



The Vitruvian Man of Leonardo da Vinci as a Representation of an Operational Approach to Knowledge

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Abstract

The Vitruvian Man of Leonardo da Vinci is one of the most famous and most studied drawings over the world as well as one of the most reproduced ones, e.g. in coins (Italian euros), space suit patches (NASA), books and movies. The aim of the present work is to discuss the Vitruvian Man as a figurative representation of the Leonardo's scientific method. Our analysis is based on scientific elements both present in the drawing and provided by Leonardo in his approach to this drawing. Our thesis is that the square symbolizes the measurable physical world and that the man inscribed within the square refers to the physics measurement process based on the operational definition of quantities, including the measurement unit system and the quantities conversion factors. Therefore, the measurement process is fundamental for the Leonardo's approach to the scientific knowledge, albeit, the drawing also suggests that this latter does not correspond with the true knowledge. The circle, which has a different center with respect to the square, symbolizes the truth, to which the man inscribed in the square yearns, without ever achieving it, the truth being reachable only by the man inscribed within the circle.

Keywords Leonardo da Vinci · Science · Art · Vitruvian Man · Scientific method · Operational definition

1 Introduction

In the variegated panorama of the “Vitruvian Men”, elaborated between the fifteenth and sixteenth centuries, a high originality content has to be attributed to the Leonardo's man, whose meanings and inspiring motivations are still today far to be fully understood.

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First of all, it is important to note how the human body representations by authors, such as those of Cennino D'Andrea Cennini (1999), di Giorgio Martini (Fig. 1a) (di Giorgio Martini 1967), Filarete (Spencer 1965), Gauricus (1969) and, to some extent, of Ghiberti (1998) essentially follow a criterion different from that of Vitruvius, which responds to the so-called *Byzantine criterion*; this latter is founded on a “modular” system based on multiple and submultiple quantities and therefore on the “arithmetic juxtaposition of pre-established metric modules” (Ciocci 2016).

On the contrary, the criterion followed by Leonardo, as well as by Caesar Cesarianus (1521), Pacioli (1978) and partly by Alberti (1782), is a “proportional” criterion, founded on the observation of the relations among the different portions of the human body and therefore presupposes a geometric proportioning operation (Ciocci 2016). In the words of Cesarianus, in fact, the human figure “consta de Symmetrie cioè di proporzionale commensuratione distincta numerabilmente in diverse quantità e particule”, that is, “is characterised by Symmetry, that is, by proportional commensuration distinguished in different quantities and particles”, as shown in Fig. 1b) (Cesariano 1521).

2 The Philosophical Conception of the Human Body

The philosophical conception of the human body as an expression of aesthetic-geometric perfection is not the result of the Leonardo's invention. The Genius of the Renaissance, thanks to the Vitruvian Man, in fact, inserts an interesting *variatio* within a centuries-old tradition that boasts the most diverse declinations.

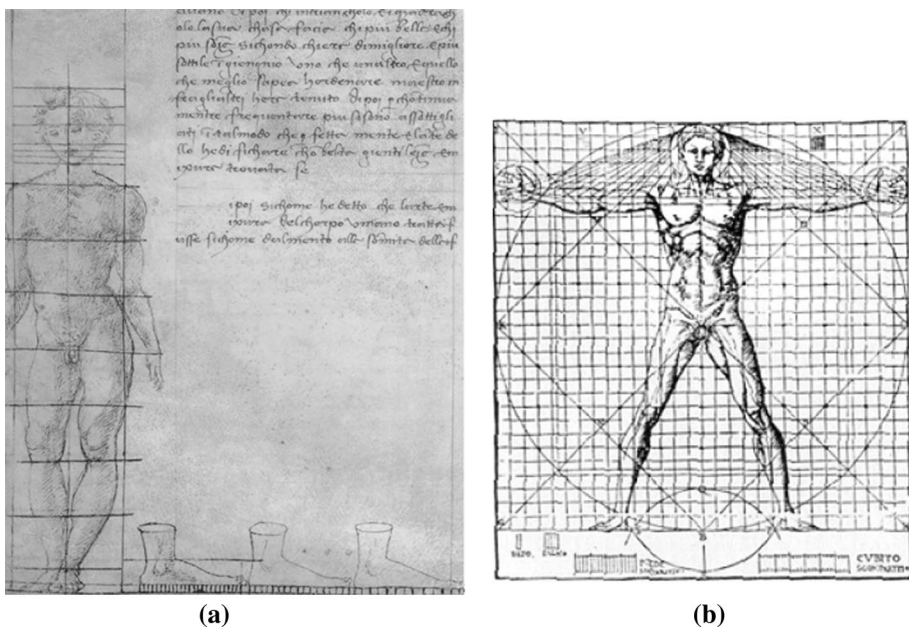
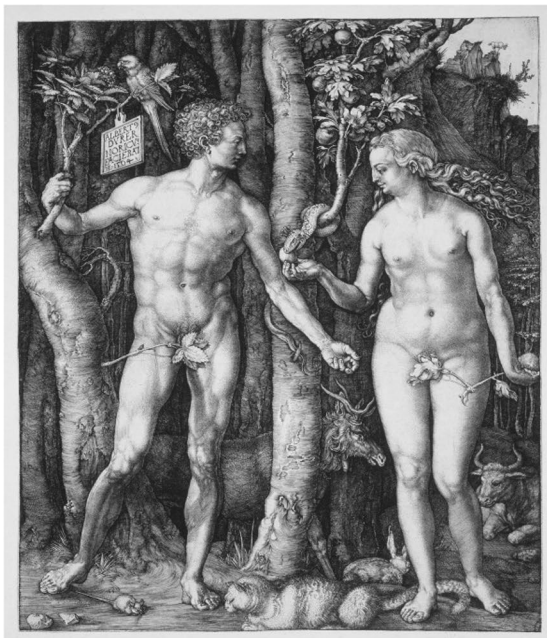


