Leonardo da Vinci

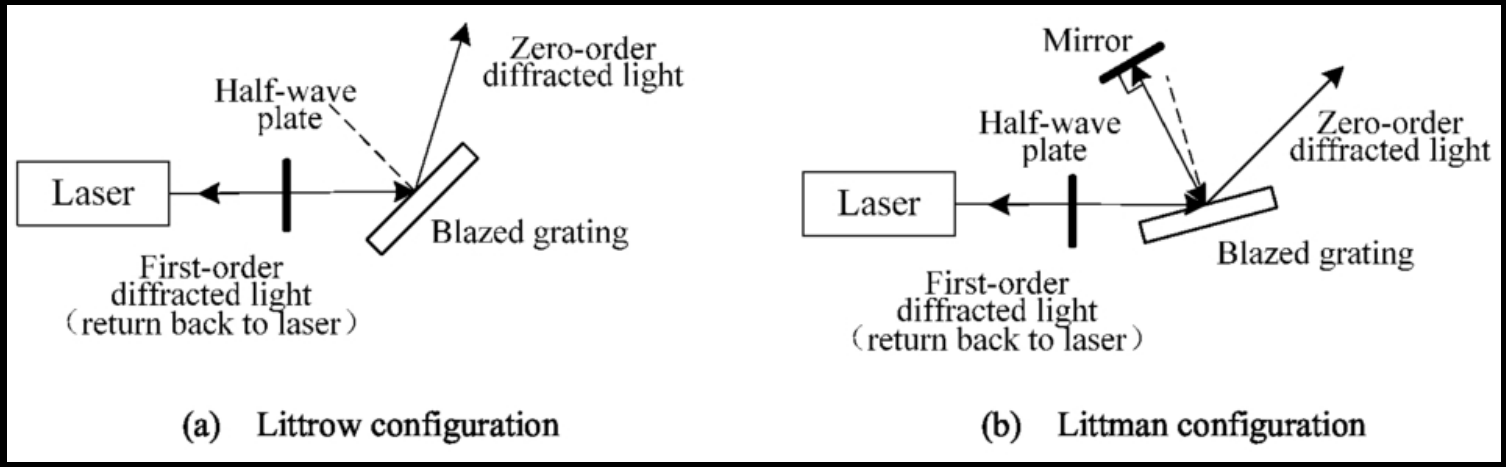
Painter / Military Engineer / Inventor

Michael Littman
Mechanical and Aerospace Engineering
Princeton University

Mar 17, 2020

Who am I? Physicist and Engineer with specialty in OPTICS

1) Design of Tunable Lasers



2) Design of Space-based Telescopes for Planet Finding

The Shaped Pupil Coronagraph for Planet Finding Coronagraphy: Optimization, Sensitivity, and Laboratory Testing

N. Jeremy Kasdin[a], Robert J. Vanderbei[b],
Michael G. Littman[a], Michael Carr[c] and David N. Spergel[c]

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Why am I lecturing about Leonardo?
I teach a course about the History of Engineering

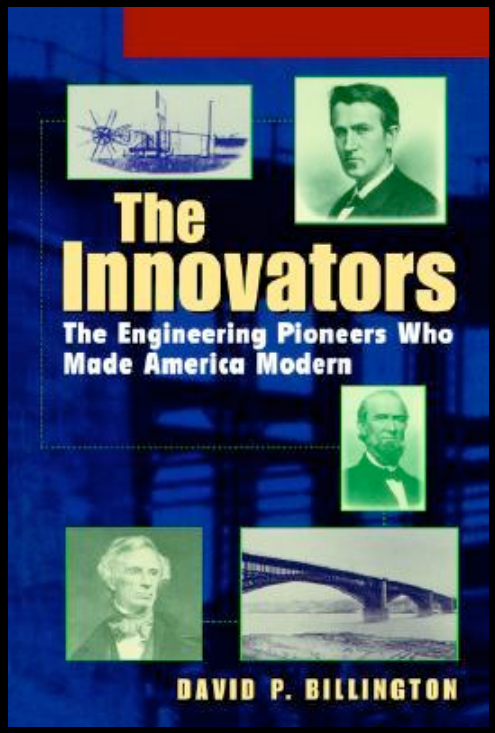
CEE 102 "Engineering in the Modern World"

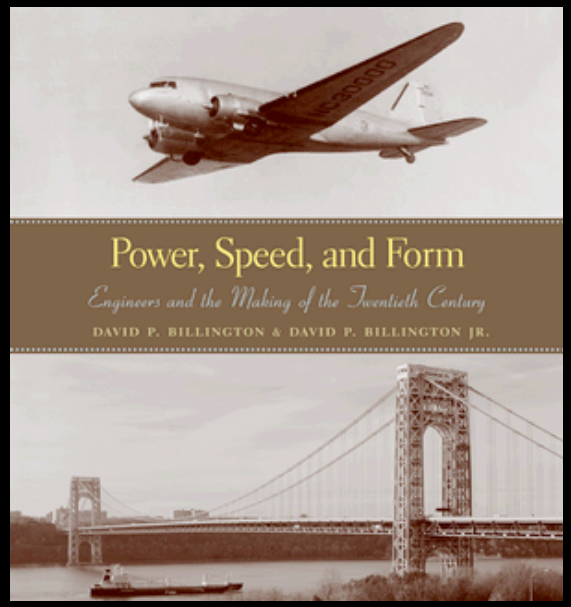
PERSPECTIVES

Scientific	Formulas
Social	Context
Symbolic	Meaning

CATEGORIES

Structures	Civil
Machines	Mechanical
Networks	Electrical
Processes	Chemical





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PERIODS

Iron, Independence, and Industry
1776 - 1855
Connecting the Continent
1830 - 1883
Rise of the Great Industries
1876 - 1939
Regional Restructuring
1921 - 1964
Information and Infrastructure
1946 - present

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CEE 102 "Engineering in the Modern World"

How do innovations happen?

Scientific: **How does it work?**
Social: **What is it good for?**
What is the context?
Symbolic: **Why should one care?**

Person: **Who did what?**
Motivation: **Why did they do it?**
History: **When and Where?**
What is the impact?

- Influential people
- Influential objects and systems

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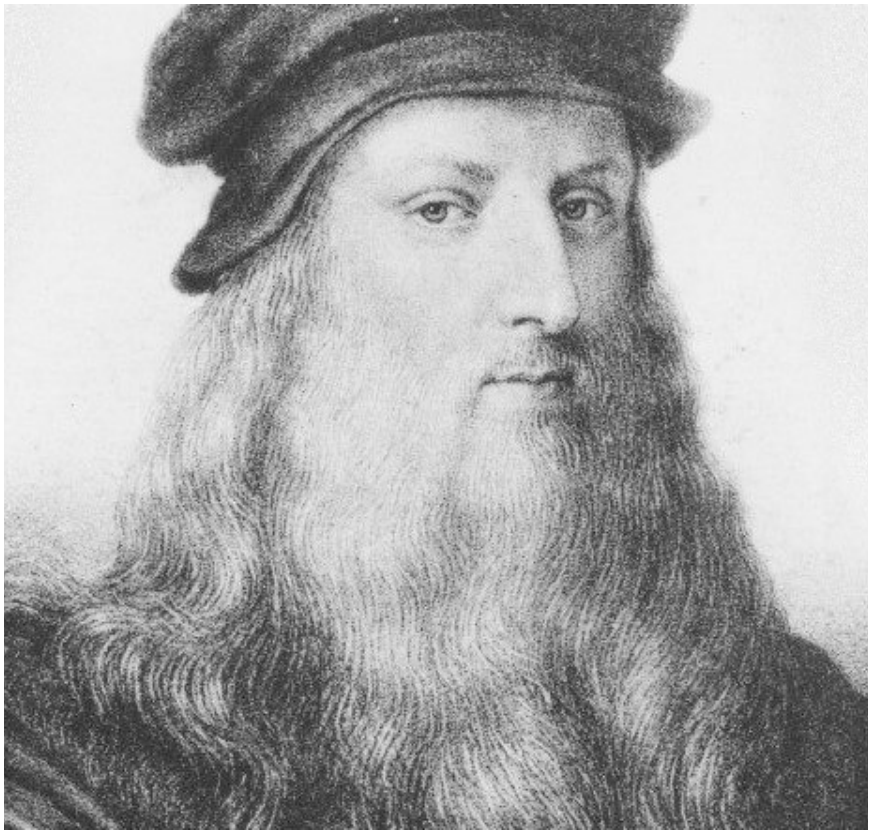
19th Century American Innovators

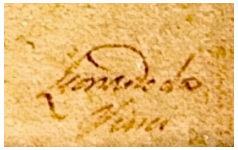
20th Century American Innovators

Leonardo da Vinci – Painter / Military Engineer / Inventor



1452-1457	Vinci
1457-1472	Florence
1472-1499	Milan
1500-1505	Florence
1506-1513	Milan
1513-1516	Rome
1516-1519	France

Fillipo Brunelleschi
Donatello
Andrea del Verrocchio
Ludovico Sforza
Fra Luco Pacioli
Charles VIII
Louis XII
Francis I



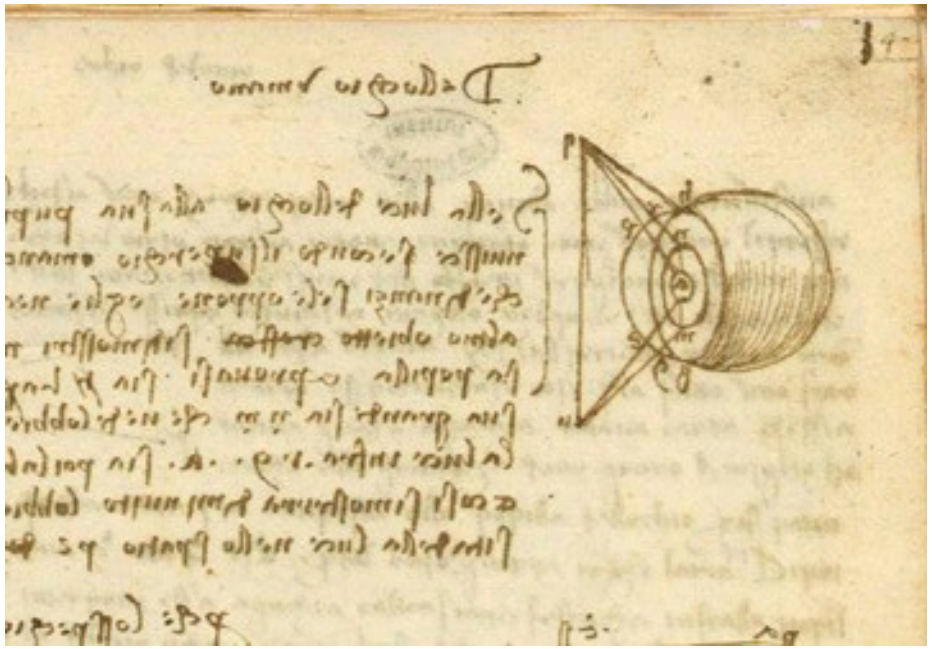
Admonition to readers.
Let no man who is not a Mathematician read the elements of my work.

Subjects..
The Book of the science of Mechanics must precede the Book of useful inventions.—Have your books on anatomy bound!

The disorder in the MSS.
Begun at Florence, in the house of Piero di Braccio Martelli, on the 22nd day of March 1508. And this is to be a collection without order, taken from many papers which I have copied here, hoping to arrange them later each in its place, according to the subjects of which they may treat. But I believe that before I am at the end of this [task] I shall have to repeat the same things several times; for which, O reader! do not blame me, for the subjects are many and memory cannot retain them [all] and say: 'I will not write this because I wrote it before.'

The function of the eye.

Painting is concerned with all the 10 attributes of sight; which are:—Darkness, Light, Solidity and Colour, Form and Position, Distance and Propinquity, Motion and Rest. This little work of mine will be a tissue [of the studies] of these attributes, reminding the painter of the rules and methods by which he should use his art to imitate all the works of Nature which adorn the world.



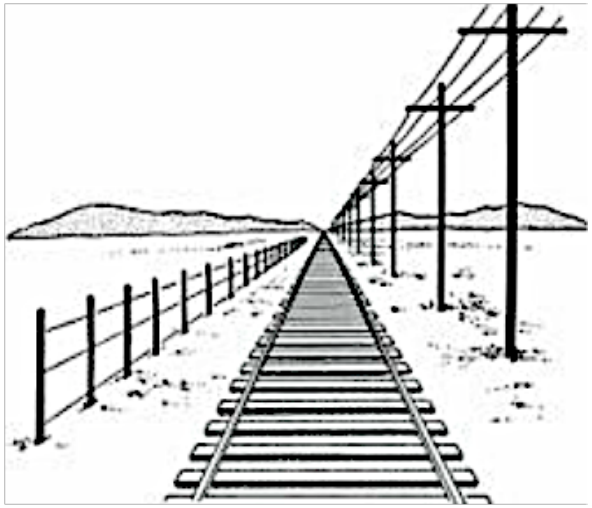
Necessity of theoretical knowledge.

