



"We shall therefore borrow all our Rules for the Finishing our Proportions, from the Musicians, who are the greatest Masters of this Sort of Numbers, and from those Things wherein Nature shows herself most excellent and compleat." Leon Battista Alberti (1407-1472)

## Harmony and Proportion

by John Boyd-Brent, M.A.(Royal College of Art)

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## Introduction

**P**roportion within a geometrical figure, a musical scale , or indeed a mathematical sequence, can be said to be

"an harmonious relationship between the parts, with and within the whole".

These pages attempt to provide as simple as possible an introduction to, and explanation of, the principles governing harmony and proportion in space.

In Chapter V of Book IX of his Ten Books Of Architecture, completed in 1452, Leon Batista Alberti begins to define the natural beauty of form which takes a **mean between two extremes**;

"I will make use of an Example to illustrate my Meaning. Some admire a Woman for being extremely slender and fine shaped; the young Gentleman in "*Terence*" preferred a Girl that was plump and fleshy: You perhaps are for a Medium between these two Extremes, and would neither have her so thin as to seem wasted with Sickness, nor so strong and robust as if she were a Ploughman in Disguise, and were fit for Boxing: In short, you would have her such a Beauty as might be formed by taking from the first what the second might spare"

He then goes on to propose that beauty is a consent and agreement, where the constituent parts are congruous with what the "principal Law of Nature requires".

"The Ancients....did in their Works propose to themselves chiefly the Imitation of Nature, as the greatest Artist at all Manner of Compositions."

For Alberti, "Law of Nature" is no imprecise term; in fact he goes on to develop a line of enquiry which is designed to illuminate just how such a "Law" operates in our world of shapes and forms and figures:

"We are now to treat of the Figure:

"By Figure I understand a certain mutual Correspondence of those several Lines, by which the Proportions are measured, whereof one is the Length, the other is the Breadth, and the other is Height.

"The Rule of these Proportions is best gathered from those Things in which we find Nature herself to be most compleat and admirable; and indeed I am every day more and more convinced of the Truth of Pythagoras's Saying, that Nature is sure to act consistently, and with a constant Analogy in all her Operations:

"From whence I conclude that the same Numbers, by means of which the Agreement of Sounds affects our Ears with Delight, are the very same which please our Eyes and Mind. We shall therefore borrow all our Rules for the Finishing our Proportions, from the Musicians, who are the greatest Masters of this Sort of Numbers, and from those Things wherein Nature shows herself most excellent and compleat."

By linking proportion with underlying harmonious causes, Alberti was refering back to a long tradition of philosophical thought, one which, in the West at least, began with Plato and Pythagoras.....

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# Plato

## The Timaeus

### The Composition of the Soul

In The Timaeus, Plato (d. 347 B.C.) was one of the first to write an explicit description of how all that exists is ultimately a single being:

"God, purposing to make the universe most nearly like the every way perfect and fairest of intelligible beings, created one visible living being, containing within itself all living beings of the same natural order."

"There exists:  
*first*, the unchanging form, uncreated and indestructible, admitting no modification and entering no combination,.....  
*second*, that which bears the same name as the form and resembles it.....and  
*third*, space which is eternal and indestructible, which provides a position for everything that comes to be."  
(Timeus, 20)

For Plato one of the "best, highest or fairest ways" in which Being and Existence, the one God and the multiplicity of things, are bound together as a single reality, is the suffusion of harmony and proportion throughout creation.

"The fairest of all bonds is that which makes of itself and the terms it binds together most utterly one, and this is most perfectly effected by a progression." (Timeus, 4)

*also translated as.....*

"The best bond is the one that effects the closest unity between itself and the terms it is combining; and this is best done by a continued geometrical proportion"

The idea is that the harmoniously interdependent relationship of parts, within the whole, and to the whole, symbolises the relationship of ourselves and our universe of space and time, with the "single" whole; our metaphysical reality.

Thus, to be concerned with harmonious creation, be it architectural, artistic, musical, or even agricultural, came to be seen as a natural consequence of awareness of our harmonious relationship with God.

Although the world of the so-called Dark Ages also inherited the Graeco-Roman "Classical" philosophical outlook which informed much of the thought of the time, there was a sudden impetus which arose in the early Medieval period: Many Greek texts which were lost in Christendom, had been preserved by Jewish and Islamic scholars and were reintroduced to Europe at about this time. This came about partly through increased contact due to trade in the Mediterranean, partly as a result of increased contact during the crusades, and partly through an exchange of ideas which occurred between the great monastic centres of learning in Europe, such as the School of Chartres, and Moorish Spain, especially Grenada in the 13th and 14th centuries. Scholars in Europe became aware of the writings of Maimonides (Moses ben Maimon 1135-1204), the Aristotelian Averoes (Ibn Rushd 1126-1198) and the work of Muhyiddin Ibn 'Arabi (1165-1240), who was known as "The Son of Plato" and *Doctor Maximus*.

