
Meet Me
at the
Whispering
Spot

HOW DO ARCHITECTS THINK ABOUT ACOUSTICS?

by Brittany Moya del Pino

Architects use computers, curves, zigzags, and plaster petals to make you hear what they want.

Deep in the belly of the United States Capitol, there is a grand old room with high curved ceilings where something strange will happen if you stand in just the right place and listen.

This room is called the National Statuary Hall. In the white marble floor, look for a small plaque made of brass that marks where John Quincy Adams once kept his desk. If you stand at this point, you'll be able to hear the voice of your friend who's standing at a corresponding location a few dozen feet across the room. But her voice will sound clear and loud, as though she is speaking only inches away from your ear.

Tour guides call this the "whispering spot." They tell a story about it: back in the 1800s when the House of Representatives used this room for meetings, they say, Adams would pretend to fall asleep at his desk so that he could eavesdrop on his fellow legislators who happened to be standing at that other spot. The part about the eavesdropping is just a rumor. But the part about the sound qualities of the room being so weird that the legislators couldn't stand it and eventually switched their meetings to the current chamber? That's totally true.

This isn't the only building with a whispering spot. St. Paul's Cathedral in London has one. So does the Mormon Tabernacle in Salt Lake City. And in a part of New York City's Grand Central Terminal, if you cuddle into the corner and listen, you'll hear the same effect.

What's the secret to these spaces? The answer can be found in geometry.

A PERFECT SHAPE

The curves of the ceiling and walls in the Statuary Hall, like the other rooms with whispering spots, follow the shape of an ellipse.

The ellipse—a certain kind of oval—has a curious role in human history. It started with the ancient Greeks, who noticed that diagonal slices of a cone are elliptical. Elliptical shapes can also be found in the paths of planets that orbit our sun, the shadow cast by an orange resting on a tabletop, and the surface of water in a tilted glass.

Mathematicians figured out that an ellipse contains two fixed points called foci (pronounced "FOE-sigh"). Each point is known as a focus. The distance from one focus to the edge of the ellipse and back to the other focus is always the same, no matter what path you take.

It's easier to see this if you have a piece of cardboard, two pushpins, and a length of string. Press the pins into the cardboard several inches apart. These pins are now your foci. Then tie the string in a loop that fits loosely around the two pins. Hook your pencil inside the string and draw a swoop around the center. The line you make will be an ellipse. (If you rotate a 2D ellipse on its axis, the resulting 3D shape is called an ellipsoid.)

When sound waves originate from one of the two foci—say, John Quincy Adams's desk—in a partly ellipsoidal room, the waves spread out to the surrounding walls and ceiling, reflect off their curves, and arrive simultaneously at the other focus. The time that it takes for sound to travel between the two foci is constant, just like the length of your string. Because all of the reflected sound arrives at once, the volume is unusually loud at the foci of the room and strangely quiet or muffled everywhere else.

This is why architects today who understand acoustics will generally avoid designing rooms with a perfect elliptical shape, according to Gary Siebein, a professor and consultant in architectural acoustics who works in Florida. "There were theories in the Renaissance . . . copying from the Greeks and Romans, that said if you had a room with perfect geometry, it would have to have perfect sound," Siebein explains. "But this wasn't scientifically correct. People continued to build elliptical rooms all the way up until the 1800s."

A NOT-SO-PERFECT SOUND

In 1800, a German architect named Carl Ferdinand Langhans debunked the idea that elliptical rooms sound the best.

His father had designed a theater in Berlin that was shaped like an ellipse, believing it would have excellent acoustics. But in reality, the theater was riddled with echoes. In some zones, the performance was way too loud, and in other areas sounds were so muddled that listeners couldn't distinguish vowels from consonants or timpani from trombones.

Langhans, junior, said that the problem was timing. The first sound to reach the audience came straight from the stage. But then the audience heard the sound reflecting off of the walls, which came a little later because it had to travel farther. The sound reflecting off the ceiling arrived last, a few dozen milliseconds after the sound that was reflected from the walls. That difference in timing might not seem like much, but to the human ear, it matters a lot.