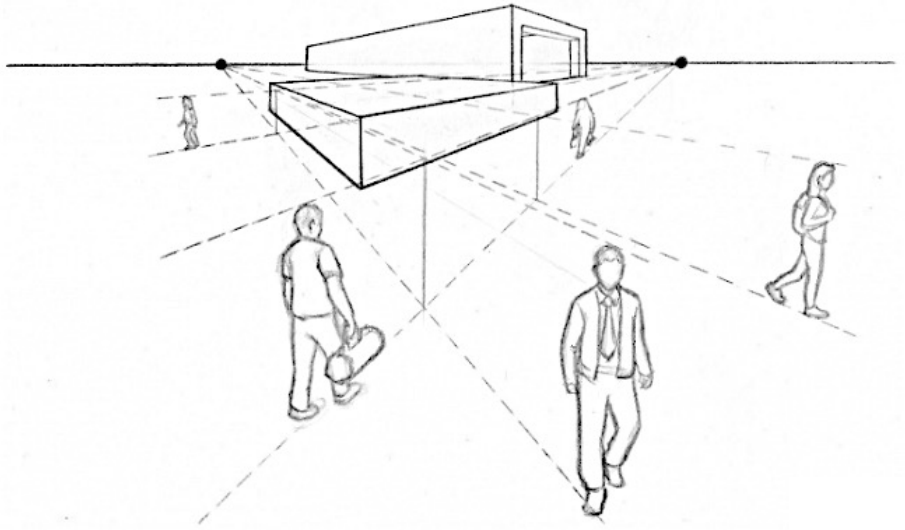
Those who are in love with practice without knowledge are like the sailor who gets into a ship without rudder or compass and who never can be certain whether he is going. Practice must always be founded on sound theory, and to this Perspective is the guide and the gateway; and without this nothing can be done well in the matter of drawing.

The plan of the book on Painting.

There are three branches of perspective; the first deals with the reasons of the (apparent) diminution of objects as they recede from the eye, and is known as Diminishing Perspective.—The second contains the way in which colours vary as they recede from the eye. The third and last is concerned with the explanation of how the objects [in a picture] ought to be less finished in proportion as they are remote (and the names are as follows):

Linear Perspective. The Perspective of Colour. The Perspective of Disappearance.



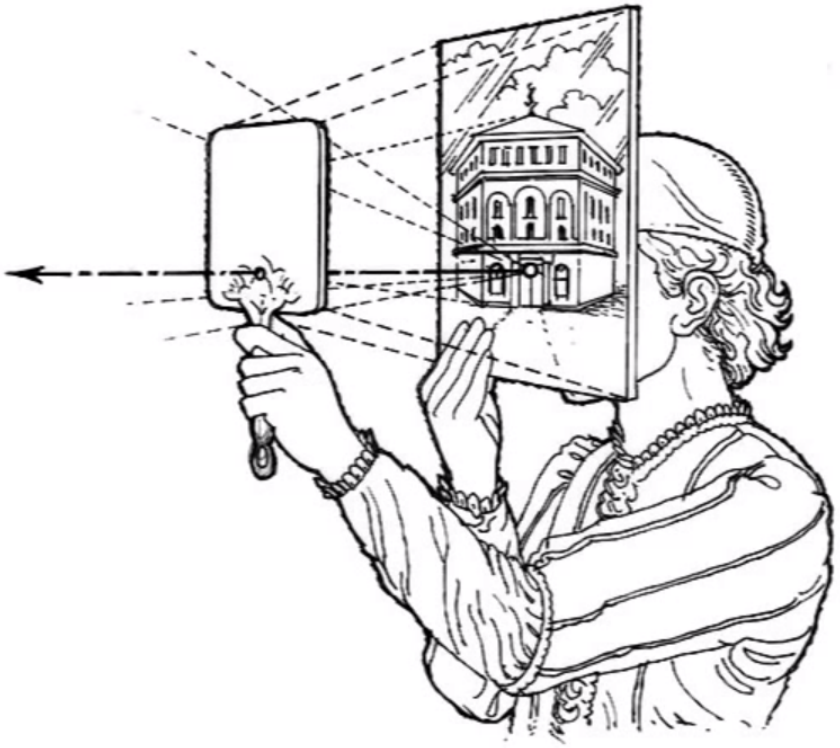


Perspective is the best guide to the art of Painting.

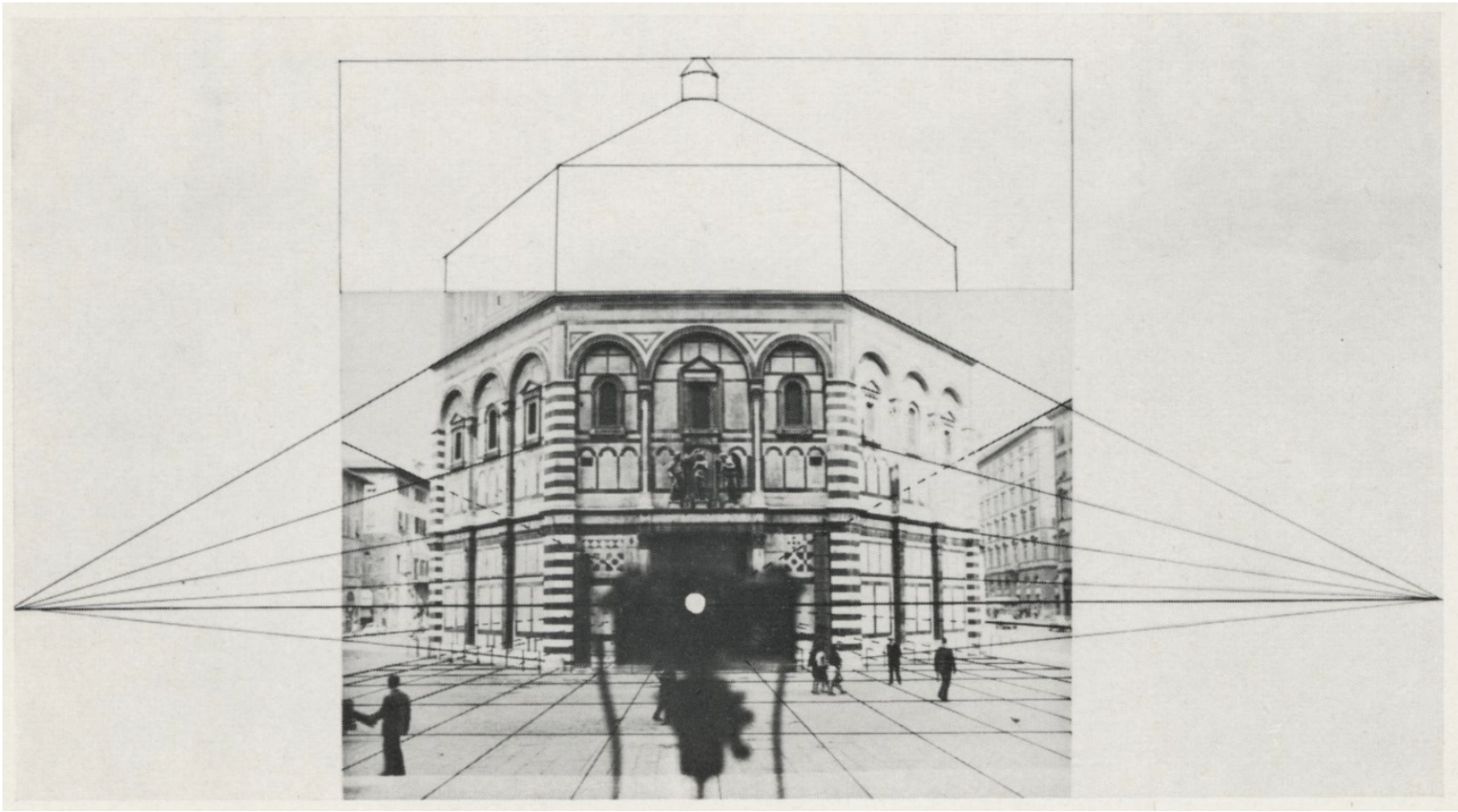
The art of perspective is of such a nature as to make what is flat appear in relief and what is in relief flat.

All the problems of perspective are made clear by the five terms of mathematicians, which are:—the point, the line, the angle, the superficies and the solid. The point is unique of its kind. And the point has neither height, breadth, length, nor depth, whence it is to be regarded as indivisible and as having no dimensions in space. The line is of three kinds, straight, curved and sinuous and it has neither breadth, height, nor depth. Hence it is indivisible, excepting in its length, and its ends are two points. The angle is the junction of two lines in a point.

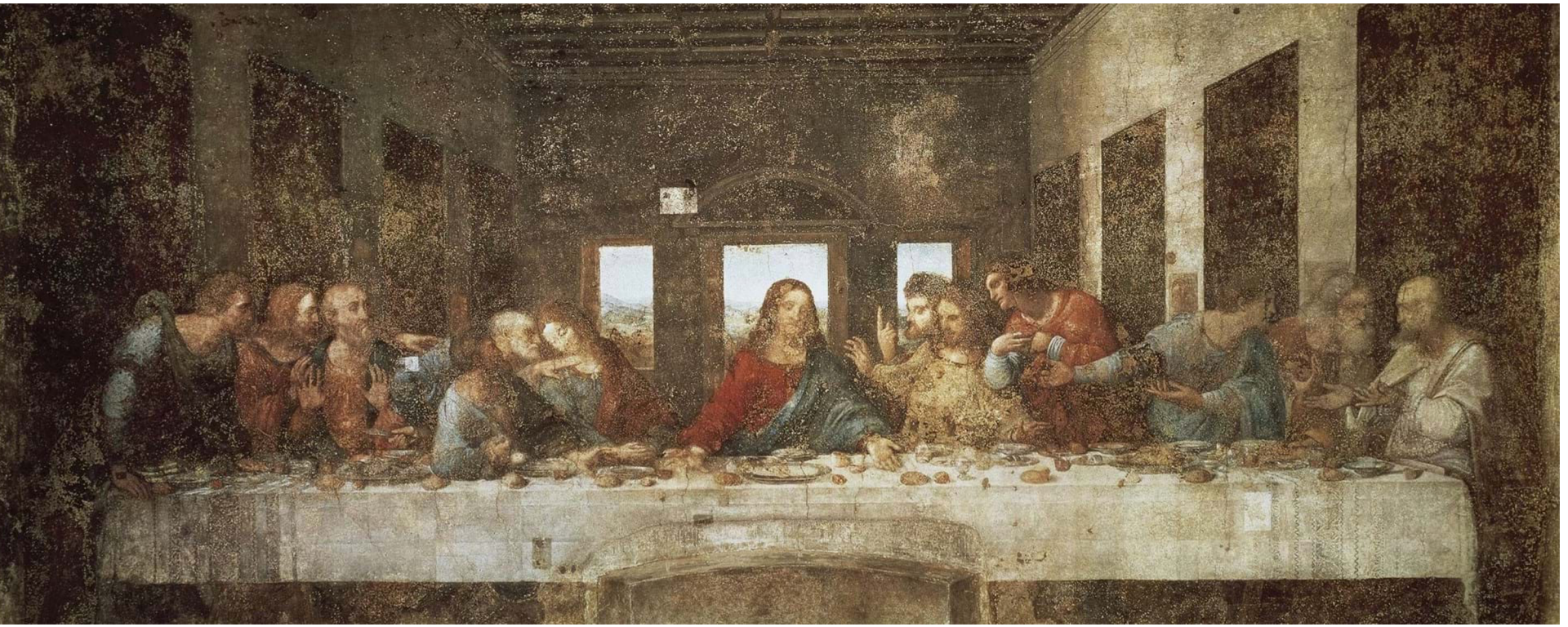
Baptistry of St John - Florence



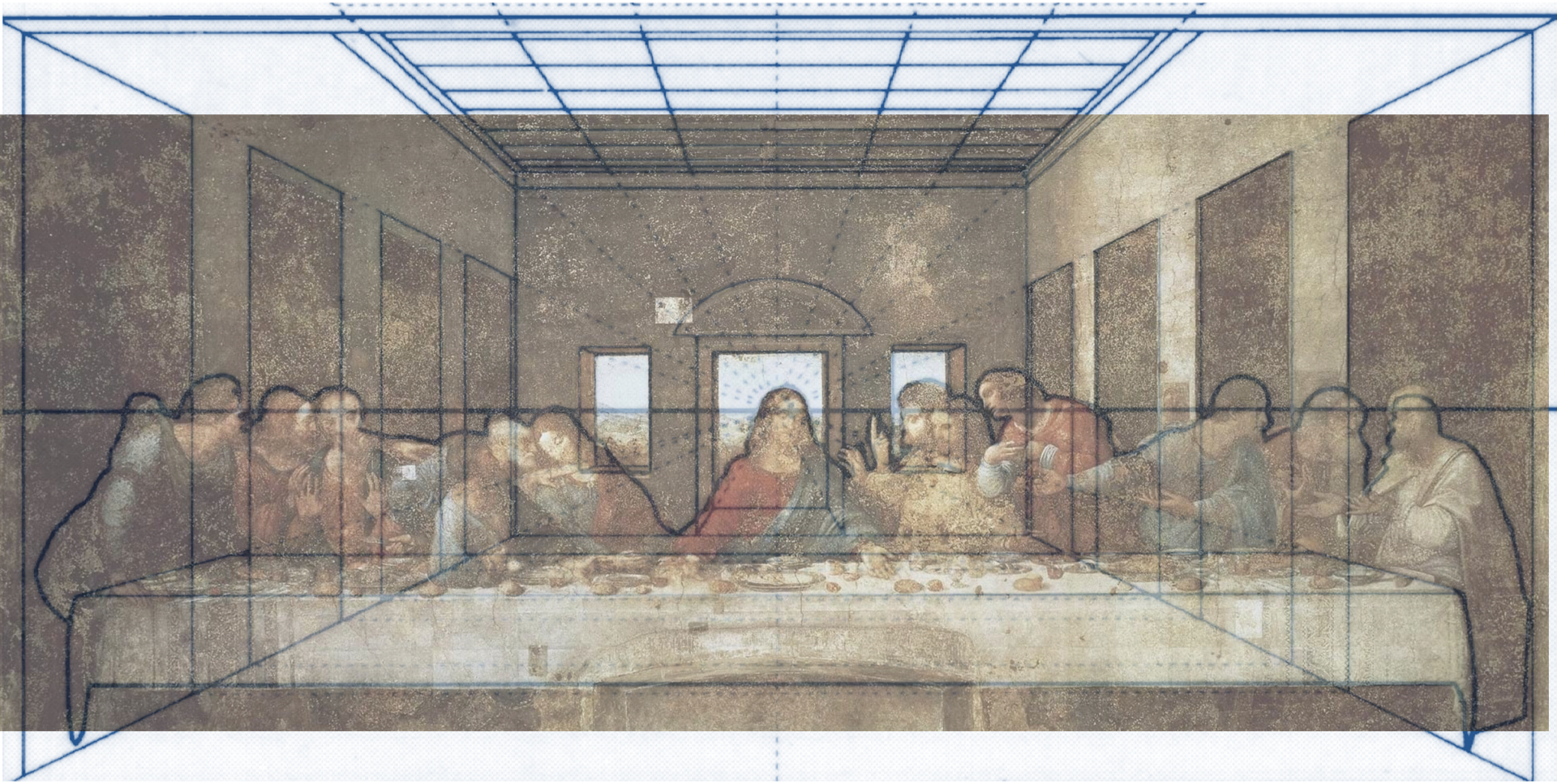
Filippo Brunellesci experiment – 1425
Alberti book, “On Painting” – 1435