One re-occurring theme was Aesthetics. What was the beauty of being? How was beauty linked with form. There was less division between the concept of beauty and the concept of usefulness than there is today. That is to say; beauty as a state was seen as integral with its property as being a functional aspect of existence. The way beauty appears is a result of it being the way in which the universe is put together . . . . and as such it is naturally congruent with such concepts as; number, proportion, harmony, and music. The creation, the universe, is beautiful because it perfectly reflects God's beauty who made it according to that beauty.

William of Auxerre, (1140-1231):

"The goodness of a substance and its beauty are the same thing.... The beauty of a thing consists in these three attributes (species, number and order)- the very same in which Augustine says its goodness consists"

"John Scotus Eriugina conceived of the universe as a revelation of God in His ineffable beauty, God reflected both in material and in ideal beauty, and diffused in the loveliness of all creation." ( Umberto Eco, Art and Beauty in the Middle Ages, p.18. )

Dionysius the Areopagite, ( early 6th C. AD), from "De Divinis Nominibus",:  
"The Superessential Beautiful is called "Beauty" because of that quality which it imparts to all things severally according to their nature, and because It is the Cause of the harmony and splendour in all things, flashing forth upon them all, like light, the beautifying communications of its originating ray; and because It summons all things to fare unto Itself (from whence It hath the name of "Fairness"), and because It draws all things together in a state of mutual Interpenetration."

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To conclude this page, here is more from Plato's Timeus (6), which introduces the profound idea of the "soul" being the synthesis and intermediary between the Essence of the universe and the universe itself: Taking "Same " to refer to the "indivisible, unchangeing Existence (Essence)" and "different" to refer to "the divisible, changing existence of the physical world", (or vice versa...) it appears that Plato is describing the soul as the intermediate "synthesis which links and unites the Essence with the world. It is this "soul", this "intermediate existence" which has been divided into harmoniously "appropriate subdivisions" summarised in the ""lamda" configuration at the bottom of the page, and which for Pythagoras summed up the essence of harmony.

"God did not of course contrive the soul later than the body, as it has appeared in the narrative we are giving; for when he put them together he would never have allowed the older to be controlled by the younger.

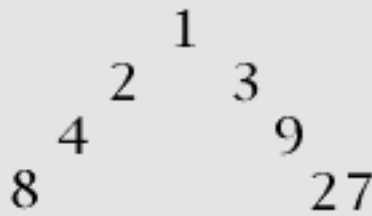
Our narrative is bound to reflect much of our own contingent and accidental state.

But God created the soul before the body and gave it precedence both in time and value, and made it the dominating and controlling partner. And he composed it in the following way and out of the following constituents;

From the indivisible, eternally unchanging Existence [Essence] and the divisible, changing Existence of the physical world he mixed a third kind of existence intermediate between them: again with the Same and the Different he made, in the same way, compounds intermediate between their indivisible element and their physical and divisible element: and taking these three components he mixed them into a single unity, forcing the Different, which was by nature allergic to mixture, into union with the Same, and mixing both with Existence.

Having thus made a single whole of these three, he went on to make appropriate subdivisions, each containing a mixture of the Same, and Different, and Existence. He began the division as follows.

He first marked off a section of the whole, and then another twice the size of the first; next a third, half as much again as the second and three times the first, a fourth twice the size of the second, a fifth three times the third, a sixth eight times the first, a seventh twenty-seven times the first."



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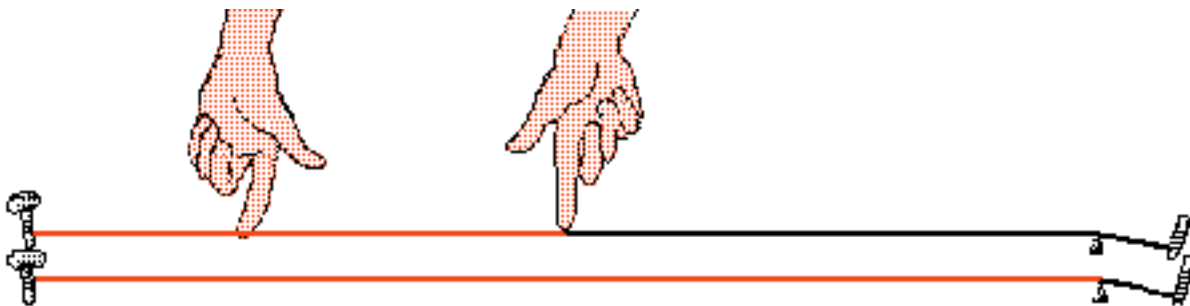




**P**ythagoras (6th C. B.C.) observed that when the blacksmith struck his anvil, different notes were produced according to the weight of the hammer. Number (in this case "amount of weight") seemed to govern musical tone. . . .

