



ACOUSTICAL PROBLEMS IN BUILDING  
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# ACOUSTICS IN ANCIENT THEATERS

– What is acoustic in general, general information about the importance of acoustics

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– Information about theatres and examples

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– Antic theatre parts and sections

# SUMMARY

- *1-) What is acoustic in general, general information about the importance of acoustics and the operating steps of acoustics was given.*
- *2-) Historical information was given about some ancient theaters, and after this information, important information was given about the functioning of the acoustics of ancient theaters and examples of some ancient theaters that have survived to the present day are given.*
- *3-) General information about the important parts of the ancient Greek and Roman theaters was given and interesting information about how the acoustics of the ancient theaters worked was presented on the slide. Sharing the acoustic elements of the results of measurement research with the reader  
The benefits and uses of velaria in the ancient theater*
- *and vitrivus has a few little bits of information about the acoustic elements of ancient theaters.*

# Contents

- *WHAT IS ACOUSTICS ?*
- *WHAT IS ARCHITECTURAL ACOUSTICS ?*
- *THE IMPORTANCE OF ACOUSTIC IN ANCIENT THEATRES*
- *IMPORTANT INFORMATION ABOUT ANCIENT THEATERS*
- *EXAMPLES*
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- *What were some of the Challenges with Orchestra*
- *How acoustic Works in A.G. Theatre*
- *Factors affecting acoustics in ancient theaters during measurement*
- *Field information about ancient theaters*
- *Does Velaria have acoustic role on theatre?*
- *Vitruvius aspects of acoustics and Ancient Theatres*
- *REFERENCES*

# WHAT IS ACOUSTICS ?

- Acoustics is defined as the science that deals with the production, control, transmission, reception, and effects of sound.

# WHAT IS ARCHITECTURAL ACOUSTICS?

- **Architectural acoustics** is the science and engineering of achieving a good sound within a building and is a branch of acoustical engineering.
- Architectural acoustics can be about achieving good speech intelligibility in a theatre, restaurant or railway station, enhancing the quality of music in a concert hall or recording studio, or suppressing noise to make offices and homes more productive and pleasant places to work and live in.



(1)What is Acoustics (byu.edu)

(2)Templeton, Duncan (1993). *Acoustics in the Built Environment: Advice for the Design Team*. Architectural Press. [ISBN 978-0750605380](https://doi.org/10.1016/B978-0-7506-0538-0).



The steps shown in the above diagram can be found in any acoustical event or process.

[3] definition part  
<https://en.wikipedia.org/wiki/Acoustics>

# The importance of acoustics in ancient theaters

- There are some reasons why ancient theaters still survive and do not lose their function. People still react with surprise that the sound of ancient theaters can reach everywhere, the biggest reason for this is acoustics, and the shape, height and surrounding objects of ancient theaters are transformed into an acoustic space, so that a person on the stage can transmit their voice to the target of the theater.



# EPIDAUROS ANCIENT THEATRE

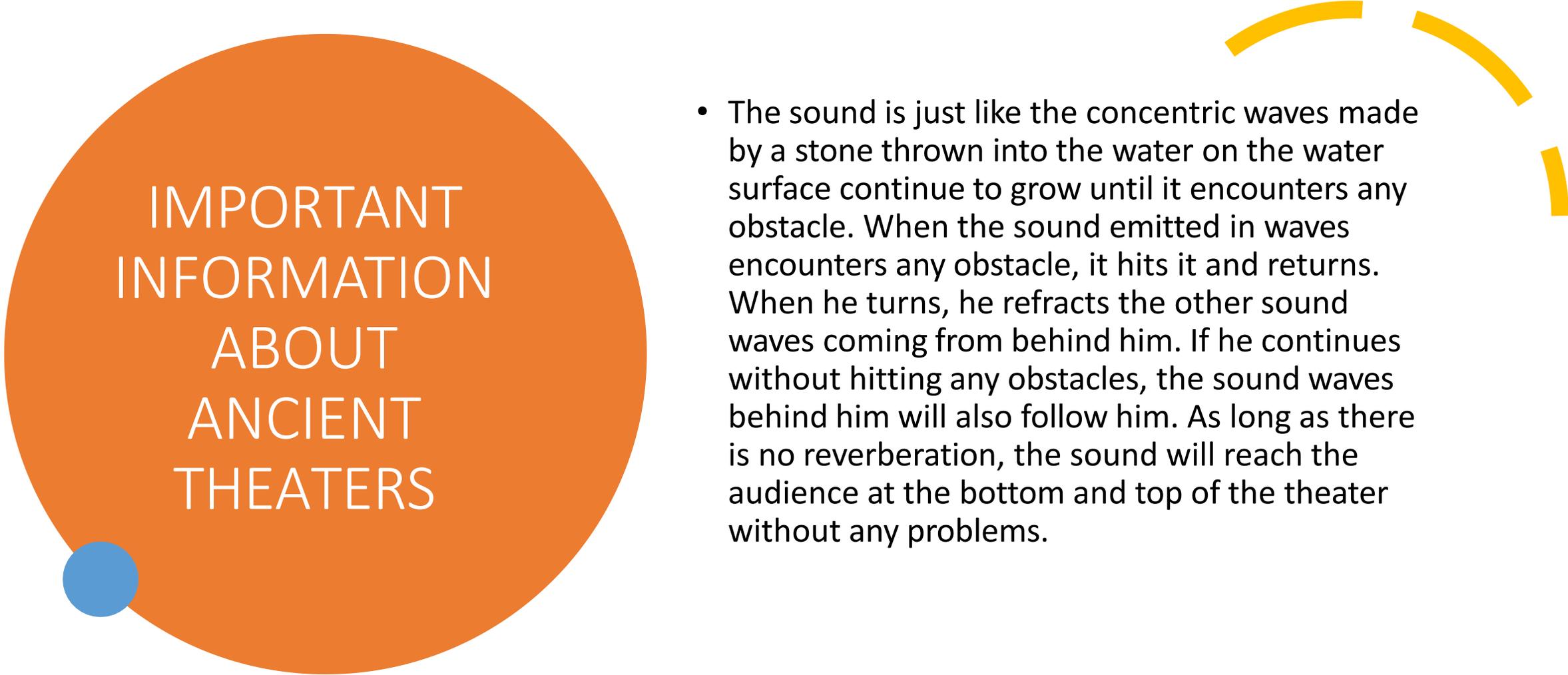
# HISTORY

- In the XIX century, when installing limestone material in the magnificent theater in Epidaurus, it was discussed that they unwittingly created a sophisticated acoustic filter. In the ancient theater, the voice of the actors was transmitted very smoothly to the back rows. A lot of research conducted in this theater has not found the reason why the acoustics are very good. It is mentioned that they could not establish the same acoustic balance when there was an attempt to rebuild because they could not find the reason. No matter how unique the location of the theater, its unique symmetry in architecture and masks made it, the real answer was in the seats.[4]



- Declercq began to solve this mystery and determined that the reason was the limestone used in the seats. However, he still did not guess how well this controls background noise. While conducting experiments with ultrasonic waves and numerical simulations of theater acoustics, Declercq's team discovered that frequencies up to 500 Hz are held back and frequencies above 500 Hz are allowed to play. After all, this means that the material used creates the same effect as the professional materials currently preferred for acoustics. [4.1]





## IMPORTANT INFORMATION ABOUT ANCIENT THEATERS

- The sound is just like the concentric waves made by a stone thrown into the water on the water surface continue to grow until it encounters any obstacle. When the sound emitted in waves encounters any obstacle, it hits it and returns. When he turns, he refracts the other sound waves coming from behind him. If he continues without hitting any obstacles, the sound waves behind him will also follow him. As long as there is no reverberation, the sound will reach the audience at the bottom and top of the theater without any problems.

# THEATERS THAT HAVE COME UP TO THE PRESENT DAY IN THE BEST CONDITION AND HAVE THE BEST ACOUSTICS;

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10) Side Antik Tiyatrosu - Türkiye

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9) Bosra Roma Tiyatrosu - Suriye

---

8) Delphi Tiyatrosu - Yunanistan

---

7) Amman Roma Tiyatrosu – Ürdün

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6) Taormina Tiyatrosu - Sicilya

---

5) Merida Tiyatrosu - İspanya

---

4) Dougga Tiyatrosu - Tunus

---

3) Büyük Efes Tiyatrosu - Türkiye

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2) Epidaurus Tiyatrosu - Yunanistan

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1) Herodes Atticus Odeon - Yunanistan

10-  
SIDE ANCIENT  
THEATRE



6-  
TAORMINA  
ANCIENT  
THEATRE



4-  
ROMAN  
THEATRE OF  
DOUGGA  
TUNUS

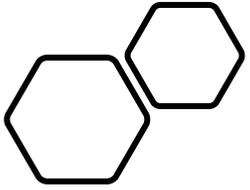


3-  
EFES ANCIENT  
THEATRE



1-  
ANCIENT  
THEATRE –  
ODEON OF  
HERODES  
ATTICUS |  
ATHENS,  
GREECE





# OTHER THEATER WITH GOOD ACOUSTICS



# ASPENDOS

Positive results for many parameters even with its current state  
Quite good acoustics for a large space of seating and seating  
the results are delivered. An even more important point is the  
theoretical

To evaluate the acoustic conditions in closed volumes

An open structure with acoustic parameters designed for the  
purpose of

the consistent values of the Aspendos theater

In other words, a single unit like a theoretical “volume”

is to give. Some simple acoustic e ancillary measures used in ancient  
times or

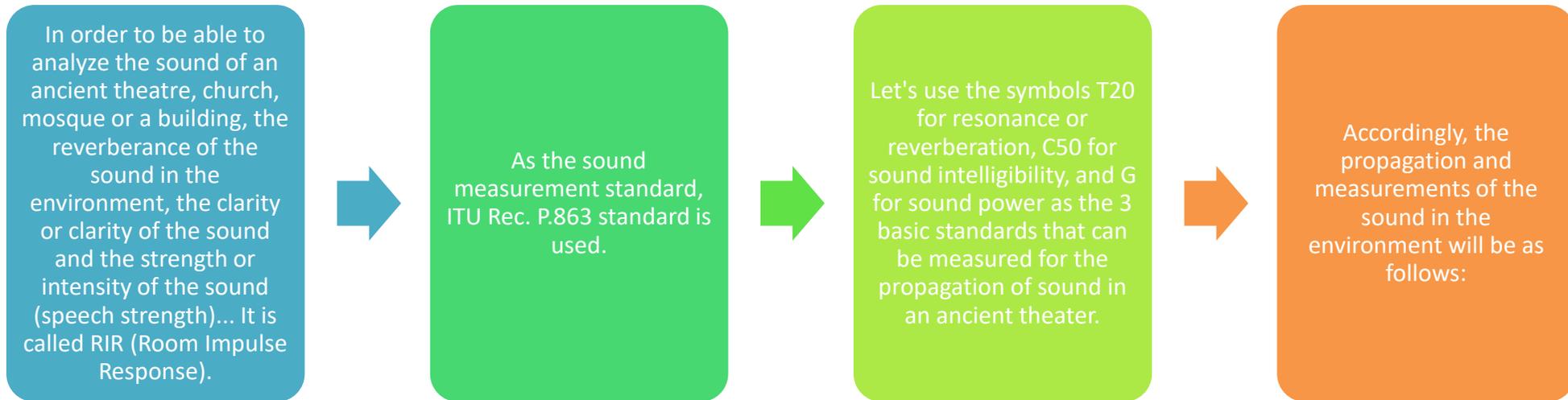
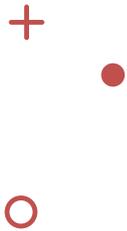
with the additions and the intricate column structures of the stage  
building.