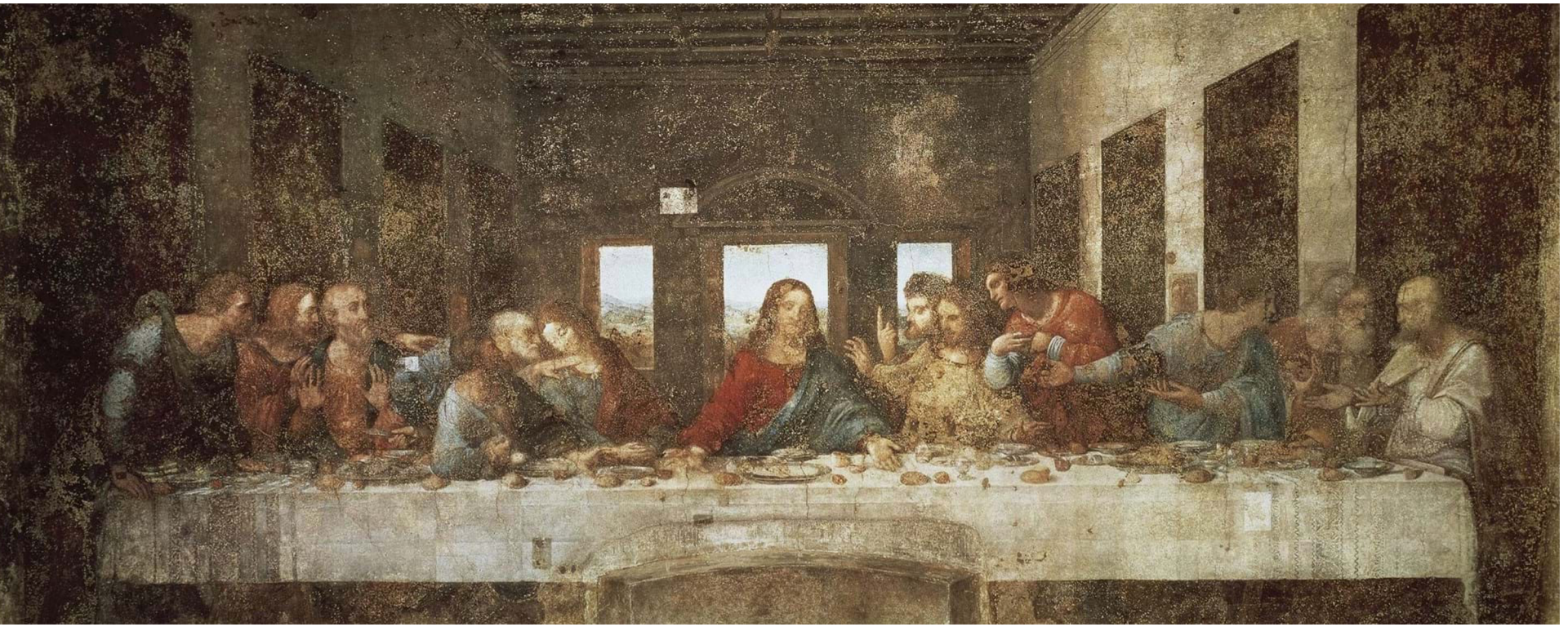


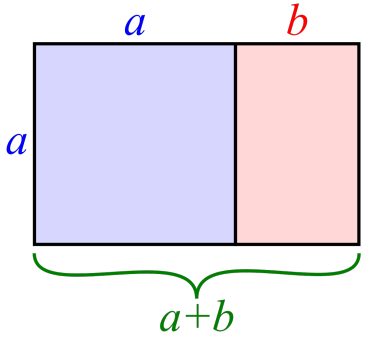
Picture in a mirror to replicate Brunesllesci's experiment
Camera on tripod with central vanishing point shown as a white dot



- Dry plaster on stone – oil paint on plaster
- Milan convent – end wall of dining hall – optical illusion
- 1495-96



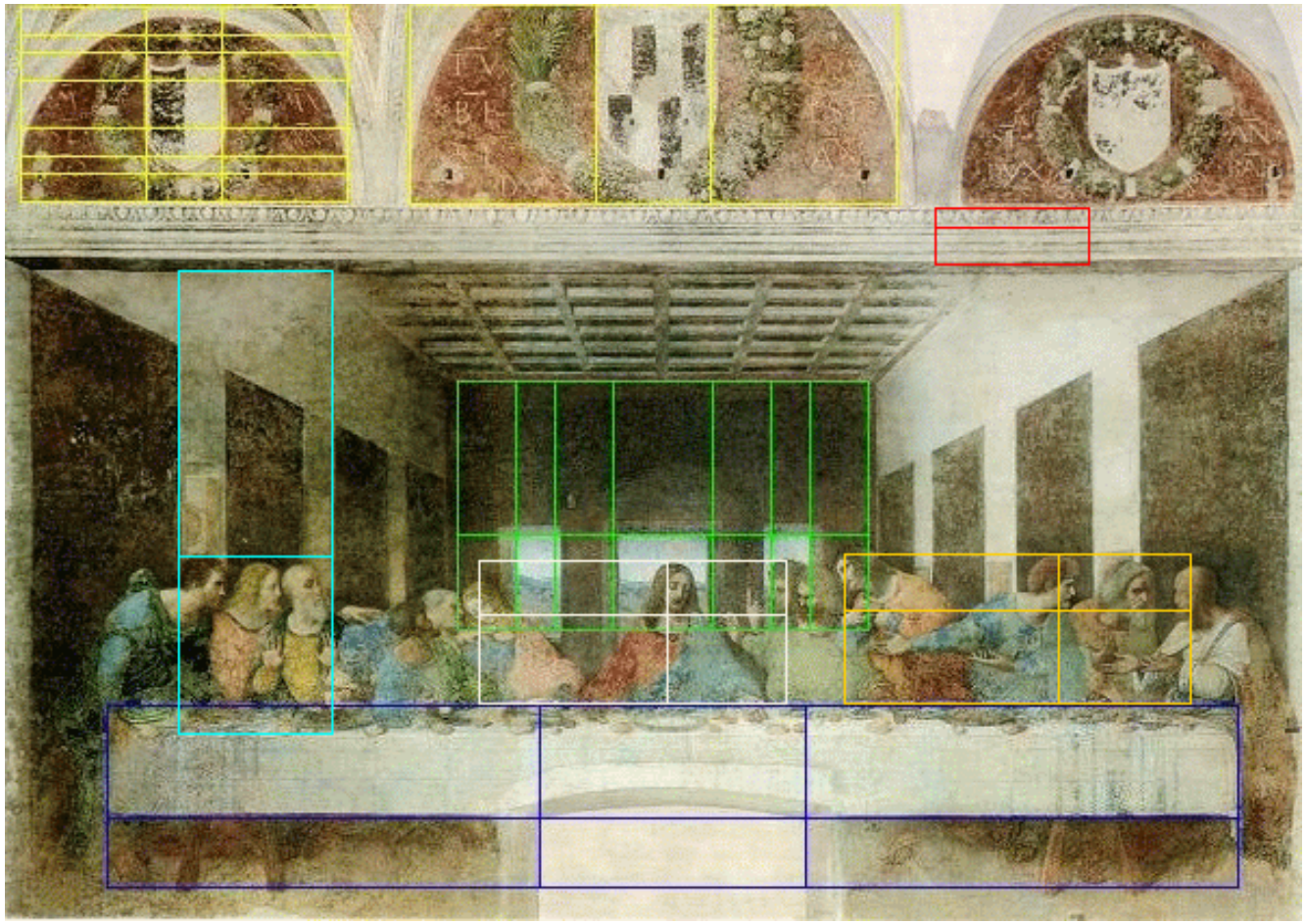


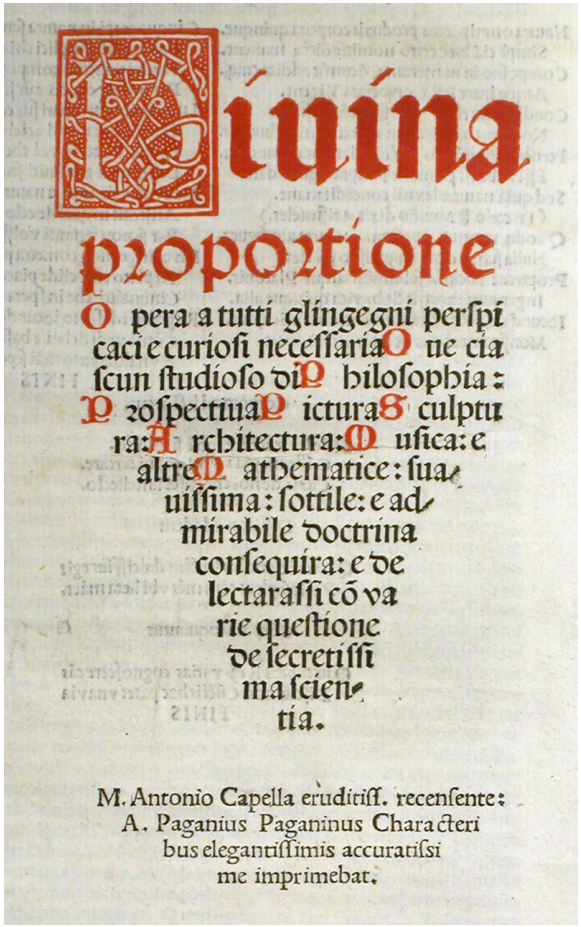


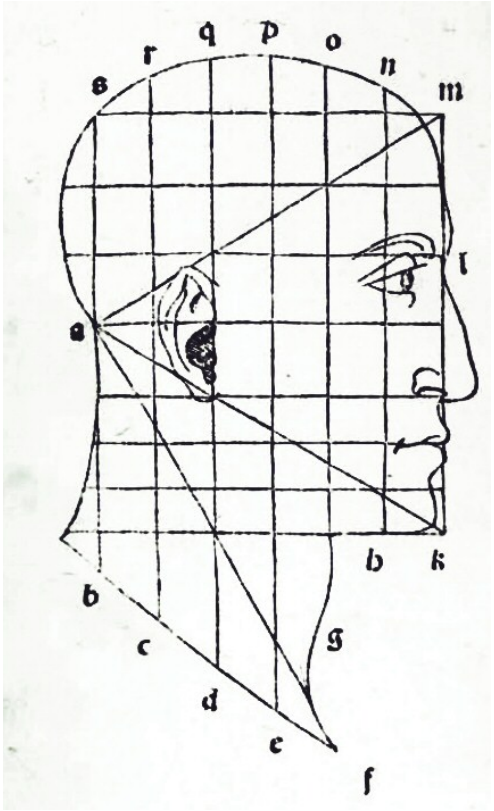
Golden ratio $\phi = a/b = (a+b)/a = 1.618\ldots\ldots = \frac{1+\sqrt{5}}{2}$

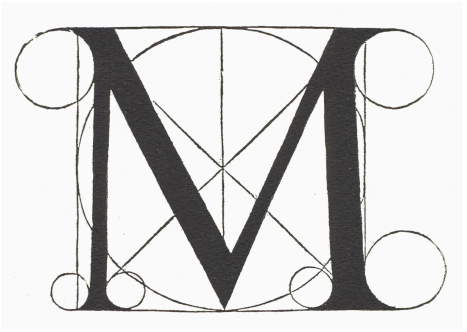
(Suggested but not supported by Leonardo's writing)