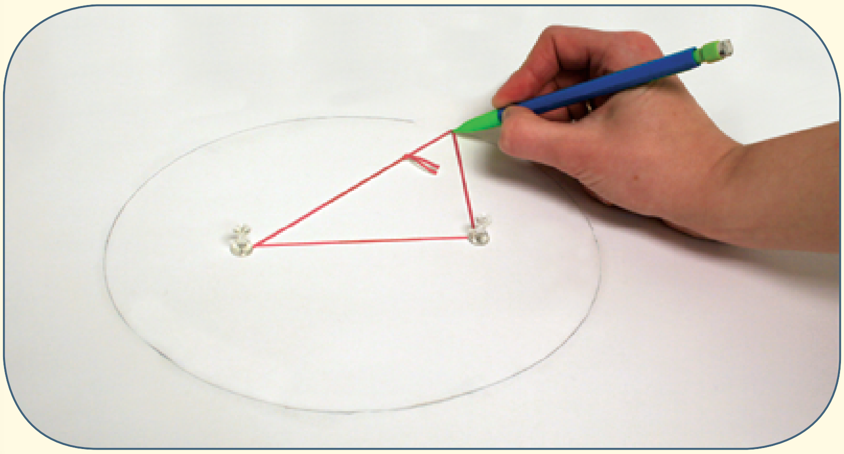
"If reflected sound waves arrive at your ear within about 50 milliseconds, your brain will add the waves together, making the overall sound louder than it actually is," Siebein says. "But if the ceiling is too high and the reflected sounds come after 80 or 90 milliseconds, you'll hear the sounds as distinct events or echoes, just as you would if you were standing at the edge of a canyon. The sound will just repeat."

Pssst! This is the National Statuary Hall in the US Capitol.

SHAPES THAT SCATTER

Siebein recounts a story about someone who hired him to solve the problem of an elliptical conference room. Anyone sitting at either end of the table (the foci of the room) could hear conversation just fine. But people sitting around the middle of the table had a horrible time hearing, even when each of the seats was fitted with a microphone. He helped his client fix the problem by hanging sound-absorbent materials on precise areas of the walls so that sound could scatter more evenly throughout the space.

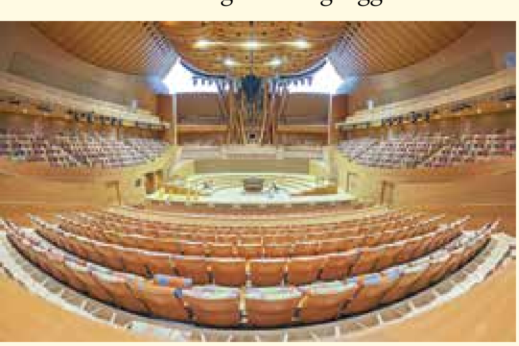
He and other acoustic architects use the same approach when they design elliptical performance spaces. If you visit the Walt Disney Concert



"Theories in the Renaissance said a room with perfect geometry would have perfect sound. But this wasn't correct."

Hall in downtown Los Angeles, you'll see that the room has a generally elliptical shape. So does Strathmore Hall in Bethesda, Maryland, along with dozens of other theaters and concert halls all over the world. They may look like elliptical rooms—but the walls, ceilings, and even the seats are sneakily working to prevent the foci problem.

"Most theaters or concert halls don't have very many flat surfaces," Siebein says. "Instead, they're curved or angled or zigzagged . . . in a number of ways to scatter sound." When he designs an elliptical room, Siebein wants sound from the stage to reflect toward two or three regions near the middle of the audience, three or four regions a little farther back, and ten or more regions at the very back of the audience. "My goal is to soften the sound and spread it over the entire room," he says.