Fig. 1 **a** The human proportions for Francesco di Giorgio Martini; **b** the human proportions for Caesar Cesarianus

Within these, we can trace at least three main directions responsible for modulating the interest of ancient science towards the problem of the human body perfection:

- (i) Firstly, one of the main interpretative perspectives lies certainly in the notion of “loss” of the original perfection. The idea of an original archetypal perfection, lost as a result of an infraction, is common to all religions and in the Christian narration, especially through the gnostic and hermetic thinking, has found its form in the myth of the Adam’s body (Rykwert 1996), originally perfect and dramatically subject to the fall into the material world and the exit from Eden (Fig. 2a) (Paravicini Bagliani 2012).
- (ii) Secondly, the process of perfection recovery has been realized within Christianity through the Christ’s body, whose mysterious “measures” have been not only source of profound veneration over the centuries, the so-called *mensura Christi* (Rykwert 1996), but also have constituted the doctrinal premise for the theoretical and practical equivalence between the human body and the architectural body; as claimed by the Gospels, beyond any metaphor, the body of Christ is a “temple”. If the temple is destroyed, then it has to be rebuilt according to an analogical model already present in the Egyptian and, in general, in Mediterranean cosmologies (also the bodies of the Greek Dionysus and of the Egyptian Osiris are dismembered and recomposed through interesting symbolic processes);



(a)



(b)

Fig. 2 a The Adam’s body before the fall (Albrecht Durer—The Fall of Man, 1504, Engraving—13.6×17.3 in., Museum of Fine Arts, Boston). b The human body of Christ (Michelangelo, Risen Christ, c. 1514–1516, marble, h. 205 cm, Church of San Vincenzo Martire, Bassano Romano, Italy)

- (iii) Thirdly, and most interestingly here, is that, in addition to the above described lost and recovered perfection, a vision of the cosmos believing in the *recoverability* of the individual perfection and, more extraordinarily, in the perfection opportunity for each individual certainly existed, in a more or less latent way, in an age characterized by a convinced anthropocentrism according to which the body of man is the body of “God”, as pointed out in Fig. 2b.

From a doctrinal point of view, the reflection on the human body, in line with the epistemological postulates of the ancient knowledge and with the analogical thought that feed it, required the simultaneous contribution of several disciplinary perspectives.

2.1 The Human Body was Simultaneously

- (i) Topological representation of space and time, thanks to its correspondences with the zodiacal belt (Rykwert 1996), constituting, in such a sense, not only a mathematical and chronological calculation instrument, but also an astrological and divinatory one;
- (ii) Reference model for the construction of sacred buildings. The numeric and geometric composition of the “perfect” human body, often knowable only through mystical and initiatory paths, has in fact provided the constructive archetypes for the most legendary old testament buildings, such as the Temple of Solomon and the Ark of Noah (Fig. 3) (Ramirez 1995);
- (iii) Paradigmatic model for Hippocratic and Galenic medicine, then object of the complex doctrine of the four temperaments which are responsible not only for the physical health of the body but also for the character and psychic configuration of the individual;
- (iv) Myth of “ideal” and experimental research in the many alchemical works on *elixir* (Pereira 1998), where the possibility of a perfect body health is linked not only to an arrest of the aging processes, but also to the achievement of a cognitive-spiritual perfection.