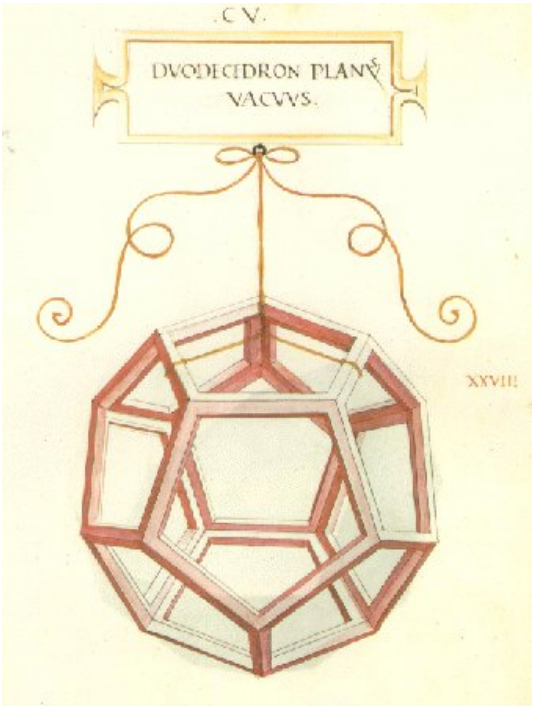
$a/b = (a+b)/a$ $a^2 = ab + b^2$ $a^2 - ab - b^2 = 0$ $a = \frac{b \pm b\sqrt{5}}{2}$





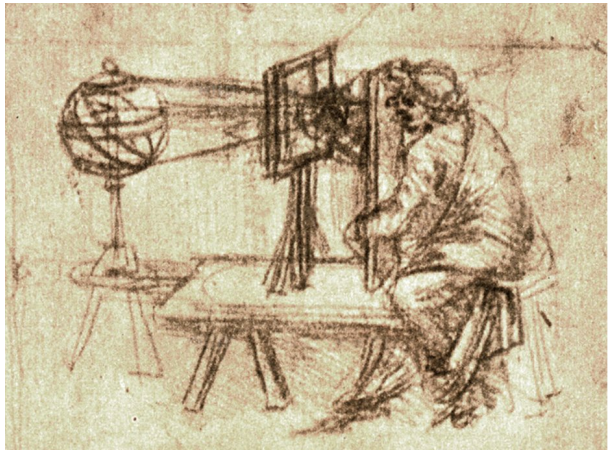


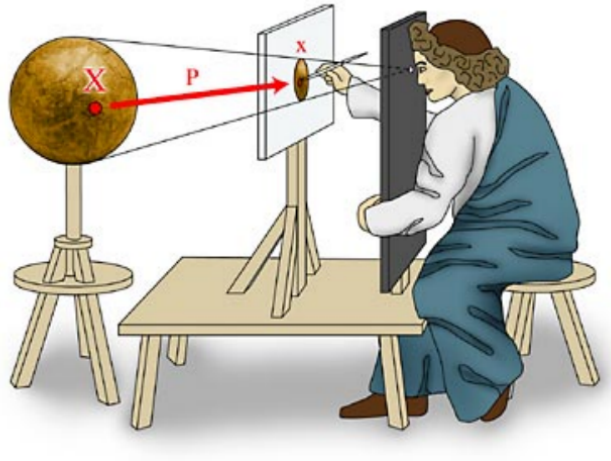




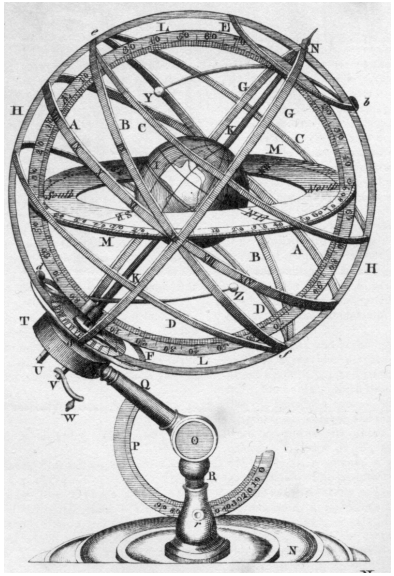
Divine Proportions – circa 1496, publ. 1509
By Luca Pacioli – Leonardo's math teacher
Illustrated by Leonardo

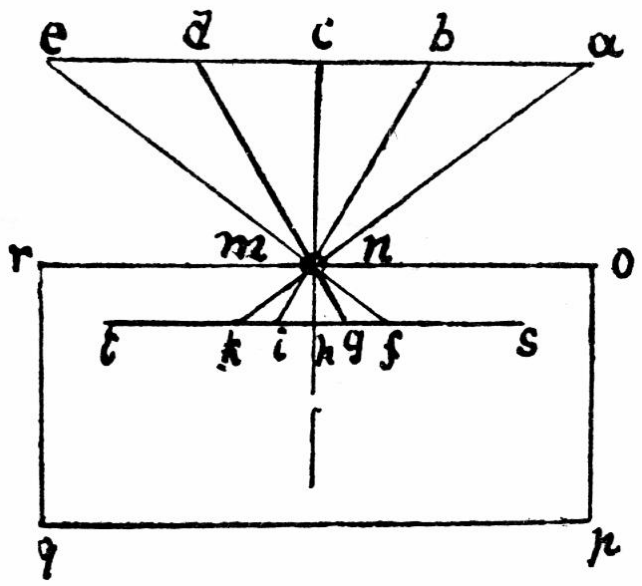
A dodecahedron with sides of length 1 embeds a cube with sides of length is phi (ϕ)





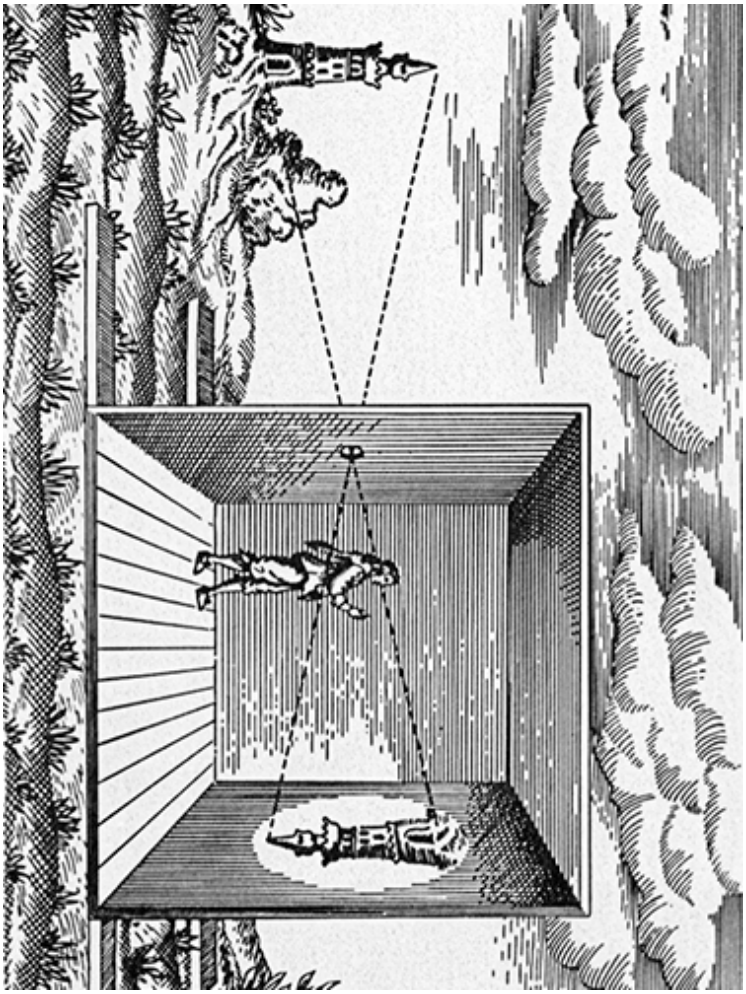
Drawing of a man using a perspectograph to draw an armillary sphere. Leonardo da Vinci (Codex Atlanticus I ~1480)

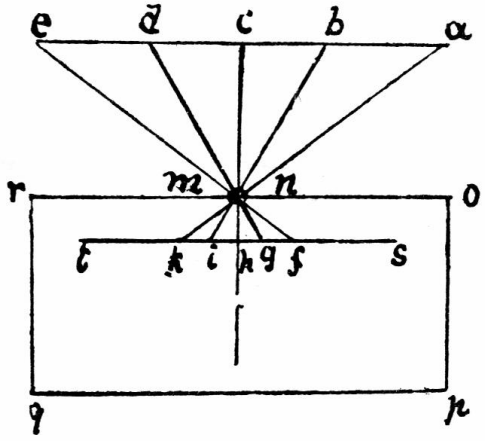




An experiment, showing how objects transmit their images or pictures, intersecting within the eye in the crystalline humour, is seen when by some small round hole penetrate the images of illuminated objects into a very dark chamber. Then, receive these images on a white paper placed within this dark room and rather near to the hole and you will see all the objects on the paper in their proper forms and colours, but much smaller; and they will be upside down by reason of that very intersection. These images being transmitted from a place illuminated by the sun will seem actually painted on this paper which must be extremely thin and looked at from behind. And let the little perforation be made in a very thin plate of iron. Let a b c d e be the object illuminated by the sun and o r the front of the dark chamber in which is the said hole at n m. Let s t be the sheet of paper intercepting the rays of the images of these objects upside down, because the rays being straight, a on the right hand becomes k on the left, and e on the left becomes f on the right; and the same takes place inside the pupil.

Camera Obscura – pinhole camera as model of human eye

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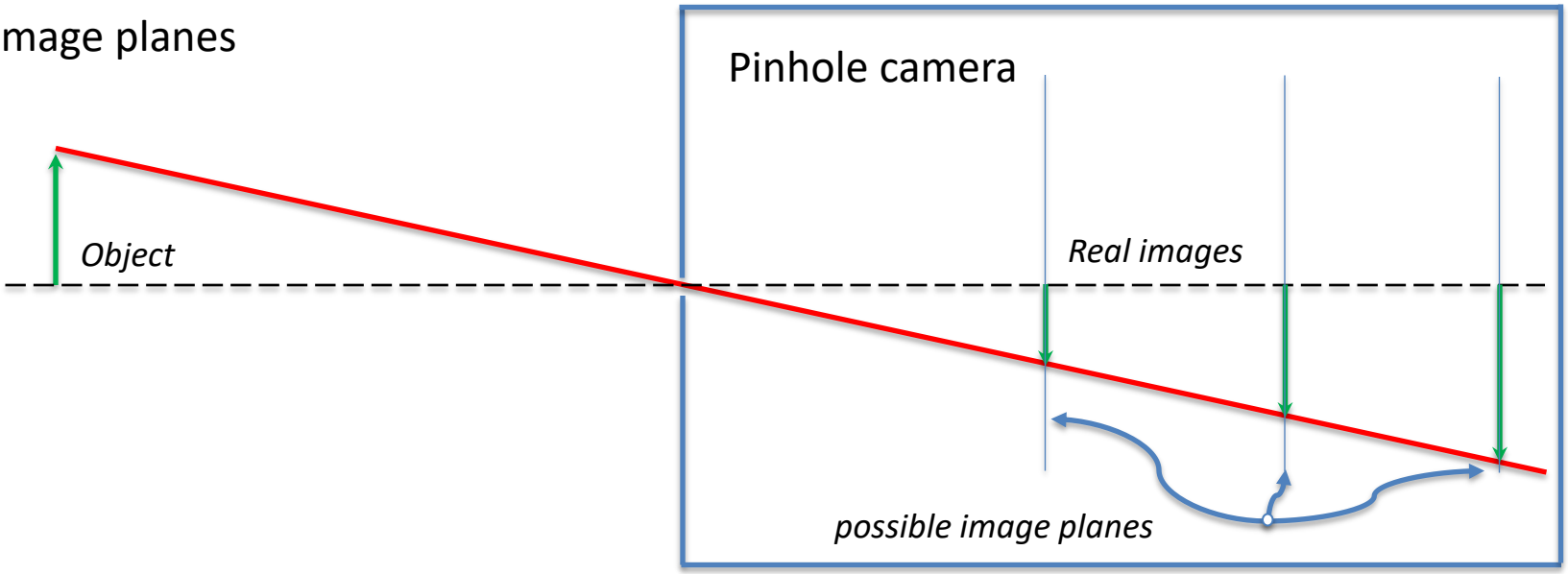
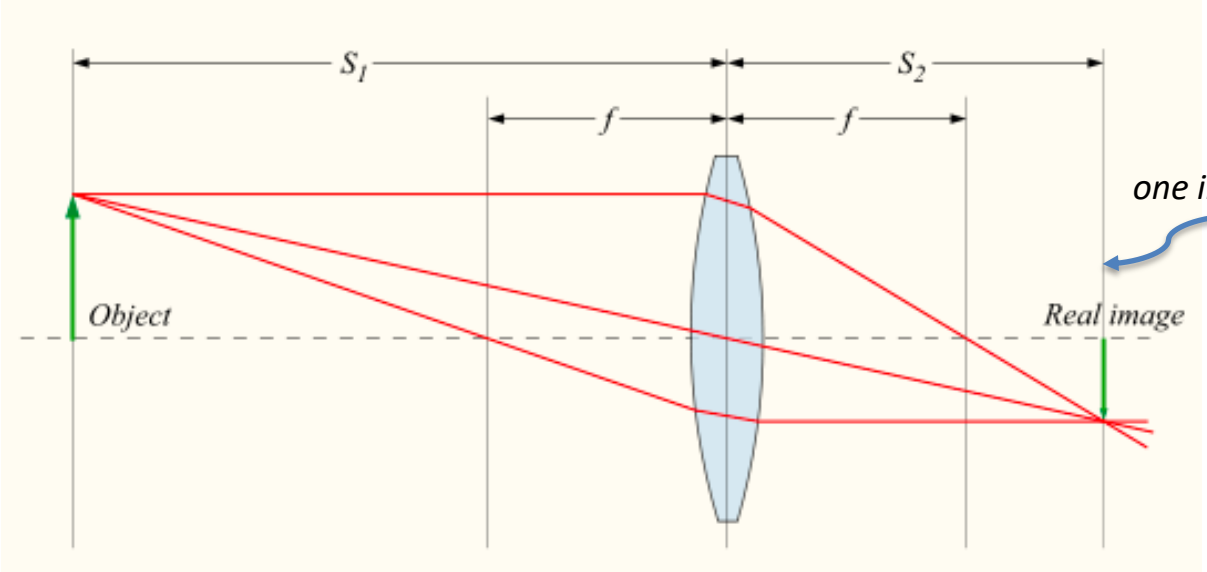
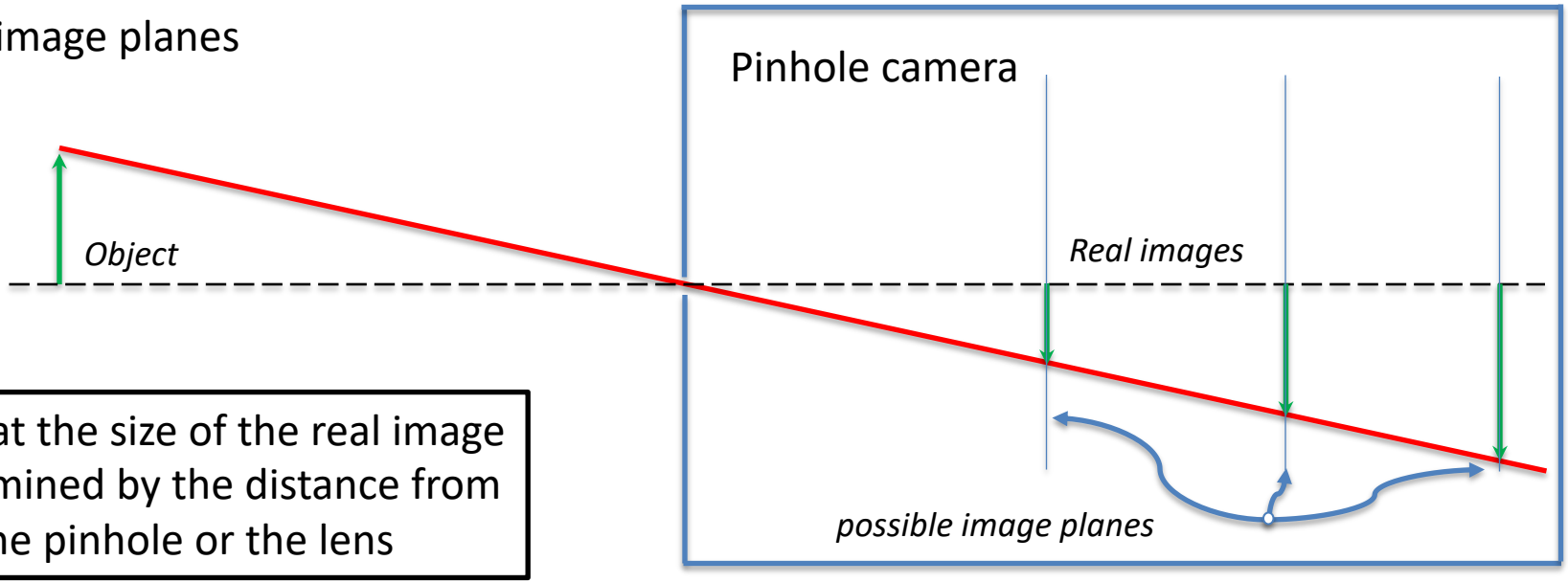
Pinhole camera – in focus for all possible image planes