It can be brought closer to perfection by putting it in its place with  
restoration work.

The existing features of the Aspendos theater should be  
utilized.[4.2]



# ACOUSTIC MEASUREMENTS IN ANCIENT THEATERS



[4.3]

### RING TIME:

Reverberation time T15 (the value at which the sound value drops to 15 decibels), T20 (the value at which the sound value drops to 20 decibels), T30 (the value at which the sound value drops by 30 decibels) duration according to ISO 3382-1 standard,

### CLARITY OF SOUND

STI (Speech Transmission Index) and RASTI (Room Acoustical Speech Transmission Index) values, which are the intelligibility of the voice, are measured according to the IEC 60268 standard.

### SOUND CLARITY (C50)

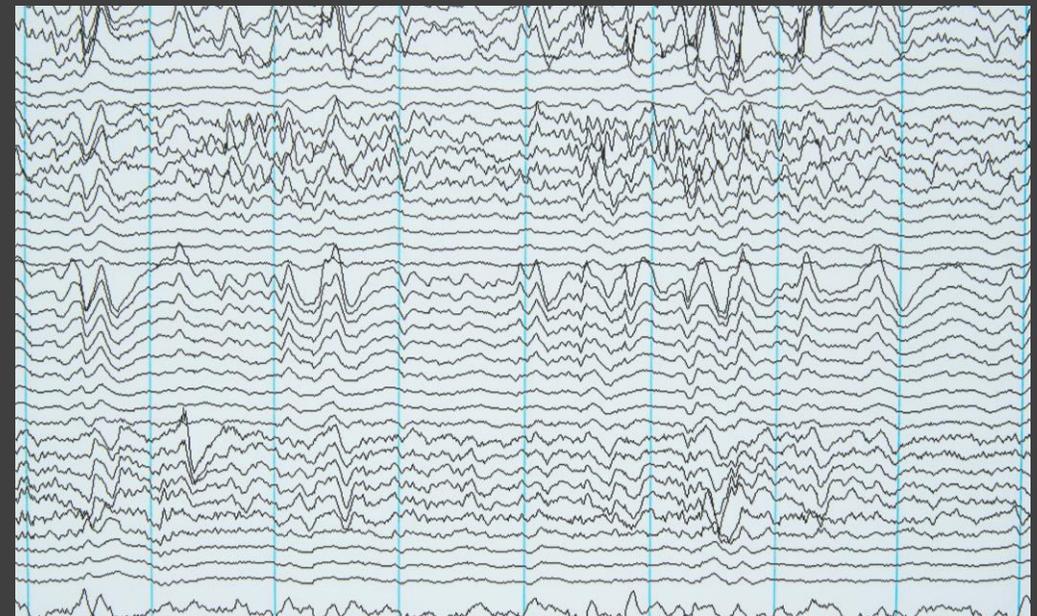
Measurements are made according to ISO 3382-1 standard. The formula for C50 is given below. This value is obtained by multiplying the logarithmic value of the ratio of the sum of the squares of the sound power between 0-50 ms and 50ms to infinity by 10. [4.3]



$$C_{50} = 10 \cdot \log \frac{\int_0^{50\text{ms}} p^2(t) dt}{\int_{50\text{ms}}^{\infty} p^2(t) dt} \text{ dB}$$

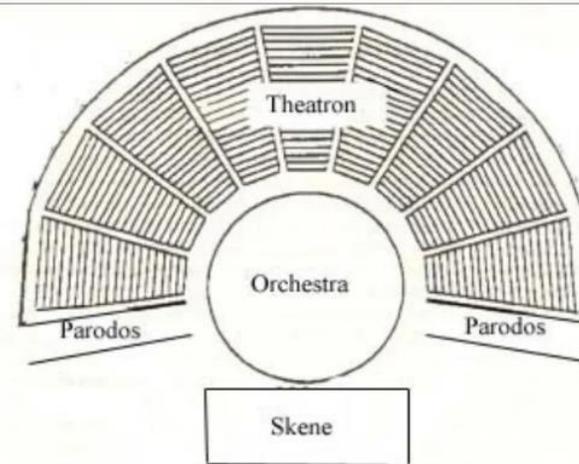
SOUND POWER (G) G value, which is the power of the sound, is measured according to the ISO 3382-1 standard and the following formula is used. [4.3]

$$G = 10 \cdot \log \frac{\int_0^{\infty} p^2(t) dt}{\int_0^{\infty} p^2(t) dt} \text{ dB}$$



[4.3] <https://www.fajans.com/antik-tiyatrolarda-akustik-olcumler.htm>  
[https://www.arkeotekno.com/pg\\_50\\_antik-tiyatrolarda-akustik-olcumler](https://www.arkeotekno.com/pg_50_antik-tiyatrolarda-akustik-olcumler)

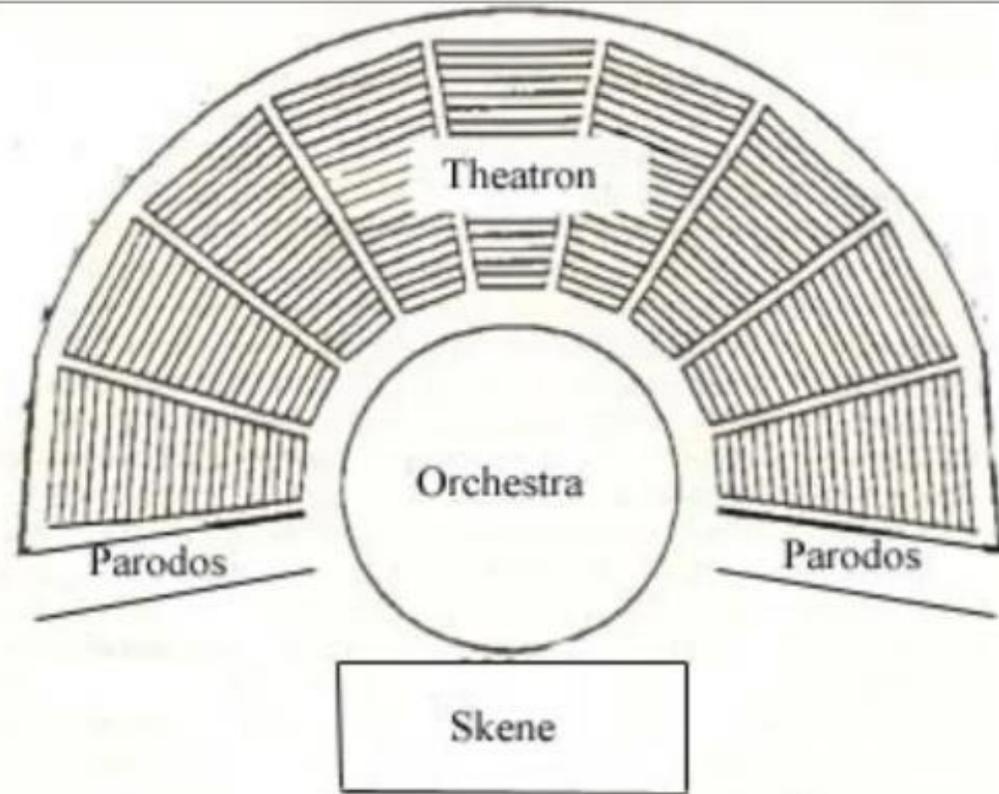
# Parts of Greek Theatre



Parts of a Greek Theater

# What is Scene

- skene, (from Greek *σκηνή*, “scene-building”), in ancient Greek theatre, **a building behind the playing area that was originally a hut for the changing of masks and costumes; but eventually became the background before which the drama was enacted.**[5]



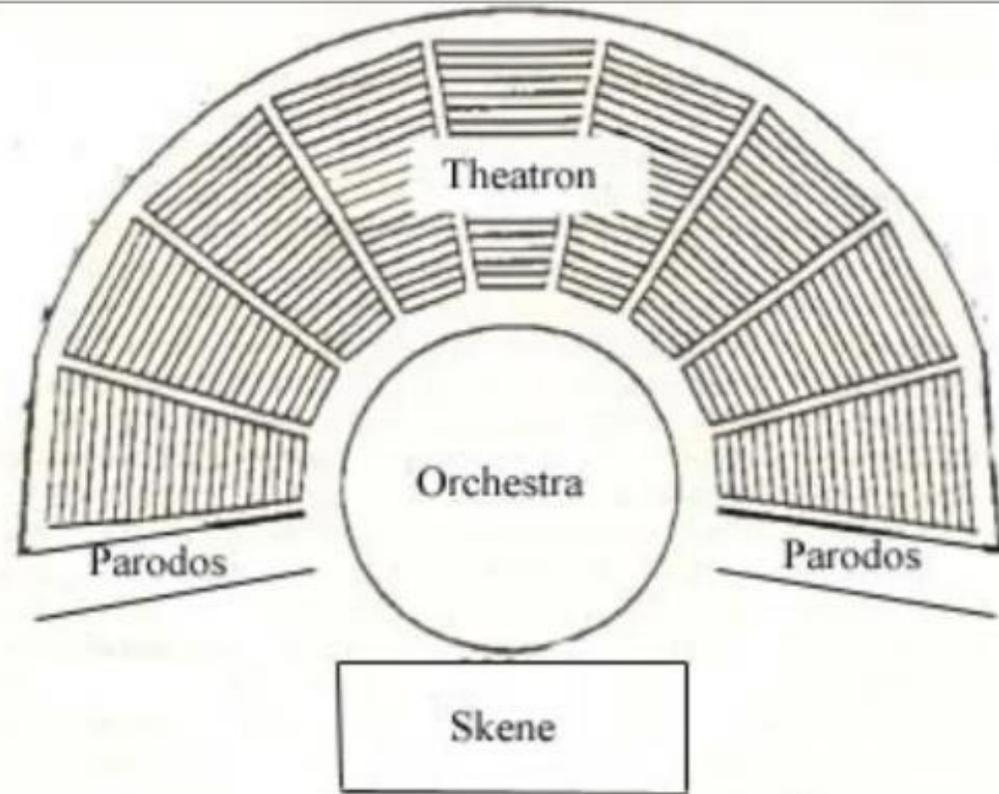
Parts of a Greek Theater

[5]

