Ear Building: Listening through Modern Architecture

Joseph L. Clarke

The field of architectural acoustics derives its name from the Greek for "hearing" and retains connections to the ancient study of how sound propagates through the physical environment, enters the orifice of the ear—the *póros akoustikós*—and makes its way through the organ of hearing to be converted into nerve impulses. The movement of sound across space is, in short, fundamental to human hearing. Whether space can factor meaningfully into sound's experiential content, however, was a vexed question in the era of Ludwig van Beethoven. E.T.A. Hoffmann, in his essay on Beethoven's Fifth Symphony, suggested that it would be improper to apply the category of space, at least in the familiar, three-dimensional sense of the term, in interpreting musical sound:

> Music discloses to man an unknown kingdom, a world having nothing in common with the external sensual world which surrounds him and in which he leaves behind him all definite feelings in order to abandon himself to an inexpressible longing.... How could you possibly conceive of using plastically that art which is just the opposite of sculpture?[1]

Georg Wilhelm Friedrich Hegel made the point more concisely when he described music as "the sublation of spatial objectivity."[2]

Beethoven himself, however, knew firsthand how dependent auditory experience could be on spatial conditions. At an early stage of his hearing loss, he confided to a friend: "At the theater, I must lean in very near to the orchestra in order to understand the actor. If I am some distance away, I do not hear the higher notes of instruments and voices."[3] In a subsequent letter, he likened deafness to an architectural barrier between self and world: "My ears are, alas, a partition wall, through which it is not easy to have any communication with my fellow human beings."[4] His references to the spatial qualities of sound were not all negative: "Is the concert hall large and sonorous?" he inquired of a contact in London planning a symphonic concert.[5]

It is ironic that in an era when the study of deafness and the development of hearing aids were bringing unprecedented attention to the spatial conditions of listening, Romantic writers felt compelled to insist that music was an art that transcended or negated space. Due in part to their insistence, the problem of the spatial conditions of hearing did not become a major subject of

cultural inquiry until a resurgence of interest in so-called “spatialized sound” in the second half of the twentieth century. This resurgence was precipitated by advances in stereo and binaural audio technology, and it is in this context that spatial hearing has been most extensively examined.

Beethoven’s use of architectural terms to describe his own auditory experience suggests a different and considerably older avenue of investigation, however: the history of buildings patterned on the ear. This architectural figure, an important subtheme of the ancient Western architectural topos of the building as body, is examined in the present essay.[6] An “aurocentric” approach to the history of European architecture, pursued here through three significant examples, is a useful corrective to the more conventional analysis of buildings as visual icons, designed to frame and mediate optical experience. The argument that follows is that the development of architectural acoustics has been explicitly informed not just by the normative structure of the healthy human ear, but also by fantasies of superhuman, nonhuman, and disabled organs of hearing, and that an ongoing struggle over how to translate the model of the ear into architectural form has been among the most important sources of acoustic invention.

A King Listens

A desire to dislocate sound was expressed at the very origin of modern architectural theory. Leon Battista Alberti, in his *On the Art of Building*—the first printed book on architecture—advises that in the design of a palace, “a tyrant will find it very useful to have secret listening tubes concealed within the fabric of the wall so as to eavesdrop on the conversation of guests or family.”[7] Alberti’s book was not illustrated and he did not cite a specific built example, but in the ensuing centuries, the most vivid and influential model for this kind of auditory monitoring system was the Sicilian cave known as the Ear of Dionysius. This grotto, located off the bottom of an ancient limestone quarry near Syracuse, was promoted in the early seventeenth century by architect Vincenzo Mirabella for its eerie echoes.[8] According to the cave’s origin myth, the ancient despot Dionysius I detained high-value prisoners here, and their conspiratorial conversations were conveyed with perfect clarity, through a process of acoustic reflection and focusing, to a secret chamber accessible from the palace.

