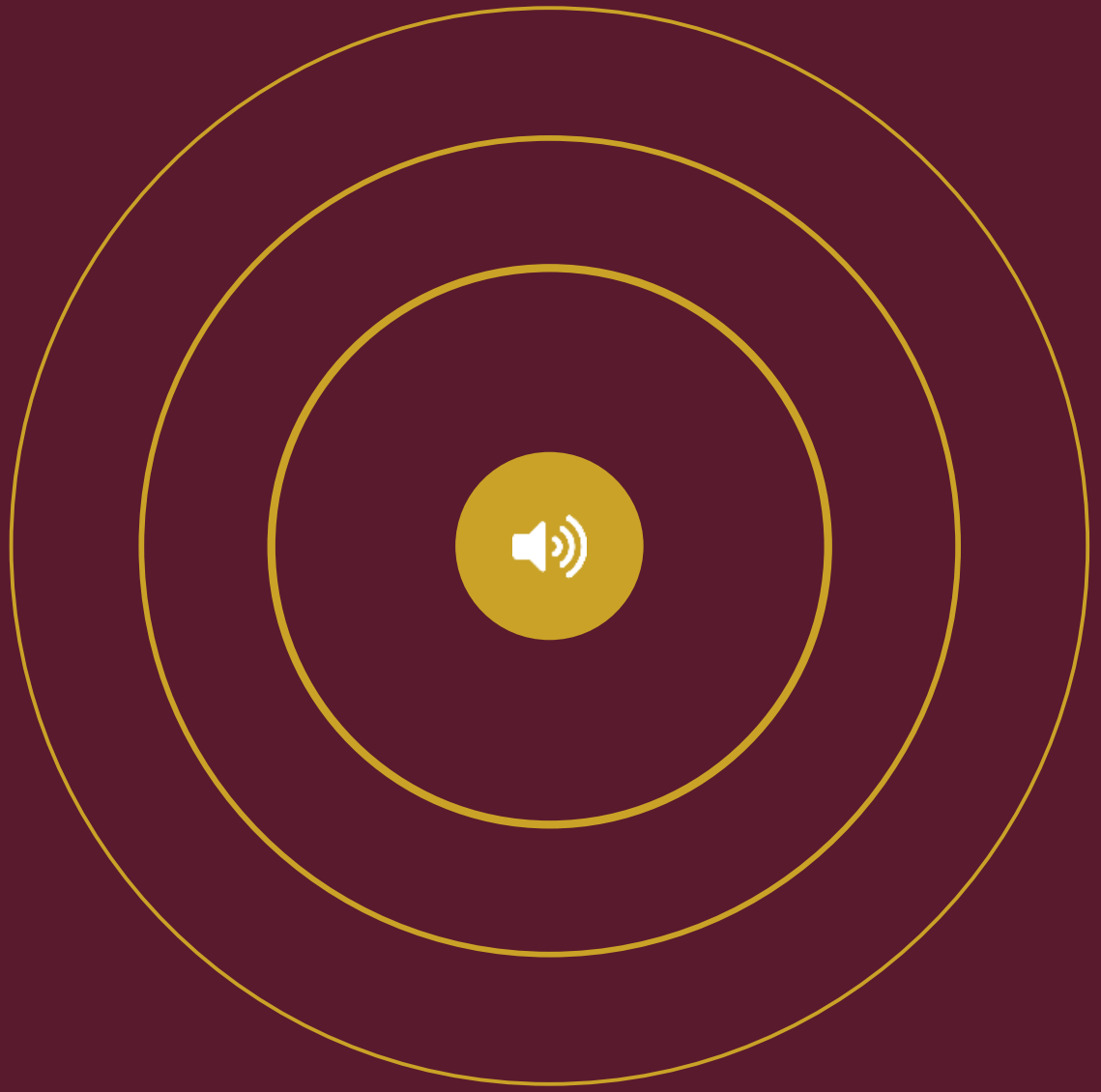
Room Acoustics

Why your voice sounds different in the shower, the classroom, and the cathedral

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Three Questions for Today



Where does the sound go?

Direct sound, early reflections, and the long tail that follows.



How long does it ring?