Further, he observed that if you take two strings in the same degree of tension, and then divide one of them exactly in half, when they are plucked the pitch of the shorter string is exactly one **octave** higher than the longer:

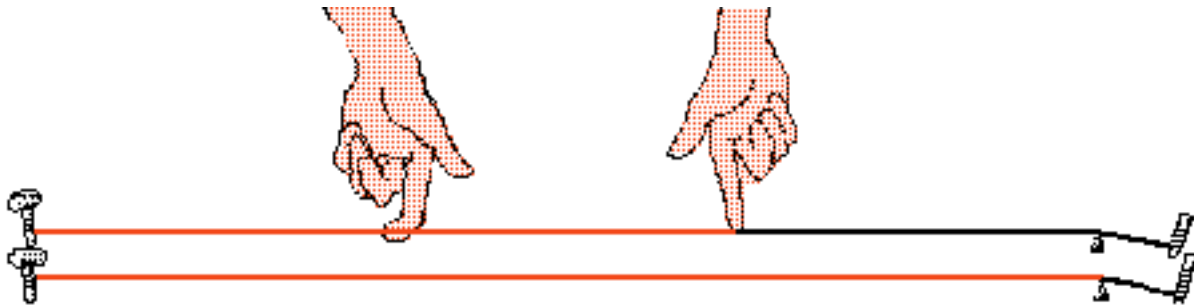
If you have something like SoundMachine that can play sound (.av), you can pluck the strings to hear the notes: the sounds may take some seconds to reach you *but each is under 22K....* See if you can hear the sound in your imagination before it comes, by judging from the proportions of the string lengths (the first one's easy.....)



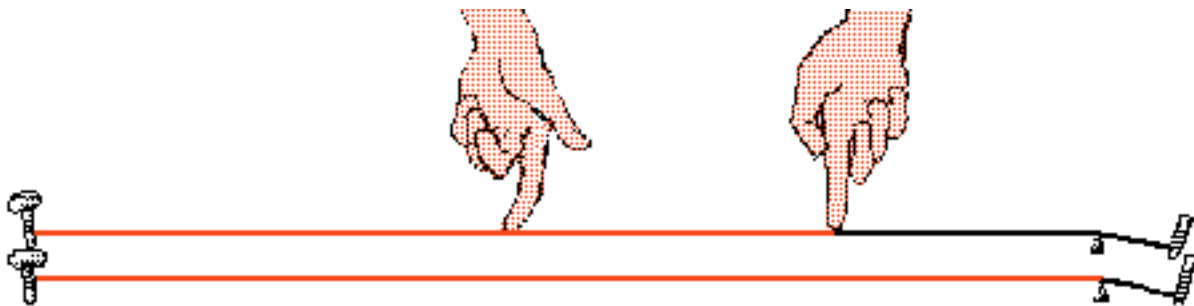


Again, number (in this case "amount of space") seemed to govern musical tone. Or does musical tone govern number?

He also discovered that if the length of the two strings are in relation to each other **2:3**, the difference in pitch is called a **fifth**:



...and if the length of the strings are in relation to each other **3:4**, then the difference is called a **fourth**.

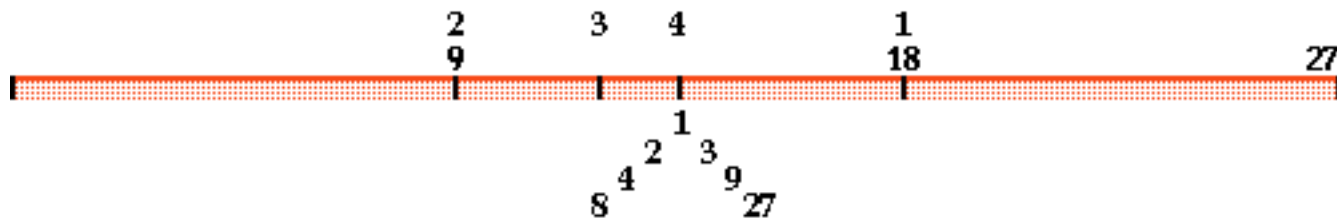


Thus the musical notation of the Greeks, which we have inherited can be expressed mathematically as **1:2:3:4**

All this above can be summarised in the following.



(Another consonance which the Greeks recognised was the octave plus a fifth, where  $9:18 = 1:2$ , an octave, and  $18:27 = 2:3$ , a fifth;)



This triangular figure of numbers in the shape of the Greek letter **Lambda** is the **Tetrad** of the Pythagorians.

As was discussed by Plato in his dissertation on [the Composition of the Soul](#), it is a set of numbers whose relationships with each other seemed to summarize all the inter-dependent harmonies within the universe of space and time.

Thus to have established the relationship between music and space/number fired the imagination of the Pythagorians and was taken up especially by the School of Plato and the subsequent Neo-Platonists. Pythagoras himself wrote nothing which has survived, and so it is the Platonists we have to thank for recording and developing what had hitherto been passed down through two hundred and fifty years of oral tradition.

Pythagoras taught that each of the seven planets produced by its orbit a particular note according to its distance from the still centre which was the Earth. The distance in each case was like the subdivisions of the string referred to above. This is what was called *Musica Mundana*, which is usually translated as Music of the Spheres. The sound produced is so exquisite and rarified that our ordinary ears are unable to hear it. It is the Cosmic Music which, according to Philo of Alexandria, Moses had heard when he received the Tablets on Mount Sinai, and which St Augustine believed men hear on the point of death, revealing to them the highest reality of the Cosmos. (Carlo Bertelli, Piero della Francesca, p. 60.) This music is present everywhere and governs all temporal cycles, such as the seasons, biological cycles, and all the rhythms of nature. Together with its underlying mathematical laws of proportion it is the sound of the harmony of the created being of the universe, the harmony of what Plato called the "one visible living being, containing within itself all living beings of the same natural order".

