ACOUSTIC ORNAMENT

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These six thousand words were not culled from books and journals, or distilled via loudspeakers and microphones. They did not come from a project, epiphany, or interview with an expert. They emerged, instead, from a long and turbulent confrontation with acoustic architecture. This process was slow and uncertain, with a purposeful arc, and more akin to artistic exploration than scientific research. Many ideas within this essay are understood in the acoustics community. To my knowledge, the structure and beautiful consequence—the Sphericity Conjecture proposed here—are new. Observation and the physics of sound seem to point in this direction, even though a precise definition will take more time. For this essay, imprecision is intentional. The hope is that intuition will take hold in the mind of the architect, and the Conjecture will begin to improve the sound of the built environment without delay. Further evidence can arise from intentional designs, and aggregate with that which extant architecture already yields.

ACOUSTIC ORNAMENT

"Ornament and architecture was a topic, albeit a negative one, and objects and architecture was another; but no questions connected the three."

— Alina Payne
From Ornament to Object
Yale University Press, 2012

Imagine floating,
surrounded by nothing.

There is air to breathe but no ground or surfaces of any kind. There is no gravity. You clap your hands a single time. A spherical wave of sound expands outward in all directions. It passes your ears and continues away from you, never to return. This is the driest possible acoustic environment: anechoic, no reflections.

A large spherical mesh appears around you. You are floating inside, at its center. The mesh is light and open and made of sparse, fine strands that allow air to traverse easily. You clap again and the spherical wave expands and passes your ears as before. It continues and crosses the ghostly boundary, uninterrupted. To your ear, the sound is again anechoic.

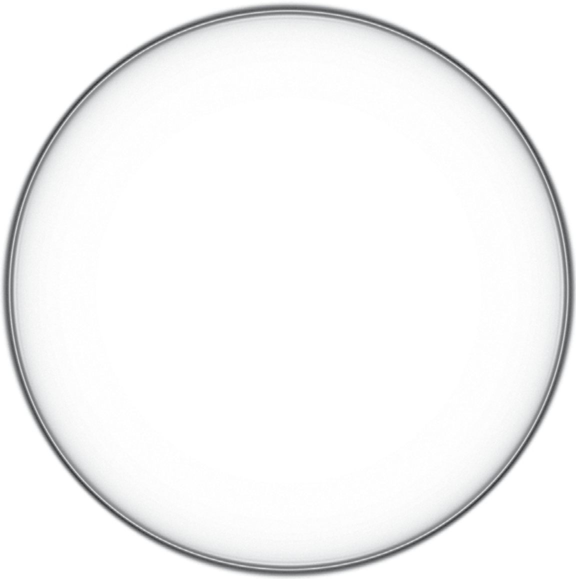
The openings of the mesh slowly close. The thin strands widen and merge to form a continuous, uninterrupted, perfect sphere. It is smooth, infinitely rigid, and lets no air pass. Now fully enclosed, you clap again and the spherical wave expands and passes your ears again. This time, when it reaches the boundary, every point on the wavefront strikes the spherical surface simultaneously. The surface reflects the sound of the clap, which contracts back to the center where it momentarily becomes a concentrated point of energy. It then expands, and reflects again at the boundary. This expanding and contracting spherical wave repeats ad infinitum.

In this thought experiment, neither you nor the air around you dissipate the sound.

The sound energy disappears and it is quiet again. The sphere that surrounds you starts to morph. Six regions of it flatten into intersecting planes: right, left, front, back, below, and above you. Call the surfaces walls, a floor, and a ceiling if you like; you are floating at the center of a rectangular room. You clap again and the wave expands again, traveling past your ears and toward the boundaries. In a rectangular enclosure, unlike the sphere, the distance to the boundary depends on direction. The center of each flat surface is closer to you than its edges and corners. The spherical wavefront encounters the closest portions first and the furthest portions last, reflecting and continuing to spread rather than focusing back to the center. The sound eventually fills the entire enclosure. To your ear this is a slow sonic decay as the energy of the wave weakens to occupy every enclosed point in the space. Inaudibility arrives after a few seconds—a notably long, but finite, amount of time.

The sound energy again disappears and another enclosure distortion begins. Peaks and valleys emerge from the flat surfaces, like a range of mountains viewed from above. On these variations fractal-like textures form. The smallest details are a few millimeters and the largest deformations are a few meters. You clap again and the expanding spherical wave strikes these surfaces, reflecting, diffracting, bending, and quickly filling every crevice of the room. The wavefront is smeared and the sound energy is dispersed rapidly over the entire volume of the space. Any semblance of order that remains after the first reflection is obliterated by the second or third. The coherent sphere of sound is now a blur occupying all locations and traveling in all directions simultaneously. The decay sounds much faster to you in this diffuse field of energy.