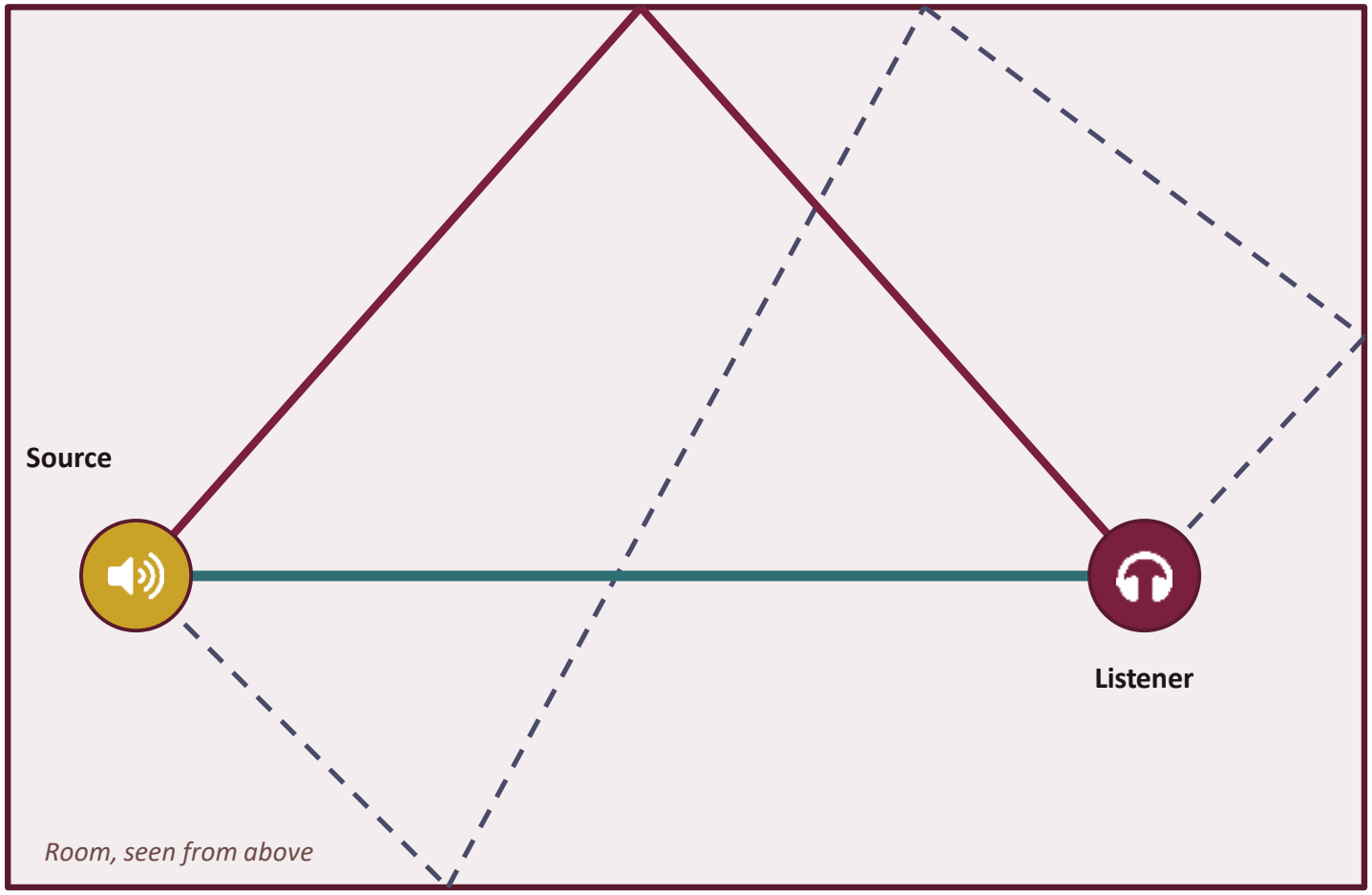
Reverberation time, and Wallace Sabine's elegant equation.



Speech or music: who wins?

Why a glorious hall for Bach can be a terrible classroom.

Sound's Journey Through a Room



Direct sound

Arrives first, in a straight line. This is the sound at its purest.

Early reflections

Bounce once or twice, arriving within roughly 50 to 80 ms. They add fullness.

Late reverberation

Reflections of reflections: a dense, fading tail. The room's signature.