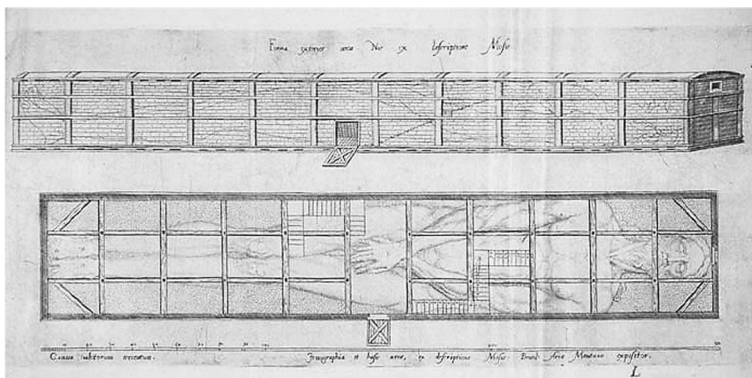


Fig. 3 Christ's body in the ark of Noah (Benito Arias Montano, *Antiquitatum Iudaicarum libri IX*, Apud Franciscus Raphelengium, Leiden 1593)

All this has to be seen in the light of a temperamental conception of the four humours that sees in the expected achievement of an *aureo* equilibrium the possibility for the individuals to attain the Christ perfection, which is the Adam's perfection, i.e. the perfection of the human body before the exit from Eden, remembering the myth of the *homunculus*, the man "created" in the alchemical laboratories (Newman 2005).

The Christian doctrine, from its beginning, has acquired the methodological tools of the classical and Mediterranean world to feed the multi-perspective reflection on the human body. Pythagoras is within Christianity through his science of number and his musical theory. Experts of the number science are certainly the Fathers of the Church Augustine and Ambrose, as well as Boethius and Bonaventure (Vinassa De Regny 1988) and, just to mention the greatest ones, the doctrines of Marsilius Ficinus, Giovanni Pico della Mirandola, Giordano Bruno and Tommaso Campanella were inspired by Pythagoras.

At the basis of the Pythagorean conception is the concept that the number is "an intrinsic and active virtue of the supreme One" and not an abstract quantity (Vinassa De Regny 1988). The universe according to Pythagoras expresses itself through the number as *ratio* and *rhythm* and manifests itself through the symmetry of multiples, organizing itself in ordered relationships, the same ones that, as he has shown, are at the basis of music. In turn, the proportional intervals between the musical notes are the same that regulate the distances between the planets.

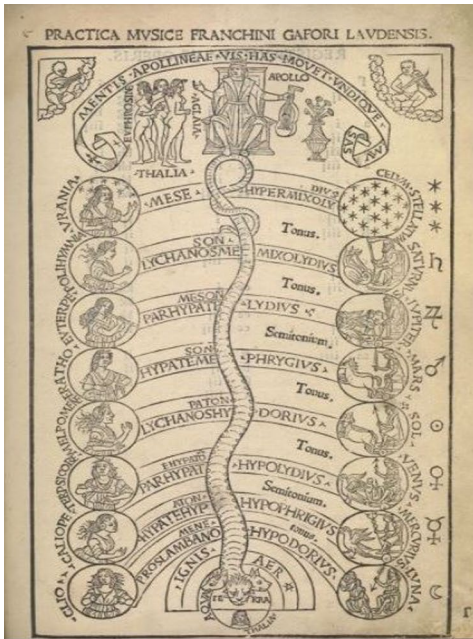
Although the Pythagorean school has not left manuals (the tradition of the Greek philosopher has been handed down orally and initiatically), a method which is at the basis of the organization of scientific knowledge is found: arithmetic and geometry are the disciplines on which the musical theory is based and the "dance" of planets, i.e. astronomy, is based on the musical theory (as it is well known, the "harmony of the spheres" is a Pythagorean construct (Livio 2000; Cerchio 1993) (Fig. 4).

The above mentioned four disciplines, i.e. arithmetic, geometry, music and astronomy constituted the so-called *quadrivium*, the quaternary possibility that the medieval university teaching offered to the man who wished to get access to a thought worthy of a "free" man (they were also called "liberal arts" as opposed to "mechanical arts", as represented in Fig. 5).

The ideology underlying the architecture of the sacred buildings, then, starting at least from Durando, bishop of Mende, with his *Rationale divinatorum officiorum* (Durandus 2007) or from Honorius of Autun (Honorius 1895), is certainly supported by the analogy human body—building body and, consequently, the doctrines related to the arts of the quadrivium converge towards it. If astronomy describes a large-sized universe defined as a *macrocosm*, the man who is its inhabitant will be a sort of scaled paradigmatic reproduction of the aforementioned universe; therefore, he will be a *microcosm* (Fig. 6).

The term "microcosm" seems to have been for the first time transliterated from the Greek by Isidore of Seville (Rykwert 1996) who uses it with reference to the musical harmony («sed haec ratio quemadmodum in mundo est ex volubilitate circulorum, ita et in microcosmo in tantum praeter vocem valet, ut sine ipsius perfectione etiam homo symphoniis carens non consistat» (Etym. III. 23) (di Siviglia 2006).