The name “Ear of Dionysius” was apparently proposed by the painter Caravaggio during his time in Sicily. This sobriquet casts the cave as an artificial organ of hearing for the ruler, an “extension of man,” to use Marshall McLuhan’s expression. The Jesuit polymath Athanasius Kircher, who made a special trip to Syracuse to visit the cave, published a schematic illustration (fig. 1). If one imagines the grotto as an immense ear, the room where the tyrant ostensibly monitored his prisoners’ scheming would correspond to the auditory nerve, where the ear canal was understood to convey sound. Peter Szendy associates the cave with Italo Calvino’s short story “A King Listens,” in which a solipsistic ruler’s paranoia keeps him immobilized on his throne, where he can only listen nervously for seditious whispers using various acoustic contrivances. “The palace is all whorls, lobes,” Calvino writes. “It is a great ear, whose anatomy and architecture trade names and functions: pavilions, ducts, shells, labyrinths.”[9] These words could equally describe some of Kircher’s own architectural speculations, a significant influence on later acoustic theorists, such as his often-reproduced engraving of a palace with a cochlea-like listening structure that would redirect sound from an adjacent plaza into the mouth of a statue (fig. 2).

But was surveillance really the purpose of the Ear of Dionysius? The most interesting detail of Kircher’s account is his remark that the presumed sound-transmitting mechanism no longer functioned:

> Today the conduit is blocked by a masonry wall, so instead the cave gives a strange and beautiful echo; hence it is commonly called *La Grotta della favella* [the speaking cave]. The voice is not simply reflected, but rather the most quiet speech is raised to a shout, clearing one’s throat yields a sound like thunder, and striking one’s cloak produces something like an explosion.[10]

This echo, which still impresses contemporary travellers, is complemented by the cave’s remarkable ambient murmuring even when no humans are making noise. The notoriety of the cave and its sound effects established it as an important precedent as European thinkers endeavoured to systematize the principles of building acoustics. Notably, its legend established a template for the persistent compulsion to explain or justify unusual acoustic environments by citing a putative utilitarian rationale.

One further aspect of the cave deserves consideration. Above the quarry, almost directly over the cave, the Syracusans built a magnificent outdoor theatre. The layout of a classical theatre was designed principally to facilitate visual experience, as is suggested by the word *théatron*,

related to the Greek for “sight.” In the semicircular *cavea*, one might even discern a likeness to the platonic sphere of the eyeball, as the neoclassical architect Claude-Nicolas Ledoux implied in the eighteenth century (fig. 3). It is easy to understand how generations of travellers to Syracuse would be moved by this arrangement of structures to imagine a dualistic relationship between the geometrically pristine architecture of sight and the more sinister labyrinth of hearing underpinning or perhaps undermining it. This assumed sensory dichotomy, so central to later acoustic thought, was powerfully manifest here in built form.

Acoustic Enchantment

The type of the building as auditory prosthesis is not the only way architects have interpreted the model of the ear. A different approach emerged in the early 19th century, in the design of buildings for opera. Prior to this, the most influential theories of performance hall acoustics held that sound should be reflected off the sides of an auditorium and focused into a single point where it would be heard most intensely, often the royal box (fig. 4). Opera houses were sometimes even likened to the ear trumpets that proliferated during this period for catching and focusing sound. This arrangement effectively transferred into the theater building the pattern suggested by the Ear of Dionysius, where sound had ostensibly been redirected to the locus of the all-hearing ruler. Theater became an *audiovisual* spectacle configured around a hierarchical social order.

This arrangement was challenged in 1810 by the theatrical architect Carl Ferdinand Langhans, who went on to design major halls in Breslau, Berlin, Liegnitz, Stettin, Dessau, and Leipzig. Langhans contended that an auditorium should not focus sound into a point, but rather disperse it as evenly as possible. He was inspired by the shape of the human ear, with its strange assemblage of knobbly auricle and ear canal that funneled sound into the hidden interior organs of hearing. “In observing the human outer ear, it seems to me as though nature itself had established these same principles of the uniform diffusion or use of sound rays,” he wrote. “In the shaping of the outer human ear, the problem was constructing a form to pick up sound rays from every direction and to direct them toward the inner ear.”[11]

The geometry of a theater interior should complement this anatomical structure, Langhans argued. While the auricle’s purpose was to collect scattered sound rays from all directions and

focus them inward toward the cochlea, the auditorium had the reciprocal function of dispersing sound from a single source on the stage into a diffuse ambience. In developing his theory, Langhans's aim was, first, to achieve the functional objective of allowing as many people to hear as possible—an economic imperative in a bourgeois theater where spectators paid to witness the performance. But he was also captivated aesthetically by the soft reverberation resulting from this diffusion of sound:

> Even an untutored person likes to go into buildings where music and sound are pleasantly diffused. We praise churches and halls where music can be heard well; yet we have never sought to be free from a sweet, delightful reverberation. One wonders what is it that makes reverberation so enjoyable. *A gradually dissolving reverberation in both small and large buildings is pleasurable and indeed necessary for us to enjoy the enchantment of music and sounds*.[12]

In theorizing reverberation as an architectural effect, Langhans conceived the theater building and the "architecture" of the human ear as two contrary yet corresponding parts of the same acoustic circuit. He went so far as to diagram the outer ear in elevation and plan—as though it were a building—arguing that its shape was surprisingly well-suited to its purpose of reflecting sound into the ear canal. To dramatize the point, he drew several hypothetical alternative ears with simpler forms, which might superficially seem better at catching incident sounds but would actually be ineffective (fig. 5). His final image is of a conical design that, he writes, would simply have bounced the sound back out.

Just as the ear's peculiar asymmetrical geometry helps channel sound properly, a theater interior might likewise need to be visibly non-uniform—incorporating an arrangement of flat and convex surfaces—in order to scatter sound as widely as possible and thereby produce acoustic uniformity: "If we consider a series of raised surfaces on a flat area of the proscenium… we will clearly grasp that every sound originating onstage is reflected from each part [of the proscenium] to all points in the theater."[13]

A case in point is the new auditorium he designed for Berlin's Königliche Opernhaus (today the Staatsoper) on the Forum Fridericianum, a structure Langhans was commissioned to redesign after a fire in 1843 (fig. 6). Under a flat—not concave—ceiling, the horseshoe auditorium was defined by curved galleries terminating in straight segments inclined inward toward the stage. Langhans's most innovative gesture was to articulate these segments as a single, stretched-out proscenium, with a tripartite triumphal-arch motif incorporating large columns to reflect and distribute sound.[14] A similar arrangement is evident in his theater for Leipzig, completed in 1868.

These structures and the acoustic theory that informed them—based on the inverse functioning of theatre building and human ear—proved instrumental in moving German theatre architecture away from the neoclassical fondness for geometric purity, to embrace more spatially complex, morphogenic interior designs.

The Cicadas and the Fountain

Langhans's use of flat and convex elements to diffuse sound was one alternative to the earlier practice of acoustic focusing. In France, however, the design of concave reflectors persisted into the twentieth century, and was championed by Le Corbusier in the 1920s. An architect and painter, Le Corbusier is often thought to epitomize modern architecture's concern with the visual. But he grew up in a family of musicians, and his early associations with the music critic William Ritter and the composer Émile Jaques-Dalcroze inculcated a lifelong interest in sound.

His initial acoustic designs hewed closely to older paradigms. An unbuilt 1927 scheme for the main hall of the League of Nations in Geneva, designed with his cousin Pierre Jeanneret, featured a swooping acoustic surface rising behind the speaker's rostrum and soaring overhead to become the ceiling (fig. 7). Even as some acousticians disputed whether the design would work, Le Corbusier maintained that the building form could act as an immense amplifier, projecting sound to an audience of over 2,500 without the need for electronic loudspeakers. The goal of diffusing sound to a large audience recalled the designs of Langhans, but comments of the architect and his defenders made clear that they were also thinking along the lines suggested by the Ear of Dionysius. Architectural critic and historian Sigfried Giedion, one of Le Corbusier's staunchest defenders, wrote that the League of Nations hall needed "to be all ears" and that the design achieved this aim by functioning as "a singular ear trumpet."[15]

Le Corbusier himself raised a similar idea a few years later, in his 1935 book *Aircraft*, which included a photograph of a reflective acoustic locator for pinpointing the locations of enemy planes through triangulation (fig. 8). His caption invoked nonhuman hearing: "The most exact laws of acoustics will help in aerial defense. Like the ear of a dog or of a horse the three sounding conches turn their tympana to various quarters of the horizon."[16]

These cases illustrate the architect's lingering indebtedness to classical acoustic tropes. His ideas took a different direction, though, as he began to engage with new sound media.