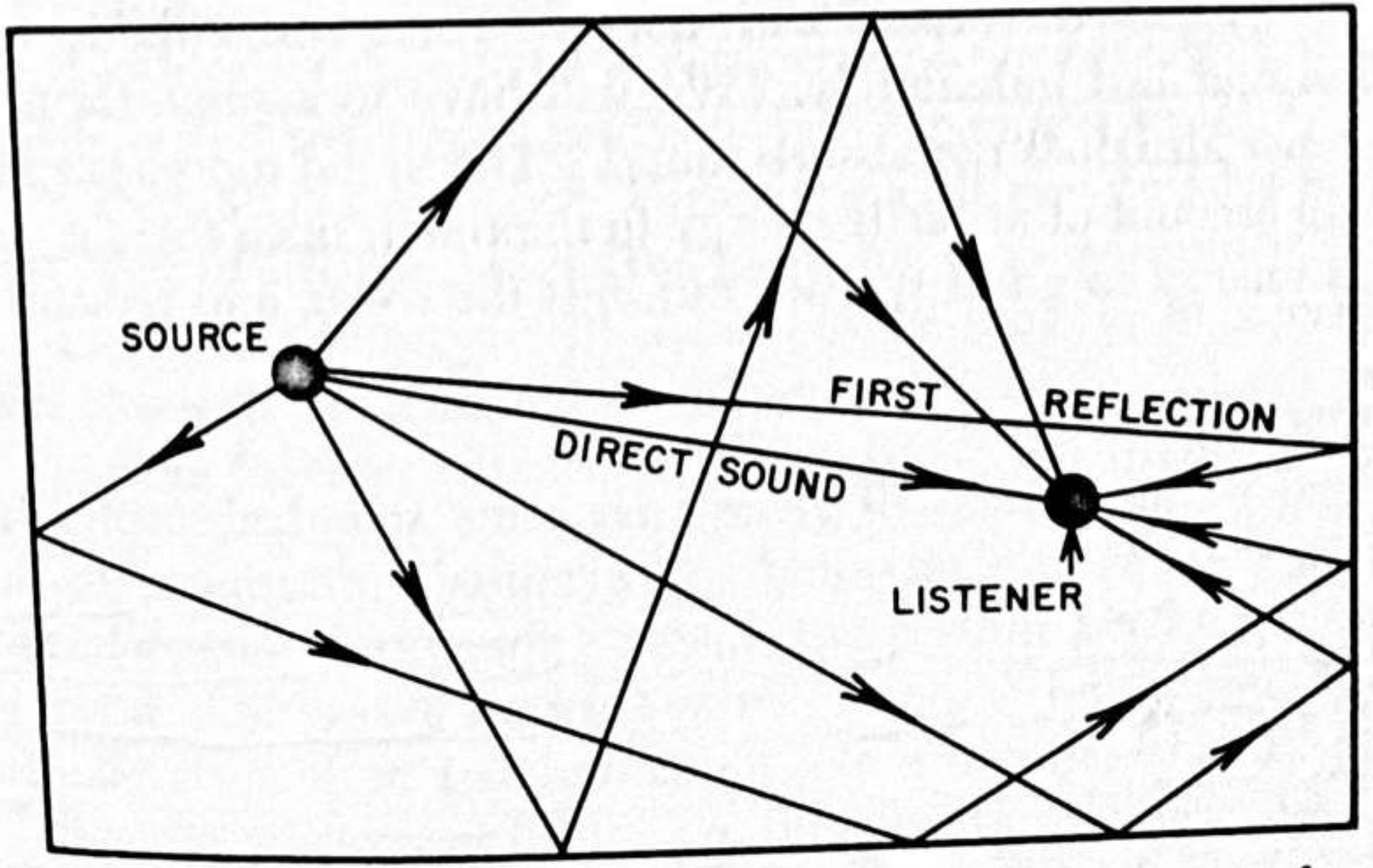


FIG. 1. Multiple reflections from the walls of a room of a single impulse produced by a sound source.