For the Pythagorians different musical modes have different effects on the person who hears them; Pythagoras once cured a youth of his drunkenness by prescribing a melody in the Hypophrygian mode in spondaic rhythm. Apparently the Phrygian mode would have had the opposite effect and would have overexcited him. At the healing centers of Asclepieion at Pergamum and Epidauros in Greece, patients

underwent therapy accompanied by music. The Roman statesman, philosopher and mathematician, Boethius (480-524 A.D.) explained that the soul and the body are subject to the same laws of proportion that govern music and the cosmos itself. We are happiest when we conform to these laws because "we love similarity, but hate and resent dissimilarity". (*De Institutione Musica*, 1,1. from Umberto Eco, *Art and Beauty in the Middle Ages*. p. 31).

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# Leon Battista Alberti

Music with Arithmetic, Geometry and Astronomy, made up the Quadrivium, the four ways, or liberal arts, advocated in the Middle Ages as essential for the education of the human being, (together with their outward expression in Grammar, Rhetoric and Logic; the Trivium). Although the educated person would often have learnt to master a musical instrument, it was the mathematical and proportional aspect of music which was held to be of most relevance. Actually playing music, and even composing, because in the creative moment instinctive faculties seemed to have the upper hand, were, at least up to the end of the Middle Ages, seen as inferior to the purity of theory alone.

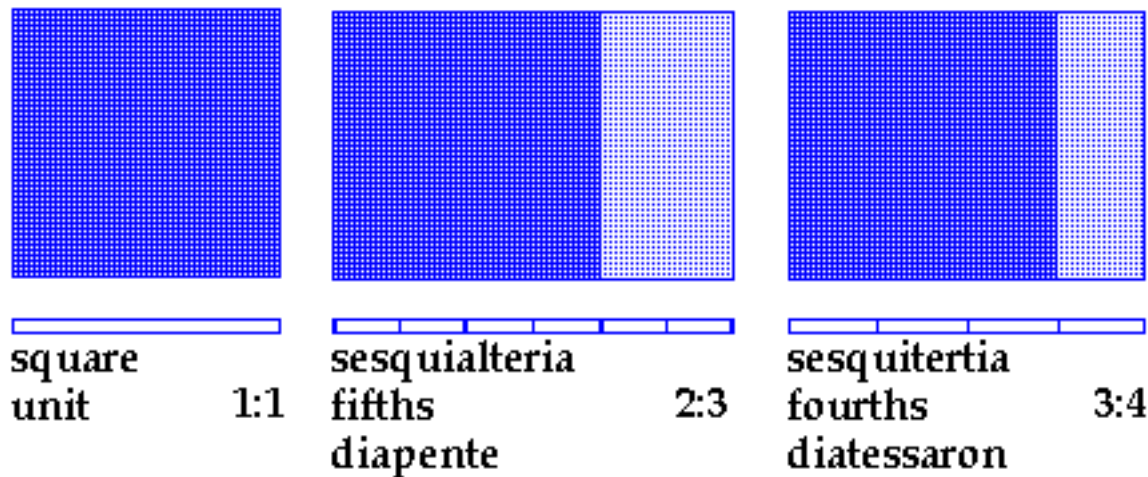
## from The Ten Books of Architecture, continued...

In Chapter VI, Alberti develops the relationship between the proportions of numbers and the measuring of areas.

Methodically, he lists three types of area; short, middle, and long.

The shortest of all is the square, and in this category of short areas he includes, sesquialteria, or fifths, or diapente, and sesquitertia, or fourths, or diatessaron:

### Alberti. "short areas"



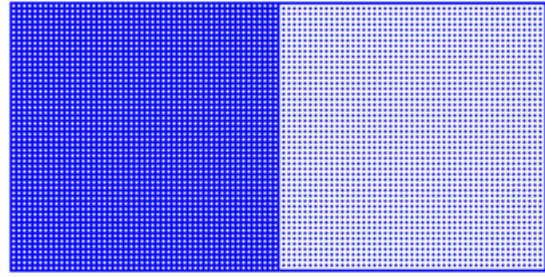
"These three Proportions therefore, which we may also call simple, are," he says, "proper for the smaller Platforms."


Then he lists three further Proportions "Proper for middling Platforms":

First the Double, which he says is best;  
second, the Sesquialtera Doubled;  
and third, the Sesquitertian Doubled.