Furthermore, in his *Hexameron*, the Father of the Church Ambrose discussed about the formation of the human body as the union of the four elements (the Empedocles' *stoicheia*) present in man as a harmonious mixture of sounds capable to join («atque ita sibi per hunc circuitum et chorum quendam concordiae societatisque conveniunt. Unde et Graece *stoicheia* dicuntur, quae latine elementa dicimus, quod sibi conveniunt et concinant» (Hex. III.4. Xviii) (St. Ambrose 2010).



(a)



(b)

Fig. 4 The “harmony of the spheres” and Pythagoras: **a** The music of the spheres: Franchinus Gaffurius, *Practica Musicae*, Gulielmum signer Rothomagensem, Milan 1496. **b** The School of Athens (detail): Pythagoras, Raffaello Sanzio, 1509–1511, fresco, 200×300 in., Stanza della Segnatura, Palazzi Pontifici, Vatican

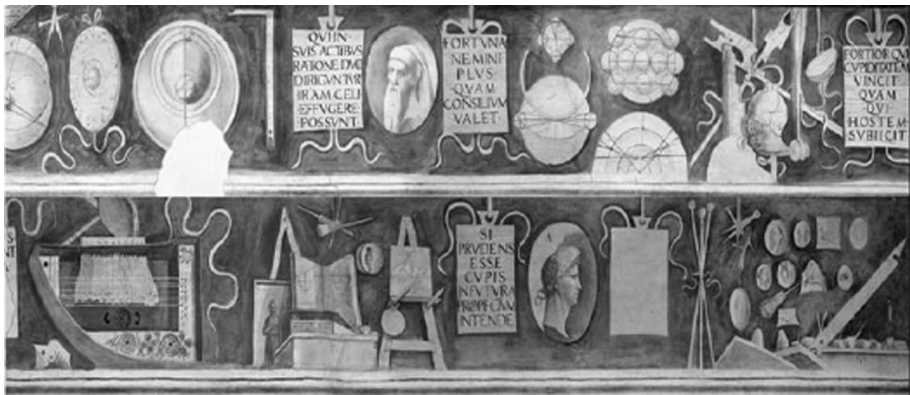


Fig. 5 “Liberal arts” and “mechanical arts” (Giorgione, Frieze of the Liberal Arts and Mechanics, c. 1496–1500, fresco 77×1588 cm, Casa Pellizzari, Castelfranco Veneto, Italy)

Fig. 6 The man as a microcosm (Circular diagram of a microcosmic man, or zodiac man, c. 1400, Ms 282, f. 72v, British Library, London)



3 The Vitruvian Man of Leonardo as a Paradigm of the Scientific Method

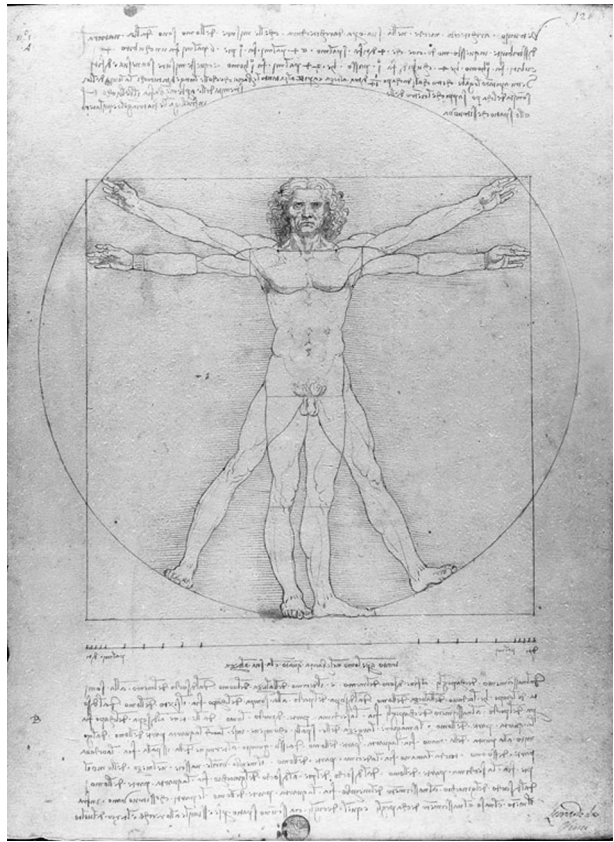
The Vitruvian Man of Leonardo, as shown in Fig. 7, is to be collocated in a proven tradition of the Fifteenth century art (it should be noticed that both *art* and *science* do not yet exist as we know them today).

Just to cite a few authors, Marianus Jacobus Taccola in his *Liber de ingeneis* (Taccola 1984) or di Giorgio Martini (1967) had inscribed the man in a square and in a circle following personal reworkings of the Vitruvian criterion. In fact, the *auctoritas* of Vitruvius served as an ideological and operational paradigm, but, evidently, it did not prescribe in an exclusive way the use of the measures that he had noted in his *De architectura* (Vitruvius 1586).

