum of sound reflections from all surrounding surfaces. In an exterior space, a sound pressure wave bounces back from a wall or a building facade; in an interior space, sound can travel much longer, from surface to surface, and create extended reverberations. Sound reflections that occur with a delay are referred to as echoes. It is important for the scope of this chapter to keep in mind that the sound waves hit our eardrum directly or by reflecting off surfaces such as walls, ceilings, furniture, floors, and even other people. Reverberant sound as the collection of these reflected waves dies away quicker when the sound energy is absorbed by the surfaces of the room, furnishings, and bodies. In a very simplified way, the process of hearing can be described as sound waves traveling from their source to our outer ear. Here, they are then channeled along the ear canal to our eardrum. The vibrations the eardrum sends off are transformed into nerve impulses, which are then interpreted and recognized by the hearing center of the brain as certain sounds. Spaces of total absorption, such as in anechoic chambers of acoustic laboratories, but also in the air on top of a mountain, can be described as "acoustically dead." The room is considered

"acoustically live" when the sound lingers before dying away. Highly reflective surfaces (such as concrete or glass) lengthen the reverberation time. The trick is to find a balance—a "live" room without echoes or too much reverberation time.

The optimum reverberation time for an auditorium depends on its intended use. For a medium-sized all-purpose auditorium where music and speech should be heard clearly and distinctively, one to two seconds is desirable. As a rule of thumb, the smaller the room, the shorter the reverberation time should be. The bigger the auditorium, the longer the sound waves take to travel to their receptors' ears. For example, Paris' Notre Dame Cathedral has a reverberation time of 8.5 seconds. Sacral music written for pipe organs is often conceived for such reverberant spaces. Speech, on the other hand, will be difficult to understand, as the same sounds would remain audible for 8.5 seconds. (Imagine hearing even three words, each 8.5 seconds in duration, quickly spoken after one another!) Commonly, lecture halls have a reverberation time of less than one second to make sure that all spoken information can be parsed and understood.

It is not only the size and shape of a hall that influences its reverberation time; it is also the hall's surfaces and construction materials. When in 1895, at the age of twenty-seven, the aforementioned physicist Wallace C. Sabine was asked to investigate the miserable acoustics of Fogg Museum's lecture hall at Harvard University, he quickly discovered that the reverberation time of the lecture hall was not proportional to its volume. During his patient and exhaustive experiments conducted at night, when no other sounds would disturb the measurements, he found out that the length of added curtains and the number of seat cushions in the hall—borrowed during these nights from the nearby Sanders Theater—had an impact on the reverberation time as well.[14] Thus the seat cushion became the initial "unit" of his experiment. Since cushions have different sizes, shapes, and fabrics, Sabine introduced the "open window-unit" as his standard measurement; its definition is based upon a one-square-foot area of open window—an equivalent surface of no reflections, which thus is equivalent to a complete sound absorber. Soon thereafter, the "Sabin" was used as a standard unit of absorption in the early twentieth century, until it was replaced by "equivalent absorption area,"[15] which is used in science today.

In tables of absorption coefficients, one can find different absorption coefficients for various materials. This coefficient typically also changes with frequency, so the reverberation time is likewise frequency dependent. While the new metric measure has replaced Wallace C. Sabine's initial unit, the "open window-unit" or "Sabin" created more of a narrative. To give a few examples: one square foot of thick Oriental carpet equaled 0.25 Sabins, and four square feet of the same carpet equaled one Sabin; a seat cushion from Sanders Theater equaled 0.7 Sabins; one square foot of brick equaled about 0.02 Sabins; and one adult human, sitting in an audience, equaled about 4.7 Sabins.[16] Sabine was able to calculate the relations of the different parameters and came to his famous formula, which relates surface areas (according to the absorbing quality of each material) to the total volume of the space. In solving the acoustic problem of Fogg Hall as a young assistant professor, he had created the new field of architectural acoustics. The Sabine Formula for reverberation time became the main parameter of room acoustics.[17] It is still applied in room acoustics today, yet it is complemented with considerations of the ratio of direct sound and early reflections to the overall sound.