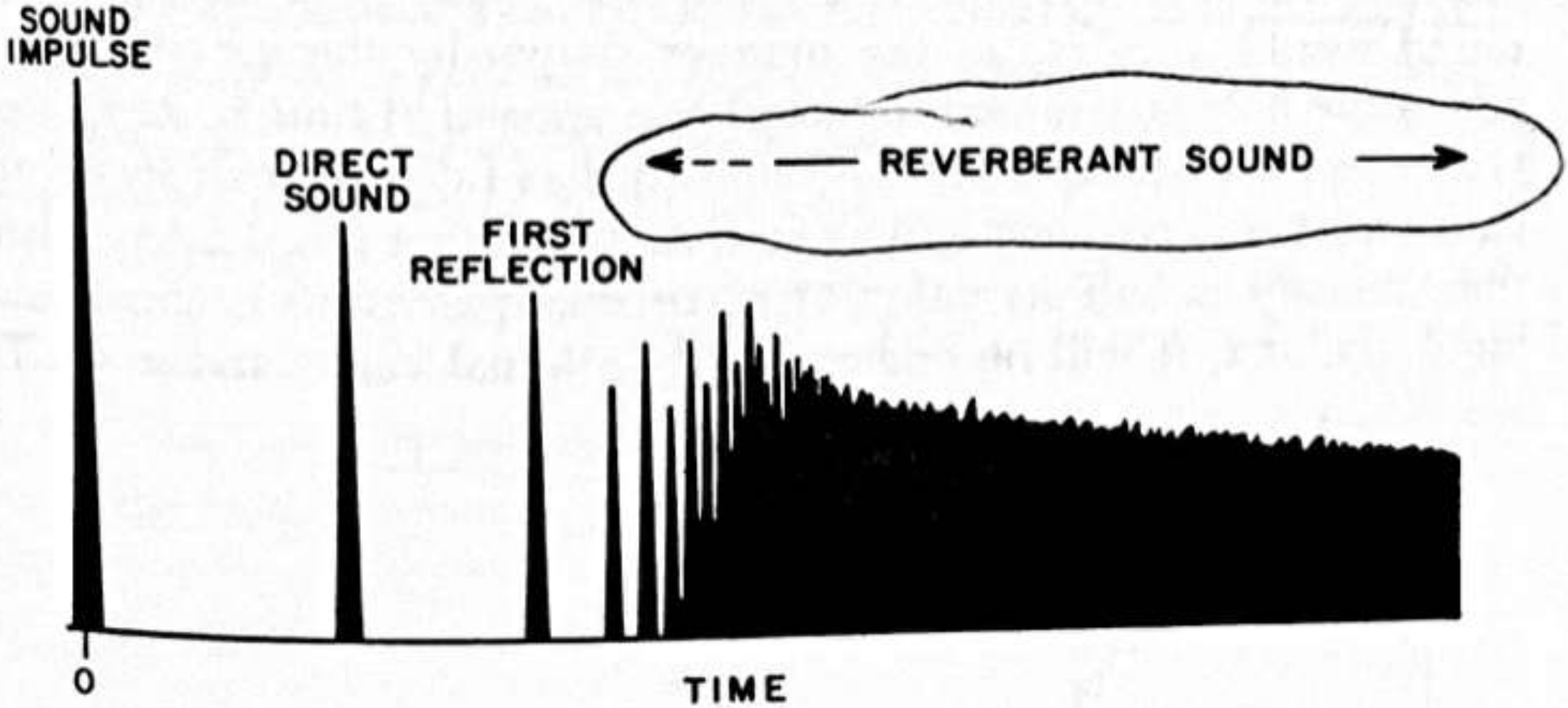


FIG. 2. Multiple reflections of a sound impulse as heard