It is useful to remember that Leonardo, in deciding to geometrize the human body providing measurements and proportions in relation to polygonal shapes, is certainly working not only within the figurative art framework, which necessarily uses arithmetic and geometry, but he is also thinking *ipso facto* about the disciplines related to it, i.e. music, astronomy and, above all, medicine (Frascardi 1982). In such a context, the words of Leonardo on the profession of doctor-architect are very clear:

“Signori padri diputati, s̀ come ai medici, tutori, curatori de li ammalati, bisogna intendere che cosa ̀ omo, che cosa ̀ vita, che cosa ̀ sanità, e in che modo una parità, una concordanza d’elementi la mantiene, e così una discordanza di quelli la ruina e disfà, e conosciuto ben le sopra dette nature, potrà meglio riparare che chi n’è privato... Voi sapete le medicine, essendo bene adoperate, rendon sanità ai malati, e quello che bene le conosce, ben l’adopererà, quando ancora lui conoscerà che cosa ̀ omo, che cosa ̀ vita e complessione, che cosa ̀ sanità; conoscendo queste, bene conoscerà i sua contrari; essendo così, più visino sarà al riparo ch’alcun altro. Questo medesimo bisogna al malato domo, cioè uno medico

Fig. 7 The proportions of the human body according to Vitruvius, Leonardo da Vinci, 1490, metallic tip, pen and ink, touches of watercolor on white paper, 34.4 × 24.5 cm; Venice, Gallerie dell'Accademia



architetto, che 'ntenda bene che che cosa è edificazio, e da che regole il retto edificare diriva" (Codex Atlanticus, 730 r).

"Gentlemen, fathers, as well as doctors, tutors, curators of the sick, must understand what is man, what is life, what is health, and how a parity, a concordance of elements, keeps it, and so a discordance of those destroys it, and well known the above said natures, who is deprived of it will be able to better repair... You know that the medicines, being well used, give health to the sick, and who knows them well will use them well; when he will know what is homo, what is life and complexion, what is health; knowing these, he will know well his opposed; so he will be sheltered more than others. He, a medical architect, must understand what is edificatium, and from what rules the right building derives".

In his search for the understanding of "what is man", Leonardo evokes medicine in analogical relation to architecture. In particular, he refers to the concepts of "health", "complexion" and "right building" through the fundamental concordance–discordance dichotomy. The speculative basis of temperamental medicine, as well as of music, was in fact found in the concept of "harmony (or equilibrium)" of humours (i.e. temperaments) (Fig. 8) (as in the *concordia discors* of Philolaus, philosopher of the Pythagorean school).

Therefore, by "conceiving" the man according to the Vitruvian criterion, Leonardo was aware of the symbolic value and of the heuristic power of the number and of its multiples.

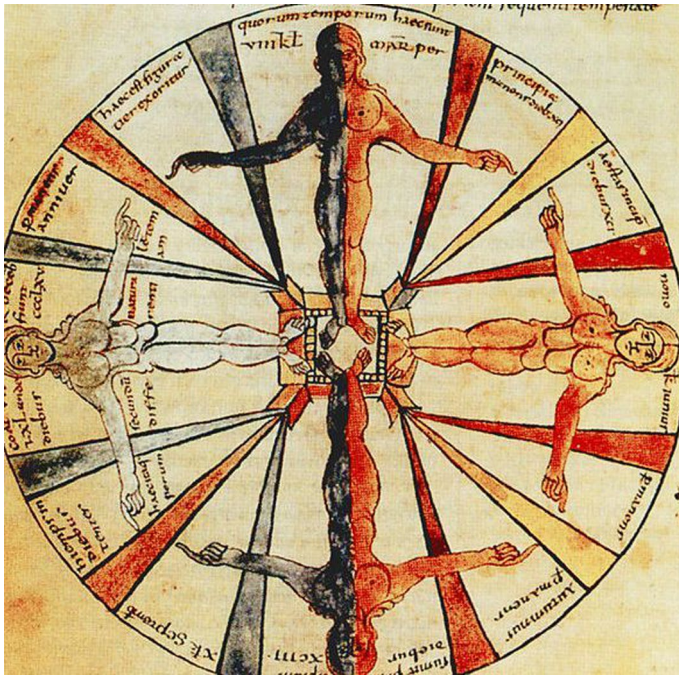


Fig. 8 The wheel of the four temperaments in Isidore of Seville's *De natura rerum*, IX sec., Ms. 422, fol. 6v, Bibliothèque Municipale, Laon, France

3.1 At the Top of his Vitruvian Man, Leonardo States

“Vetruvio, architecto, mecte nella sua op(er)a d’architettura, chelle misure dell’omo sono dalla natura distribuite inquessto modo cioè che 4 diti fa 1 palmo, et 4 palmi fa 1 pie, 6 palmi fa un chubito, 4 cubiti fa 1 homo, he 4 chubiti fa 1 passo, he 24 palmi fa 1 homo ecqueste misure son ne’ sua edifiti. Settu ap(r)i ta(n)to le ga(m)be chettu chali da chapo 1/14 di tua altez(z)a e ap(r)i e alza tanto le b(r)acia che cholle lunge dita tu tochi la linia della somita del chapo, sappi che ‘l cie(n)tro delle stremita delle ap(er)te me(m)bra fia il bellichio. Ello spatio chessi truova infralle ga(m)be fia tria(n)golo equilatero”.