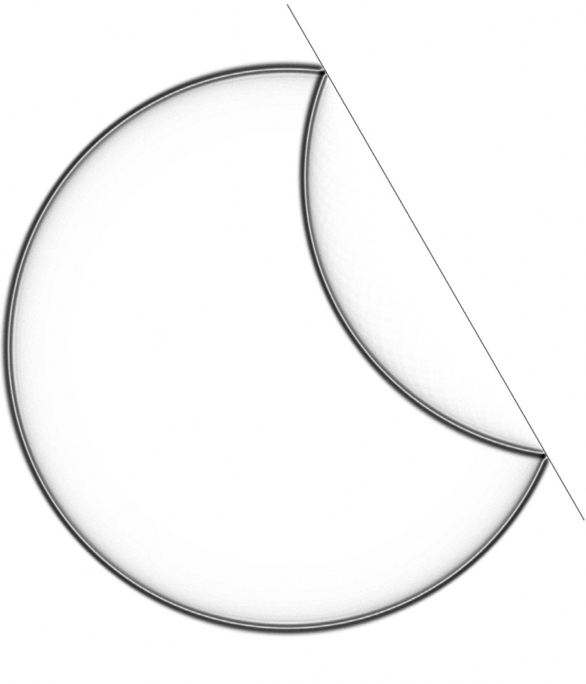
In a final and dramatic act, the enclosure morphs once more, this time at an extended range of scales. Its surface area rises exponentially as its form is pulled and stretched at every point on its surface. The peaks and valleys exaggerate, and the textures on them deepen into a network of airy, interconnected pores and struts jutting at all angles. From your vantage the large variations of form are clear, but the small are too small to be visible. The enclosure is like a deep sculpted foam with a fine porosity. From the outside it is still solid, non-porous; its complexity is exposed to the interior. You clap again and the wave of sound expands again. When it encounters the enclosure this time, the air molecules that carry the sonic energy violently interact with the complex shaping, and their energy is converted to heat. The wave is swallowed and nothing is returned. This is an anechoic chamber. It has zero decay time and is the driest possible acoustic environment. To your ear, it sounds the same as with no enclosure at all.



a wave expanding in a free field

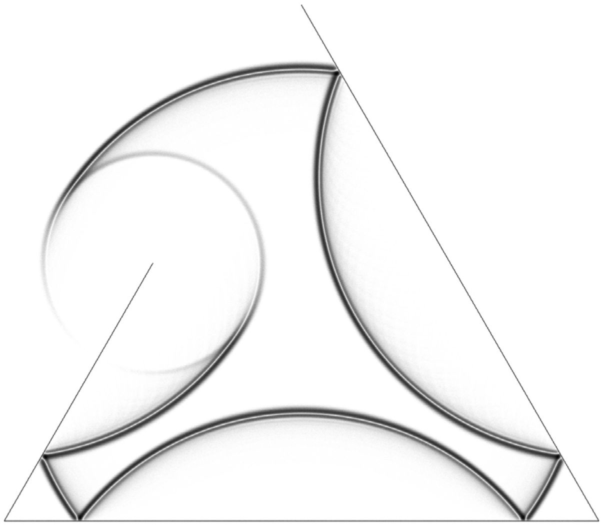
A sound wave without boundaries expands without interruption,

weakening continuously as its energy covers increasingly more area. This is called a free field, the initial condition of the thought experiment.



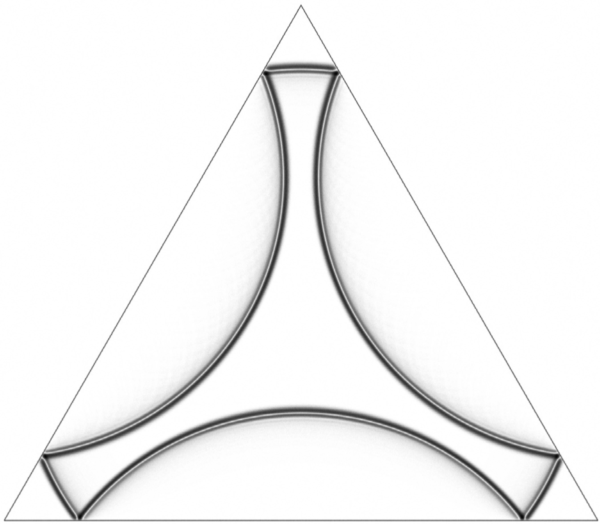
a wave reflecting from a surface

If a flat surface is introduced into the path of expansion, it will reflect a portion of the wave and send it in another direction. A similar condition can be experienced outdoors with the facade of a distant building, or the smooth underside of a bridge overhead. If the surface is far enough away, the reflected sound will be perceived as an echo—a distinct sonic event.



energy escaping from a partial enclosure

More or extended surfaces can increasingly surround the expanding sound wave. Voids allow portions of the wave of energy to exit, either directly or following interaction with multiple surfaces. Partial enclosures can be experienced as band shells, pavilions, and parking garages, the enclosures of which are arrangements of solid and void. To a listener within, enclosure voids are indistinguishable from complete absorption: whether sound exits or is obliterated by a deep porous surface, it is not returned into the space.



a fully enclosed wave of sound energy

If more surfaces are added to form a full enclosure, the expanding wave will be contained.