by a listener.

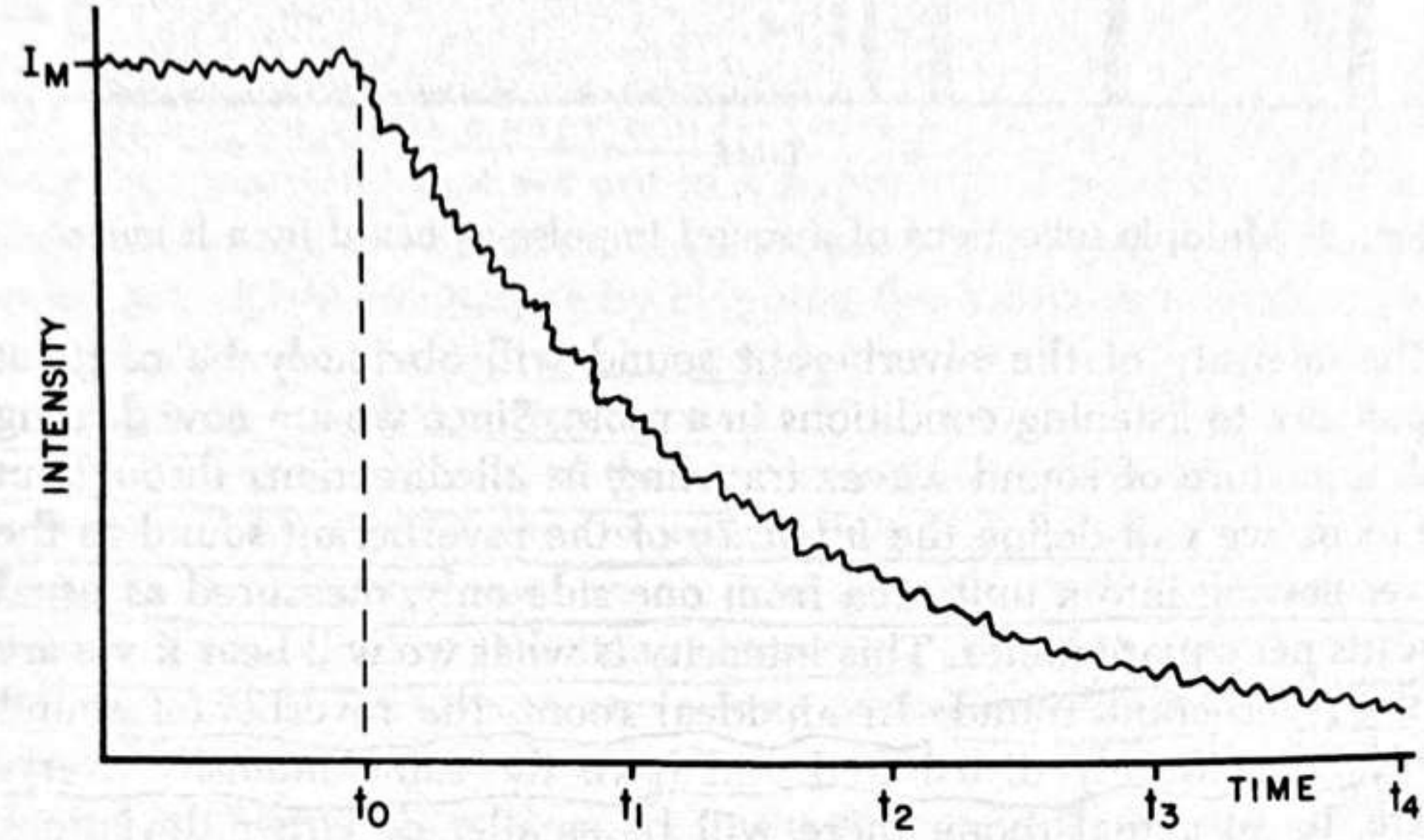
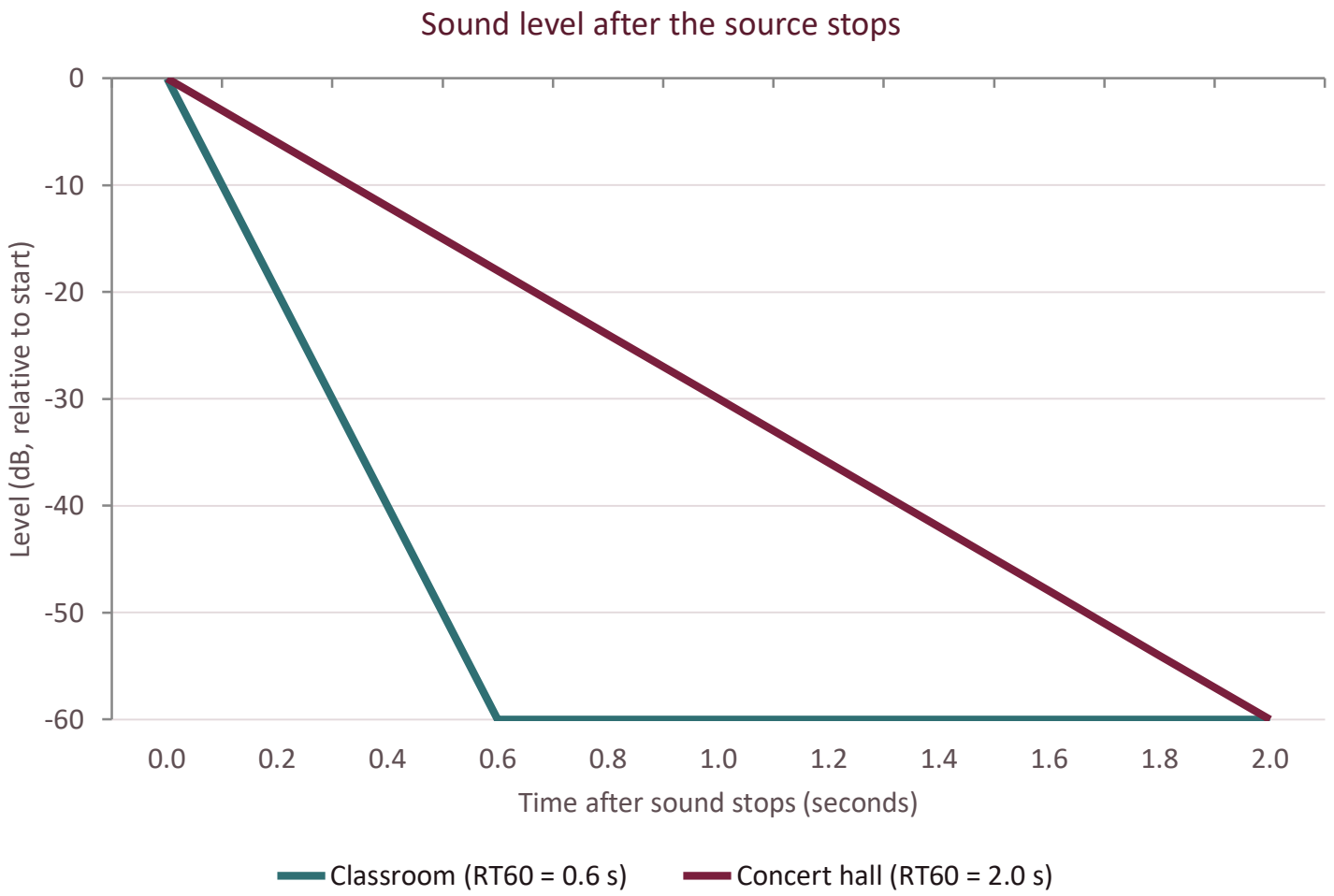