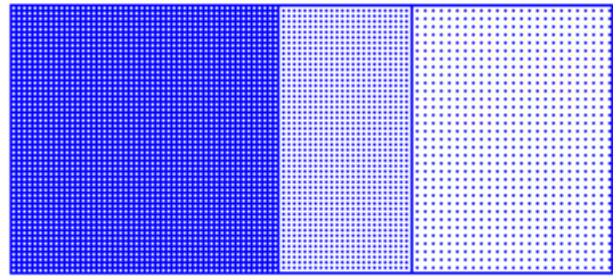
The first is a straightforward:


**Alberti. "middle areas"**



 **double square** **1:2**

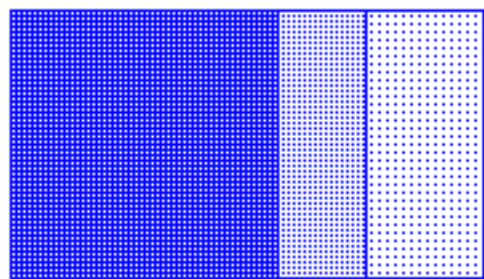
The second is found by taking a square, finding its fifth or sesquialtera, and extending the area by that amount, and then, in turn, extending that area by its fifth:




 **sesquialtera doubled** **4:9**

"Thus the Length will exceed the Breadth by a double Proportion plus one Tone more"

The third Proportion is found by doing the same with the square and its Fourth

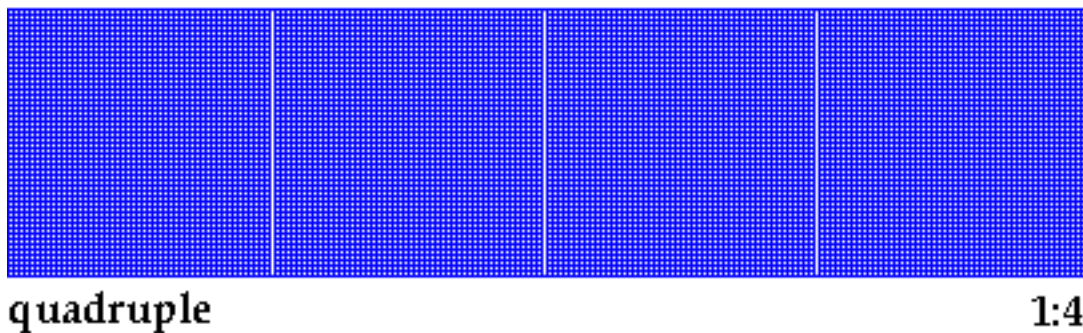
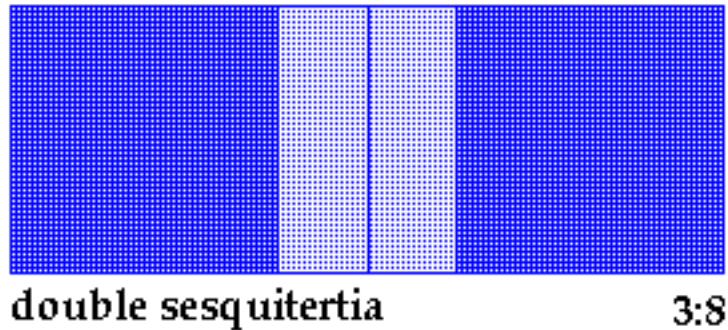
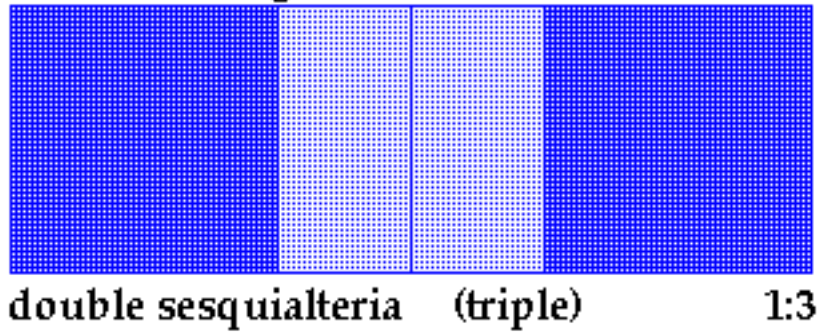


 **sesquitertia doubled**  
**9:16**

"Here the longer Line contains the shorter twice, excluding one Tone of that shorter Line."

For his category of "long" areas he lists three: Double Sesquialtera, Double Sesquitertia, and Quadruple.

## Alberti. "long areas"



## Alberti's own summary:

Short: 1:1, 2:3, 3:4

Middling: 2:4, 4:9, 9:16

Long: 1:3, 3:8, 1:4

"By the help of these Mediocrates the Architects have discovered many excellent Things, as well as with Relation to the whole Structure, as to its several Parts; which we have not Time here to particularize. But the most common Use they have made of these Mediocrates, has been however for their Elevations." (p, 200, 1775, Leoni Edition.)

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(Note: 18th Nov. 1997: I hope soon to add the sound files which correspond to these areas.)

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# Palladio



When Andrea Palladio, (1508-1580), in "The Four Books of Architecture", published in 1570, suggested **seven sets of the most beautiful and harmonious proportions to be used in the construction of rooms**, he chose measurements which reflect musical consonances. He suggests;

1. Circular



2. Square



1:1

3. The diagonal of the square



1:1.414....etc.