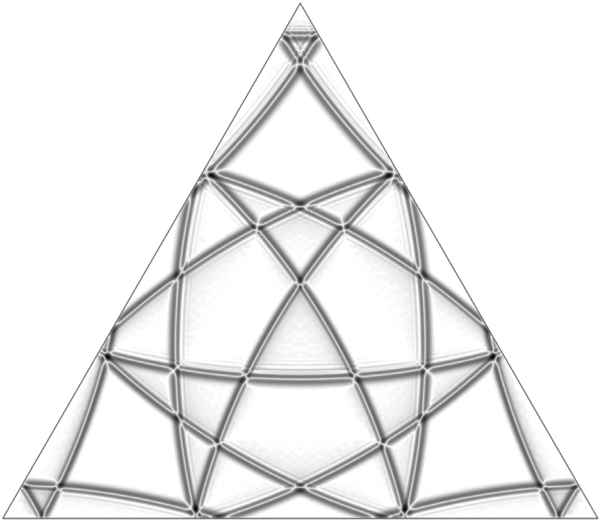
focus, diffuse, inside, and outside depend on source location

The behavior of an enclosure depends on its shape and spatial relationship to the sound source.

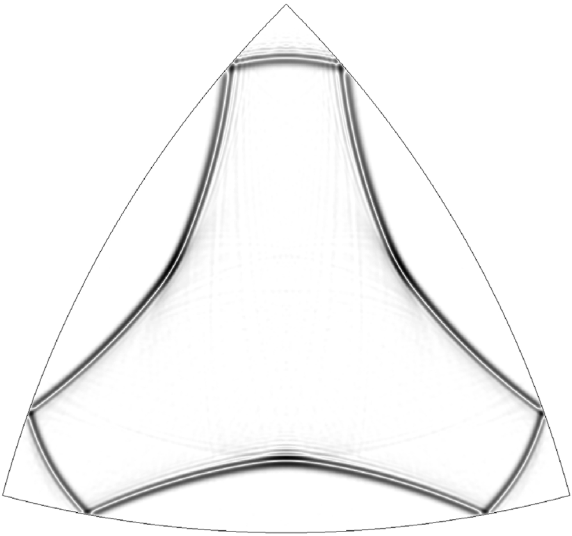
A curved surface will focus sound in a limited region on one side, and diffuse it everywhere else. The location and extent of focusing depends on the severity of curvature. An enclosure will contain sound if the source is located within its boundaries, and will usually disperse it if located without.

In enclosures made entirely of flat surfaces, an expanding wavefront will keep expanding, but its footprint will be limited by the enclosure. Like the lengthening of the roots of a plant in a pot, the wave will grow and distribute within a defined space. Unlike roots, which adapt in complex ways, the wave of sound can be thought of as perpetually folding at the boundary, over and over again as time advances. The energy of the wave eventually fills the entire interior. The listener within hears a barrage of steadily weakening reflections that become increasingly dense in time. Enclosures made of relatively few planar surfaces—like pyramidal, rectangular, and trapezoidal spaces—all tend to distribute energy at a similar rate, assuming similar interior volume. They all allow the waveform to expand like it does in the free field condition, except that it is folded over and over at the boundary. This is a benchmark in acoustic architecture. The large planar surfaces that dominate the built environment yield spaces that all exhibit similar sonic character.

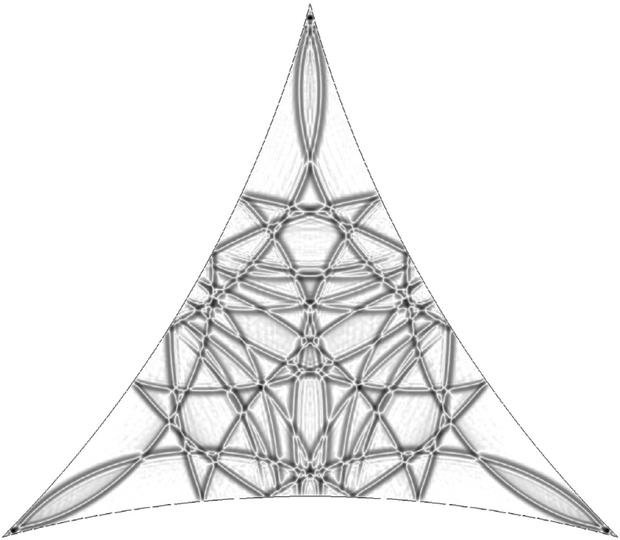
Departures from this benchmark can happen in two directions. The enclosure shape can either concentrate sound energy and slow its dispersion, or dissipate it more quickly. The architect can choose which. If the surfaces are large, sweeping, and concave to the listener, such that they focus sound, the rate of dispersion is slowed. This is why domed and cylindrical spaces are so often acoustically problematic; they prevent the dispersion of energy. In the other direction, of surfaces that are convex, concave of small radius, or otherwise complicated such that they spread sound out, the rate of dispersion is quickened.