“Vitruvius, architect, says in his architectural work that the measurements of man are in nature distributed in this manner, that is 4 fingers make a palm, 4 palms make a foot, 6 palms make a cubit, 4 cubits make a man, 4 cubits make a footstep, 24 palms make a man and these measures are in his buildings. If you open your legs enough that your head is lowered by 1/14 of your height and raise your arms enough that your extended fingers touch the line of the top of your head, let you know that the centre of the ends of the open limbs will be the navel, and the space between the legs will be an equilateral triangle”.

Here Leonardo calls into question, as per tradition, Vitruvius; however, the measures he notes do not correspond to those of the Latin author. It is interesting to notice that the Leonardo’s choice fulfils a criterion essentially based on the recursion of the number 4 (4 diti, 4 palmi, 4 cubiti, 24 palmi, 1/14 di tua alteza), which was interrupted in one case by

the number 6 (*6 palmi fa un cubito*) and by the allusion to the number 3 through the equilateral triangle.

Leonardo marks at the bottom of the Vitruvian Man the following comments:

“Tanto ap(r)e l’omo nele b(r)accia, qua(n)to ella sua alteza. Dal nasscime(n)to de chapegli al fine di sotto del mento è il decimo dell’altez(z)a del(l)’uomo. Dal di socto del mento alla som(m)ità del chapo he l’octavo dell’altez(z)a dell’omo. Dal di sop(r) a del pecto alla som(m)ità del chapo fia il sexto dell’omo. Dal di sop(r)a del pecto al nasscime(n)to de chapegli fia la sectima parte di tucto l’omo. Dalle tette al di sop(r) a del chapo fia la quarta parte dell’omo. La mag(g)iore larg(h)ez(z)a delle spalli chontiene insè [la oct] la quarta parte dell’omo. Dal gomito alla punta della mano fia la quarta parte dell’omo, da esso gomito al termine della isspalla fia la octava parte d’esso omo; tucta la mano fia la decima parte dell’omo. Il memb(r)o birile nasscie nel mez(z)o dell’omo. Il piè fia la sectima parte dell’omo. Dal di socto del piè al di socto del ginochio fia la quarta parte dell’omo. Dal di socto del ginochio al nasscime(n)to del memb(r)o fia la quarta parte dell’omo. Le parti chessi truovano infra il me(n)to e ‘l naso e ‘l nasscime(n)to de chapegli e quel de cigli ciasscuno spatio p(er)se essimile alloreche è ‘l terzo del volto”.

“The length of the outspread arms is equal to the height of the man. From the hairline to the bottom of the chin is one-tenth of the height of the man. From below the chin to the top of the head is one-eighth of the height of the man. From above the chest to the top of the head is one-sixth of the height of the man. From above the chest to the hairline is one-seventh of the height of a man. From the chest to the head is a quarter of the height of the man. The maximum width of the shoulders contains a quarter of the man. From the elbow to the tip of the hand is a quarter of the height of a man; the distance from the elbow to the armpit is one-eighth of the height of the man; the length of the hand is one-tenth of the man. The virile member is at the half height of the man. The foot is one-seventh of the man. From below the foot to below the knee is a quarter of the man. From below the knee to the root of the member is a quarter of the man. The distances from the chin to the nose and the hairline and the eyebrows are equal to the ears and one-third of the face”.

Furthermore, in the Vitruvian Man Leonardo makes reference to the “Golden ratio”, i.e. 1:1.618, an harmonic balance spread over the natural world. In the proportions taken into account by Leonardo, the Golden ratio is used on the face, on the hand and on the whole body with reference to the navel. Table 1 summarizes the used proportions and rules.

It is fundamental to notice that Leonardo rejects two main criteria introduced by Vitruvius, i.e. the human body proportions and the concentricity of the circle and the square, which had significant and even symbolic implications for other authors of “Vitruvian men” (Panofsky 1968).