In 1912, when Loos wrote his text defending the acoustic mystery of the Bösendorfer Hall, the understanding of sound propagation was a very young science. Loos mocked the idea that sound paths could be predicted like "billiard balls bumping through space." These physicists "drew straight lines from the sound source to the ceiling and assumed that sound would be sent on its way by bouncing off the board in the very same angle. All these constructions," he concluded "are nonsense."[18] By writing this in such a polemical manner, Loos possibly wanted to expose his understanding of the modern science, which accounted not only for the geometric behavior of sound, but also for the energies contained in a wave of sound. Loos thought of himself as a modern man and did not categorically oppose the sciences, yet he was a skeptic toward anything that could be thought of as just fashionable. This might be the explanation of why he countered the new science of architectural acoustics with such mystical arguments as the quality of the "tuning over time" that "impregnates" the walls and essentially forms the sound of a space. To underscore his argument, he claimed that all halls ever built sounded poor on the occasion of their first concert.[19] In his plea for the preservation of the Bösendorfer Hall, he played up his doubts that the reconstruction of the Bösendorfer Hall could ever constitute the "same space," even when rebuilt identically. Nevertheless, the Palais Liechtenstein was demolished after the final concert on May 2, 1913, to give way to a high-rise of the property's new owner. The last performance featured Beethoven's String Quartet in F Major, Schubert's String Quintet in C Major, and Haydn's Variations on the National Anthem. The famous Bösendorfer Hall was never reconstructed.[20]

In 1900, when Wallace C. Sabine first published his findings on reverberation time, a new era of concert hall design, devised by scientific principles, began. In the same year, Boston's Symphony Hall was inaugurated, designed by McKim, Mead, and White with advice on acoustics by Sabine and inspired by the rectangular geometry of the Old Leipzig Gewandhaus. Its reverberation time was estimated by Sabine through his formula, and it was the first concert hall to be designed according to quantitative findings. The reverberation time was later measured by various acousticians as ranging from 1.2 up to 4 seconds, depending on the occupancy and the frequency measured.[21] While praised by many, especially for the clarity of the tones, a music critic of the *Boston Evening Transcript* wrote about the opening night on October 15, 1900: "Everything was clean-cut and distinct, the tone was beautifully smooth, and, so to speak, highly polished; but it had no life."[22] Like several others, as Emily Thompson recounts in *The Soundscape of Modernity,* the critic resisted "the very idea of a scientifically controlled sound, as it contradicted his own romantic conception of the unpredictable nature of all music."[23] It is the same resistance that Adolf Loos would express twelve years later in Vienna: music could not simply be calculated beforehand in the realm of science, but it had to be of a different, more artistic or even celestial nature.

When we say that something is "music to one's ears," we mean that it is pleasant to hear. This does not mean that we actually hear music as a culturally specific art form or as a new dimension of experience, but what has been said fulfills expectations and is in accord with our (aesthetic) values. Ironically, even the acclaimed Symphony Hall in Boston at first was received with doubt by the audience: the music played on the opening night was not "music to the ears." Thompson assumes that the ears of the audience were not ready to hear the well-tempered resonances of a modern concert hall. It was only after some time that Boston's Symphony Hall was recognized as one of the world's greatest concert halls, and after a few decades, architectural acoustics became an internationally recognized discipline of science; was considered in some architecture curricula; and, in the postwar period, led to the founding of institutes of technical acoustics.

PROPORTIONS AND SHAPES

Designing a space for sound means assigning a permanent geometry to volatile matter. Since Vitruvius, considerations of volume and resonance and, since Alberti, proportional studies are part of every architect's education; yet, the forms that result from these foundations could not vary more. One popular preconception among architects of the twentieth century is that a space for music has to adopt wave-like shapes, materializing the immaterial form of sound waves. Another geometric concept is the wedge shape, which has largely been informed by visual criteria: the frontal stage is visible from all angles, as in a cinema. The form seems to take the visual more into consideration than the acoustic. Each of the many possible formal concepts has produced a number of acoustically acceptable and remarkable concert halls, as well as many of lesser success. In *Concert Halls and Opera Houses—Music, Acoustics and Architecture,* a rigorous and comprehensive assessment of one hundred concert and opera halls, the acoustician Leo Beranek compared volumes, dimensions, geometries, materials, acoustic measurements, and verbal judgments on internationally renowned music auditoriums. The geometries vary greatly from rectangular to elliptical, rounded, irregular, or fan shaped—and opinions on them range no less—yet rectangular halls repeatedly appear among those rated "superior" or "excellent."