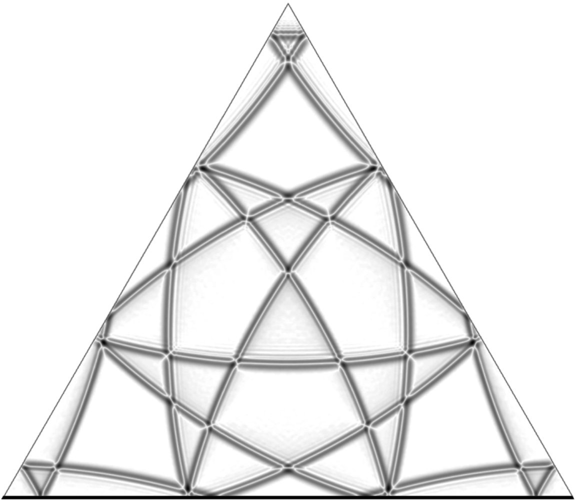
the planar benchmark



slowing the dissipation of energy



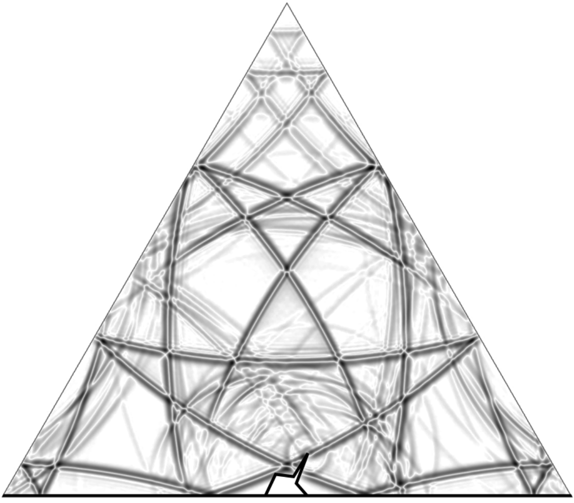
quickening the dissipation of energy



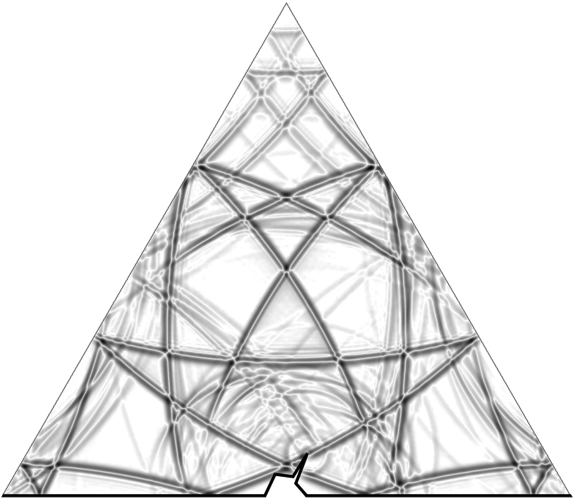
sound energy in an empty space

Place an object in a space, and it will change the sound of that space.

Changes of enclosure shape of any kind will modify acoustic behavior. Sound does not distinguish between objects added and surfaces deformed. It does not distinguish between that which is intentionally acoustic and that which is not. A room with a floor shaped to express the form of a chair will sound the same as a room with a chair placed as an object.



sound energy in a space with an added object



sound energy in a shaped space

Three-dimensional ornament influences the sound of spaces. It usually increases the surface area of the enclosure and therefore quickens the decay of sound within. When architecture shifted away from ornament in the late nineteenth and twentieth centuries, acoustically-dissipative spaces shifted toward the more reverberant planar benchmark. Sound sustained longer in the spaces of intersecting planes than it did in the more complex enclosures that preceded them. Manufacturing technology pushed this even further by giving rise to nearly-true surfaces; a planar wall of machine-made gypsum board is more flat than one of hand-applied plaster. The acoustically-significant subtle variations of the craftsperson were lost, and architecture locked into the planar benchmark.

The loss of ornament left a sonic void, into which a new type of applied architectural product arose: acoustic panels. This was partially in response to the need for acoustically dead environments for new audio broadcasting and recording technology, but it also acoustically corrected for the loss of complexity in room shaping. Manufacturers offered architects an additive option, the purpose of which was to shift rooms in the direction of quicker dissipation. Manufacturers also recognized that products added cost and an unwanted visual impact, so they worked to maximize the acoustic effect of every square meter of surface while hiding, as well as they could, the visual expression of the complexity of form this required. This was the moment sound and light separated within architecture. If the acoustics of a room needed to be improved, it was to be done with minimal visual impact.

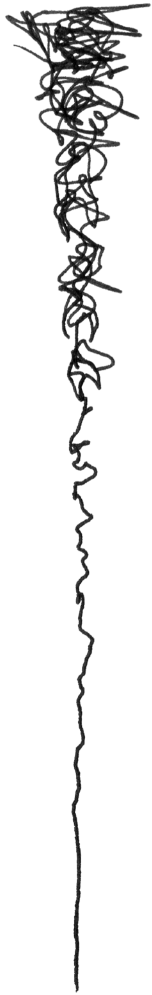
Manufacturers vied to be the sole solution rather than a mild contribution to the shape of spaces. Acoustic absorption became engineered and efficient. The innate acoustic influence of the non-acoustic—the integral surfaces, ornament, objects, furniture, textiles, plants, and people—began to be forgotten. Acoustics became equated with the selection of a product. An entire field of expertise simultaneously arose which was dedicated to understanding sound in spaces; its work centered on which products, and how much to use, to treat each space. These experts were, and still are, employed on only a small fraction of projects, and their knowledge has yet to merge into architecture. Acoustics is something outside of architecture, to be minimized if not avoided altogether.

Some manufacturers produce acoustic products that express visual complexity. Custom solutions driven by the architect can be found. This is a recognition that objects have acoustic influence, and acoustic geometries have visual implications, but composing the sound of rooms with the subtle acoustic effect of every part of the interior is the future that has yet to be realized.

