Marrying art, science and magic

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Observe a conductor or singer testing the sound of an opera house. Fingers snap. Hands clap. Syllables are shouted, then whispered. A vocalise wafts through the empty space. Head cocked, ears strain to listen.

How is great sound achieved? It starts with the acousticians and architects who design, build and fit the theater. Today's acoustic specialists use a combination of physics, sophisticated measuring and calculating tools, and a specialized palette of building materials to give modern concert halls their wonderful sound.

Sound waves propagate through the air to our ears following the same laws of physics as ocean waves crashing on a beach. The cycle of highs and lows determines the frequency (our perception of pitch) and amplitude (our perception of volume). Two sounds reaching our ears at the same point in their cycles are "in phase," while sounds that arrive at different points are "out of phase."

In fact, it is the subtle phase differences reaching our two ears in stereo that allow us to locate a sound source in space. Phase relationships have enormous consequences on the acoustics of enclosed spaces.

Vibrations from an "exciter" (for example, a diva's vocal chords) cause sympathetic vibrations in a "resonator" (the diva's head and chest cavity), which propagates waves outward in all directions. Waves striking a hard surface like a floor are reflected. Sound waves striking a soft surface like a carpet or curtain are absorbed.

The combination of direct sound, early reflections (sound reflected back a single time) and reverberations (multiple reflections) determine the ambient quality of a theater or hall. The time it takes for a sound to decay completely (reverberation time) depends on the size and shape of the hall and the reflective or absorptive properties of everything in it, including the audience.

A full hall sounds different from an empty one because warm bodies absorb more sound than empty seats. These acoustic phenomena taken together determine our perception of a hall as "bright," "warm," "dark," "wet" or "dry."

Higini Arau, an acoustician from Barcelona, oversaw the acoustical makeover of Milan's La Scala. He and his team used a myriad of measurements, calculations and design techniques to improve the sound dramatically. "Before, singers had to stand in particular places on the stage to be heard," says Arau. "There was even a Maria Callas spot!"

The acoustic modifications delved into every detail, down to the material of the

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