The hall that most tenaciously turned over the dogma of the rectangular hall is the Berliner Philharmonie, home to the Berlin Philharmonic Orchestra, designed by architect Hans Scharoun (1893–1972) and according to the advice of acoustician Lothar Cremer (1905–1990), an exterior view of which is shown in Figure 4.1. It is everything but a box: none of the walls are parallel, and its "music in the center" spatial concept was rated as "a most

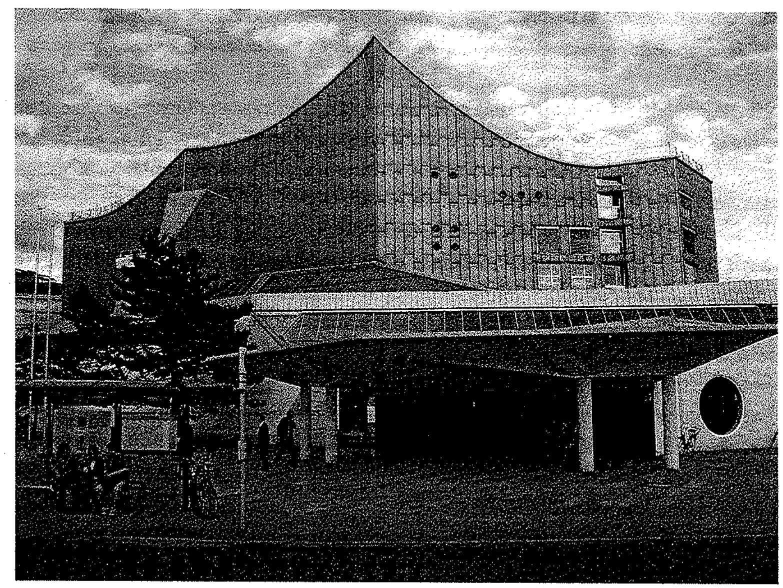

Figure 4.1
The exterior of Scharoun's Philharmonie.
Photograph by Frank Swenton, 2010.

dramatic room" and as "one of the models of successful acoustical design."[24] Others have said and written that the design was primarily informed by visual criteria and that the acoustic qualities have been neglected.[25]

In 1956, Scharoun, a key figure in twentieth-century architecture in Germany by virtue of his contributions to 1920s avant-garde architecture, as well as his postwar buildings, won the competition for a new concert hall on a site located at the edge of Berlin's Tiergarten with an unprecedented layout. The building with its curved roofline over the two multifaceted concert halls and foyers was asymmetrically and freely formed, unlike any other famous concert hall at the time. The building was partially received as a late expressionist variation of Scharoun's earlier, more classically modernist period; however, the only thing that can be said with certainty is that it is unique in its form and expression. Today, the Philharmonie complex inaugurated in 1963 is on a different, yet nearby, site, just a few steps west of where the Wall had divided Berlin (1961–1989). The complex features one larger and one smaller concert hall; the form of the large hall however, the key space of the project, remained faithful to the initial concept. In his 1957 article "Music in the Middle" ("Musik im Mittelpunkt"), Scharoun explained his competition entry with the following words:

> The next consideration was this: is it mere coincidence that, whenever people hear improvised music, they immediately gather around in a circle? This quite natural process whose psychological aspect everyone can comprehend, one would have to transfer into a concert hall setting—that was the task the architect had set for himself. The music should also be the spatial and visual focus. This was the starting point for the form of the Philharmonie.... Last but not least, the design was made spatially and technically feasible only through advances in acoustic science. "New territory" was conquered and developed here in close collaboration with the acoustic engineer, Professor Cremer.[26]

The asymmetrical layout of seats enveloping the center, as seen in Figure 4.2, placed only about a tenth of the audience behind the orchestra; the majority listened from either in the front or from the side; this takes into account the directionality of the human voice and of certain instruments. Early reflections off wall sections around the orchestra disperse directional sound to all listeners. The staggering of the terraced layout averts focus points as they occur in circular and elliptical auditoriums and helps deliver the music in such a manner that all members of the audience receive both direct and indirect sound.

Like a "hillside vineyard," as Scharoun described it in his own words,[27] the concert hall unfolds around the stage in the center—an idea that Frank Gehry also adopted for his Disney Concert Hall in Los Angeles of 2003, a structure often criticized for compromising acoustics in favor of the visual, just as its Berlin predecessor had been criticized. The terraced layout can be seen in the architectural plans for Scharoun's hall, in Figure 4.3.