Following his 1935 lecture tour of the United States, he declared that in the machine age, "everything in our auditory habits changes." He grew enthusiastic at the way phonography and radio enabled new kinds of music, such as jazz, to flourish: "Mechanical recording makes possible the most fruitful—the most admirable—investigation in every part of the world.... Records sing in homes. The reformation reaches the very foundation of sensibility."[17] His design projects began to call for integrated electroacoustic systems, such as the microphone and loudspeaker installation he specified for the Palace of the Soviets cultural complex in Moscow.

At the same time, he remained fixated on the geometry of sound's reflection in three-dimensional space and the belief that acoustic processes could be manifest in plastic form. Even the Palace of the Soviets design featured a *conque sonore* or "sound shell," related to the architect's ongoing fascination with seashells. Increasingly, though, he thematized these ideas in an aesthetic register. Consider the series of wood carvings he designed in the postwar period in collaboration with the Breton woodworker Joseph Savina (fig. 9). Their most frequently recurring motif is a slender, alert ear, whose gently concave form seems to anchor in place assemblages of bulbous, vaguely biomorphic nodules. "This kind of sculpture is an example of what I call acoustic plasticity [*la plastique acoustique*]," Le Corbusier wrote—"that is to say, forms which speak and listen."[18] Strikingly, he describes these objects not as aids to *human* hearing but as though *they themselves* emitted and attended to sound. He began to apply the same logic to buildings. In his 1946 essay "L'espace indicible," he wrote:

> *Action of the work* (architecture, statue, or painting) on its surroundings: vibrations, cries or shouts (such as originate from the Parthenon on the Acropolis in Athens), arrows darting away like rays.… *Reaction of the setting*: the walls of the room, its dimensions, the public square with the various weights of its facades, the expanses or the slopes of the landscape.… A phenomenon of concordance takes place, as exact as mathematics, a true manifestation of plastic acoustics [*l'acoustique plastique*].[19]

According to this imagery, a building's form could emit a kind of metaphorical sound and then somehow receive the echo back into itself.

Le Corbusier sought to implement this idea in his pilgrimage chapel of Notre Dame du Haut near Ronchamp, possibly his most celebrated project but one whose acoustic dimensions have been little examined. Completed in 1955, the chapel was the brainchild of French Dominicans who championed the cause of modern art in the Catholic Church. Even though Le Corbusier was a self-described agnostic who had been raised in Protestant Switzerland, these Dominicans

sought his assistance in reimagining the practice of pilgrimage through an innovative chapel that would draw new kinds of seekers.

His solution was to turn the conventional Christian church building inside out. Although he placed several small altars within the chapel, special pilgrimage Masses held several times a year and attended by tens of thousands of worshipers would take place outside, at an exterior altar on the east side (fig. 10). Probably with these outdoor liturgies in mind, he incorporated acoustic references in the chapel's form. The large tower at the southwest corner and the two smaller ones on the north side, which rise from the central volume to confront the horizon in different directions, resemble conventional church bell towers, or the ears in the wood carvings created with Savina. At Ronchamp, however, in a synaesthetic inversion, the towers' function is to admit light rather than admit—or emit—sound.[20]

Likewise, the chapel's warped walls appear to refer back to the curved acoustic shells that Le Corbusier had designed earlier in the century for large auditoria, and that loudspeaker technology had rendered largely obsolete. Once again, however, these notionally acoustic structures perform no actual sound-distributing function. The critic Alan Colquhoun has observed in Le Corbusier's work a propensity for "displacement of concepts," as the architect appropriated formal motifs from industry and other sources and altered their function. Hence, when Le Corbusier claimed, in designing the chapel, to have revealed an "acoustic component in the domain of form," he was actually using the formal language of sound reflectors to refer broadly to the purported psychic effects of geometric exactitude.[21]

This acoustic rhetoric was not mere metaphor, however. Le Corbusier's design *also* incorporated actual sound, meant to come from an adjacent electronic installation that was never built. His drawings and models show a large metal grid adjacent to the chapel's north portal, his version of an electronic "campanile" or bell tower (fig. 11). At set times of day, he wanted loudspeakers mounted on this structure to make the hillscape resound with deliberately unsettling noises. The year before the chapel was finished, he approached the composer Edgard Varèse about creating "violent, impersonal" electronic music for this purpose.[22] The campanile idea fell afoul of Pope Pius XII's distrust of electroacoustic technology and artistic modernism, however, and never came to pass.