Material limits shape and scale.

In acoustics, material should mean the substance, like glass or concrete, and not configuration, such as fiber glass or concrete block. Some materials can take forms that access any category of acoustic behavior: transmission, focus, reflection, diffusion, and absorption. These materials expose a continuous spectrum of geometric and acoustic possibility. The enclosure in the thought experiment morphs from one condition to the next without material changes or a distinction between that which is acoustic and that which is not.

Evidence for the importance of form is empirical. Any material when shaped into felt of ample depth and density will absorb, when made into peaks and valleys will diffuse, and when made into flat sheets will reflect. Glass is common in planar form, which acts as a flat, reflective sonic mirror. Glass can be perforated to allow sound to pass through unimpeded. It can be cast, bent, or slumped into three-dimensional forms that focus or diffuse sound energy. The atrium at the Charles H. Wright Museum of African American History in Detroit is a space that focuses with glass; the acoustic wonder of its visually transparent dome can be experienced by standing at the center of



the acoustic continuity of materials

the floor and making any sound at all. If glass is drawn into fine fibers and woven or needled into blankets, it becomes absorptive to sound. Glass spans the range of acoustic properties traversed in the thought experiment, including the underexplored regions that lie between established moments of acoustic behavior. Resin, metal, stone, and frozen water are just as acoustically versatile. The Great Lakes Region offers the acoustic range of frozen water, from specular reflections off expansive, flat surfaces of ice, to the diffusion of ice formations, to the quiet absorption of newly-fallen snow.

Arrange an acoustic reflector, diffuser, and absorber side by side, and an increase in complexity will be apparent.

The reflective surface is smooth and flat, and will have a surface area that is easy to determine. The diffuser breaks into the third dimension; it has greater geometric complexity and an increased dispersive effect on sound energy. This progression is taken further into the realm of absorption with smaller scales and innumerable tortuous pores or intertwined fibers. The complexity of porous acoustic absorption is very high. One square meter of absorptive melamine foam, ten centimeters thick, has an exposed surface area of hundreds of square meters if its small-scale structure is counted. Hanging a panel of foam is not just adding an object; it is a substantial increase in the complexity of the geometry of the space. The geometry of a rectangular slab of foam has been limited to length times width; let it now be far richer and include the scale of pores and struts.

Sources of light—artificial and natural, intentional and incidental—illuminate rooms and the objects they contain. Humans perceive a combination of direct and indirect light, in a straight line from the source and following interaction with the room surfaces and objects. The speed of light is 299,792,458 meters per second and its wavelengths range from about 380 to 700 nanometers. It outpaces any other movement in the universe and is orders of magnitude smaller than the width of a human hair. Light is so fast and small that, to humans, it seems immediate and of almost unlimited spatial precision. It conveys great detail: the weave of a textile, the structure of a song in the grooves of a record, or the gradual shift in color over a surface. Light is easily modified with thin applications, like a layer of paint, because its wavelengths are minuscule. If the texture of a frosted pane of glass is magnified, it reveals intricate and complex shaping, the variations of which are similar in size to the wavelengths of light they are diffusing. This is a general property of waves of energy.

In acoustics there are also sources that are artificial and natural, intentional and incidental. People speak, loudspeakers thump, objects slide on surfaces, rain falls on metal rooftops, and cars pass outside, their sonic energy crossing the envelope of the building to join the chorus of sounds within. As with light, direct and indirect paths are perceived. Audible sound is much slower and larger than light. It moves at about 343 meters per second in air, and ranges in wavelength from a few centimeters, like the sound of rustling leaves, to twenty meters, like the deep bass of a thunderclap. When a light source is switched off, darkness comes instantaneously. When a sound is ceased, silence can take seconds to arrive. Sound energy interacts with its enclosure, slowly diffracting, reflecting, interfering, resonating, and mixing until the energy dissipates beyond audibility. The shape and material of the enclosure determine precisely how this unfolds.

Since sound has large wavelengths, the breadth and depth of geometric surfaces need to be large to influence those wavelengths.

Large areas have greater influence than small areas because they occupy a larger fraction of the enclosure. Deep shaping reaches lower in frequency than shallow shaping. The wavelengths of sound are often too large to resolve the shaping of objects and surfaces, which makes small coverage areas and shallow geometries frequently ineffective.

The precise geometry of a space is variable to sound, with precision of detail increasing as wavelengths grow smaller.

In practice, the architect does not need to invoke the entire range of scales necessary to influence all audible wavelengths. Limited ranges work because most of the built environment serves the human voice, which occupies a smaller wavelength range within the large range of audibility—from about eight to one hundred centimeters. To simplify even further, a surface only needs a depth of about one quarter of the wavelength to have an influence. In other words, if the designer invokes geometries with features in the two to twenty-five centimeter range, the sound of the human voice can be dissipated. Deeper and wider geometries influence the larger audible ranges of music, machine, and the non-human.