That fact that the hall was completed in 1963, seven years after the jury's vote for Scharoun's project and after long debates primarily about its unprecedented form, is largely indebted to the persistent support throughout the competition and planning process of the Berlin Philharmonic's acclaimed conductor Herbert von Karajan (1908–1989):

> Music as the focal point: this was the keynote from the very beginning.... Here you will find no segregation of "producers" and "consumers" but rather a community of listeners grouped

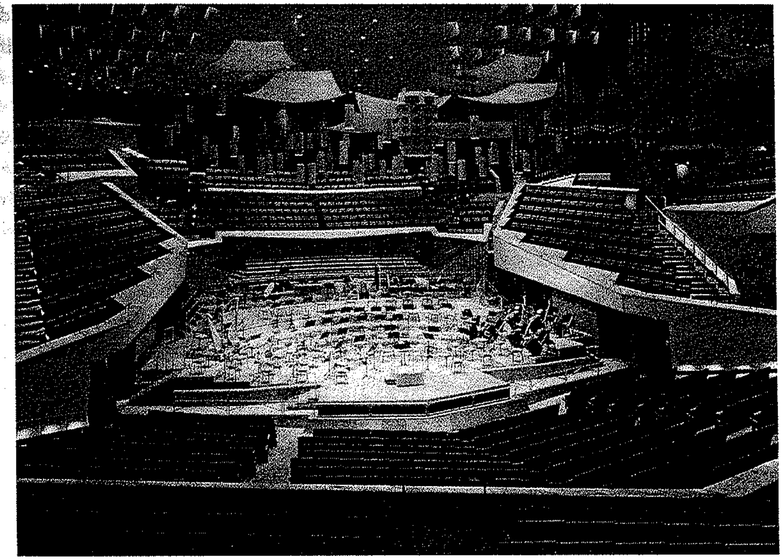

Figure 4.2
The interior of the Berliner Philharmonie's larger hall.
Photograph "Philharmonie Innen." © Lauterbach/Berliner Philharmoniker.

> around an orchestra in the most natural of all seating arrangements.... Man, music and space come together in a new relationship.[28]

This, of course, prompts a series of questions: should a concert hall be designed for the eye at all? Does the visual impression impact our hearing? On the one hand, it was the unusual layout of the "music in the middle" that aroused criticism; on the other hand, the expressive shapes and presence of the hall's acoustic devices for reflecting sound into the entire space were unknown in classical concert hall layouts. Already during the 1950s, after the jury's decision for Scharoun's project, not everyone reacted enthusiastically. "Not all concertgoers," as the *Spiegel* reported in its 1957 article "Achteckige Philharmonie" ("Octagonal Philharmonic Hall"), "wish to be reminded by visible constructions—acoustic reflectors—that the miracle of hearing is a physical process controlled by science, just as the spectator of a theater performance is not keen to have the headlights visible before his eyes."[29] Karajan, though, claimed that the enveloping, revealing layout was especially adequate for the performance style of his orchestra. Austrian by descent, Karajan conducted the Philharmonic Orchestra for thirty-five years and remains a legend for his animated appearances, which led to the nickname of the orchestra as the "Circus Karajani."

Despite Karajan's praise and the international acclaim of the Berlin Philharmonie, each concert experience remains a subjective one; it is subject to personal taste whether the spectacle of Karajan's directing had a suitably formidable setting in Scharoun's building, which placed the music in the center, or whether one finds it disturbing to witness a concert as a collective event. Scharoun's reasoning of the immediacy of the musical experience, granted