<https://www.britannica.com/art/skene>

# What is Orchestra

- The orchestra (literally, "dancing space") was normally circular. It was **a level space where the chorus would dance, sing, and interact with the actors who were on the stage near the skene.**[6]



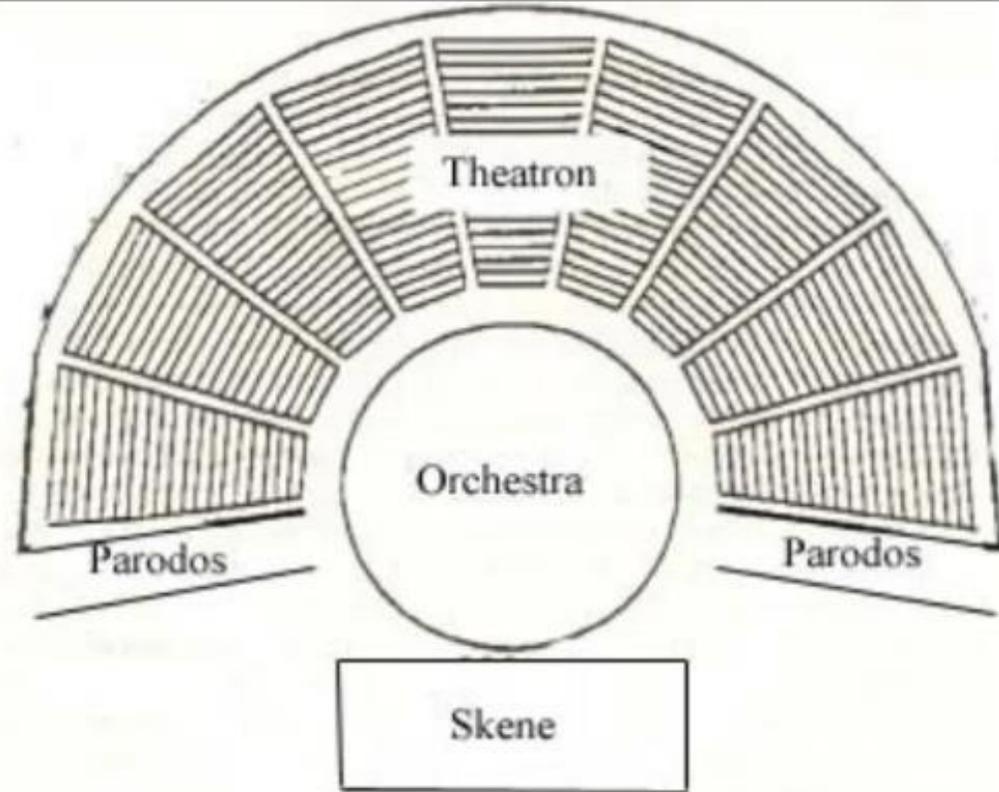
Parts of a Greek Theater

[6]

<https://www.reed.edu/humanities/110Tech/Theater.html>

# What is Parados

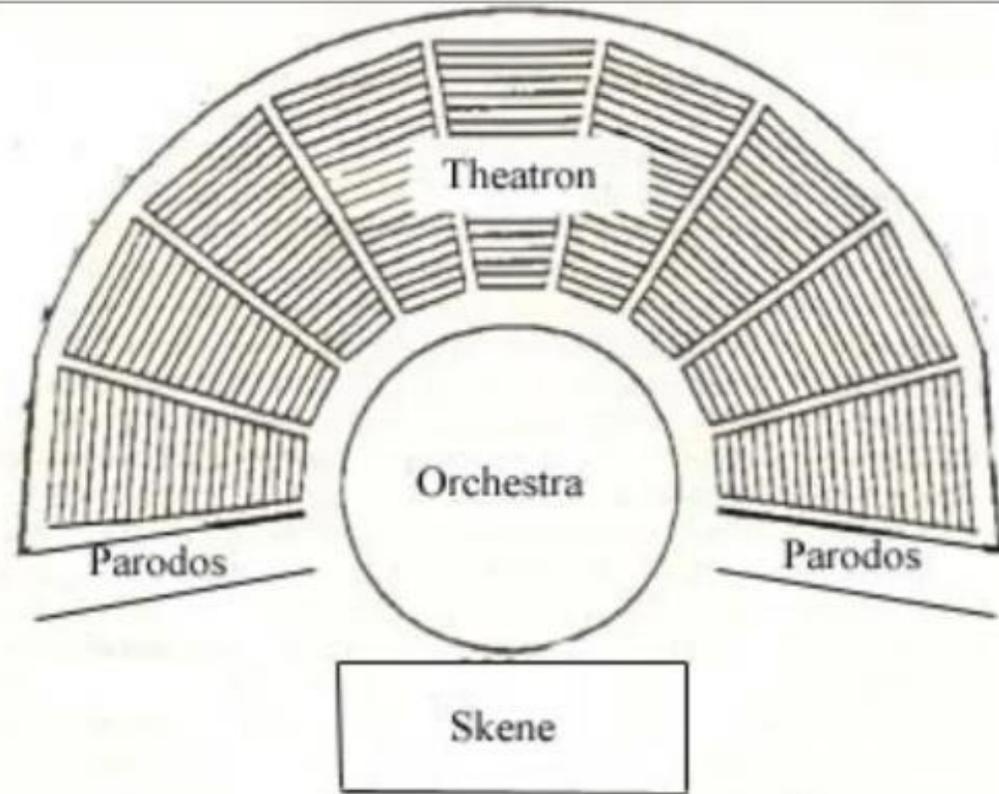
- A parados was **one of two gangways on which chorus and actor, made their entrances from either side into the orchestra.** Episode/Stasimon- First comes the episode, and then follows the stasimon.



Parts of a Greek Theater

# What is Theatron

- The theatron (literally, "viewing-place") is **where the spectators sat**. The theatron was usually part of hillside overlooking the orchestra, and often wrapped around a large portion of the orchestra



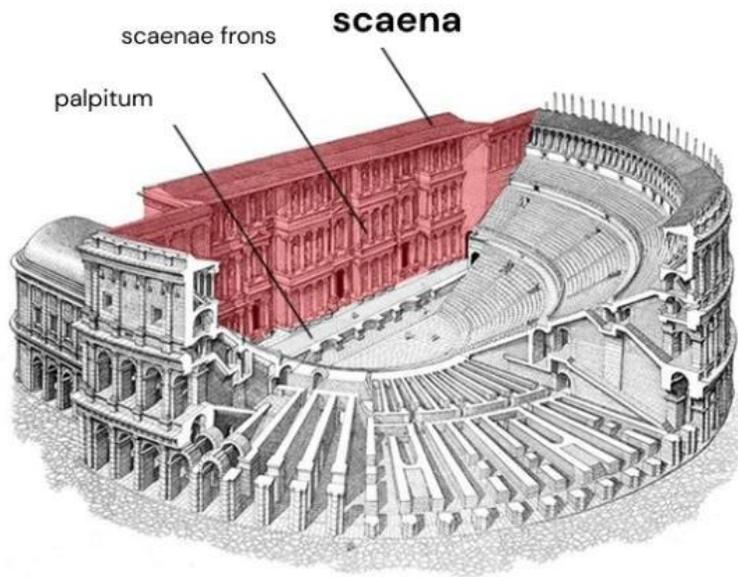
Parts of a Greek Theater

# Parts of Roman Theatre



# Parts of Roman Theatre

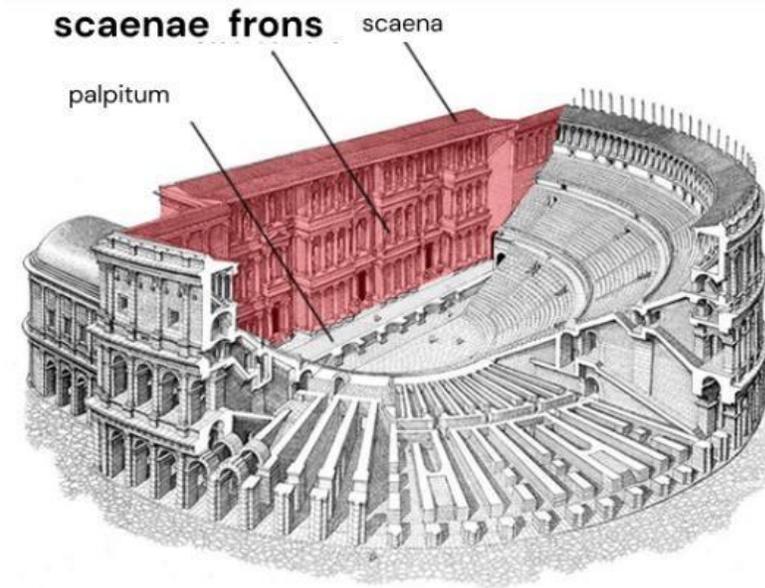
## What is Scaena



## SCAENA

A roofed house at the back of the stage.