FIG. 3. Decay of reverberant sound in a room.

RT60: How Long Does the Room Ring?



60 dB

drop in level = one millionth of the original sound energy

RT60 is the room's stopwatch.

Start it when the sound stops. Stop it when the sound has faded 60 dB.

Short (about 0.6 s): dry and clear. Long (about 2 s): lush and blended.

Wallace Sabine's Equation

Harvard, 1895

- A young physicist is asked to fix the muddy Fogg Lecture Hall.
- His lab: organ pipes, a stopwatch, and seat cushions borrowed from another theater.
- He timed how long sound lingered as he added cushions.
- Result: a law linking the ring to room size and absorption.
- Boston Symphony Hall (1900) was the first hall designed with it.

$$T = 0.049\ V / A$$

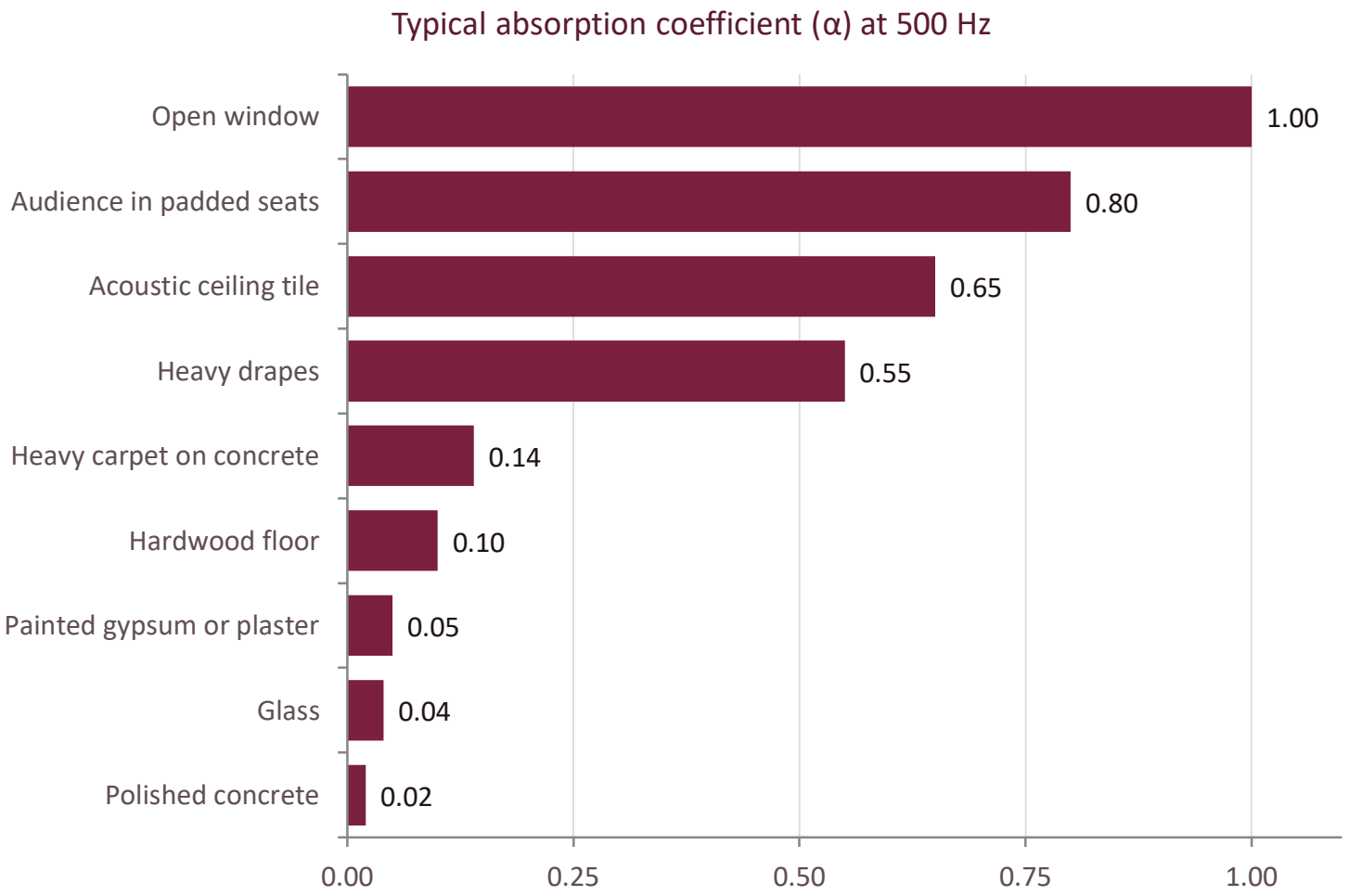
T = RT60 in seconds · V = volume in ft³ · A = absorption in sabins

$$A = S_1\alpha_1 + S_2\alpha_2 + \ldots$$

Surface area (ft²) × absorption coefficient, added up over every surface.

In meters: T = 0.161 V / A (V in m³, A in m² sabins)

Not All Surfaces Are Equal



α is the fraction of sound energy a surface absorbs

- 0 = perfect mirror
- 1 = open window

Soft, porous, fuzzy: absorbs. Hard, smooth, dense: reflects. (See: shower.)

Approximate values; α also changes with frequency.