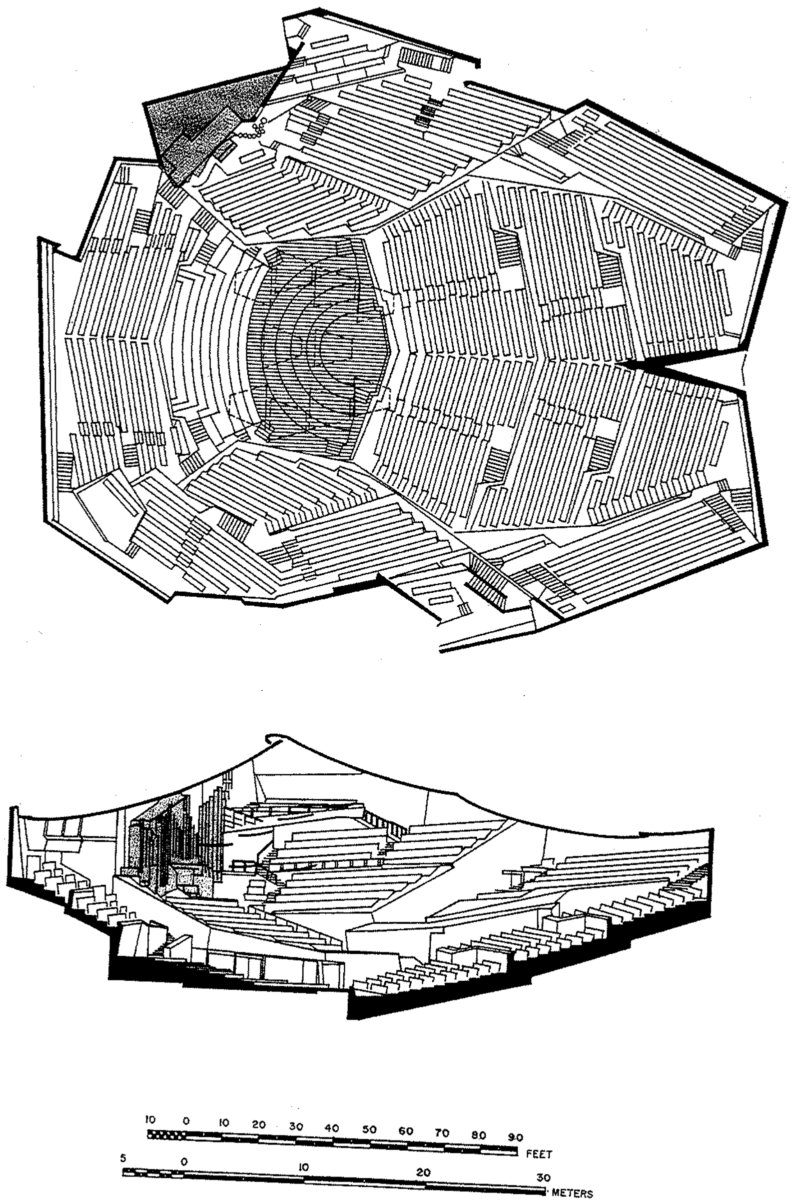

Figure 4.3
Architectural plan of the interior of the Berliner Philharmonie's larger hall. Image from Leo Beranek's *Concert Halls and Opera Houses: Music, Acoustics, and Architecture.*
Reproduced with permission of the author.

by the spatial layout (none of the 2,335 listeners is more than thirty-two meters away from the orchestra), cannot be achieved by any rectangular hall, not even by smaller halls of the nineteenth century.

Despite the criticism of some, the design of the relatively large Berlin Philharmonie of 21,000 cubic meters with its 2,335 seats accomplishes an exemplary time of 1.5 to 2.4 seconds of reverberation for the different frequencies and occupancies.[30] Yet it must be noted that additional acoustic reflectors were added to the hall's ceiling in the 1970s to adjust the reverberation of sound toward the orchestra, another important factor determining the quality of music; an orchestra that cannot hear its own playing is not able to perform well.

Not only according to audiences and musicians, but also to experts of technical acoustics, does the verdict of which hall is the best one remain undecided. The acoustic engineer Leo Beranek, one of the most prolific acousticians of our time, attempted in the 1996 edition of his in-depth documentation of seventy-six existing concert halls to establish a rating based on many factors such as scientific measurement and judgments by professional and lay listeners; however, in the second edition of the work that appeared eight years later, extended to one hundred halls, he had dropped the ratings in favor of a critical discussion of the parameters at hand for the evaluation of the quality of the opera and concert halls.

In Beranek's rating of 1996, the Berlin Philharmonie scored in the "B+" category, which accommodates more than half of the halls. Only nine halls were ranked "superior (A+)" and "excellent (A)," among them Amsterdam's Concertgebouw, the aforementioned Boston Symphony Hall, New York's Carnegie Hall, and Vienna's Großer Musikvereinssaal. Beranek rated the majority of his examples as "good to excellent" (B or B+), as a result of the experts' range of opinions that allowed for no definite conclusion. In other words, from lack of agreement among the experts, many halls ended up with a midrange rating.[31] Despite Beranek's admirable effort to provide all available information on size, shape/geometry, and material; conducting the acoustic measurements; and interviewing conductors, musicians, and audiences, much of the halls' acoustic quality remains, as Loos had described it in 1912, a mystery. Because it was long demolished when Beranek conducted his research, the Bösendorfer Hall, a simple rectangular hall inserted into a riding school, remains a myth beyond the inexplicable qualities of sound.