As Stanislaus von Moos points out, Le Corbusier often intentionally set up ironic or contradictory relationships among the elements of a project.[23] When the unbuilt campanile is considered as

an integral part of Le Corbusier's intentions for Ronchamp, the overall design can be read as a critical commentary on architecture's mediation of visual and auditory communication. By periodically sending out unsettling noises, the electronic structure would have defamiliarized the surrounding topography, jolting visitors with the dislocating effects of modern communication technology. Le Corbusier staged an encounter between the kind of inflected surfaces that architects had once designed as sound projectors and the visually anonymous, seemingly formless electronic loudspeaker technology that had largely supplanted them in function. It was as though the chapel's curved surfaces, instead of amplifying sound for the benefit of users, "listened" on their own, in a language of plasticity inaccessible to human audition. The acoustic fable of Ronchamp is one in which the formally vacant campanile projects music out to the surrounding hills and the chapel building attends to the answering report, registering it in its three-dimensional form and thereby affirming its awareness of its own position in space, like an animal checking its bearings by echolocation.

To make sense of this strange, animistic conception of architecture, involving the mutual displacement of analogue and electronic sound onto one another, it is helpful to consider Le Corbusier's own difficulties with hearing near the end of his life. A few months before he died in 1965, he wrote his brother Albert a brief letter (fig. 12) that begins by describing the serene atmosphere in his little apartment on Paris's luxe western edge, along with his own experience of tinnitus: "Silence, no car sounds. It is seven o'clock in the evening.... The only murmuring is in my ears: left ear = cicadas / right ear = a flowing fountain. In the rumble of everyday life, the spirit hears nothing. In the evening and at night, the cicadas and the fountain sing."[24] Le Corbusier, who often inserted small sketches in his letters, went on to diagram his perceived sonic environment: he drew his own head in plan, with oversized ears and arrows to indicate where he perceived the sounds to come from. Even sound that was "all in his head" could be spatially differentiated.

The letter goes on to associate his relationship to his brother with electronically mediated sound. "Your presence is with me all the time," Le Corbusier writes fondly. "We're partially hooked together [*Tu croches et décroches*]." This latter sentence is difficult to translate and might refer to the interlocking threads of crocheted fabric or, alternately, to an intermittent telephone connection: hence, "we connect and disconnect" or even "you call and hang up."[25] Le Corbusier also plays on the fact that his brother was a composer, as becomes clear at the end of the letter: "The devil is that I don't read your music (your eighth notes [*tes croches*])." He continues:

"I have (deluxe) devices to produce sound [*faire du bruit*]. But the voltages, the amperages confuse me [*m'embrouillent*]."[26]

In this letter, Le Corbusier moves from a vivid account of his personal acoustic world, expressed in spatial and indeed architectural terms, to a discussion of the complex ways—inscrutable to him—in which auditory experience is communicated with others, both the formalized language of music notation and the increasingly ubiquitous regime of electroacoustics. The letter reads as the plea of a man keenly attuned to spatial hearing but also painfully aware of both his lack of fluency in the ways sound is mediated and his own creeping hearing loss.

The year before he wrote this letter, Le Corbusier had sought treatment for his hearing from Alfred Tomatis, the famed French otorhinolaryngologist, psycholinguist, and pioneer of electronically-assisted music therapy. Tomatis argued that hearing difficulties were connected to much broader psychological imbalances, and could lead to problems with vocal agility, spatial coordination, and interpersonal skills. He developed an innovative therapeutic method he called "audio-psycho-phonology," based on the mutual interdependence of ear and voice, that he administered to numerous celebrity patients with voice problems, including Maria Callas and Gérard Depardieu.