Worked Example: Tame a Bare Room

Room: 30 × 24 × 12 ft, so V = 8,640 ft³

Hardwood floor: 720 ft² × 0.10 = 72.0

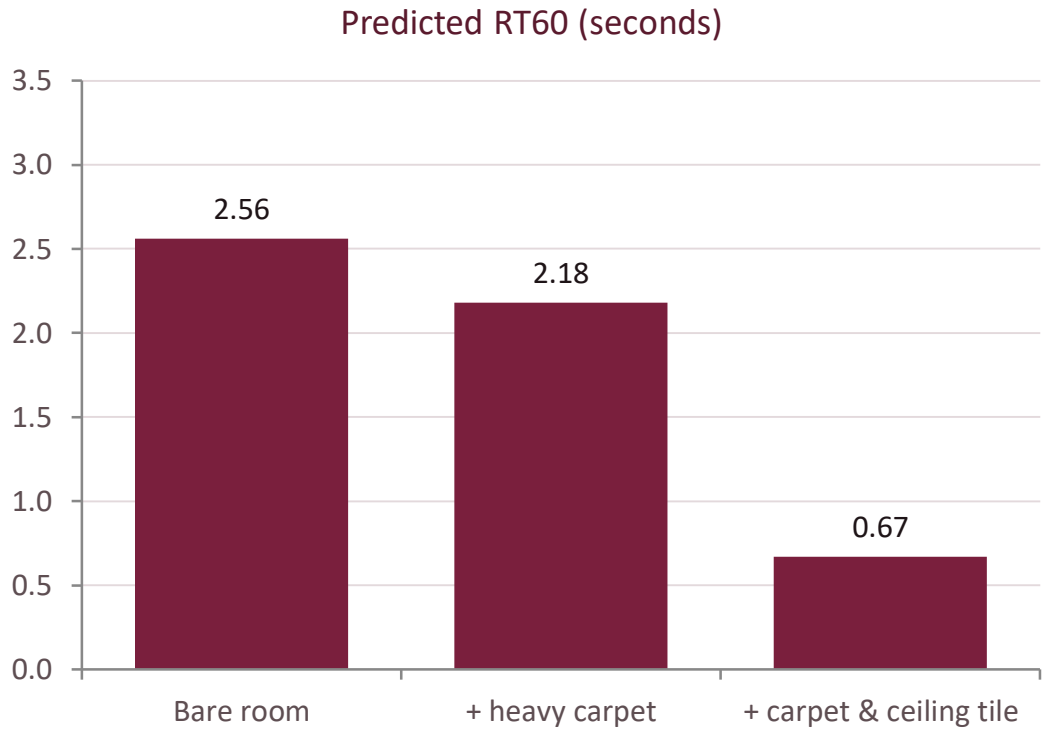
Plaster ceiling: 720 ft² × 0.04 = 28.8

Gypsum walls: 1,296 ft² × 0.05 = 64.8

Total A = 165.6 sabins

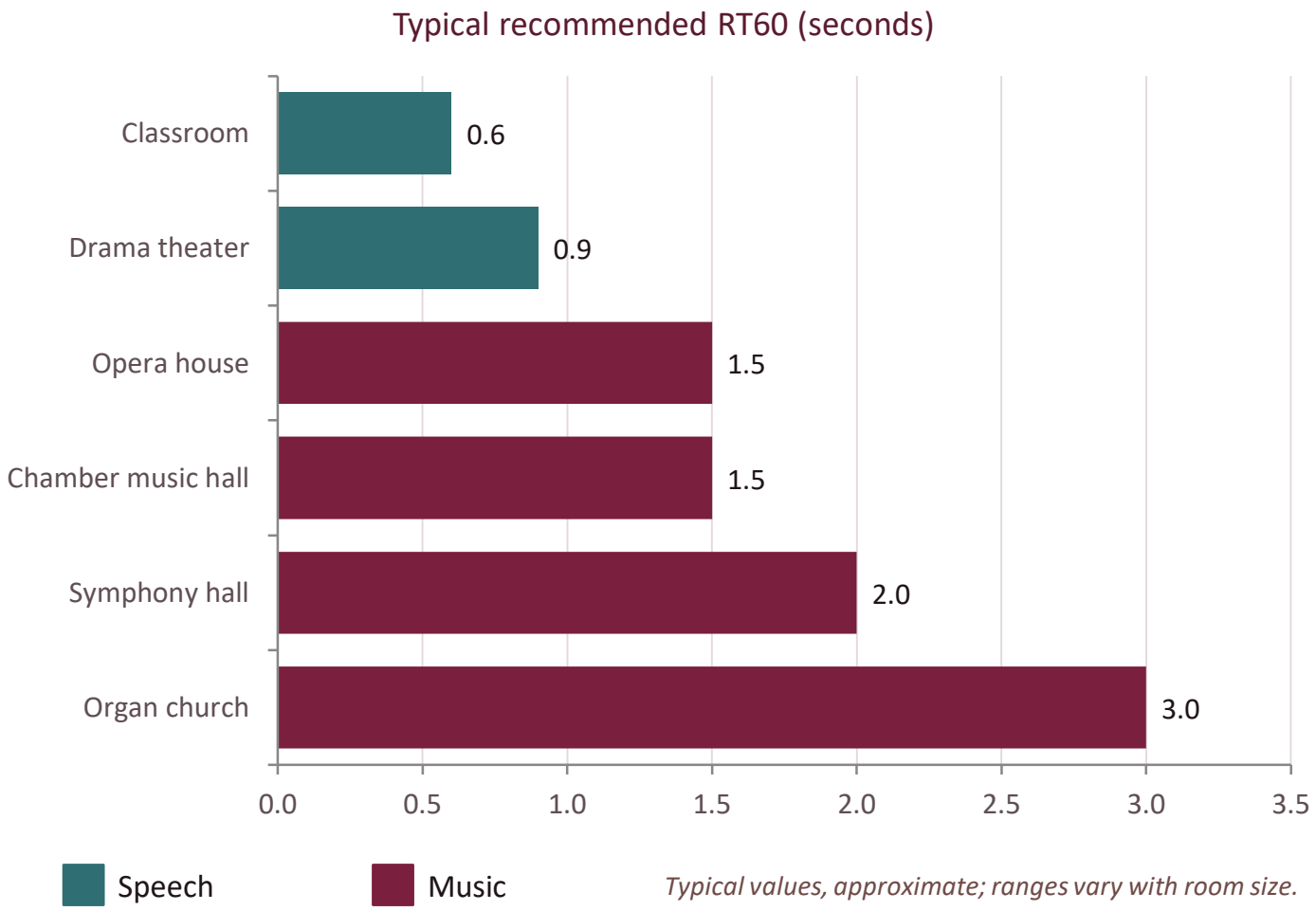
T = 0.049 × 8,640 ÷ 165.6

≈ 2.6 seconds



Carpet helps a little. The ceiling tile does the heavy lifting.