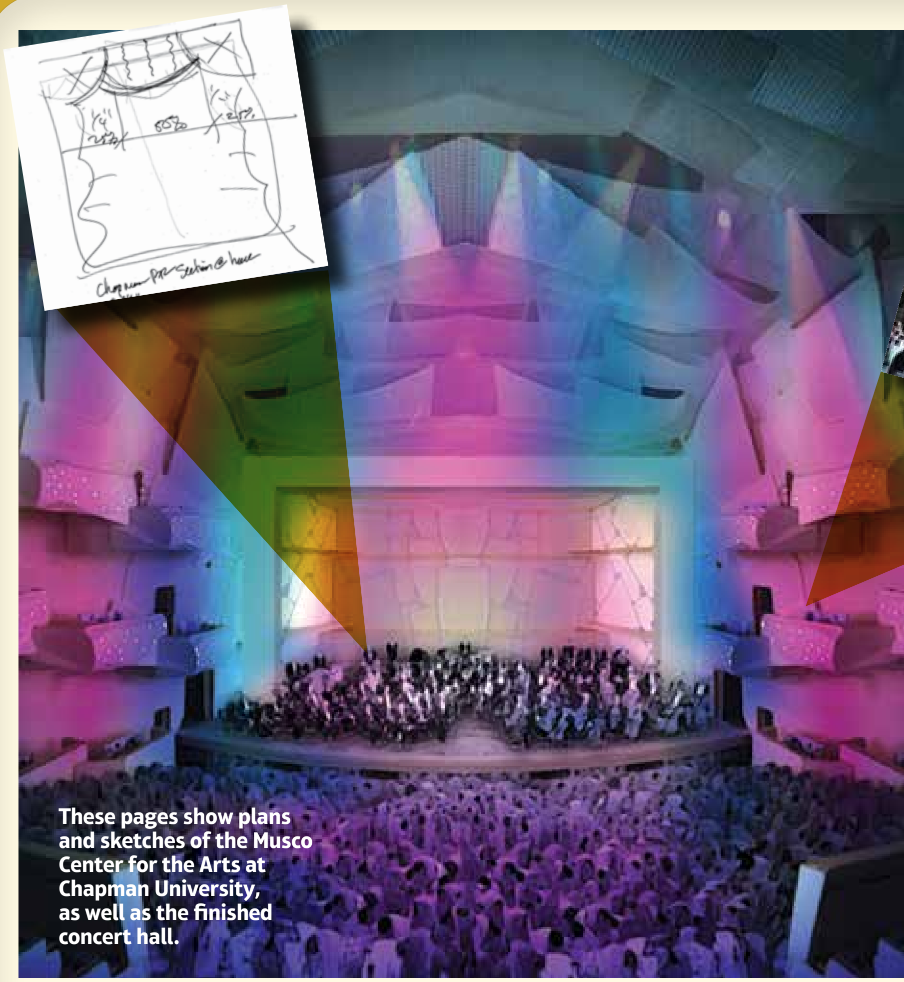
You can't just tack up a bunch of blankets or arrange statues at random if you want a room to spread sound correctly. Instead, acoustic architects use high-powered computer programs to build a virtual model of the room. The model will include every detail, from the size of the stage to the fabric on the seats, the number of audience members, and whether the act onstage is a jazz band, a solo acoustic guitarist, or an author reading from a book.

This lets the architects test how sound will be absorbed and reflected with each type of performance. The process is called auralization, and with it architects can use headphones to test the sound at a particular seat. They can also see a picture of how sound will bounce and collect, just like ripples on the surface of a pool.

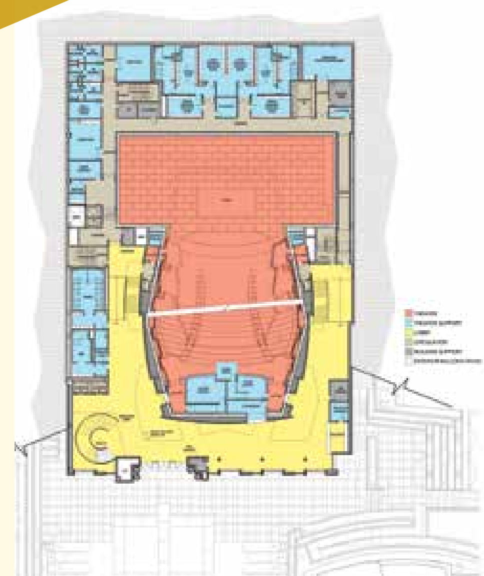
BUILDING A PERFECT ROOM

Once the architect has a room design that looks and sounds good, someone has to take that design and turn it into a real building. Every shape and surface has to be just right so the room functions with the same precision and beauty as a finely tuned musical instrument.

Felipe Engineer-Manriquez is a director at McCarthy Building



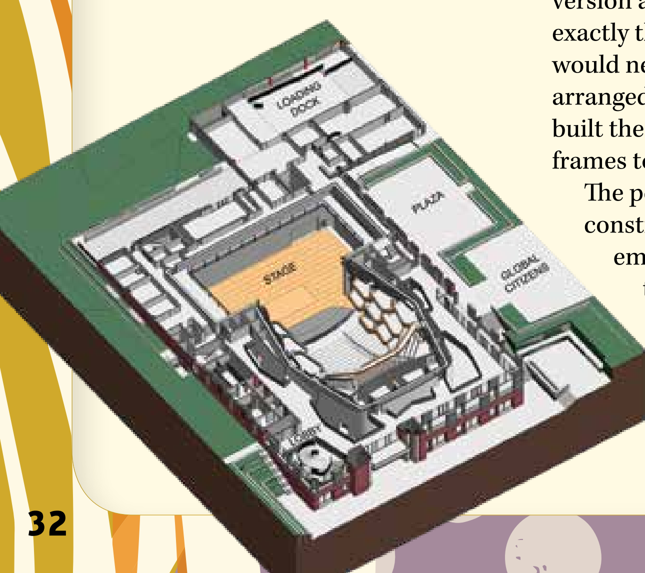
These pages show plans and sketches of the Musco Center for the Arts at Chapman University, as well as the finished concert hall.