## What is Scaenae Frons

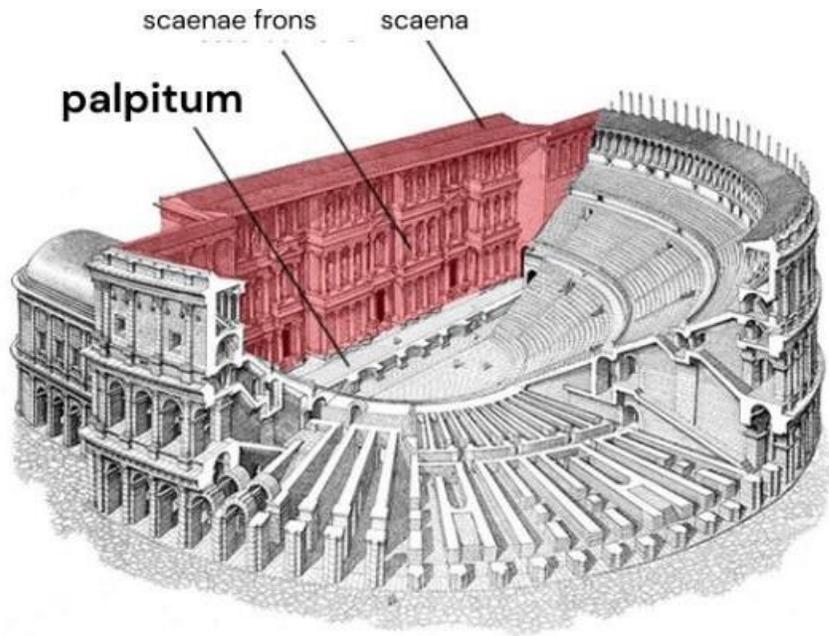


## SCAENAE FRONS

the front wall of the scaena that could be up to three stories high and often featured a balcony and three doors on the ground level.

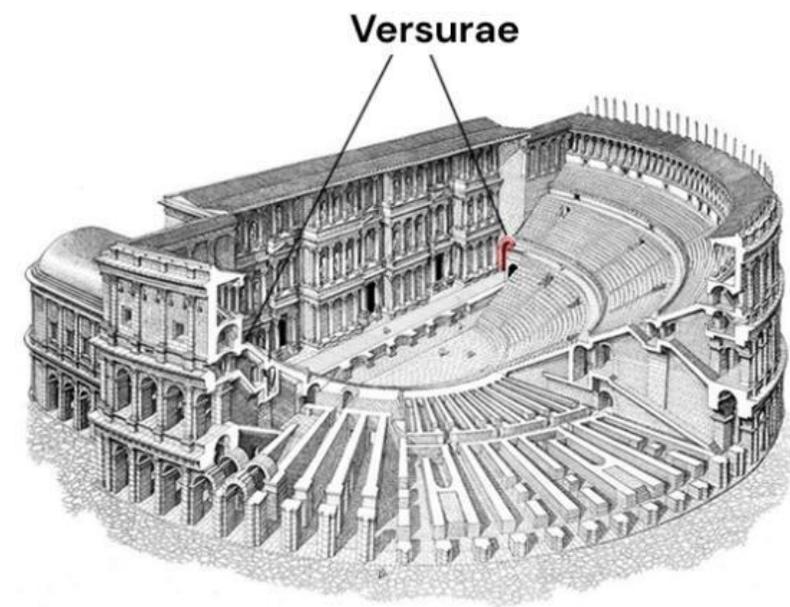
# Parts of Roman Theatre

## What is Palpitum



PALPITUM  
the stage

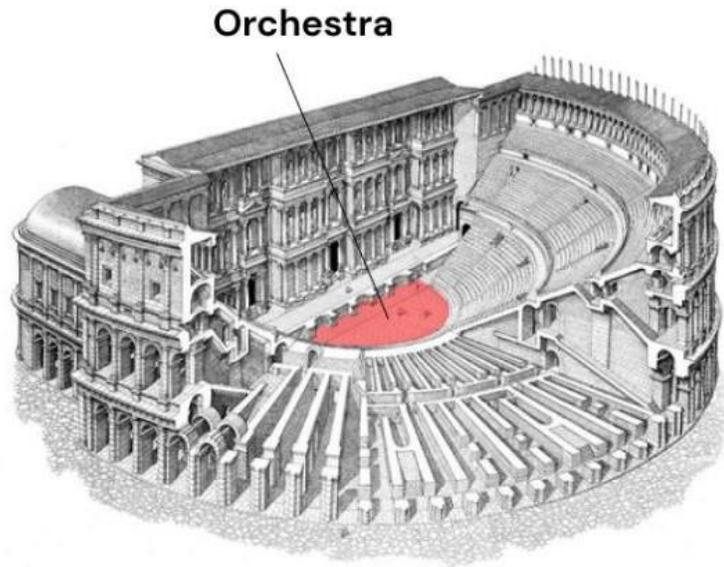
## What is Versurae



VERSURAE  
the wings of the stage that each feature an entrance

# Parts of Roman Theatre

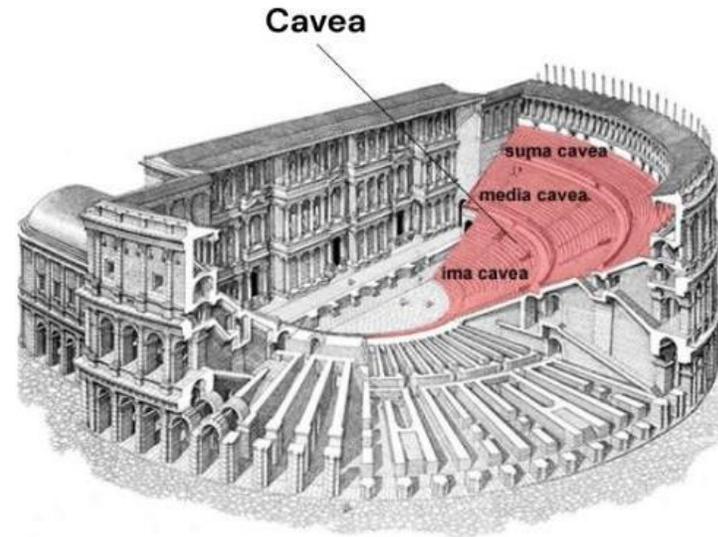
## What is Orchestra



### ORCHESTRA

the area where dignitaries sat and where musicians and dancers sometimes performed.

## What is Cavea



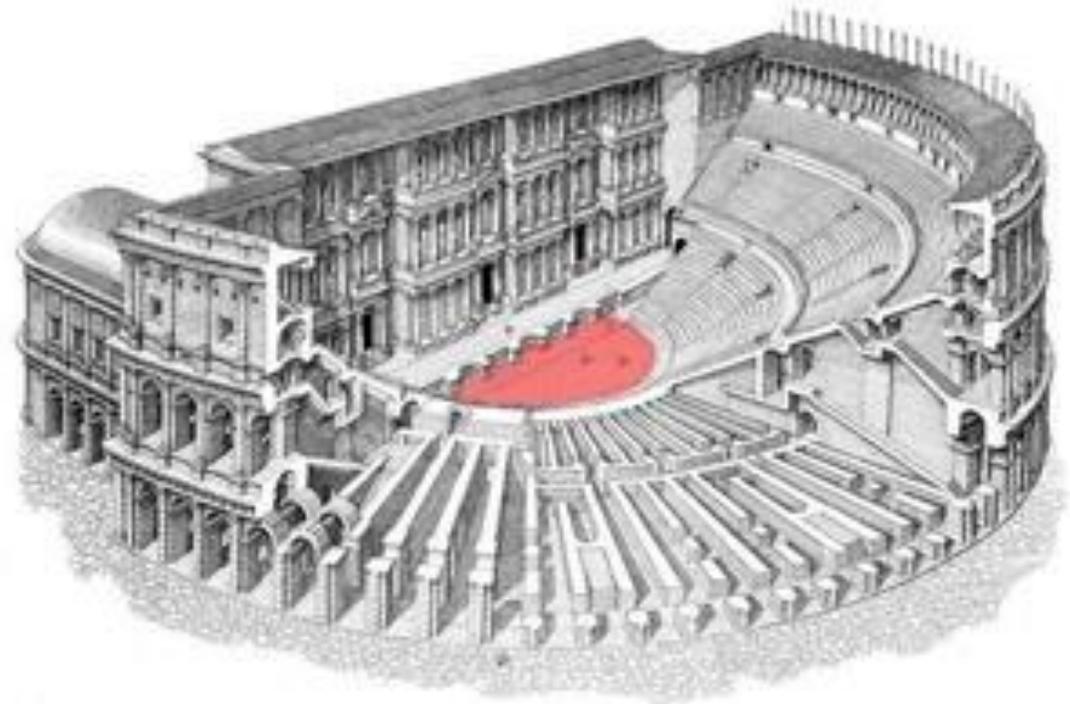
### CAVEA

the large auditorium, round in shape, where all the commoners sat when they attended the theater.

# What were some of the Challenges with Orchestra

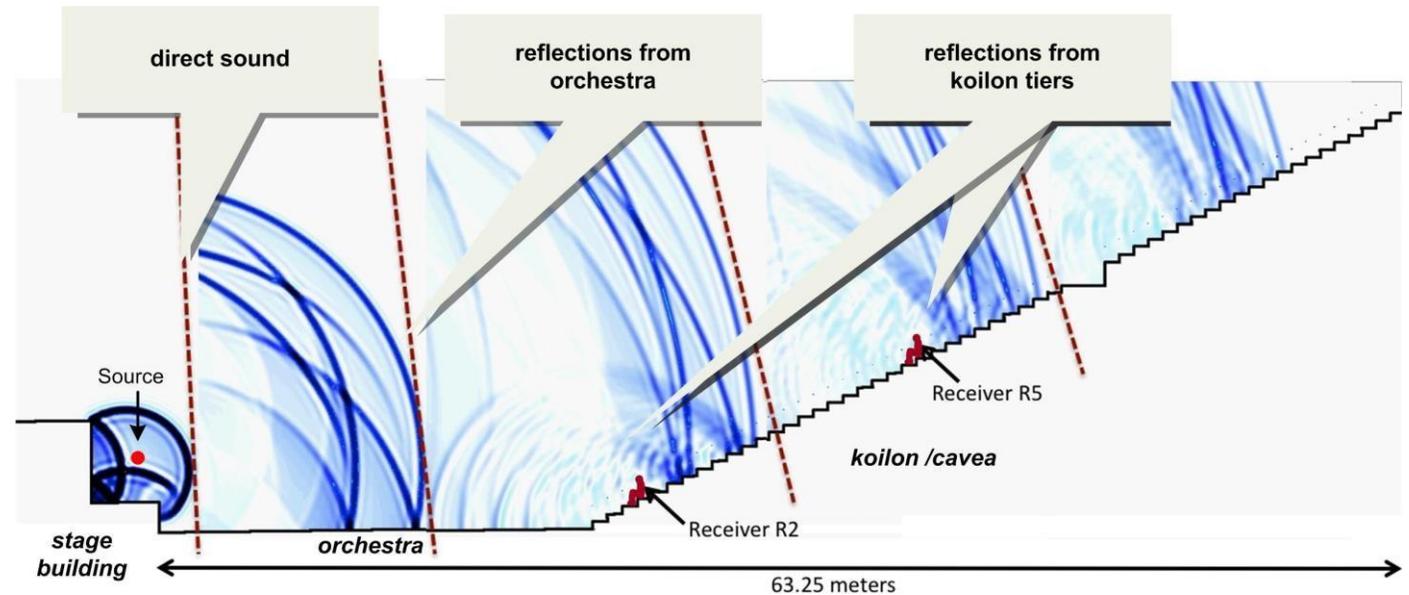
- Size
- Distance From Audience
- Holding Interest

orchēstra

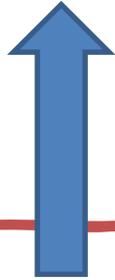


# How acoustic Works in A.G. Theatre

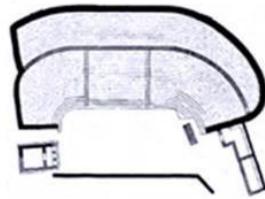
- Mathematics plays a large role in the construction of these theatres, as their designers had to be able to create acoustics then such that the actors' voices could be heard throughout the theatre, including very top row of seats.