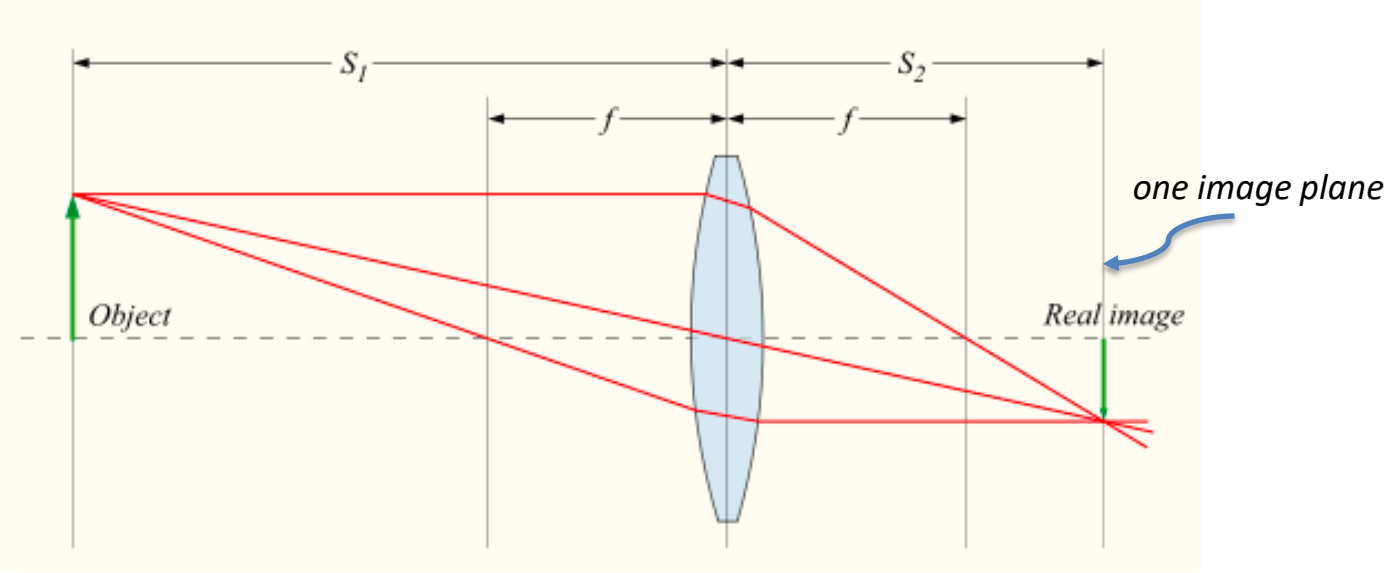


Camera using lens – in focus only for one image plane

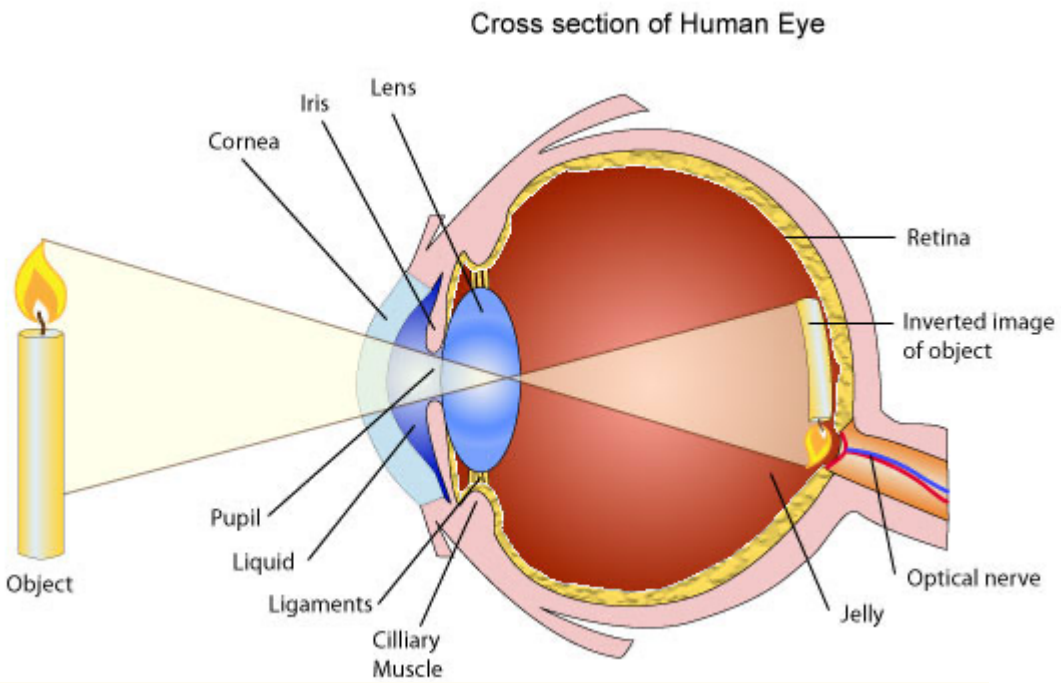
Pinhole camera – in focus for all possible image planes

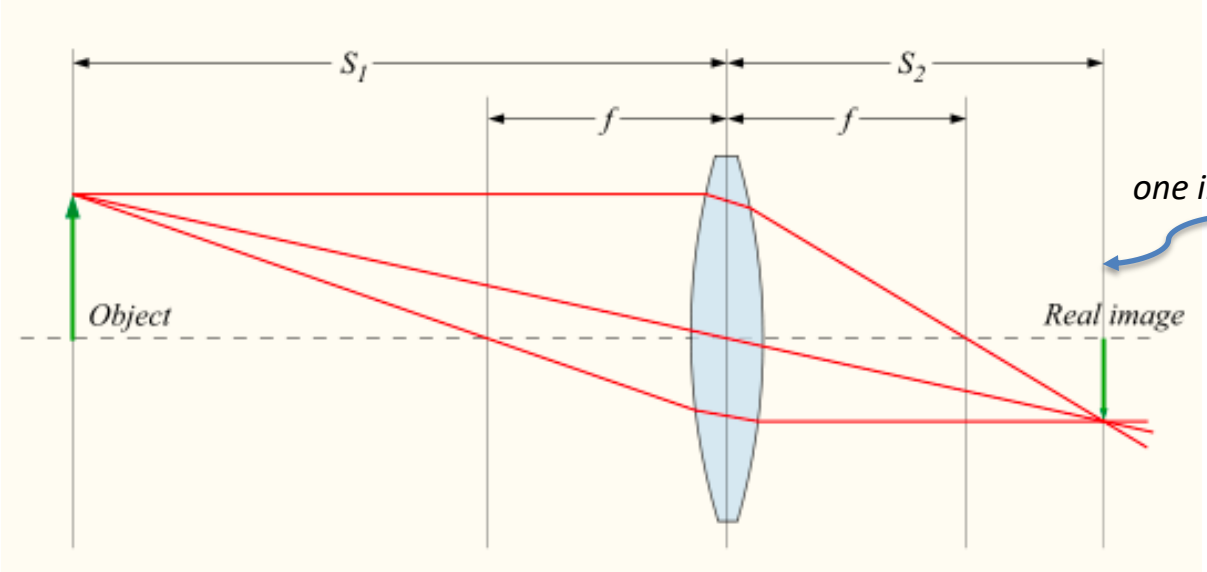


Note that the size of the real image is determined by the distance from either the pinhole or the lens