Geometric systems of smaller scale can be acoustically powerful in aggregate. The fibers and struts that compose felts and foams have diameters far smaller than two centimeters, but they are assembled into larger-scale systems that reach effective dimensions.

fine structures yield large-scale systems

The blank planar spaces of glass panes, polished concrete, and painted gypsum board lack geometric complexity in the two to twenty-five centimeter range. They sustain sound longer than is conducive to human communication. People, furniture, curtains, thick carpet, plants, and dedicated acoustic panels all have depth and complexity. Even the products that appear flat, such as lay-in ceiling tile, exhibit depth and complexity on the right scale for the human voice. Books, among the most important objects of human communication, are usually of dimensions easy to hold and manipulate—a few centimeters to a few tens of centimeters. They offer acoustically beneficial variation of shape at the right scales. The objects humans design for use by their bodies tend to complement the scale of the sound their bodies produce, but they are not yet designed with acoustic intent.

These ideas
are connected.

Material is substance

composing surfaces and objects

all acoustic, all moments on a continuum

integrally determining the shape of enclosure

giving it form

from the tiniest pore

to the largest sweeping curve

the whole of which decides the quickness of the fate

of sound made within

Collectively, there is an underlying structure: the room and everything in it determine shape, and the more complex this shape, the more quickly sound will dissipate within.

An idea emerges and a new conjecture is proposed.

The Sphericity Conjecture: The more the shape of a room deviates from the sphere of equal volume, the more quickly sound will dissipate within.

Sphericity is a mathematical measure of deviation, of complexity of form. It can be defined in numerous ways, including relating enclosure surface area to that of the sphere, which has the minimum possible surface area for any given volume. A precise determination that considers the complexities of acoustics, such as the ability of different wavelengths to resolve scales of detail, is beyond the scope of this essay, but the concept offers a useful qualitative guide for the design of spaces. The more complex the room boundaries—the higher their surface area, whether from surface shaping, textiles, objects, or any other three dimensional form—the more quickly sound will dissipate within. The volume of the enclosure also matters, with greater volumes yielding longer dissipation times, and smaller volumes yielding shorter dissipation times.

The architect can design acoustically by using volume and surface area as guides, regardless of material. The spherical room is the most extreme acoustic space. In the absence of material resonances and air absorption—in consideration of shape alone—it will sustain a centrally-originating, spherical wave forever. Deviations from the spherical form break the enclosure away from this extreme, infinite condition. The built environment abounds with evidence in support of the Sphericity Conjecture when the terms acoustic, material, shape, and scale are clarified.

The sphere is balanced at the opposite end of the geometric spectrum by the most complex acoustic enclosure: the anechoic chamber. This research-grade annihilator of acoustic energy has such a large surface area that dissipation happens upon first interaction with the expanding wave. These two conditions define the range of possible sound dissipation time, from infinite to zero, with all enclosures in architecture falling between.

$$T = k\frac{V}{S\alpha}$$

No single parameter is sufficient

to describe the dissipation of sound in a room. Reverberation time is the parameter that dominated twentieth century acoustics. It, like all parameters, is a simplified representation of the complex behavior of sound. Reverberation time is useful because it can be correlated with the experience of a listener. Few rooms are successful if they exhibit reverberation that is too long or short, yet rooms that meet accepted targets are not guaranteed to have good sound.

Reverberation time can be measured, calculated, or simulated. It is usually defined as the number of seconds required for a sound to decay by sixty decibels, or a typical speaking voice dropping to inaudibility. The easiest method is calculation using an equation devised by Wallace Sabine in the 1890s.

The Sabine Equation is simple and elegant. It requires only four numbers: the constant k, room volume V, room surface area S, and average absorption coefficient α. Surface area in this case is traditional, meaning a rectangular wall of foam would use length and width, and not include the small-scale contributions of pores or struts. Absorption coefficient α usually ranges from zero to one, where higher values mean more absorption. The Sabine Equation can be used for each frequency under consideration or for the average behavior of the room across the audible range.

The equation represents common experience: large reflective spaces are more reverberant than small absorptive spaces. But it deviates from reality if the total absorption is too high, or if the proportions of the room are too extreme. This is not a problem as long as its limitations are understood and it is used only on spaces for which it is accurate. Other equations have been proposed since Sabine's, some extending its functionality, and each with their own merits and limitations. They all exhibit the same basic behavior, and all require the variables V, S, and α.

In his essay *Architectural Acoustics*, published in The Journal of the Franklin Institute in January 1915, Sabine wrote of reverberation: "Broadly considered, there are two, and only two, variables in a room—

shape (including size) and materials (including furnishings)." In the Sabine Equation these two variables are not as distinct as they are in the statement. Sabine's "two, and only two, variables" are actually spread across the three mathematical variables—V, S, and α—and confusion over where shape ends and material begins is common.

Volume, V, is straightforward. This is what Sabine means by "size", and its role in his equation fits the observed built environment well. The larger a room, the more reverberant it will tend to be. Surface area S and absorption coefficient α are where confusion between shape and material arise. A rectangular wall of flat glass has S determined by its length and width, and a low value of α because flat glass absorbs little sound. The same wall, but of fiberglass, has the same S and a high value of α because fiberglass absorbs sound well. In this view, S does not change and the difference in acoustic behavior is represented by a rise in α. Flat glass sheets and fiberglass are considered different materials. Yet, both panels are made of glass. The change in acoustic behavior cannot be due to a change in material-as-substance. If a different material such as resin, metal, or stone were substituted the same result would be observed: flat sheets would have low absorption, and fibrous systems would have high absorption. α is clearly influenced by shape if the right range of scales is considered. The architect is asked to accept that two panels of the same footprint and material exhibit different acoustic behavior. No explanation is given as to why this is. There is simply a claim that one is an absorptive material and one is not; one is acoustic and one is not.