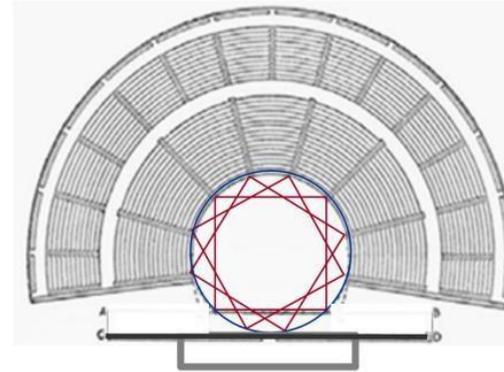
Super B Acoustic system



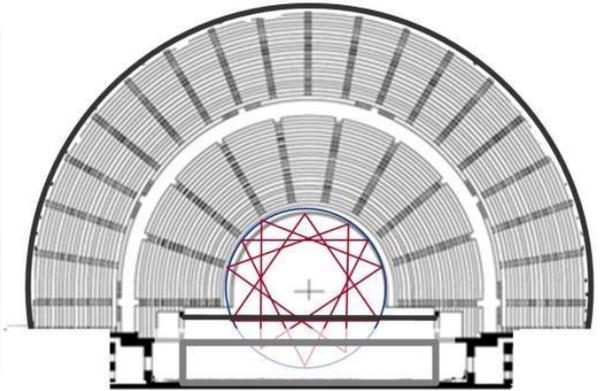
- **The Circular shape of Ancient greek and Roman Theatre provides acoustical environment. The ancient Greek theater was designed to spread the sounds on the stage evenly.**



archaic Greek  
non-amphitheatric  
*circa 600 BC*



classical Greek  
amphitheatric  
*circa 450 BC*



Roman  
semi-amphitheatric  
*circa 100 BC*

[7] ARTICLE-Acoustics of ancient Greek and Roman theaters in use today

[https://www.researchgate.net/publication/272318122\\_Acoustics\\_of\\_ancient\\_Greek\\_and\\_Roman\\_theaters\\_in\\_use\\_today](https://www.researchgate.net/publication/272318122_Acoustics_of_ancient_Greek_and_Roman_theaters_in_use_today)

## Sound at the theater of Epidaurus improved by limestone

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- Researchers at the Institute of Technology have discovered that the limestone material of the seats provides a filtering effect, suppressing low frequencies of voices and thus minimizing background crowd noise.

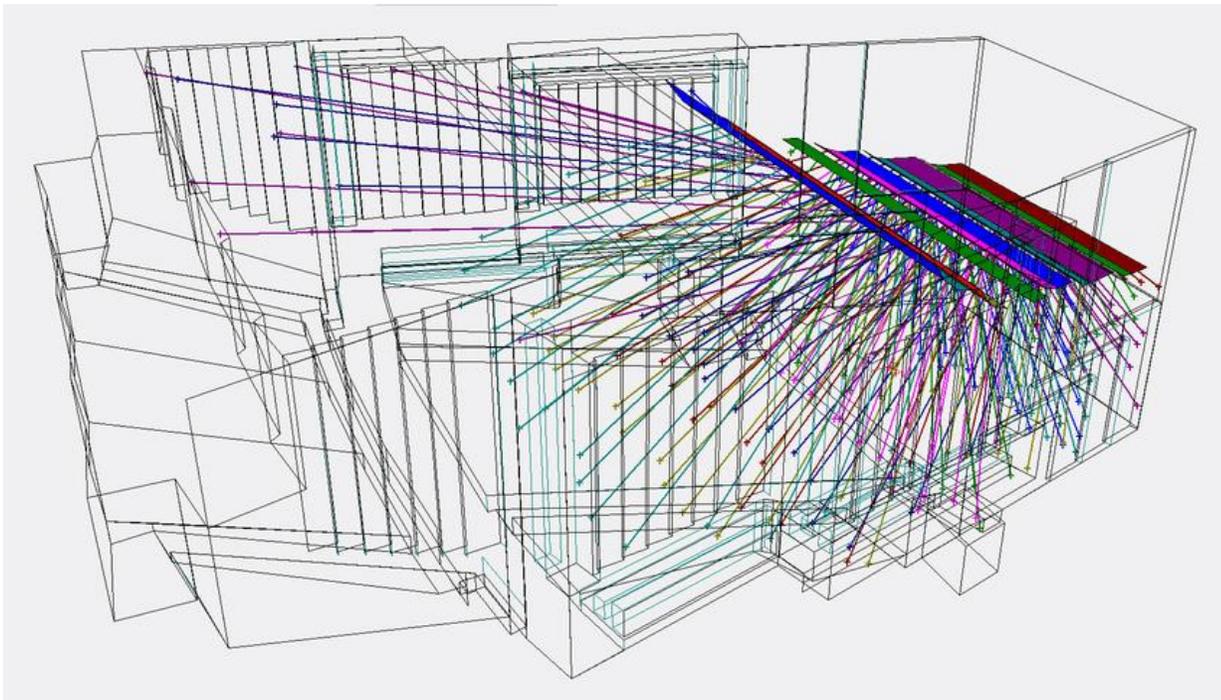


# Factors affecting acoustics in ancient theaters during measurement

- *Seat Risers used as a panel.*
- *Scattering effects due to the acoustic roughness of panel surface.*
- *Diffraction due to limited panel size.*
- *Diffraction from a panel edge*
- *The scattering and diffraction from seat risers.*
- *Ancient theatres examined in the past based on general acoustic principles or on site measurement.*
- *The influence of the form evolution and material use on the acoustic quality has been limited.*

# Field information about ancient theaters

The results of a series of acoustic simulations in six typical theatre forms, using a beam-tracing program.



# Roman Theatre of Casino (Rebuilt)

Site: hill

Shape: Semi Circular

Stage Material: Timber

Cavea Material: Stone & Mortar (cavea surrounded by walls)

Capacity: 1000 spectators



# Roman Theatre of Taormina (Rebuilt)

Site: hill

Shape: U shaped

Cavea Material: Brick of Terracota (cavea surrounded by walls)

Capacity: 4500 spectators



# Roman Theatre of Pompeii (Rebuilt)

Site: Flat area

Shape: U shaped

Cavea Material: Hard court, timber & metal

Capacity: 1800 spectators



# Roman Theatre of Benevento (Rebuilt)

Site: Flat area

Shape: Semi Circular

Cavea Material: Bricks of Terracota

Capacity: 1200 spectators



# Roman Theatre of posillipo (Rebuilded)

Site: Hill next to the sea

Shape: Semi Circular

Cavea Material: Marble

Capacity: 1000 spectators

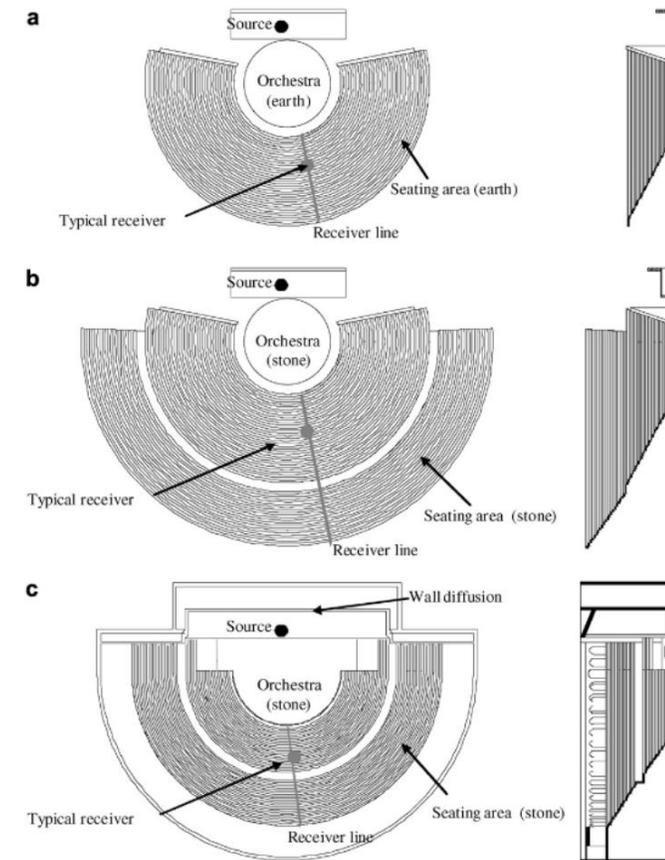


Main dimensions of the theatres considered in the present study.