As it has been well discussed (Torrini 2009), the non-concentricity of square and circle is the original novelty introduced by Leonardo with respect to the widespread versions of contemporary authors (Saxl 1957), leading to a figure which maintains two distinct centers: the center of the circle, which coincides with the center of the human body with open legs, is the navel; the center of the man inscribed in the square is the one that the scientist and musicologist Athanasius Kircher in his *Musurgia unieversalis* calls the “*spermaticeae partes*” (“In qua videt quoque hominem perfectissimum quadrato, circuloque esse commensurabilem, et circulo quidem centrum duplex in homine statui potest, pro duplici membrorum habitu; si enim manus pedesque divaricatos, quantum potest, in formam crucis Andreeanae accomodet, erit centrum circuli extrema manus expandent,

Table 1 Proportions and rules used by Leonardo in his Vitruvian Man

| | Dimensions (cubits) | Height | Face | Finger | Foot | Golden ratio |
|------------------|------------------------|--------|------|--------|------|--------------|
| Height | 4 | | | | | X |
| Head | | 1/8 | | | | |
| Head-chin | | 1/8 | | | | |
| Hair-chin | | 1/10 | 1/3 | | | |
| Eyelashes | | | 1/3 | | | |
| Ears | | | 1/3 | | | |
| Face | | | | | | X |
| Hair-breast | | 1/7 | | | | |
| Armspan | | 1/1 | | | | |
| Head-breast | | 1/6 | | | | |
| Head-nipples | 1 | 1/4 | | | | |
| Nipples-genitals | 1 | | | | | |
| Genitals-knee | 1 | 1/4 | | | | |
| Knee-feet | 1 | 1/4 | | | | |
| Shoulders | 1 | 1/4 | | | | |
| Elbow-shoulder | | 1/8 | | | | |
| Elbow-hand | 1 | 1/4 | | | | |
| Hand | | 1/10 | | | | X |
| Palm | 1/6 | 1/24 | | 1/4 | 4 | |
| Legs | | 1/14 | | | | |
| Foot | | 1/7 | | | | |
| Step | 4 | | | | | |

centrum circuli extrema manuum pedumque tangenti ipse umbilicus; si vero pedibus contractis, recta manus expanderit, centrum circuli extrema manuum pedumque tangenti, spermaticarum partium medium erit” (Mus. X, 1) (Kircher 1650), i.e. the groin, evoking once again the change of the center in *homo quadratus* and in *homo circularis* and referring, in a sibylline way, the measures of the human body to the correspondence with the Noah’s Ark and the Temple of Jerusalem (“Nam et Arcam Noemicam et templum hierosolymitanum huiusmodi mensuris corporis respondisse, Salianus et Vilalpandus fuse demonstrant”) (Kircher 1650).

In addition, to fulfil his new rules which differ from the Vitruvius ones, two poses are proposed by Leonardo for the two men: the man inscribed in the square is standing with his arms outstretched, while the man inscribed in the circle has both arms and legs spread apart V. These poses provide a dynamic vision of the Vitruvian Man (Rykwert 1996): the movement from the groin to the navel—from the center of the square to the center of the circle—is in our view crucial in the interpretation of the relative symbolic importance and relation between the square and the circle.

The symbolic difference between the circle and the square was well known at that time and finds an exemplary expression in the complexity of the architectural forms of Humanism and Renaissance, as highlighted by the difficult work *Hypnerotomachia Polifili*, probably by the Venetian monk Francesco Colonna (Ariani and Gabriele 2010).

The square refers to the elementary quaternity and in this sense indicates the terrestrial world that has its basis in the four “fluid” principles that govern the visible world and that Leonardo well knows (Codex Atlanticus, 385v/1067r): earth, water, air and fire. The four elements, traditionally brought back to Aristotle, were defined as “roots” already by Empedocles of Agrigento (Wright 1981) who added to the 4 principles the 2 fundamental processes of concord (constructive and cause of harmony) and of discord (destroyer and cause of conflict).

Since the first Greek speculations, the circle has constituted the symbolic abode, the monopoly of the divine and of the infinity. In line with such assumptions, the *ether*, or fifth element, is characterized by a perpetual and circular race (Aristotle 1984). As a geometrical figure with uncountable sides, the circle is not a figure of the universe, since the cosmos is always subject to temporality, but it is a figure of the infinity.

In the Pythagoras’ philosophy, the rational numbers reflect the “sensitive universe” organization, while the irrational quantities belong to the world of infinity (Vinassa De Regny 1988).

In the fifteenth century, Nicholas of Cusa, who was known by Leonardo (Buccaro 2011), used the geometric theme of the inscription of the square in a circle to exemplify his philosophical and theological vision. Now “a connection of Leonardo’s study and Cusa’s vision of Man appears even more probable when we realize that the Cardinal of Cusa applied the symbolic relationship of the square and the circle to a thoroughly humanistic definition of Man’s uniqueness and his unique position in the universe” (Germ 2007).