For the product industry, which is driven by reverberation time reduction, most of the spectrum of architectural geometry is not inviting because its influence on reverberation is mild. Manufacturers prefer high-α foams, fibers, and felts because they move the dial of the Sabine Equation with minimized coverage. Surfaces designed to diffuse are low-α and do not appeal, except for certain concert hall and recording studio surfaces, where their sound-blurring effect is deemed critical. Absorption has become synonymous with acoustic performance in the language of architecture. Spaces are designed with acoustically reflective planes, and high-α acoustic products are applied to fix the resulting reverberation. This is high-contrast acoustic design, akin to visual design in white with an occasional black surface or object. The approach fails to leverage the acoustic influence of every surface and object in the space. The acoustic ornament of pre-modern design has aggregated into off-the-shelf panels of concentrated acoustic influence, and the room itself and everything in it have been relegated to non-acoustic, as if they somehow do not determine room shape and therefore sound. The dominant theme of twentieth century acoustics, engineered appliqué, propagates.

The Sabine Equation tells part of the story of shape. Volume V, traditional surface area S, and absorption α all include aspects of shape. But the process and parameters of acoustics leave the story incomplete, and that which is told is inextricably meshed with unclear definitions of material. Shape is left an unusable factor in the design process.

The reconsideration of surface area as inclusive of fine scales, and of material as substance, yields sphericity, and a remarkable parallel emerges. In the Sabine Equation, the structure of the three variables under the control of the architect—V, S, and α—moves like sphericity does. For Sabine, the higher the absorption and the greater the area of coverage, the lower the reverberation time. For sphericity, the higher the true surface area of the room, the quicker the dissipation of sound.

One is not a substitute for the other. The Sabine Equation and sphericity have different origins and limitations; they accomplish different things. But they move together. The expansion of surface area to include the scale of fibers and pores encompasses the general behavior of the absorption parameter α, aggregating it into a more intuitive geometric parameter. The architect can design for precise reverberation time using the Sabine Equation, or they can opt, in many situations, to design for general dissipation using sphericity and any material. The precise quantities of physics are not necessary to design in the right direction. Objects and surfaces that were not measured in the laboratory can still be used intuitively.

I sit outside in the evening with my friend, the architect,

enjoying the fall Detroit air and colors.

“It seems I need some acoustic materials. It is unavoidable. The cylindrical space will be too reverberant.” she says. She is disheartened. Material and form are important to the project.

“You’ll want high absorption to minimize coverage.” I offer, empathizing and preparing to disappoint her.

“What do you mean by minimize?”

“There is a range. Probably twenty percent. Most of the ceiling and part of the walls. I can run the numbers to know for sure.”

“Covering twenty percent of the surfaces? With acoustic panels?”

“Yes. An α of least 0.50. Some options at least look like solid surfaces.”

I sit outside in the evening with my friend, the architect,

in the cool spring air. The trees are budding.

"I want to make sure I understand this. I don't need acoustic materials?" she asks. The project is in early stages.

"Think of them all as acoustic materials. The cylindrical design will be reverberant. If you don't want that, you need to get the surface area up."

"With the concrete or the glass?"

"Either. Or both. Or introduce new materials. Every gesture helps. Express the lines of force that move through the concrete. Facet the concave glass, or turn it inside out entirely and make it convex. Give it patterns and depth. Think sculpturally. If you want less reverberation, find more surface area."

"The cylindrical form is important."

"Then there is a conflict. The cylinder is too close to the sphere to yield the acoustic behavior the space needs. You could separate the visual from the acoustic by invoking the small-scale geometries, like the acoustic panel manufacturers do. Fibers, pores, and microperforations bring exponential increases in surface area and can look like large-scale geometries. That is all acoustic absorption is."

There is a long pause. Detroit is a good place to think.

She breaks the silence: "If concave shapes focus sound and fibers absorb sound, what happens in the geometric realm between the two?"

Three-dimensional ornament was never without function.

Objects and shaping were never non-acoustic. Complex rooms dissipate sound more quickly than simple rooms, even if every deviation in shape, including every object within, is made of polished stone. The vast region of architectural enclosure geometry between the stark, flat reflector and the finely-structured absorber is usually only accessed unintentionally in waffle slabs of concrete, undulations of brick walls, corrugations of steel ceilings, and the sculptural form of art, furniture, ornament, and object. This vast region includes the surfaces that diffuse sound but it can be more usefully thought of as a region of increasing geometric complexity, bridging reflection to absorption, with the entire spectrum marked by increasing dissipation.

The simplest and most extreme acoustic enclosure is the sphere. It has the minimum possible surface area for any interior volume, and it preserves the spherical waveform forever. This assumes idealized conditions, with a central source and without material resonances or air absorption. Such idealized departures offer a starting point for the design of acoustic spaces.