It comes as no surprise, then, that many acousticians today refer to the "shoebox" auditorium not only as a traditional solution, but as the only one. Recently built famous examples are the ones in Lucerne, Switzerland or Lahti, Finland by the late Russell Johnson (1923–2007) and his firm Artec. They demonstrate that even relatively large concert halls can have excellent sound quality and yet be flexible in serving multiple musical purposes. Their walls are neither an illustration of sound waves nor of any rhythm or angle, but enclosures of a space with the purpose of reflecting a previously determined amount of the array of traveling sound. Reverberations in "shoebox" auditoriums can be predicted with more accuracy than in irregularly shaped spaces and can be adjusted or enhanced with movable elements, secondary chambers, or other means. The possibility of electro-acoustic augmentation of the natural sound of a space had appeared at the horizon of technological innovation since the 1930s, but was not considered appropriate for a concert hall, where the purpose of attending is to hear live instruments, not loudspeaker playbacks.

Today, especially as newly designed concert halls (often for economic reasons) become larger and larger, creating longer paths, and thus extended delays for traveling sound, hidden loudspeaker amplification seems to be gaining acceptance among engineers. Blesser, a digital audio engineer himself, fundamentally questions the term "natural acoustics" when it comes to the debate of electro-acoustic support for musical performances. In his argument, even before the appearance of loudspeakers, "acoustic interventions of sound-dispersing statues, stand-reflecting ceiling panels, sound-diffusing walls, and sound-absorbing panels" rendered the sonic landscape of a room "artificial."[32]

Magnificent twentieth-century spaces for music with freer forms than the shoebox model, such as the Berlin Philharmonie or the Sydney Opera House by Jorn Utzon (1973), do not follow the standards of architectural acoustics. It seems that they derive their complex harmony from the simultaneity of physical, visual, and aural space. At the source of the intuition that has guided these and other architects must be the awareness that, while architecture relies on the three physical dimensions of space, sound occurs in the fourth dimension of time: it is a time-based phenomenon, temporal and ephemeral, and therefore a quality which architecture can never reproduce, but only enable.

TEMPORAL AND SPATIAL SENSATIONS

Architectural space is determined on an architectural drawing before any tone resounds inside of it. Therefore, designing a space for music is always an anticipation of the future. Time, the primary dimension of all sounds, cannot be built into the walls; it will enter when the music starts playing. In anticipation, yet without prejudice, architecture can enable a sound experience that is not only "music to one's ears" but a real sensation in time and space. Architects will always have to move in multisensory dimensions, hoping that the ambiguities among physical, visual, and aural space aesthetically heighten each other as constructive, rather than destructive interferences. It is no coincidence that according to *Merriam Webster* "aural" contains two meanings: the first definition is "of or pertaining to the ear or to the sense of hearing" and is from the same origin as the second, which is "of or pertaining to an aura."

Loos claimed in his text that one must also consider time to "fine tune" the concert hall; that is, architecture is not only defined by the results of geometry and surface. This notion of an ambient quality makes him a notional antecedent to contemporary architects like, for example, the Viennese architect and sound artist Bernhard Leitner who since the 1970s has explored the space-forming capacity of sound,[33] Berlin architect Gabi Schillig with her extended interest in ephemeral space and new materials,[34] or the Swiss architect Philippe Rahm. Rahm's recent writings and interventions on "physiological architecture" reflect a careful study of the way that a person interacts with and is affected by the environment, or the "electromagnetic, biological, and chemical interaction between architecture, the environment, and our organism."[35] Nearly a century before the emergence of physiological architecture, Loos had made us aware that architectural space is concerned with a wider range of parameters than just meters, which are represented proportionally in plan and section on a sheet of paper. Yet unlike Loos, this younger generation of architects is not shy about merging phenomenological truth with scientific facts and certainly puts more faith in modern technologies than Adolf Loos did in his times: sensorial experience is measured by and dependent on degrees Celsius or Fahrenheit, meters per second, lux, kelvin, decibel, hertz, and so on.

Today, with the help of ray tracing and other extensive computer simulations, acoustical engineers can compute spatial acoustics in great detail. Yet, is this enough? Does it capture the "mystery of acoustics"? Will a quantitative measurement ever encapsulate the aural experience? Most real-world acoustic calculations, therefore, still depend widely on empirical methods; even when these methods are more sophisticated than Ludwig Bösendorfer riding his pony through his hall—the "mystery of acoustics" sustains itself in many ways.