4. A square plus a third



3:4

5. A square plus a half



2:3

6. A square plus two-thirds



3:5

7. Double square



1:2

Compare these with Pythagoras's musical scale which we saw [above](#):

The exception is the incommensurable proportion of the side of the square to its diagonal, or [1 : square root of 2](#).

(This proportion often occurs in both architecture and painting)

When Palladio goes on to talk about the generation of the height of rooms, he elucidates three types of proportion which are traditionally thought to have been discovered by Pythagoras:



- The Arithmetic Mean,
- The Geometric Mean,
- The Harmonic Mean.

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# Palladio

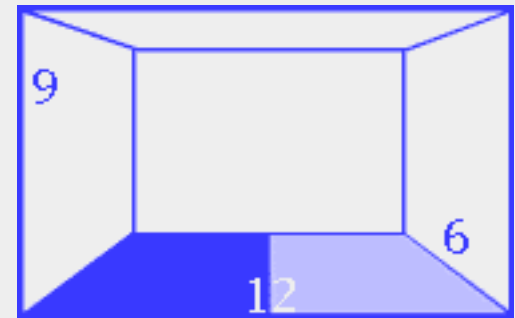
## The Arithmetic Mean.

"....let the room to be vaulted be twelve feet long and six broad; add six to twelve and it will make eighteen, the half of which is nine; the vault ought therefor to be nine feet."

In an Arithmetic Mean, the second amount exceeds the first by the same amount as the third exceeds the second, as in 2:3:4. Three exceeds two by the same amount that four exceeds three. Or, in Palladio's example:

9 exceeds 6 by 3,  
which is the same amount by which 12 exceeds 9.

Practically, this means taking the length and adding it to the width, then dividing the result in half, as Palladio described.



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# Palladio

## The Geometric Mean.

"....the length and breadth of the room being known, we will find a number that has the same proportion to the breadth as the length has to the number sought.....if the place we intend to vault is nine feet long and four feet wide, the height will be six feet"

In a Geometrical Mean the first amount is in proportion to the second amount as the second is to the third.  $a$  is to  $b$  as  $b$  is to  $c$ . Or  $a:b = b:c$ .

In Palladio's example;  
 6 exceeds 4 by a third of 6 which is 2,  
 just as 9 exceeds 6 by a third of 9 which is 3.  
 Or 4:6:9. Or 4:6 = 6:9.

Practically this means, in the words of Palladio;

"..we find this by multiplying the lesser extreme with the greater; because the square root of the number which will result from such a multiplication will be the number we seek."

In his example we multiply the lesser extreme, or width, which is 4, by the greater extreme, which is 9, to get 36. The square root of 36, (i.e. the only number which when multiplied by itself will give 36) is 6. Thus the height of the room is 6.



## Here is a summary of the Arithmetic and Geometric means:

 The Arithmetic Mean  
 $a < b = b < c$

 The Geometric Mean  
 $a:b=b:c$

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# Palladio

## The Harmonic Mean.

This is more complicated ! . . . .

It is derived from the section in Plato's Timeaus which follows on directly after his description of the Lamda (Timeaus, 6) which describes the "[composition of the soul](#)".

"Next, he (God) filled in the double and treble intervals by cutting off further sections and inserting them in the gaps, so there were two mean terms in each interval, *one exceeding one extreme and being exceeded by the other by the same fraction of the extremes; the other exceeding and being exceeded by the same numerical amount.*

These links produced intervals of  $\frac{3}{4}$  and  $\frac{4}{3}$  and  $\frac{9}{8}$  within the previous intervals, and he went on to fill all the intervals of  $\frac{4}{3}$  with the interval  $\frac{9}{8}$ ; this left, as a remainder in each, an interval whose terms bore the numerical ratio of 256 to 243. And at that stage the mixture from which these sections were being cut was all used up".

The first part of the clause in italics refers to the Harmonic Mean, the second to the Arithmetic Mean. In other words the Harmonic Mean is the mean exceeding one extreme, and being exceeded by the other, by the same fraction of the extremes.

Palladio uses the example of a room six feet wide by twelve feet long which has a ceiling height of eight feet. The mean, 8, exceeds the smaller extreme, 6, by a third of the smaller extreme; 2, just as it (the mean) is itself exceeded by the same fraction (a third) of the larger extreme, 12, which is 4.

This is expressed as:  $(8-6)$  divided by 6 =  $(12-8)$  divided by 12,

or, where b is the mean between the two extremes a and c:

$(b-a)$  divided by a =  $(c-b)$  divided by c.

Practically, this is found by multiplying the greater and lesser extremes and dividing the result by the Arithmetical Mean found in the first example.

Thus 12 times 6 gives 72, which is then divided by the arithmetical mean, 9, to give the answer 8 which is the harmonic mean; the height of the room.

Another way of doing this, if you don't want to find the Arithmetic Mean first, is to multiply the greater by the lesser,  $12 \times 6 = 72$ , then multiply that result by two,  $2 \times 72 = 144$ , and then divide that result by the sum of the two extremes (6 and 12):

Thus; 144 divided by  $(6 + 12)$ , that is, 144 divided by 18 = **8**.