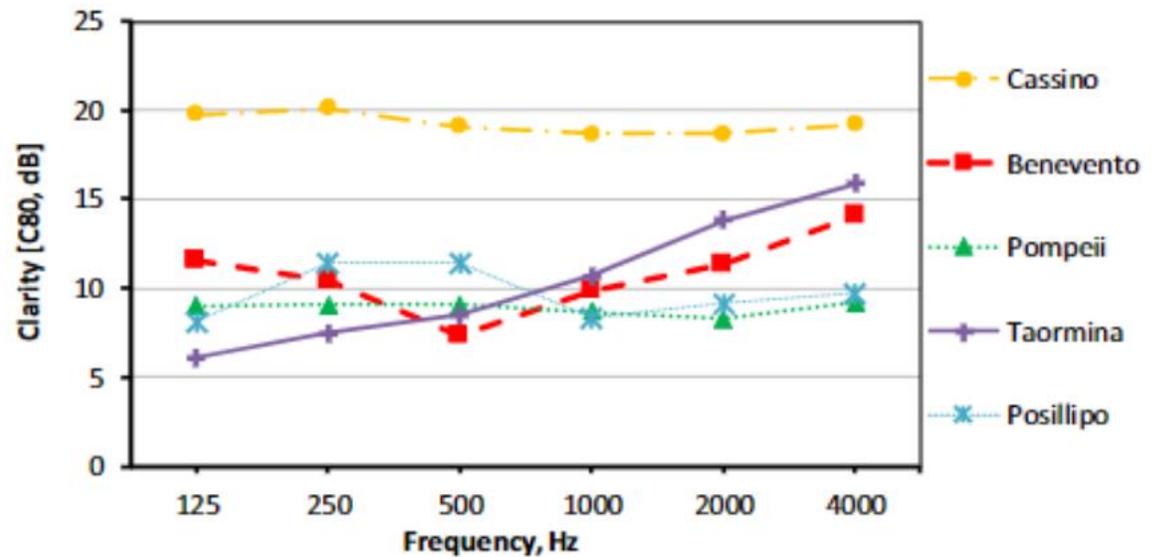
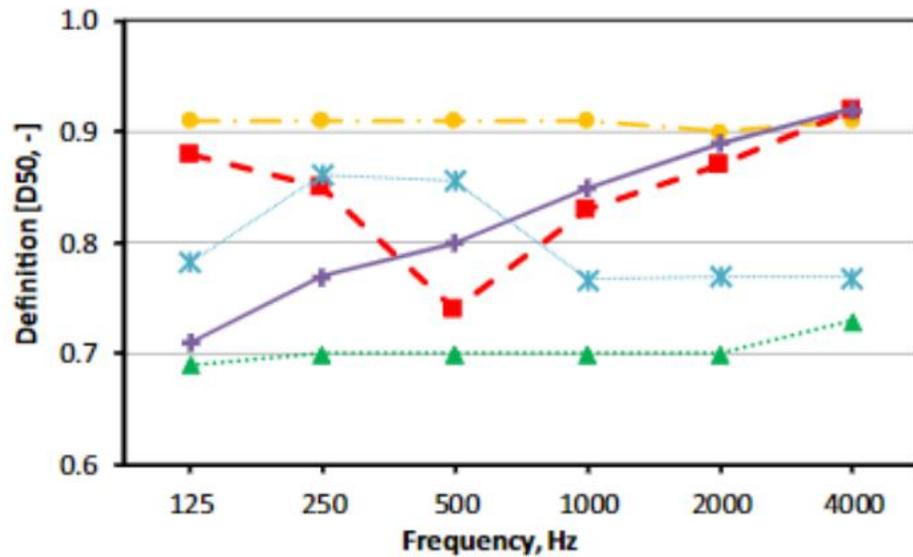
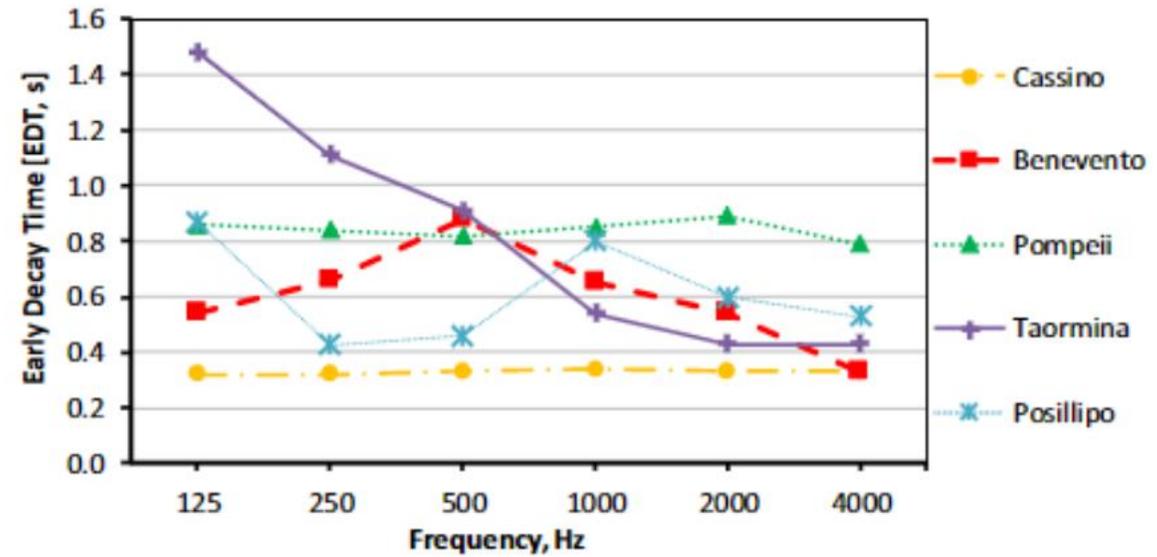
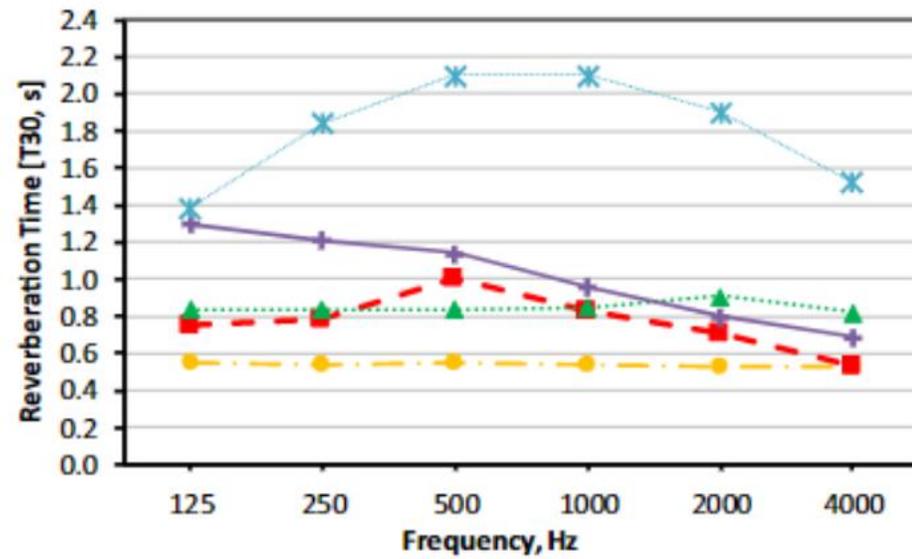
	Orchestra diameter [m]	Cavea diameter [m]	Length of the scena [m]	Historical maximum occupancy	Actual maximum occupancy
Cassino	15	53	27	2000	1000
Taormina	34	110	70	10,000	4500
Pompeii	10	60	30	3700	1800
Benevento	26	93	42	10,000	1200
Posillipo	10	47	30	1,800	1000

Table 3  
Audience absorption coefficients.