Camera using lens – in focus only for one image plane

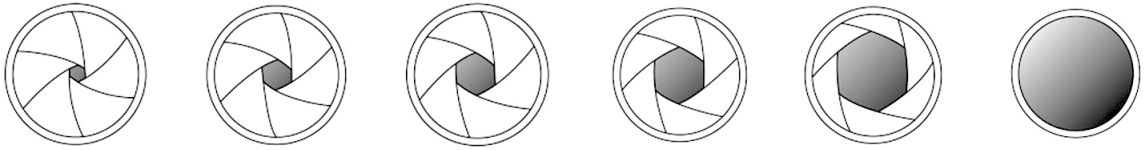




Camera using lens – in focus only for one image plane

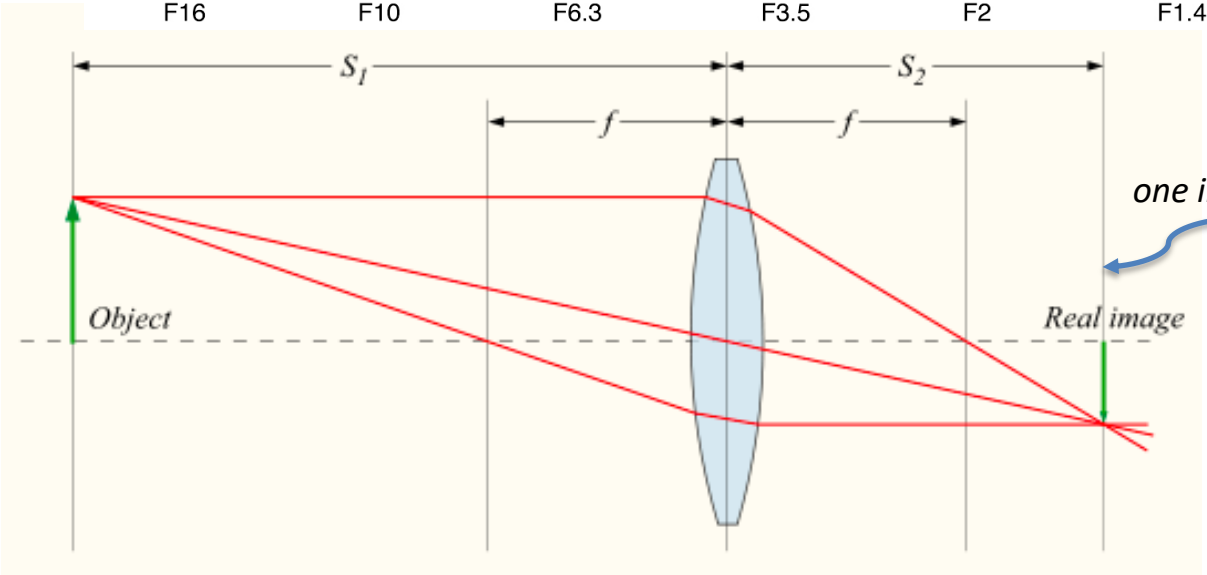
Pinhole-like

large depth of focus



Large Aperture

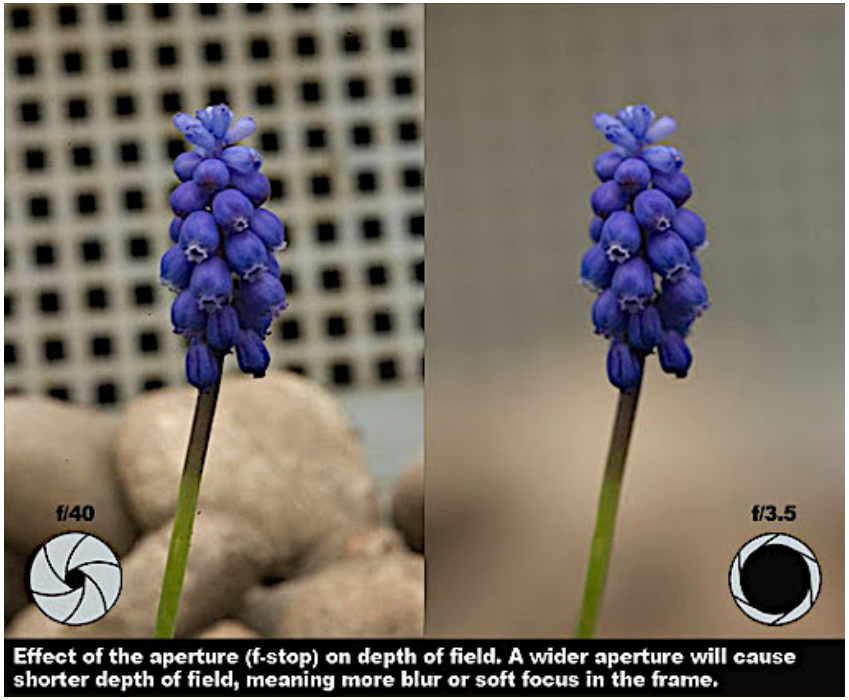
narrow depth of focus



Camera using lens – in focus only for one image plane

Pinhole-like

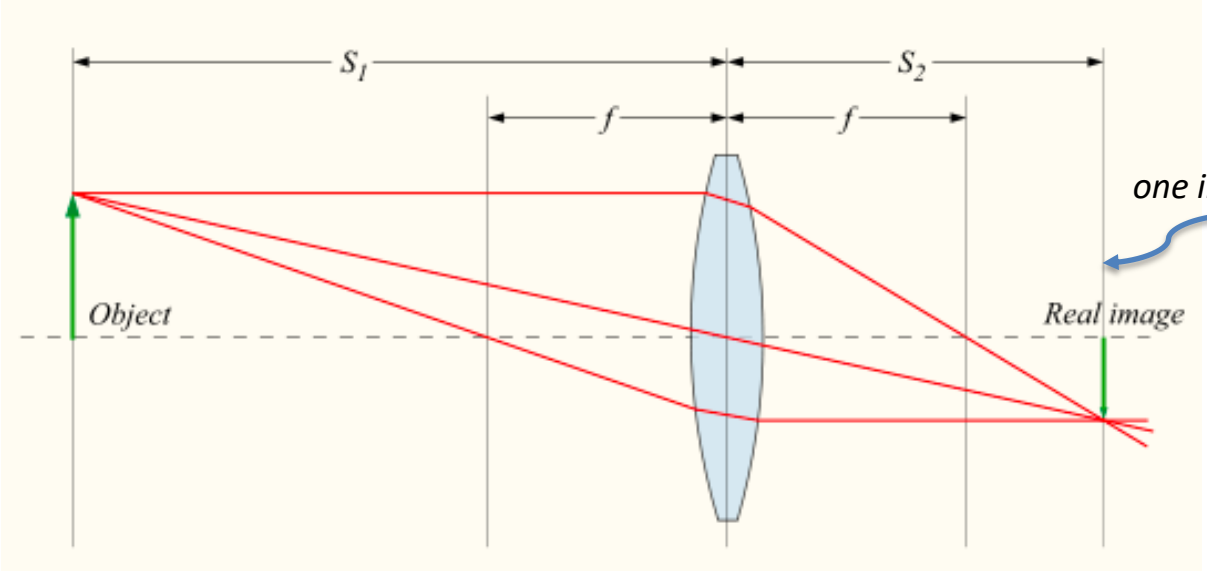
large depth of focus



Effect of the aperture (f-stop) on depth of field. A wider aperture will cause shorter depth of field, meaning more blur or soft focus in the frame.

Large Aperture

narrow depth of focus



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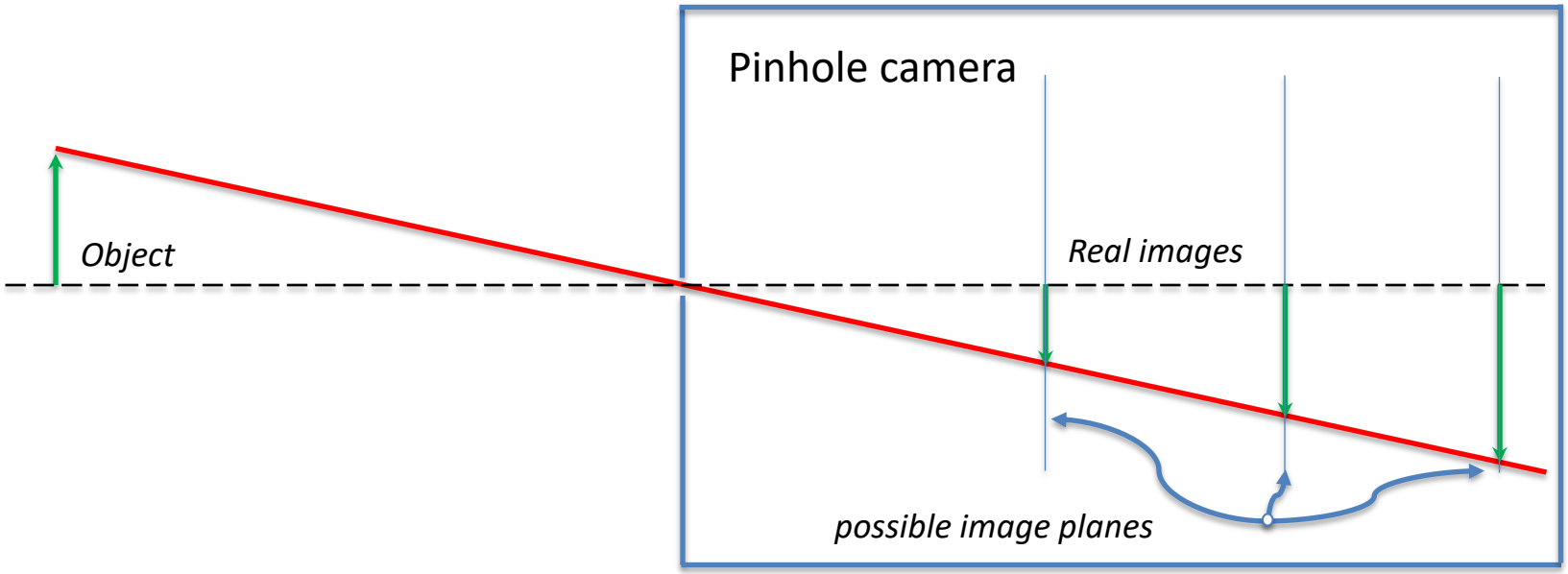
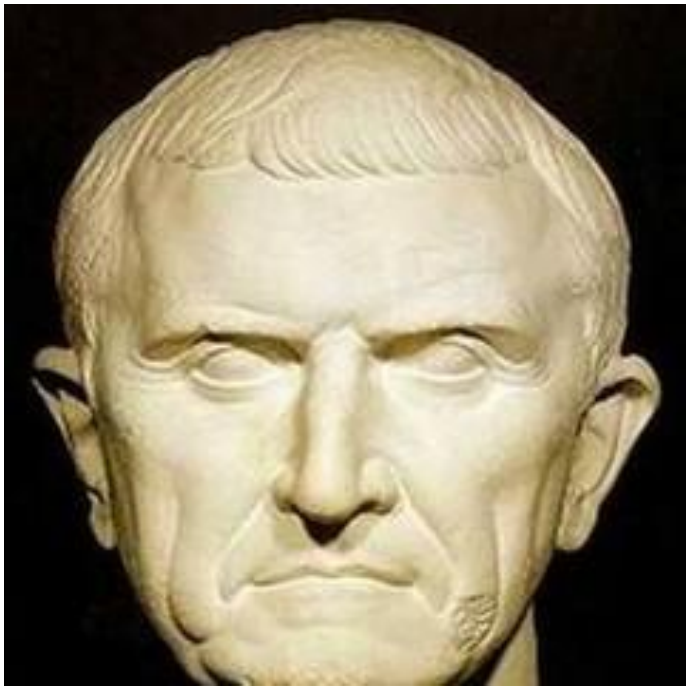


Short Lens – large field of view
OBJECT appears SMALL

Long Lens – narrow field of view
OBJECT appears LARGE (magnified)

Vitruvius – Architect / Military Engineer / Inventor - Summary of De Architectura

Book I - on an architect's ideal education, the principles and divisions of architecture, fortifications, principles of good town planning, and where best to build a Temple.
Book II - on the origins of buildings and the various materials employed in their construction such as bricks, sand, stone, and wood, and the various types of walls.
Book III - on the mathematics and correct proportions of columns and temples.
Book IV - on the Doric, Ionic, and Corinthian architectural orders, and the various types of temples and altars.
Book V - on various Roman buildings such as the basilica, the best design for theatres to obtain the best acoustics, and advice on building harbours.
Book VI - on the effect of climate on character and best foundations and layouts for private homes.
Book VII - on paving, vaults, and wall-paintings, including the best colours and their origins and history of use.
Book VIII – is concerned with water, its sources and conveyance via aqueducts.
Book IX – on the study of astronomy and its relevance to architectures and the measurement of time using sundials and water-clocks.
Book X – describes various machines and gadgets such as distance measuring devices, water-driven machines, and weapons like catapults, ballistae, and siege engines.

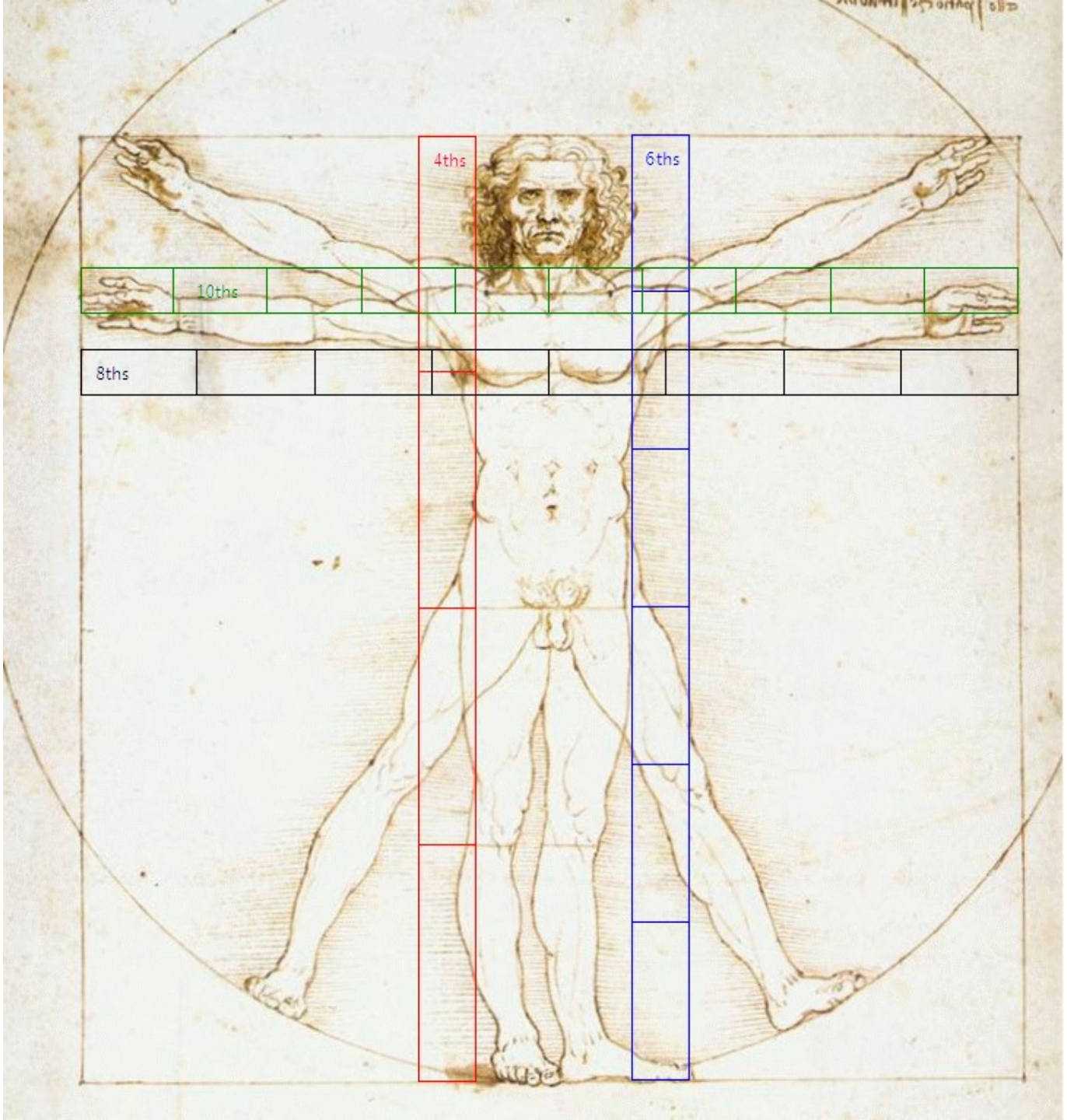


Architects should be educated, skillful with the pencil, instructed in geometry, know much history, have followed the philosophers with attention, understand music, have some knowledge of medicine, know the opinions of the jurists, and be acquainted with astronomy and the theory of the heavens

Paragraph that inspired Leonardo's Vitruvian Man

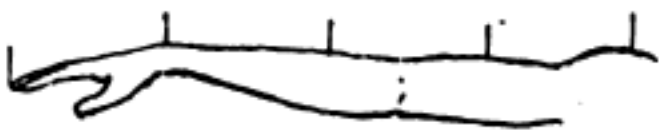
Just so the parts of Temples should correspond with each other, and with the whole. The navel is naturally placed in the centre of the human body, and, if in a man lying with his face upward, and his hands and feet extended, from his navel as the centre, a circle be described, it will touch his fingers and toes. It is not alone by a circle, that the human body is thus circumscribed, as may be seen by placing it within a square. For measuring from the feet to the crown of the head, and then across the arms fully extended, we find the latter measure equal to the former; so that lines at right angles to each other, enclosing the figure, will form a square.