NOTES

1. Wolfram Aichinger et al., eds., *Sinne und Sinneseindrücke in der Geschichte* (Innsbruck, Wien, München: Studien Verlag 2003).
2. Barry Blesser and Linda-Ruth Salter, *Spaces Speak, Are You Listening? Experiencing Aural Architecture* (Cambridge, MA: MIT Press, 2006), 13.
3. Ibid., 5.
4. Adolf Loos, "Das Mysterium der Akustik," 1912. In Adolf Loos, *Trotzdem, 1900–1930* (1931, Wien: Georg Prachner Verlag, 1997), 116–117. The date of January 1912 was assigned by Adolf Loos himself retrospectively as described in the foreword to *Trotzdem*, 15. All translations are mine, unless otherwise noted.
5. "Man hat mich gefragt, ob der Bösendorfersaal in Wien erhalten werden solle. Der frager ging wohl von der voraussetzung aus, dass es eine frage der pietät wäre, einen saal, der in der musikgeschichte eine so große rolle gespielt hat, nicht zu demontieren. Aber diese frage ist nicht eine sache der pietät, sondern eine frage der akustik." Loos 1931, 116. English translation by Michael Mitchell from: Adolf Loos, "The Mystery of Acoustics," in Adolf Loos, *On Architecture* (Riverside, CA: Ariadne Press, 2002), 108.
6. Christina Meglitsch, *Wiens vergessene Konzertsäle. Der Mythos der Säle Bösendorfer, Ehrbar und Streicher*, Musikleben 12 (Wien: Peter Lang Verlag, 2005), 97.
7. Ibid., 123.
8. Christina Meglitsch summarized the public responses: "Seine schöne Einfachheit, die einen 'sehr traulichen und doch noblen Eindruck' machte und zu der 'inneren Sammlung der Zuhörer' wesentlich beitrug." Ibid., 95.
9. Christina Meglitsch quotes the final success to establish the former stable as a concert hall as follows: "[D]er Bekanntheitsgrad und die Beliebtheit des Saales [wuchs] so stetig, dass er als gleichbedeutend—die Akustik jedoch weit übertreffend—mit dem Grossen Musikvereinssaal in die Geschichte einging." Ibid., 103.
10. Ibid., 104–105.
11. "Aber bisher war jeder *neue* saal schlecht akustisch . . . Haben sich unsere ohren geändert? Nein, das material, aus dem der saal besteht, hat sich geändert. Das material hat durch vierzig jahre immer gute musik eingesogen und wurde mit den klängen unserer philharmoniker und den stimmen unserer sänger imprägniert. Das sind mysteriöse molekularveränderungen, die wir bisher nur am holze der geige beobachten konnten." Loos 1931, 117. English translation by Mitchell, from *On Architecture* 109.
12. Meglitsch, *Wiens vergessene Konzertsäle*, 124.
13. Gustav Jäger, "Zur Theorie des Nachhalls," aus den Sitzungsberichten der kaiserlichen Akademie der Wissenschaften in Wien, math.-naturwissenschaftl. Klasse, Bd. 120, Abt. IIa, Mai 1911. In this report, Jäger repeatedly refers to Wallace C. Sabine's publication in the *American Architect and Building News* of April 7, 1900.
14. Emily Thompson, *The Soundscape of Modernity—Architectural Acoustics and the Culture of Listening in America, 1900–1933* (Cambridge, MA: MIT Press, 2002), 33–36.