Tomatis was particularly concerned with the prenatal development of the listening faculties, when he believed crucial steps in the formation of the psyche took place. Bombarded with the sounds of their mothers' voice and body, fetal listeners honed their ability to focus on important noises and tune out unimportant ones. Tomatis argued that irregularities in this developmental stage could cause problems later in life. When Le Corbusier visited the clinic, he undoubtedly encountered the "electronic ear" (*oreille électronique*) Tomatis was developing. This device was meant to simulate the way a fetus would hear sound, as conducted through bones and amniotic fluid, by emphasizing certain frequency bands and muting others. His patients spent hours each day wearing headphones, listening to music (Tomatis recommended Gregorian chant) filtered through the *oreille électronique* to recreate the conditions of intrauterine listening.

All architectural structures ultimately referred back, in Tomatis's view, to this archetypal experience of the mother's body. The womb established the standard by which any building's acoustics could be judged. Hence, he later advised an unnamed architect suffering from depression that his problems were caused by the wall-to-wall carpeting and fabric-covered walls of his office, which eliminated reverberation: "He lived like a fetus in his mother's belly, but with

no acoustic stimulus to give him energy and tone!" Tellingly, Tomatis's principal recommendation was not to tear out the office carpeting, but simply to install an *oreille électronique* to fill the office with filtered sound.[27] In other words, Tomatis understood buildings as technologies for mediating auditory experience, transforming sound to promote a more organically integrated sense of hearing and general well-being—but if the architecture were deficient, this necessary acoustic mediation could just as well be achieved by electronic supplementation.

As a patient of Tomatis, Le Corbusier clearly struggled with both the means and the very meaning of "listening" in the age of electronic media. His design for Ronchamp is neither an oversized ear trumpet nor a sound-scattering device on the model of an inverted ear, but rather an ambiguous profession of faith that as electronic devices took over the function of propagating sound, architecture could cultivate a new and different kind of hearing—and a corresponding science of acoustics—aimed at something beyond the transmission and apprehension of ordinary, audible sound: acoustics reimagined as a holistic principle of environmental consonance, and every building an alert listener.

Coda

Taken together, the Ear of Dionysius, the theaters of Langhans, and the Ronchamp chapel project illustrate how the figure of the ear has been a versatile and open-ended source of architectural experimentation. While the Ronchamp campanile was never realized, Le Corbusier's design laid the groundwork for his collaboration with Varèse several years later on the Philips Pavilion for the 1958 World Expo, a milestone in what has come to be called the "spatialization" of sound.[28] The pavilion featured Varèse's *Poème électronique*, which made use of dynamic electroacoustic effects. As a shorter interlude, Iannis Xenakis created an 11-channel composition designed to zoom around in coordinated patterns among hundreds of speakers mounted on the interior. The pavilion established a precedent for numerous experimental audio installations created over the past 60 years.

The term "spatialized sound" elides a fundamental error, however. Sound, insofar as it is perceived by means of an ear, is already spatial. It only came to seem otherwise as a result of Romantic theories of so-called absolute music, and, even more, as a result of monaural (one-

channel) electroacoustic technology. When capturing sound on mono recordings and broadcasts, audio engineers typically endeavoured to eliminate reverberation, thus effacing the indications of sound's propagation through space (Theodor Adorno criticized this practice in his essay on radio broadcasts of Beethoven symphonies).[29]

Sound is already spatial, and therefore architectural. Humans' ability to recognize locational cues in sound is a biological faculty based in the auditory cortex, but how one interprets these cues is framed by culture—and thus, to no small degree, by architecture. The multiplicity of acoustic paradigms derived from the figure of the listening ear belies the assumption, still repeated today by some architects and critics, that hearing offers an inherently more authentic and immediate way to experience buildings than vision. Architectural acoustics does not facilitate a direct affective connection with a building, but is better understood as a form of mediation. For architects grappling with this spatial mediation of hearing, the listening ear has been a vitally important model, not as a fixed type but as a more elusive ideal whose contested architectural interpretation has perennially driven creative and critical designs for the emplacement and displacement of sound.