- Vitruvius (1st century BC)

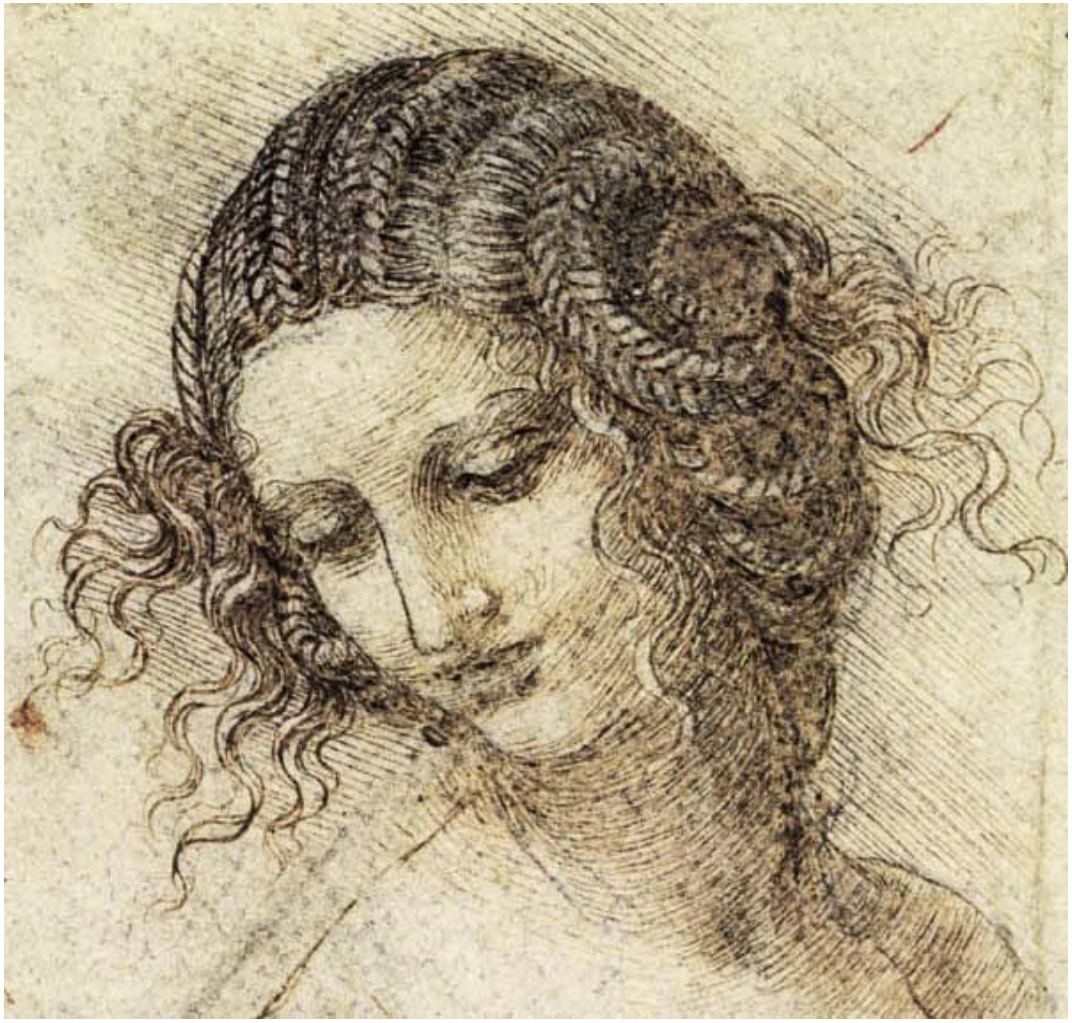

4ths
6ths
10ths
8ths

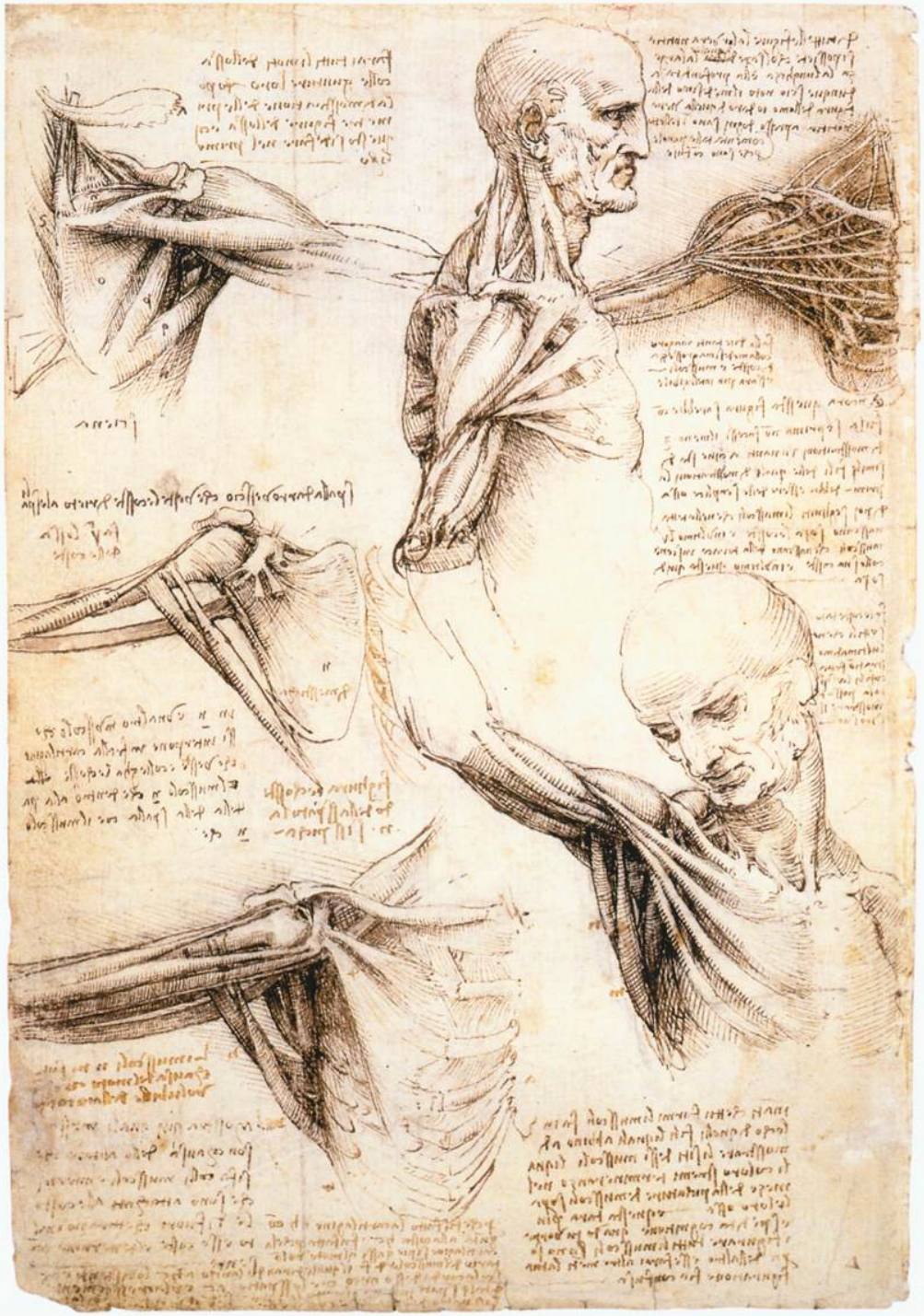
346.

La mano īsino doue si cōgivgnie col osso [2]del braccio ētra 4 volte dalla pūta del piv [3]lungo dito īsino alla givtura della spalla.



The hand from the longest finger to the wrist joint goes 4 times from the tip of the longest finger to the shoulder joint.





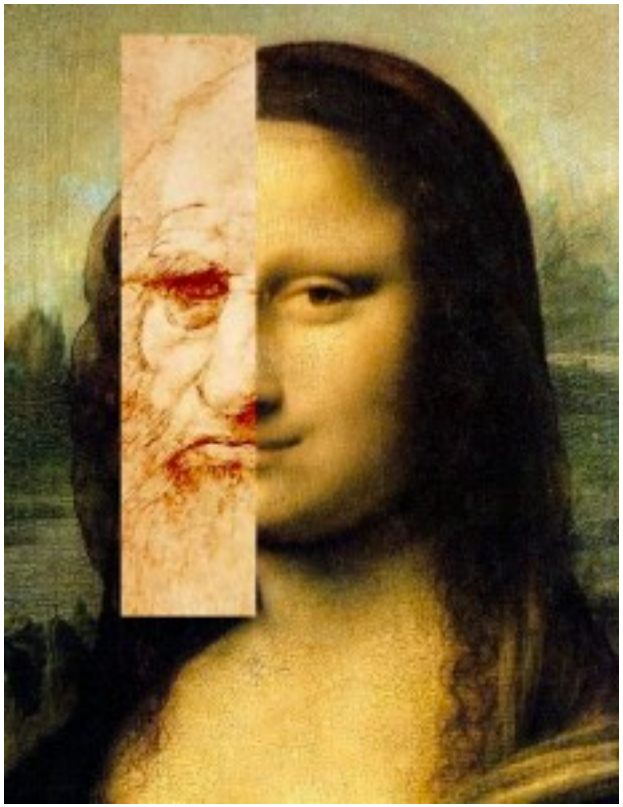
Cecelia Gallerani – Milan 1489-90

Ginevra de’ Benci – Florence 1474-8

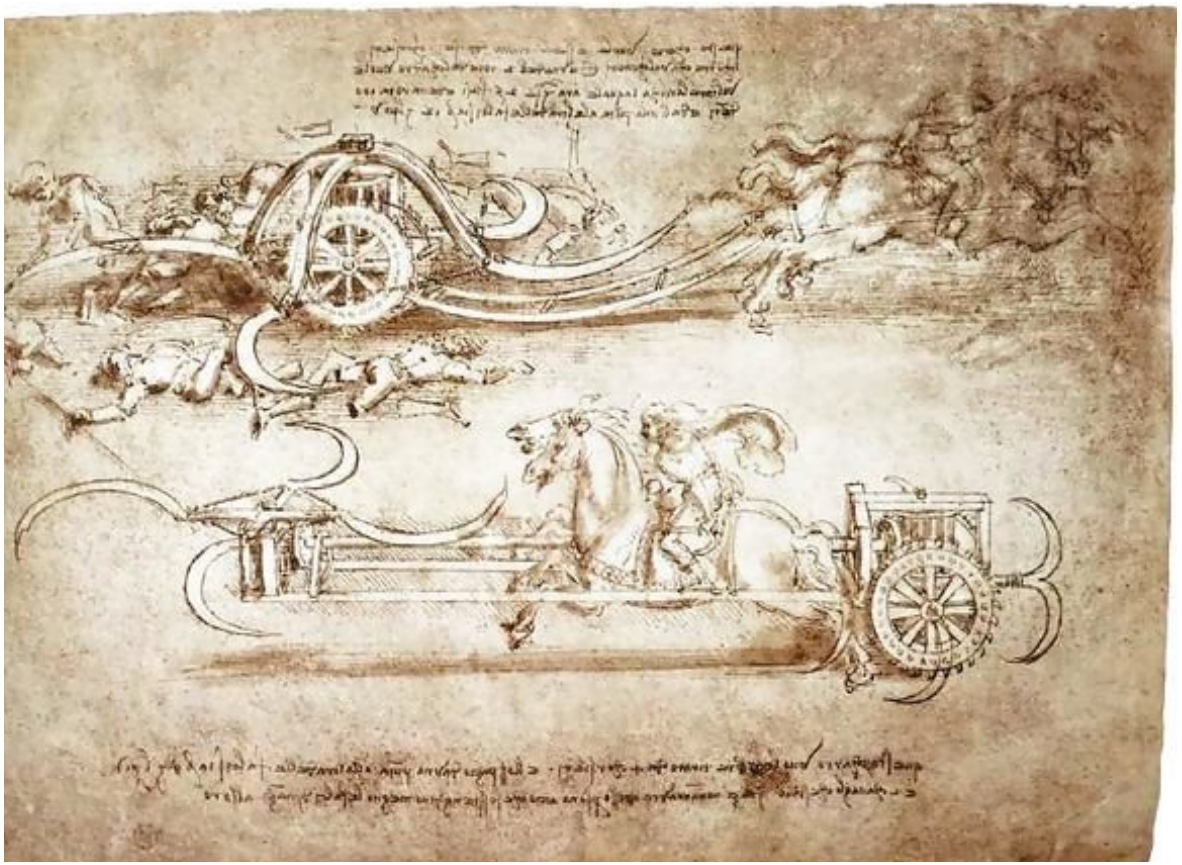
- Aerial Perspective
- Translucent Oil on Poplar