15. Deutsche Gesellschaft für Akustik e.V., "Akustische Wellen und Felder," March 2006, http://www.dega-akustik.de/publikationen/DEGA_Empfehlung_101.pdf, section 5.1.8, page 47 (accessed January 6, 2009).
16. Robert Sekuler, "Reverberation and the Art of Architectural Acoustics," *Homepage*, November 29, 2002, http://people.brandeis.edu/~sekuler/SensoryProcessesMaterial/reverberation.pdf (accessed January 6, 2009).
17. The Sabine formula as applied today is: $T = 0.161\ V/A$, where T is the reverberation time, V is the volume of the room in cubic meters, and A is the absorption area in square meters. The formula that Wallace C. Sabine had published on May 5, 1900 in the third sequel of *Architectural Acoustics* in the *American Architect and Building News* was $k = 0.171\ V$, which in principle corresponds to the current formula.
18. "Sie zeichneten gerade linien vom tongeber nach der decke und meinten, daß der schall wie eine billiardkugel im selben winkel von der bande abspringe und seinen neuen weg nehme. Aber alle diese konstruktionen sind unsinn." Loos, "Das Mysterium der Akustik," 116.
19. "Aber bisher war jeder *neue* saal schlecht akustisch." Loos, "Das Mysterium der Akustik," 117.
20. In 1983, the Bösendorfer piano company formally opened a new salon for concerts on the ground floor of their factory on Graf Starhemberg Gasse in Vienna's fourth district, which is now commonly known as the Bösendorfer Hall, see its Web site at www.boesendorfer.com. Other than the name, this hall bears no resemblance to its predecessor.
21. Leo Beranek, *Concert Halls and Opera Houses. Music, Acoustics and Architecture* (New York: Springer, 2004), 586.
22. Quoted in Thompson, *The Soundscape of Modernity*, 53.
23. Ibid., 54.
24. Leo Beranek, *Concert and Opera Halls. How They Sound* (New York: AIP Press, 1996), 245.
25. Jürg Jecklin, "Raumakustik im Wandel der Zeit—Zum Verhältnis von sichtbarem und hörbarem Raum," *werk, bauen und wohnen* 12 (2006): 8–13.
26. "Ist es ein Zufall—war die nächste Überlegung—dass überall, wo improvisiert Musik erklingt, sich Menschen sofort zu einem Kreis zusammenschließen? Diesen ganz natürlichen Vorgang, der von der psychologischen Seite her jedem verständlich ist, müsste man in einen Konzertsaal übertragen—das war nun die Aufgabe, die sich der Architekt gestellt hatte. Musik sollte auch räumlich und optisch im Mittelpunkt stehen. Davon ausgehend ergab sich die Gestaltung des Neubaues der Philharmonie. Dass der Entwurf in räumlicher und technischer Hinsicht heute realisiert ist, verdanken wir nicht zuletzt der Vorleistung der akustischen Wissenschaft. In enger Zusammenarbeit mit dem Akustiker, Prof. Cremer, wurde hier 'Neuland' erobert und erarbeitet." From: Hans Scharoun, "Musik im Mittelpunkt: Bemerkungen zum Neubau der Berliner Philharmonie, 29.7.1957," quoted in Hans Scharoun, *Bauten, Entwürfe, Texte*, edited by Peter Pfankuch (Berlin: Mann Verlag, Akademie der Künste, 1974), 279. Translation of some passages by Pamela Johnson. In Peter Blundell Jones's detailed study of the design process, Lothar Cremer appears as permanently skeptical about music in the round; later however, Cremer called Scharoun the "most accommodating architect he ever worked for," in Peter Blundell Jones, *Hans Scharoun* (London: Phaidon Press, 1995), 182.
27. "Der Saal ist wie ein Tal gedacht, auf dessen Sohle sich das Orchester befindet, umringt von den ansteigenden Weinbergen." Scharoun, *Bauten, Entwürfe, Texte*, 292. Others have described the layout as a terraced landscape, or leaves around a blossom.
28. From Herbert von Karajan's letter, when he was consulted by the judges of the architectural competition in 1956, quoted in Blundell Jones, *Hans Scharoun*, 178.
29. "Nicht jeder Konzertbesucher . . . habe den Wunsch, durch eine 'sichtbare Konstruktion'—den Klangreflektor—daran erinnert zu werden, daß das Wunder des Hörens ein physikalischer, von der Wissenschaft gesteuerter Vorgang ist, so wenig wie der Zuschauer einer Theateraufführung die Scheinwerfer . . . sichtbar vor Augen haben möchte." In "Achteckige Philharmonie," *Spiegel* 5 (1957), www.spiegel.de/spiegel/print/d-32092771.html (accessed July 8, 2010.)

30. As listed in Beranek, *Concert Halls and Opera Houses*, 603.
31. Ibid., 57–58.
32. Blesser and Salter, *Spaces Speak, Are You Listening?* 198.
33. See www.bernhardleitner.com.
34. See www.gabischillig.de.
35. Formerly the partnership of Décosterd & Rahm. Jean-Gilles Décosterd and Philippe Rahm, *Physiological Architecture = Architecture Physiologique* (Basel: Birkhäuser Verlag, 2005).