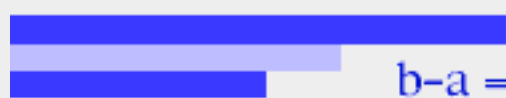
This can be remembered by the following formula;

$b = 2ac$  divided by  $(a+c)$ .

Here is a summary of all three Means:

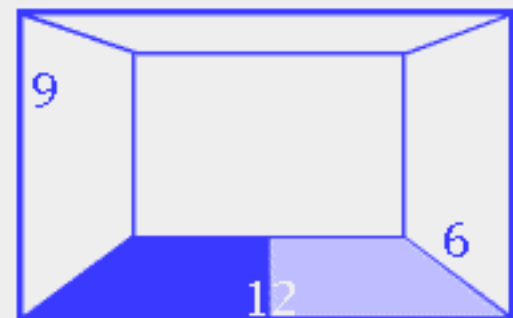
 The Arithmetic Mean  
 $a < b = b < c$

 The Geometric Mean  
 $a:b=b:c$

 The Harmonic Mean  
 $\frac{b-a}{a} = \frac{c-b}{c}$ , or,  $b = 2ac \div (a+c)$

And a summary of all three means as applied to Rooms:

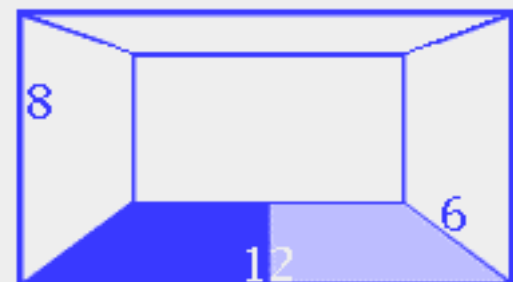
The Arithmetic Mean



The Geometric Mean



The Harmonic Mean



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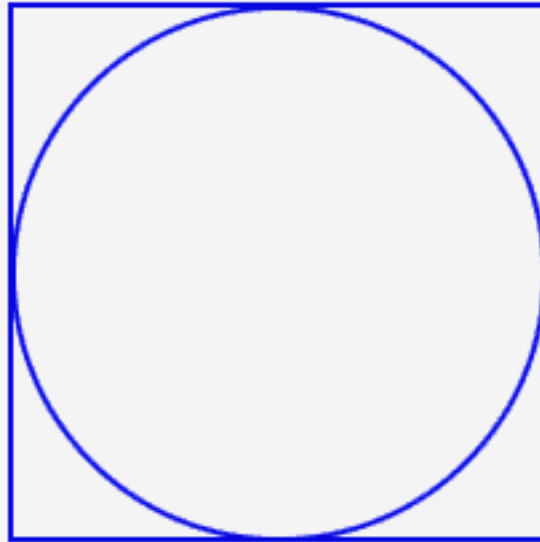
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# The Circle and the Square and the Square Root of Two



Anyone who while standing in a city street has looked up at the dome of the sky will recognise this figure as being the distillation of a fundamental condition of human life. On the one hand; *order*, sometimes man-made, sometimes natural, and on the other hand; boundless encircling *space*. On the one hand things as they appear to be, and on the other a space of unlimited possibility.

## Circle

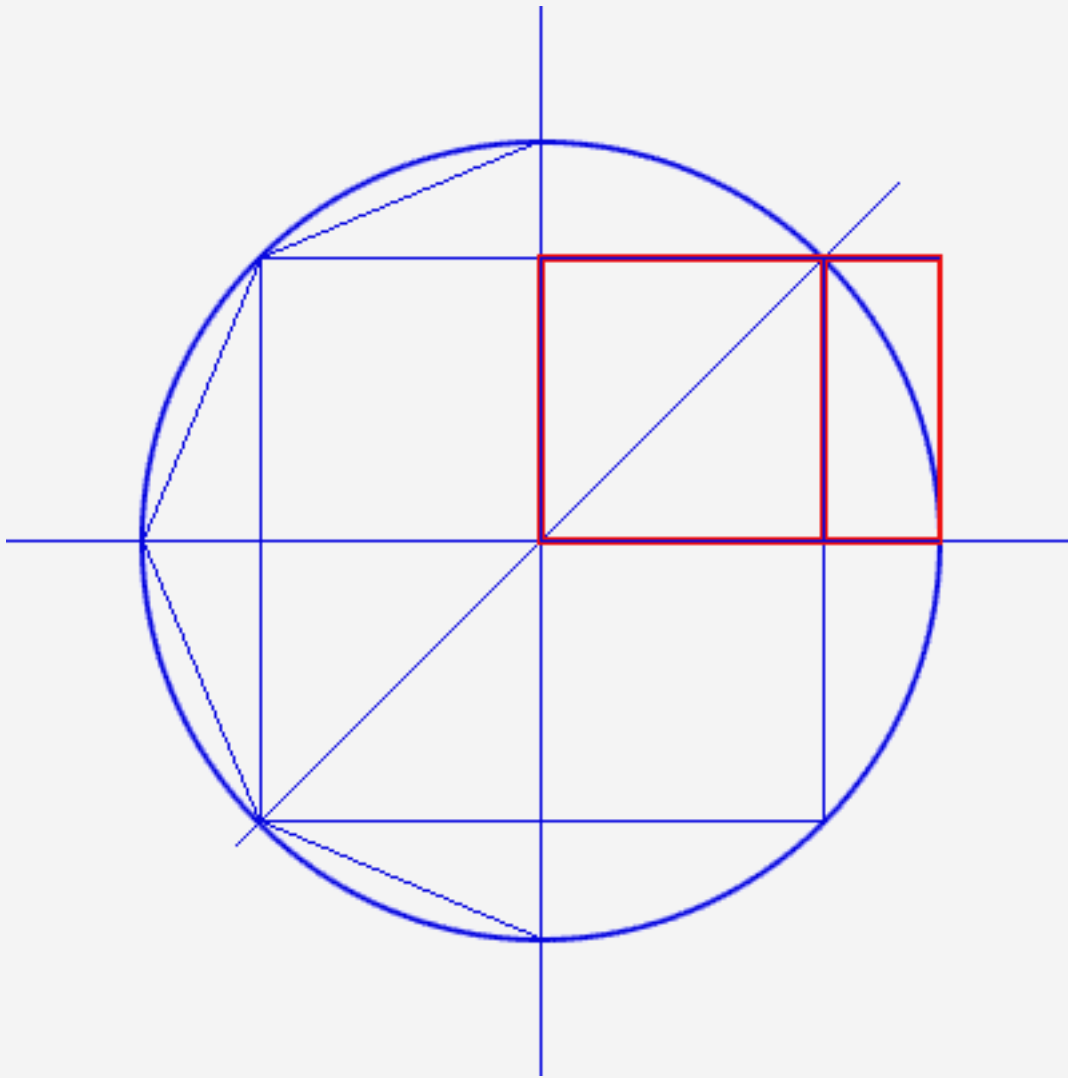
Sky  
Heaven  
Infinite  
Non-manifest Essence  
Interior Cause  
All-Encompassing  
Centre