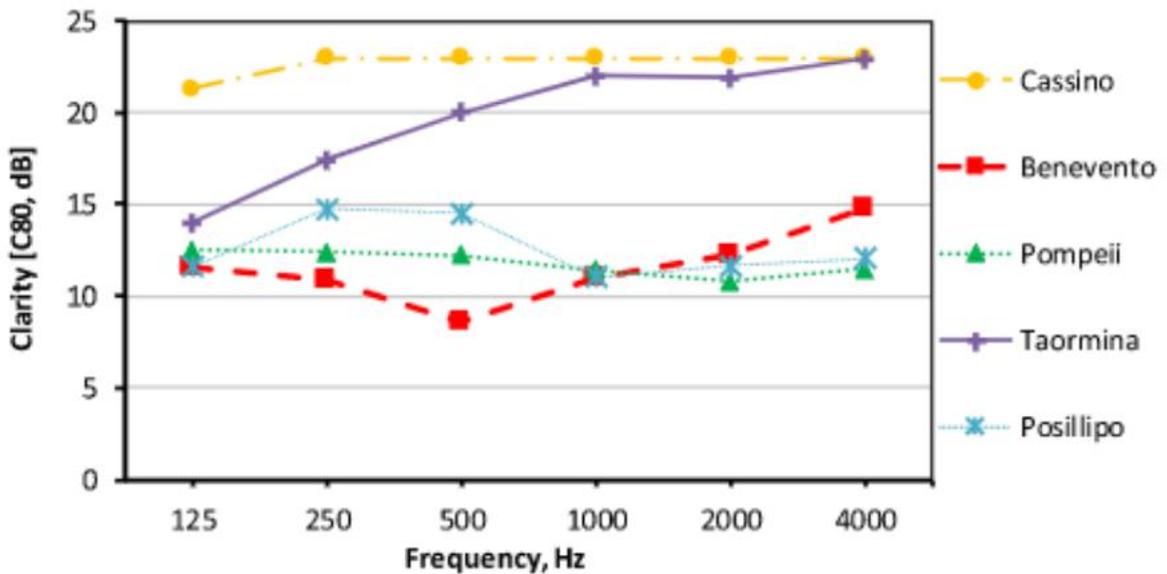
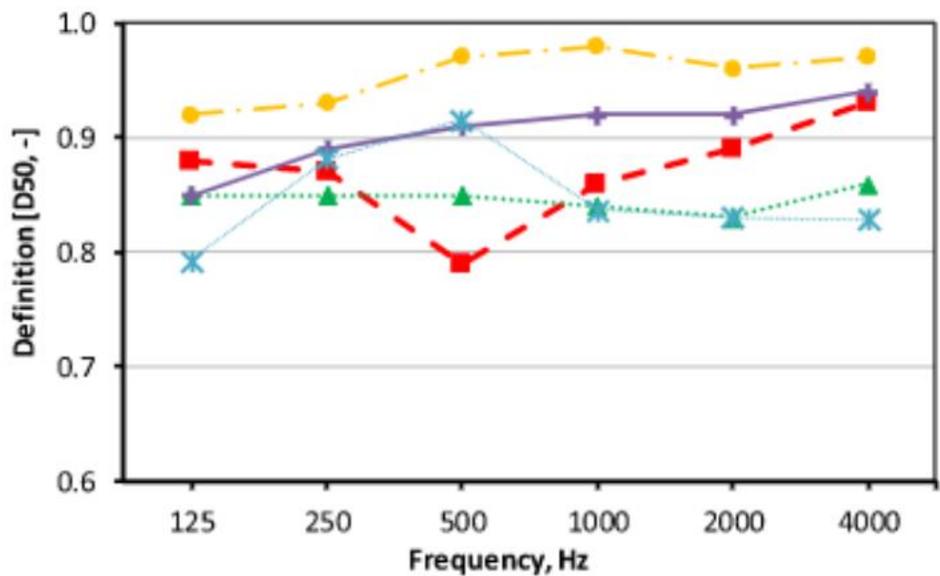
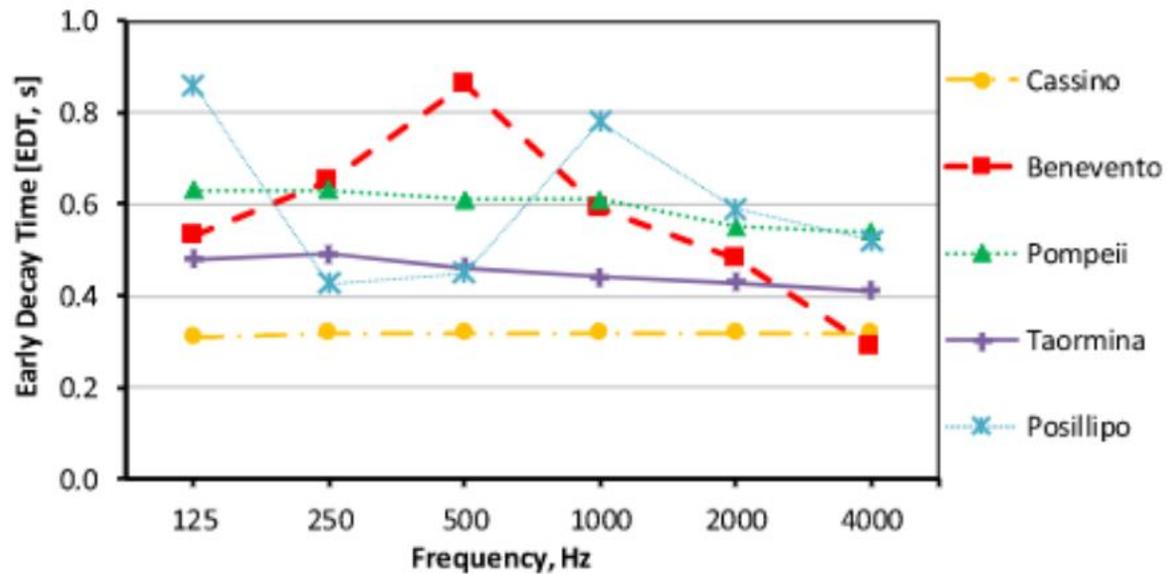
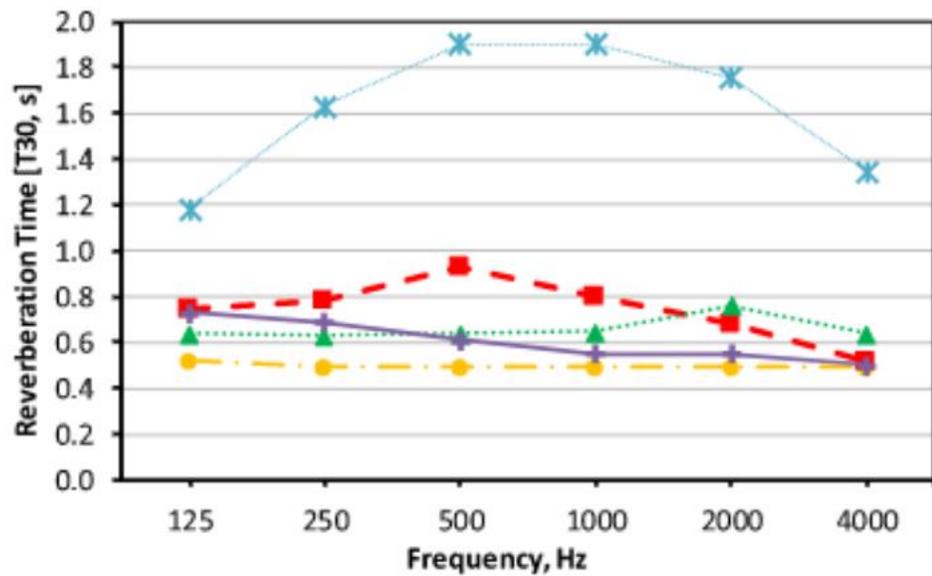
Audience absorption coefficients	Frequency					
	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Audience, seated in upholstered seats [16]	0.39	0.57	0.80	0.94	0.92	0.87
Congregation, seated in wooden pews [16]	0.57	0.61	0.75	0.86	0.91	0.86
Audience on timber seats (1/m <sup>2</sup> ) [36]	0.17	0.24	0.56	0.69	0.81	0.78
Audience on timber seats (2/m <sup>2</sup> ) [36]	0.28	0.40	0.78	0.98	0.96	0.87
Areas with audience, orchestra or seats, including narrow aisles [36]	0.60	0.74	0.88	0.96	0.93	0.85
Audience, 1 person per m <sup>2</sup> [27]	0.17	0.24	0.56	0.69	0.81	0.78
Audience, 2 persons per m <sup>2</sup> [27]	0.28	0.40	0.78	0.98	0.96	0.87
Maximum values	0.60	0.74	0.88	0.98	0.96	0.87
Minimum values	0.16	0.24	0.56	0.69	0.81	0.78



[8] Article: The acoustic of Roman theatres in Southern Italy and some reflections for their modern uses  
[The acoustic of Roman theatres in Southern Italy and some reflections for their modern uses - ScienceDirect](https://www.sciencedirect.com/science/article/pii/S0167636920300011)



*Averaged acoustic measurements results in the five theatres considered in the present study.  
 Measurements were taken in actual state and empty conditions*

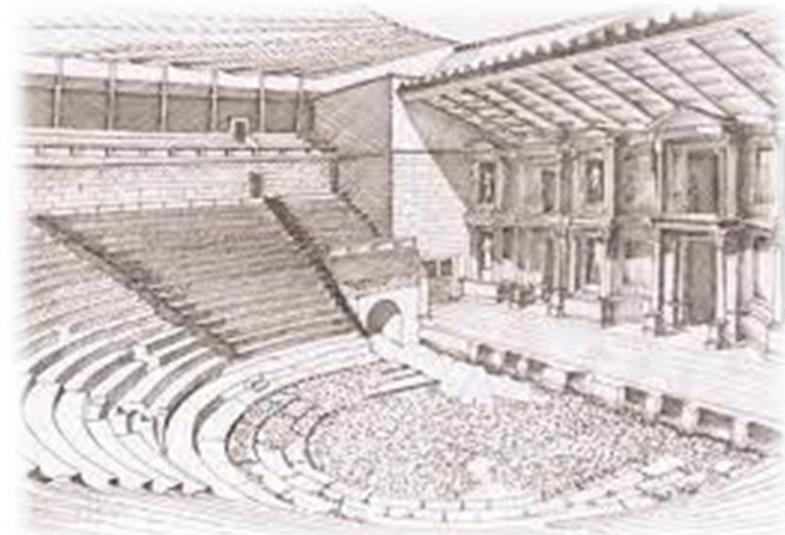
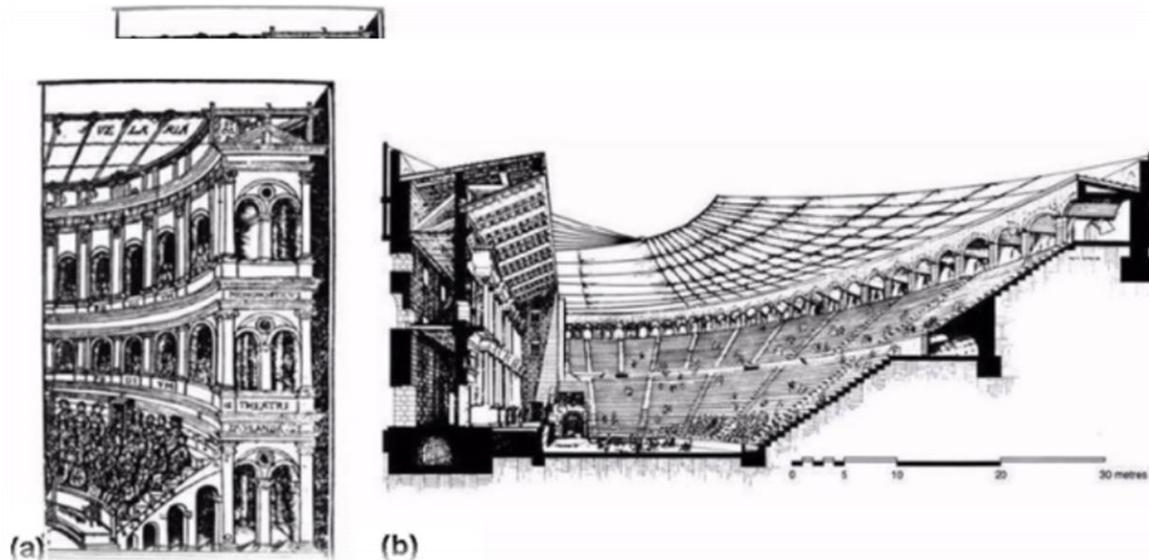


*Acoustic simulated results in the five theatres with the presence of the audience*

# Does Velaria have acoustic role on theatre?

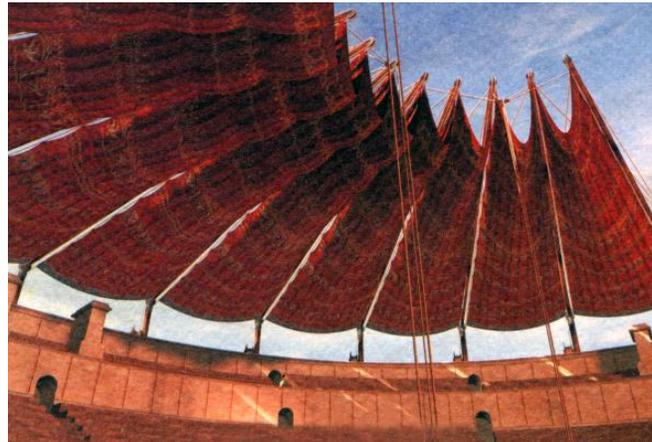
## What is Velaria/Velarium?