Dissipation is central to acoustic design, so begin with the condition that is perpendicular to the wavefront at every point, that sends it back to its origin at the center over and over again. Begin at the extreme of possible enclosure form: zero deformation.

Any deviation from the spherical shape triggers the dissipation of the original waveform, and the greater the deviation, the faster the dissipation. With small deviations the enclosure enters the realm of large domes and cylindrical walls—the classic forms that have always invoked the acoustic wonders of focusing, amplification, and whispering galleries. These forms are embraced, endured, or met with the application of absorption to turn off the dominant surfaces, without awareness that such a gesture is shifting the space across the planar acoustic benchmark into the realm of faster dissipation.

Beyond the domes and cylinders lies a realm where the focusing surfaces have flattened into rooms comprising large planes. This is the acoustic benchmark that allows sound to spread as it does in the free field, but with a repeated folding that confines it to a limited volume in space. These are the planar spaces of modern architecture, of empty rooms and two-dimensional ornament. They do not sustain sound as long as the domed and cylindrical spaces, but they are reverberant and can be detrimental to most architectural uses if they are invoked without intent.

Distorting the enclosure further, past the planar compositions, brings the realm of diffusive spaces. This comprises everything from large convex surfaces to small shaping and ornamental detail. It includes the room shape-altering presence of non-porous furniture, plants, books, and lightly-clothed people. Coffered ceilings reside here, along with the surface variations of masonry, the imperfections of hand-applied plaster, the locally-focusing small concave surfaces, the carved wood, 3D printed formations, sculpture, fixtures that provide light, and most objects that humans manipulate manually. Depth determines how much of the audible spectrum is influenced, and total coverage determines whether these mild contributors sum to significant effect.

Pushing further, exponentially-rising surface area brings the realm of absorption, accessible with minuscule formations and great depth and complexity, where changes in geometry are so severe that they seem a change in material. The geometries of this realm are tactilely soft: clothing, cushions, carpets, and textiles—the stuff of fibers and pores. These high-surface area systems are invoked in the development of corrective acoustic panels to tame the planar walls and curved surfaces of the other realms of acoustic geometry. As with diffusion, depth and coverage determine extent of influence. The extreme of this realm is bounded by a complexity that yields the briefest life for an expanding wave of sound. From the minimal surface area and infinite propagation of the sphere, deformation finally yields the maximal surface area and immediate dissipation of the anechoic chamber.

There is perhaps another realm beyond the anechoic chamber: the absence of enclosure, the transmissive meshes and voids in the boundary that expose inside to external surroundings. The open window, the doorway to a long hall, the missing wall, the oculus in the ceiling, the well deep into the ground—none return sound. Openings have always been akin to areas of high absorption in acoustics; the old tenet says an open window is like a perfect absorber. In the new language the ideas remain consistent. An opening exposes the vast surface area beyond, which provides the ultimate dissipation, not entirely unlike the absorptive surface exposing the vast surface area of the small-scale structures that live within its boundaries.

Categorizing surfaces and objects as focusing, reflective, diffusive, absorptive, and transmissive can be useful, but these elements are parts of something bigger. Enclosure geometry and its parts move continuously between them, yielding infinite possible moments and combinations. Shape connects objects with surfaces, and surfaces with rooms. The sound of a space will soon be composed by determining these moments, which lie on the geometric continuum from the sphere to the anechoic chamber. Unexplored regions will be accessed using sphericity as a guide. The expression of non-acoustic function will be optimized for sound, and ranges of acoustic influence will be traversed with adjustable, adaptive, and reactive shape-changing systems. Acoustic environments will be generated without need for measurement or simulation. Mild form and the non-acoustic will expand the idea of a single-product choice to include consideration of all objects and surfaces. Materials that access the range of acoustic scale will come to the fore, and will include new materials noted for their ability to span the range of audible geometries. Intuition will enter the acoustic design fold at a massive scale as a new understanding of acoustics takes hold, and integration and gradients of acoustic behavior will become alternatives to the patchwork of appliqué. The shape of the room at all scales will be composed for sound.

To tame reverberation, regardless of material, the architect can invoke surface area as a guide. Surfaces, structure, furniture, objects, textiles, fixtures, plants, liquids, earth, humans, clothing, ornament, and void—the tangible nouns of architecture—can be shaped and deployed with acoustic intent. It begins with the spherical enclosure. Every deviation from the sphere is an embellishment that furthers the departure of a room from minimal form and infinite sound. Every deviation is, in a way, acoustic ornament, which has always functioned as a catalyst for the dissipation of acoustic energy.

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The Mapparium at the Mary Baker Eddy Library, by Chester Lindsay Churchill, Boston, Massachusetts, 1935

Room Zero at Riverbank Acoustical Laboratories, by Wallace Clement Sabine, Geneva, Illinois, 1918

Collected Papers on Acoustics, a book by Wallace Clement Sabine, Harvard University Press, 1922

From Ornament to Object, a book by Alina Payne, Yale University Press, 2012

Thousands of unnamed spaces, each reacting to sound with their unique shape

The large planar surfaces that dominate
the built environment yield spaces
that all exhibit similar sonic character.
Departures from this benchmark
can happen in two directions.
The enclosure shape can either concentrate
sound energy and slow its dispersion,
or dissipate it more quickly.
The architect can choose which.