Speech vs. Music: Opposite Needs



Typical values, approximate; ranges vary with room size.

Speech wants it short

Consonants carry the meaning and they are quick and weak. A lingering vowel tail buries the next one.

Music wants it long

Reverberation blends notes, adds warmth, and sustains tone. For the organ, the room is part of the instrument.

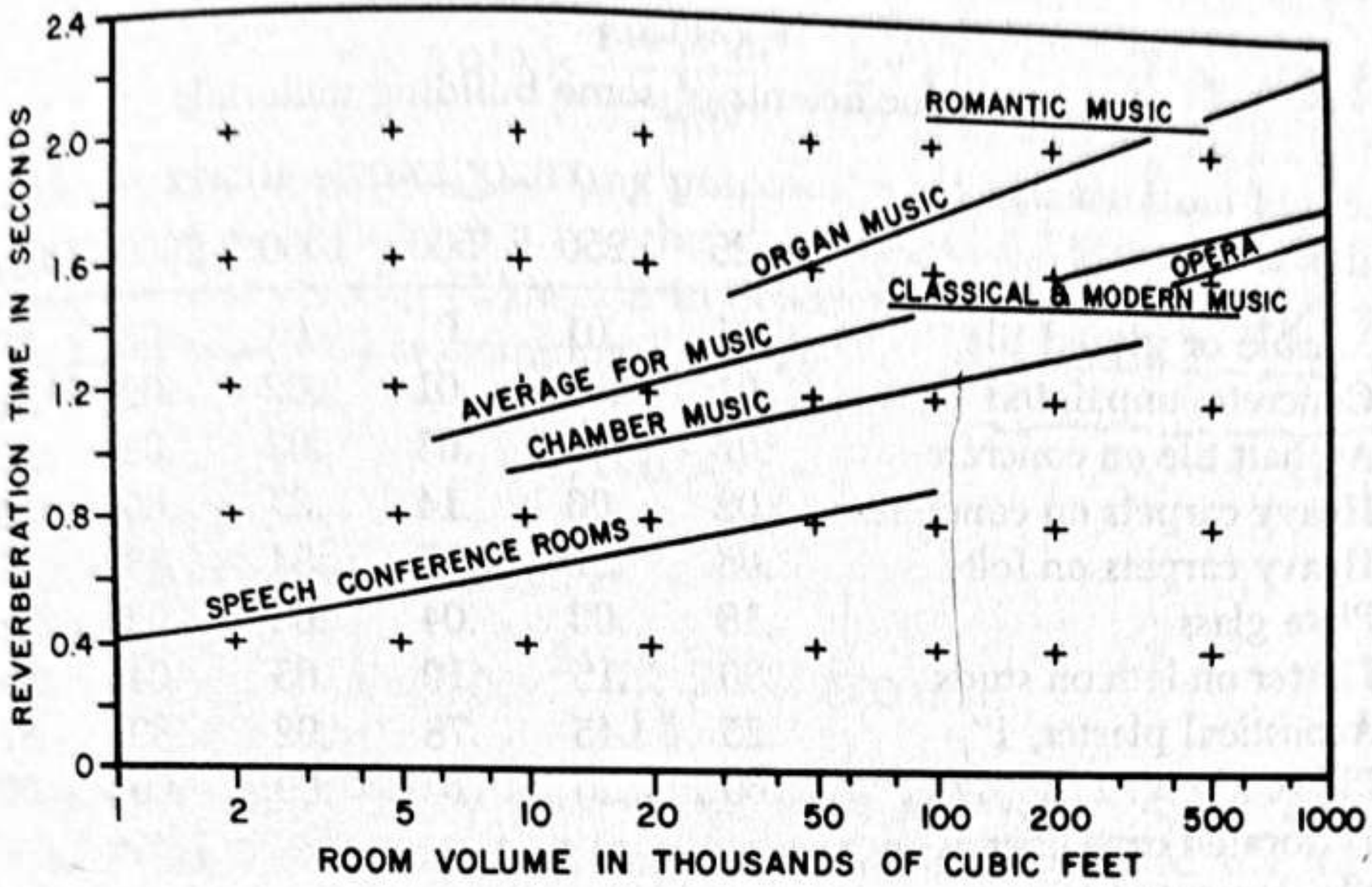


FIG. 5. Optimum reverberation time for auditoriums of various sizes and functions at a frequency of 500 hertz.

Take-Home Ideas

1. Sound in a room = direct sound + early reflections + late reverberation.
2. Sabine: T = 0.049 V / A. More absorption means a shorter ring.
3. Speech craves clarity (under about 1 s). Music craves bloom (1.5 s and up).
4. Early reflections help. Late ones smear.



Homework

Clap your hands in three different rooms and guess how long each clap lingers. Then estimate the room's volume and surfaces and test Sabine. Smiling is encouraged.