- A large awning used in roman theatre to shelter an amphitheatre from the weather.
- An inner ceiling used to improve acoustics in a theatre.



# Does Velaria have acoustic role on theatre?

- Effects of awnings on the reverberation of the two theatres in the present state.
- The awnings play the role of a large reflecting surface like a roofing. They should produce reflected sound to enrich the reverberant field.
- The awning should be flat and settled at the highed part of cavea wall and its opposite edge projected on the ground ends at the remains of the frons scanea wall.
- To evaluate the sound absorption coefficients of the material constituting the awning, be it a plain fabric weaved densely.

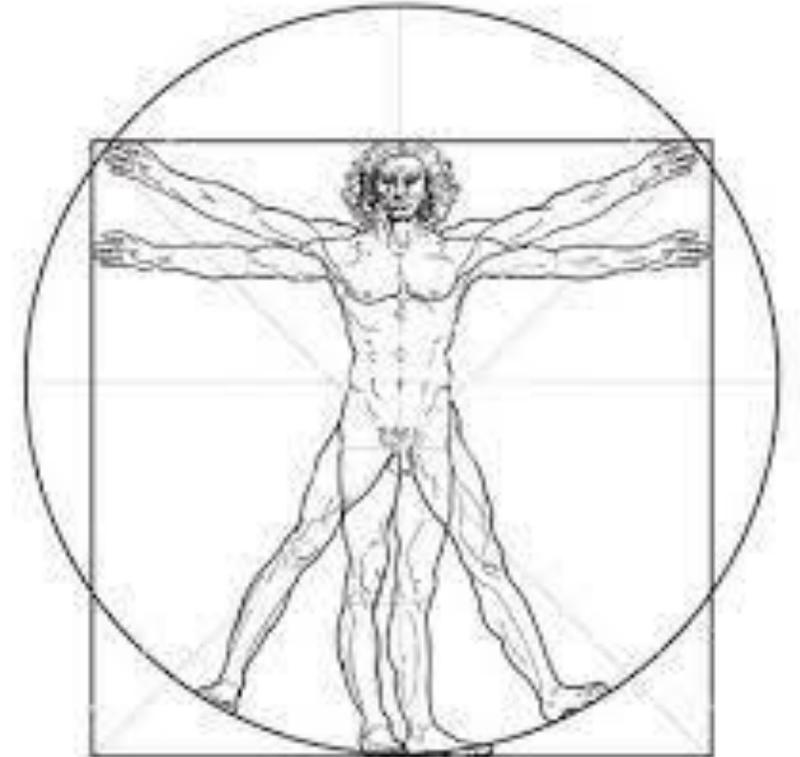


# **Vitruvius aspects of acoustics and Ancient Theatres**

The ancient theatre in its many aspects has, attracted a great deal of interest in recent years.

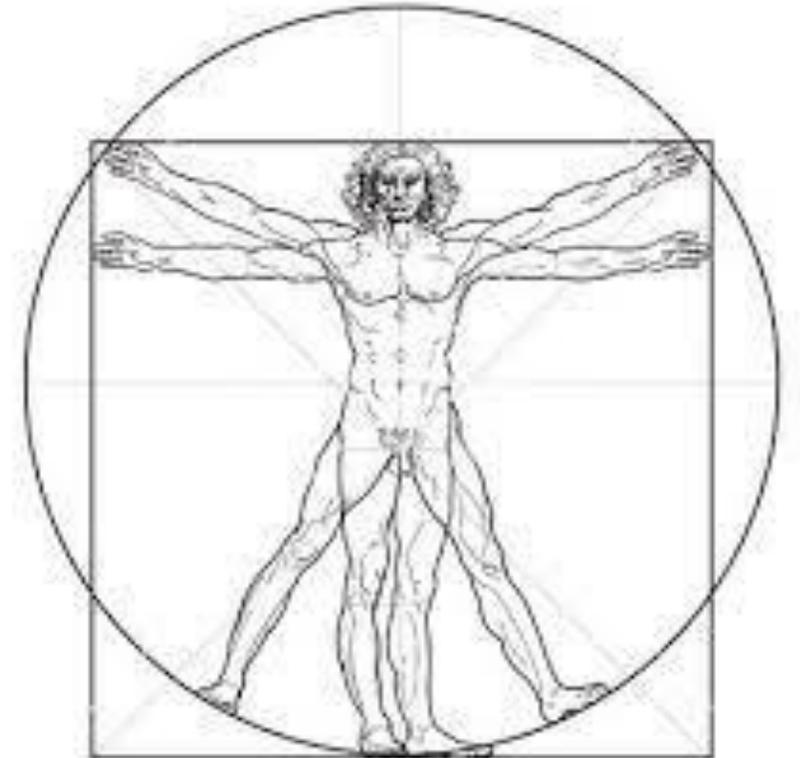
Vitruvius discussed in his Fifth Book on Architecture, *De Architectura*, the construction and proportions of the Greek and Roman theatres.

He explained where to set and how to layout the theatre and how Ancient theatres acoustical system can work.



# **Vitruvius aspects of acoustics and Ancient Theatres**

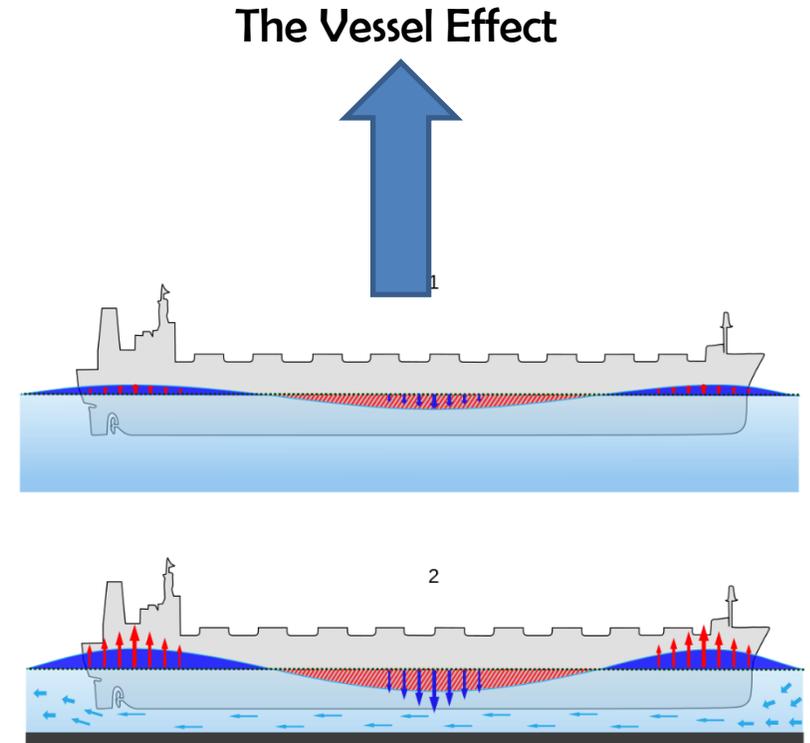
**Vitruvius is our sole source of information on classical building at a technical level although he has a lot of knowledge when it comes to outdoor acoustics, he is weak at indoor acoustics. The physical phenomenon of hearing is more complex, even though it is not directly observable. A line drawn from the first to the last step should touch the front angle of the tops of all the seats**



# Vitruvius aspects of acoustics and Ancient Theatres

## The Vessels Effect on the Acoustics of the Theatre

- What purpose could these vessels have served?
- What Vitruvius actually says about the vessels?

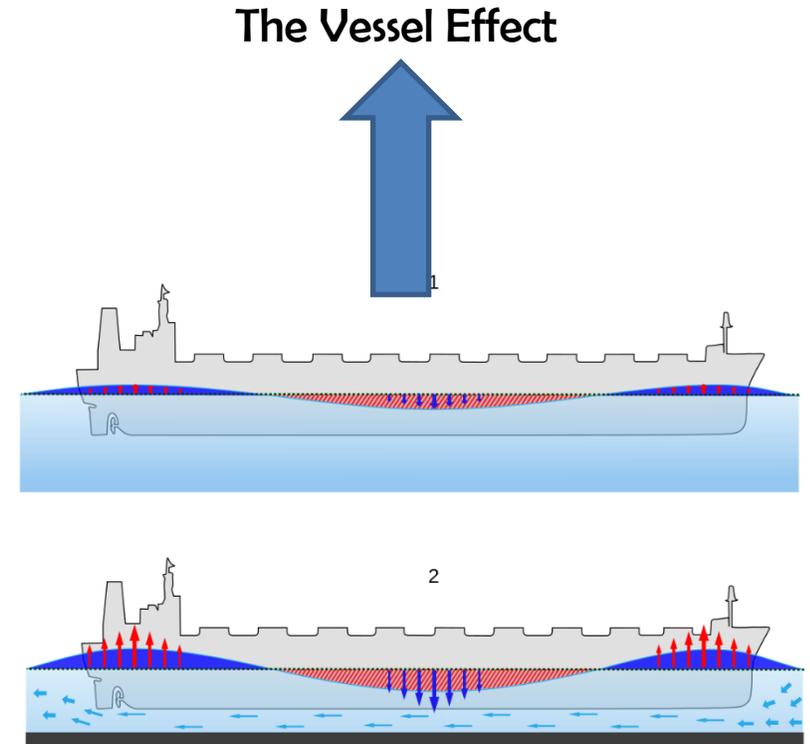


# Vitruvius aspects of acoustics and Ancient Theatres

## The Vessels Effect on the Acoustics of the Theatre

Vitruvius explains that many theatres were actually built of wood. Heavy wood construction helped to flatten the reverberation curve over the entire frequency range, and the wooden panels have a similar beneficial effect as the vessels, so the vessels are only useful in theatres built of stone.

From an acoustical point of view, such an empty vessel cannot radiate sound to the surroundings. However, such a resonator can mainly be efficient for sound absorption. The vessels were used to increase the clarity of the sound and not the strength of the sound as many have suggested. Such an acoustic resonator may amplify acoustic oscillations in a narrow frequency band around the resonance frequency, but the amplification is only inside the vessel. Though, such a resonator can be quite efficient for sound absorption, today this is often used for noise control in places where thick layers of mineral wool or textiles are not usable



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