- Red Chalk in Turin
- Self-Portrait at age 60

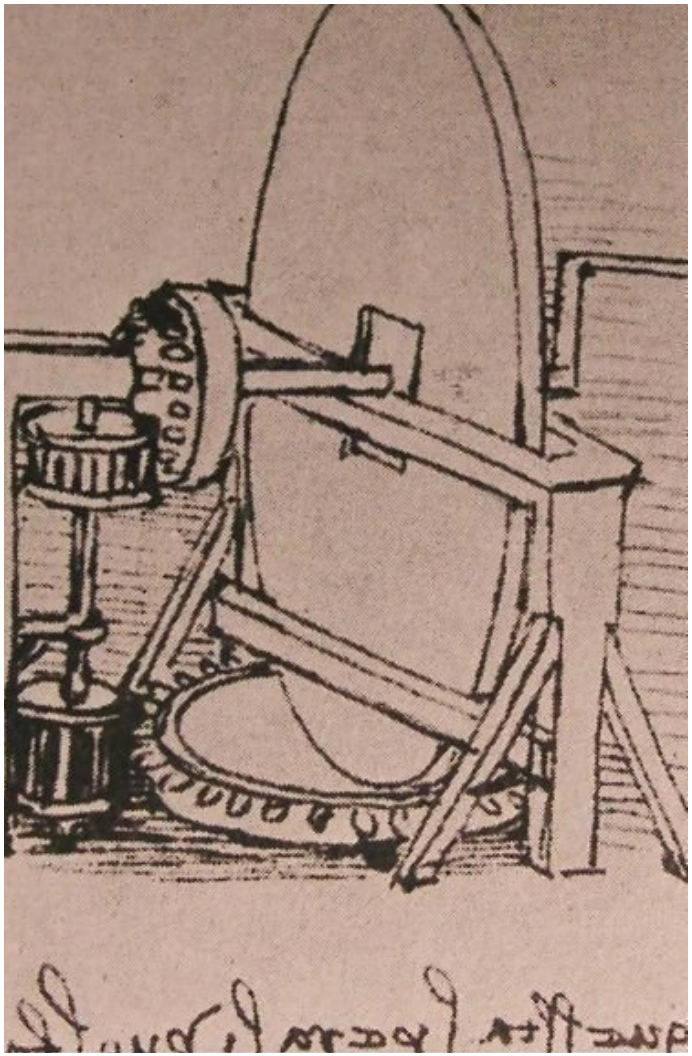
Lisa Gherardini – Florence 1503-06

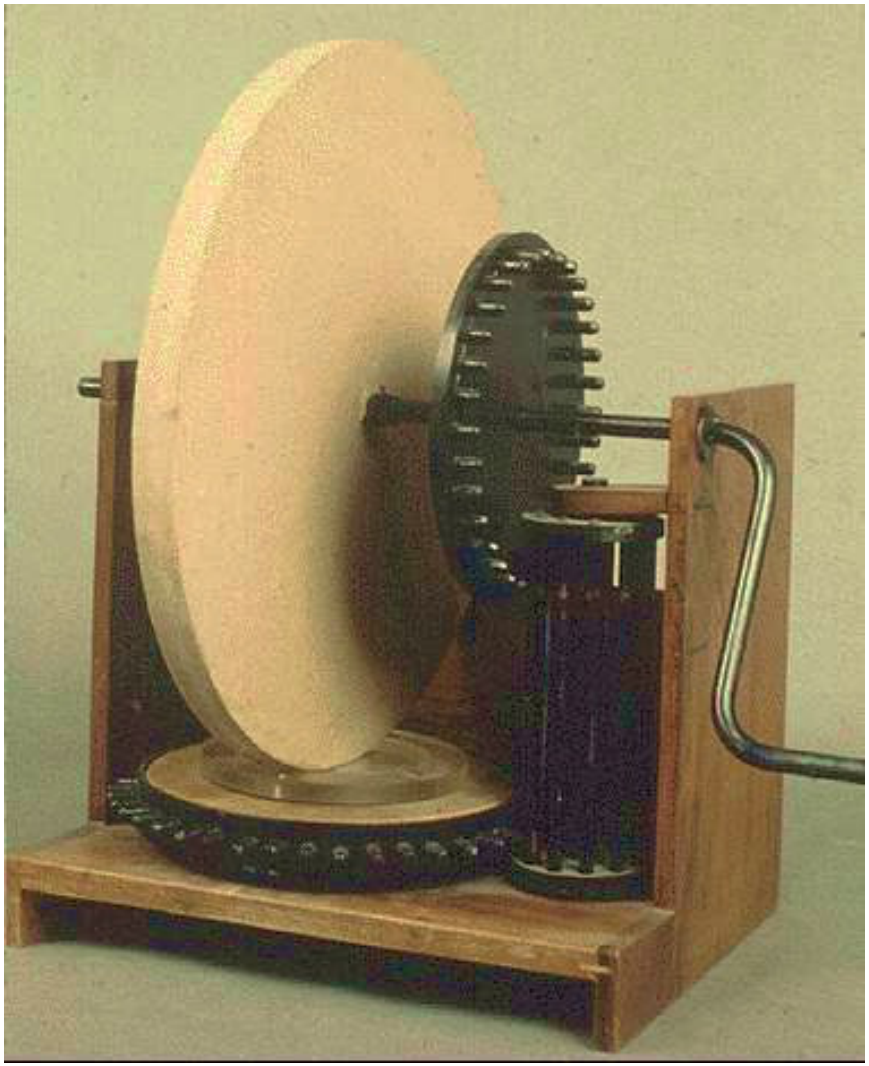


Animals

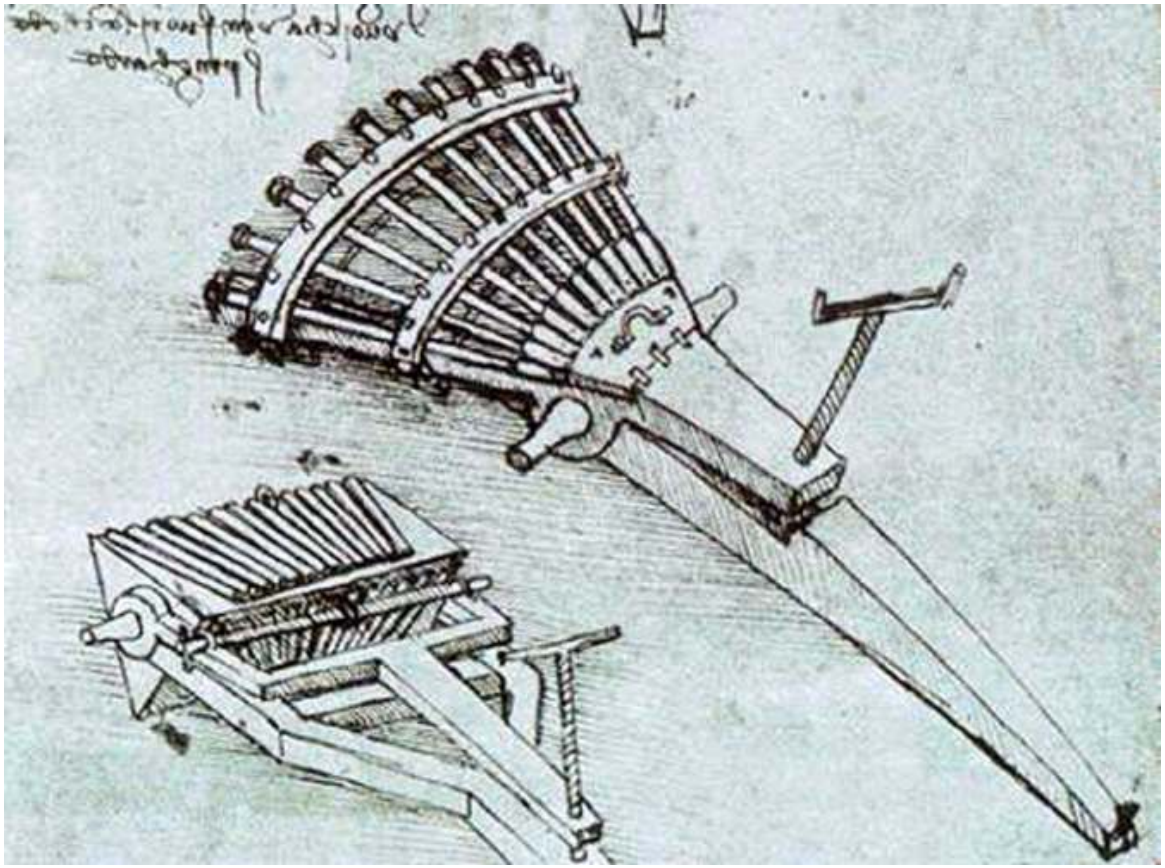


Military - Tank



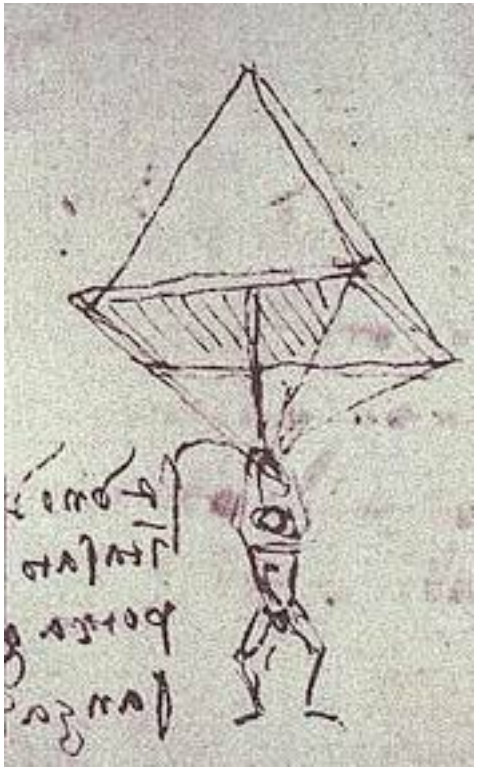


Lens grinding machine

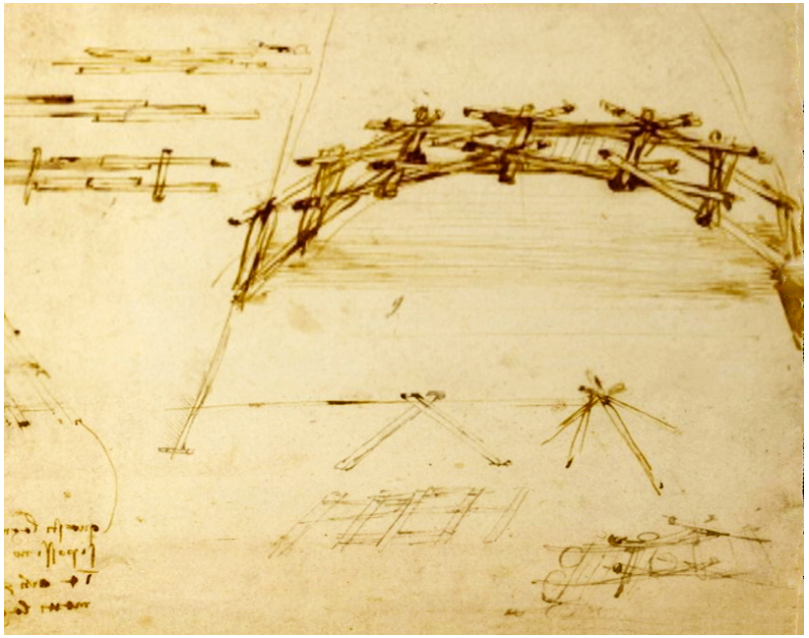


Scatter shot - gun

Helicopter – air screw



Parachute



Self supporting arch bridge

Study of turbulence

Observe the motion of the surface of the water, which resembles that of hair, which has two motions, of which one is caused by the weight of the hair, the other by the direction of the curls; thus the water has eddying motions, one part of which is due to the principal current, the other to random and reverse motion.

Necessity of theoretical knowledge.

Those who are in love with practice without knowledge are like the sailor who gets into a ship without rudder or compass and who never can be certain whether he is going. Practice must always be founded on sound theory, and to this Perspective is the guide and the gateway; and without this nothing can be done well in the matter of drawing.

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