Illustrations

1. Athanasius Kircher, illustration of the Ear of Dionysius, from *Phonurgia Nova* (Kempten, 1673). Entered at the bottom of a quarry, the cave is shown as connected to the tyrant's house on the ledge above, enabling Dionysius to eavesdrop on scheming prisoners.
2. Athanasius Kircher, illustration of a building with hidden acoustic devices, from *Musurgia Universalis* (Rome, 1650).
3. Claude-Nicolas Ledoux, auditorium of the Théâtre de Besançon reflected in an eye, from *L'architecture considérée sous le rapport de l'art, des moeurs et de la législation* (Paris, 1804).
4. Mario Bettini, illustration of sound reflection in an elliptical theater, from *Apiaria Universae Philosophiae Mathematicae* (Bologna, 1642).
5. Carl Ferdinand Langhans, diagrams of human ear as acoustical device, from *Ueber Theater* (Berlin, 1810).
6. Carl Ferdinand Langhans, Royal Opera House, Berlin, 1844. Lithograph from Louis Schneider, *Geschichte der Oper und das Koeniglichen Opernhauses in Berlin* (1852).
7. Le Corbusier and Pierre Jeanneret, Palace of the League of Nations project, 1927.
8. Swedish troops operating an acoustic aircraft locator. Photograph published in Le Corbusier, *Aircraft* (London, 1935).
9. Le Corbusier and Joseph Savina, *Ozon, Opus I* (1947). Painted wood.
10. Le Corbusier, Chapel of Notre Dame du Haut, Ronchamp, 1955. Postcard showing pilgrimage Mass, 1962.
11. Le Corbusier, Chapel of Notre Dame du Haut, Ronchamp, 1955. Plaster model with campanile from 1950.
12. Le Corbusier, letter to Albert Jeanneret, 28 March 1965. Fondation Le Corbusier.

Notes

[1] E. T. A. Hoffmann, “Beethovens Instrumentalmusik,” *Zeitung für die elegante Welt* 245 (9 December 1813): 1.
[2] Georg Wilhelm Friedrich Hegel, *Vorlesungen über die Ästhetik* 3.3.2, vol. 15 of Georg Wilhelm Friedrich Hegel, *Werke*, ed. Eva Moldenhauer and Karl Markus Michel (Frankfurt am Main: Suhrkamp, 1970), 134.
[3] Ludwig van Beethoven to Franz Wegeler, June 29, 1800, in *Beethovens Sämtliche Briefe: Kritische Ausgabe*, vol. 1 (Berlin und Leipzig: Schuster & Loeffler, 1906), 49.
[4] Ludwig van Beethoven to Bettina Brentano, August 11, 1810, in ibid., 322.
[5] Ludwig van Beethoven to Ferdinand Ries, July 9, 1817, in *Beethovens Sämtliche Briefe: Kritische Ausgabe*, vol. 3 (Berlin und Leipzig: Schuster & Loeffler, 1907), 178. See Stefan Weinzierl, *Beethovens Konzerträume: Raumakustik und symphonische Aufführungspraxis an der Schwelle zum modernen Konzertwesen* (Frankfurt: Verlag Erwin Bochinsky, 2002).
[6] See Anthony Vidler, “The Building in Pain: The Body and Architecture in Post-Modern Culture,” *AA Files* 19 (Spring 1990): 3–10.
[7] Leon Battista Alberti, *On the Art of Building in Ten Books*, trans. Joseph Rykwert, Neil Leach, and Robert Tavernor (Cambridge, MA: MIT Press, 1988), §5.3, 122.
[8] Vincenzo Mirabella, *Dichiarazioni della pianta dell’antiche Siracuse* (Naples: Lazzaro Scoriggio, 1613), 88–9. Also see Norbert Miller, “Das Ohr des Dionysios. Akustische Verkehrungen und Vorkehrungen,” *Daidalos* 17 (September 1985): 74–83.
[9] Italo Calvino, “A King Listens,” in Italo Calvino, *Under the Jaguar Sun*, trans. William Weaver (San Diego: Harcourt Brace Jovanovich, 1988), 38. Peter Szendy, “Spacing and Sounding Out,” *Grey Room* 60 (Summer 2015): 140–1.
[10] Athanasius Kircher, *Phonurgia Nova sive conjugium mechanico-physicum artis et naturae paranympha phonosophia concinnatum* (Kempten: Rudolphum Dreherr, 1673), 82–4.
[11] Carl Ferdinand Langhans, *Ueber Theater oder Bemerkungen über Katakustik in Beziehung auf Theater* (Berlin: Gottfried Hayn, 1810), 56.
[12] Ibid., 38–9; emphasis in original.
[13] Ibid., 55.
[14] Wilhelm Rohe, *Karl Ferdinand Langhans, Ein Theaterbaumeister des Klassizismus* (Bückeburg: Herm. Prinz, 1934), 27–28, 59–60. Also see Joseph Clarke, “‘Worin das Angenehme dieses Nachhall besteht’: Carl Ferdinand Langhans und räumlicher Klang um 1810,” trans. Christoph Borbach, in *Die Kunst der Romantik im Kontext von Naturphilosophie und Naturwissenschaft*, ed. Nina Amstutz et al. (Wilhelm Fink Verlag, 2020).
[15] Sigfried Giedion, “Schweizer Erfolge am Wettkampf um das Völkerbundgebäude,” in *Neue Zürcher Zeitung* 15 May 1927: 1, quoted in Sabine von Fischer, *Das akustische Argument: Wissenschaft und Hörerfahrung in der Architektur des 20. Jahrhunderts* (Zurich: gta Verlag, 2019), 225.
[16] Le Corbusier, *Aircraft* (London: Studio Ltd., 1935), 19.
[17] Le Corbusier, *When the Cathedrals Were White*, trans. Francis E. Hyslop (1937; New York: McGraw-Hill, 1947), 158–162.
[18] Le Corbusier to Joseph Savina, August 28, 1947, quoted in *Le Corbusier et Savina: Dessins et sculptures* (Paris: Fondation Le Corbusier, 1984), 97.
[19] Le Corbusier, *New World of Space* (New York: Reynal & Hitchcock, 1948), 8; translation of Le Corbusier, “L’espace indicible,” *L’Architecture d’Aujourd’hui*, January 1946: 9–10.
[20] See Charles Jencks, *Le Corbusier and the Continual Revolution in Architecture* (New York: Monacelli Press, 2000), 265–7.
[21] Le Corbusier, *Oeuvre complète*, ed. Willy Boesiger, vol. 5 (Zurich: Les Éditions d’Architecture, 1970), 72. See Christopher Pearson, “Le Corbusier and the Acoustical Trope: An Investigation of Its Origins,” *Journal of the Society of Architectural Historians* 56:2 (June 1997): 168–83; and Joseph L. Clarke, *Echo’s*