## Square

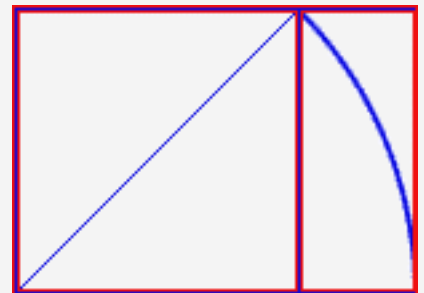
Earth  
Earth  
Finite  
Manifest Things  
Exterior Effect  
Things Encompassed  
Four Directions

Those who drew the squared circle and who investigated its geometrical relationships found that the diagonal of the square seemed to have some importance as is shown in the following figure:





When early geometers came to try to understand mathematically the proportional relationship between the side of a square and its diagonal, they found that there was no straightforward way. Cut and divide as many times as you like, there can be no numerical relationship between the two. Today our system of numbers is able to describe the relationship as  $1:1.414\dots$  (etc., a decimal without end...), but the two sides of the relationship remain incommensurable. We refer to the relationship as "irrational", not meaning "without reason", but "without numerical ratio".



Because the irrational relationship between the square and its diagonal seems to give a glimpse of a kind of order which is not resultant from (or dependent on) manifest number, but appears to indicate a "*meta-physical*" cause, it has in the past been held by architects and artists to have special significance. Its appearance in the underlying geometry of the Squared Circle echoes or symbolises the "dialogue" between the Heavens and the Earth, the Infinite and the Finite.

# Summary

*Musica Mundana*, the Music of the Spheres, the exquisite and rarified interior sound of the Cosmos, is reflected in the harmonious relationships of certain *sounds* and *geometrical forms* within the space of our universe....

The relationship between the side and diagonal of a square is not of this same order, but nevertheless fulfills the same function as a symbol (analogous to the squared circle) of the harmonious relationship between Form and Essence, Finite and Infinite.

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Selected Reading:

Leon Battista ALBERTI, The Ten Books of Architecture, 1775 Leoni Edt. (Dover)

Andrea PALLADIO, The Four Books of Architecture (Dover)

Keith CRITCHLOW, Order in Space, 1979

PLATO, The Timaeus

Rudolf WITTKOWER, Architectural Principles in the Age of Humanism 1949/1988

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Also:

Very interesting Music and Proportion pages at: <http://www.mind.net/maps/>

and Barbara Hero's Lambdoma Harmonic Keyboard at: <http://www.mind.net/maps/htmla/hero.htm>

["River Nymph"](#) by John Leicmon, based on the Square Root of 2

[Sacred Geometry](#) by Bruce Rawles.

and

by the author:

["land\(paint\)walk"](#)

*Image/poetry* : A walk in remote landscape around a West Coast Scottish Sea-Loch

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Title Page: [Introduction](#)

Plato: [The Timaeus](#)

Pythagoras: [Music and Space](#)

Alberti: [Harmony and Proportion](#)

Palladio: [The Proportion of Rooms](#)- [The Arithmetic Mean](#)

[The Geometric Mean](#)- [The Harmonic Mean](#)

Summary: The Square Root of 2

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