Companies. He co-led a project at Chapman University, in southern California, to build a five-story concert hall that seats just over 1,000 people. It is shaped, generally, like an ellipse. "For some reason, I always get assigned to build the cool buildings," Engineer-Manriquez says. "I guess I've been lucky."

Chapman University's Musco Center for the Arts uses what the builders nicknamed "petals" to shape the reflection of sound from the stage to the audience. Each petal is mounted at a precise angle and height on the ceiling or wall. The petals overlap in rows and layers around the room, almost like a loosely woven basket.

Before McCarthy employees started construction, an architect made a smaller model of the theater using Styrofoam and paper. This mini version allowed them to figure out exactly the number of petals they would need and how they should be arranged. Then another company built the petals by kinking metal frames to have just the right curve.

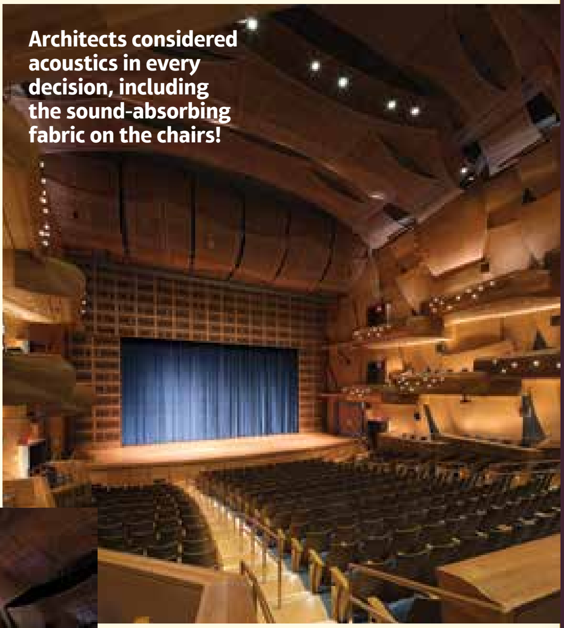


The petal frames arrived at the construction site, where McCarthy employees sprayed them with a thick coat of plaster so that the final weight of each petal was 20 pounds (9 kg) per square foot. Why so heavy? Because in a theater or concert hall, sound absorption is just as important as sound reflection. Heavier objects will absorb more sound. Lighter objects, such as ceiling petals made of metal mesh, will absorb only a little sound and reflect the rest.

"Everything in the room has to have a certain mass to prevent echoes," Engineer-Manriquez says. When the building was finished in 2016, sound engineers spent half a year "tuning the room." This involved adjusting certain moveable petals and hidden curtains to create the best listening experience for each type of performance.

"You can't help but stand on the stage when a project like this is finished," he says. "Everyone does it. We clap and hear the sound go out into the room, and it's like we're standing in a field. The sound doesn't come back to us at all. Yet we don't

The exterior of the Musco Center for the Arts



Architects considered acoustics in every decision, including the sound-absorbing fabric on the chairs!

need hand-radios to talk; we can hear each other easily, even across such a large space."

IN THE EYE (AND EAR) OF THE BEHOLDER

If the acoustic properties of an ellipse are such a problem—and if it requires so much effort to overcome an ellipse's inherent loudness, quietness, and echoes—why build an elliptical room at all?

Some people don't. Many theaters are shaped like rectangles, called a "shoebox" design. Or they might have a combination of shapes, something like a circle-rectangle hybrid. Engineers still have to do auralization in these spaces to make sure that the people who have spent their money on concert tickets will be happy with what they hear.

The real reason for designing an elliptical theater or concert hall is not about sound, but sight. "An

elliptical or otherwise roundish room will allow you to see the stage, but also see the faces of other members of the audience so that you feel like you're sharing the emotional experience of the performance," says Michael Ferguson, a theater design consultant in Los Angeles.

This takes us back to the fascination that ancient Greeks had with the ellipse. These days, however, it's not about theories of perfect sound; it's about the overall experience of a performance.

"Even the most obscure stuff in mathematics, decades later we find that it has real-world applications," says mathematician James Tanton. But that's not why researchers pursue these questions in the first place, he adds. "We are interested because it's fun and quirky. The ancient Greeks didn't study the ellipse for practical reasons. They did it for the sake of beauty."

Brittany Moya del Pino is a science writer living in Virginia. She has previously written for *Muse* about daydreaming and hibernating astronauts.