Chambers: Architecture and the Idea of Acoustic Space (Pittsburgh: University of Pittsburgh Press, 2021).
[22] Le Corbusier to Edgard Varèse, 21 January 1954. Fondation Le Corbusier G2-16.
[23] Stanislaus von Moos, *Le Corbusier: Elements of a Synthesis* (Cambridge: MIT Press, 1988), 303–6.
[24] Le Corbusier may have been thinking of a line from Friedrich Nietzsche's *Also sprach Zarathustra*, a book that profoundly shaped his development as an architect: "Nacht ist es: nun reden lauter alle springenden Brunnen. Und auch meine Seele ist ein springender Brunnen." Friedrich Nietzsche, *Also sprach Zarathustra*, ed. Giorgio Colli and Mazzino Montinari (München: Deutscher Taschenbuch-Verlag, 1999), 136.
[25] Le Corbusier's attraction to the telephone is discussed in Mark Wigley, *Buckminster Fuller Inc.: Architecture in the Age of Radio* (Zurich: Lars Müller Publishers, 2015), 36.
[26] Le Corbusier to Albert Jeanneret, 28 March 1965, reproduced in *Lettres Manuscrites de Le Corbusier*, (Paris: Éditions Textuel, 2015), 218–20.
[27] Alfred Tomatis and Loïc Sellin, *Neuf mois au paradis* (Paris: Editions Ergo-Press, 1989), 128.
[28] For example, in Marc Treib, *Space Calculated in Seconds: The Philips Pavilion, Le Corbusier, Edgard Varèse* (Princeton: Princeton University Press, 1996), 175.
[29] Emily Thompson, *The Soundscape of Modernity: Architectural Acoustics and the Culture of Listening in America, 1900–1933* (Cambridge: MIT Press, 2002), 284. Theodor W. Adorno, "The Radio Symphony," in *Radio Research 1941*, ed. Paul G. Lazarsfeld and Frank Stanton (New York: Duell, Sloan and Pearce, 1941), 118–9.