For the great philosopher of the *una religio*, the square stands to the circle in the same relationship in which the finiteness of the world stands to the infinity expressed by God. Even increasing enormously the number of the sides of a polygon, it can never achieve the same area of the circle “quasi ut poligonia circulo inscripta natura foret humana, et circulus divina” (as if the polygon inscribed in the circle were the human nature and the circle were the divine nature) (de Cusa 1932). So Nicholas of Cusa places a distance between the human mind (the *mens* as a quantitative process linked to its etymon: the *mens* is in fact *mensura*: measure) and the infinity.

The same “distance” seems to find a figurative counterpart in the Leonardo’s Vitruvian Man when one pays attention to the superior gap between the square and the circle that reminds half of a *vesica piscis*. If the feet of the *homo quadratus* and of the *homo circularis* are in fact largely linked to the basis of the polygon and of the circumference, the head of both is tangent only to the square and does not touch the circle.

In Leonardo’s words, a confirmation of this vision of the finiteness of the mind can be found:

“L’acqua percossa dall’acqua fa circuli dintorno al loco percosso; per lunga distanza la voce in fra l’aria; più lunga in fra ‘l fuoco; più la mente in fra l’universo; ma perché l’è finita non s’astende infra l’infinito” (Ms H, 67r).

“Water hit by water does circles around the beaten spot; for long distance the voice in between the air; longer in between the fire; more the mind in between the universe; but, because it is finite, it does not reach the infinity”.

Here, Leonardo performs the Pythagorean distinction between the universe as a finite cosmos, in which the mind can spread in space through circular figures in the same way of the sound moving in air and the fire, and the infinity, i.e. the limit of the mind circular motion, a different area in which the mind cannot “extend”.

As above mentioned, the original and fundamental variations introduced by Leonardo with respect to Vitruvius, i.e. the non-concentricity of the circle and the square and

the different human body proportions, could testify a specific intention of Leonardo. In line with the dictates of his scientific method, the square makes reference to the measurable physical world; furthermore, the man inscribed within the four side polygon symbolizes the measurement process based on the measure unit systems and on the related conversion factors. Leonardo, in fact, based his method for reaching a scientific knowledge on an empirical approach (Kemp 2011), the experience being the foundations of the scientific venture.

Just to cite some of the many Leonardo's sentences about the key-role of experience:

“Molti mi crederanno ragionevol mente poter riprendere allegando le mie prove per essere contro all'alturità d'alquanti omini di gran riverenza apresso dè loro inesperti iudizi, non considerando le mie cose essere nate sotto la semplice e mera sperienza, la quale è maestra vera” (Codex Atlanticus, 327 v).

“Many will think they may reasonably blame me by alleging that my proofs are opposed to the authority of certain men held in the highest reverence by their inexperienced judgments; not considering that my works are the issue of pure and simple experience, who is the one true mistress”.

“La sapienza è figliola della sperienza” (Foster III, 14 r).

“Wisdom is the daughter of experience”.

“E questa sperienza si faccia più volte, acciò che qualche accidente non impedissi o falsassi tal prova, che le sperienza fussi falsa, e ch'ella ingannassi o no il suo speculatore” (Ms M, 57 r).

“And this experience must be made several times, in order to avoid that any accident does not prevent or falsify such proof, and that it pledge or not its speculator”.

“Ma prima farò alcuna esperienza avanti ch'io più oltre proceda, perché mia intenzione è allegare prima l'esperienza e poi colla ragione dimostrare perché tale esperienza è costretta in tal modo ad operare. E questa è la vera regola come li speculatori delli effetti naturali hanno a procedere, e ancora che la natura cominci dalla ragione e termini nella sperienza, a noi bisogna seguitare in contrario, cioè cominciando, come di sopra dissi, dalla sperienza, e con quella investigare la ragione” (Ms E, 55 r)

“But first, I will make no further experience before proceeding, because my intention is to attach first the experience, and then to demonstrate with reason why this experience is constrained to operate in such a way. And this is the true rule as the speculators of the natural effects have to proceed, and again that nature begins with reason and terms in the experience, we must continue to state the contrary, that is beginning, as I said above, from the experience, and with it investigate the reason”.

The circle, which is centered in a different point with respect to the square, makes reference to the truth, which is reachable only by the man conceived as image of God; in this framework, although the man inscribed in the square yearns the truth, he never achieves it. In fact, the fundamental combination of experience and mathematics, the only two tools at the disposal of the man, do not allow to reach a complete knowledge.

If the square and the circle are assimilated to the physical reality and to the truth, respectively, the Vitruvian Man could represent the process of measurement which tends to the knowledge without reaching it. As a confirmation, Leonardo wrote:

“*La natura è piena d’infinita ragioni, che non furon mai in isperienza*” (Ms I, 18v).
 “Nature is full of infinite causes that have never occurred in experience”.

“*La sperienza, interprete in fra l’artifiziosa natura e la umana spezie, ne ‘nsegna ciò che essa natura in fra’ mortali adopra da necessità costretta, non altrimenti oprar si possa che la ragione, suo timone, oprare li ‘nsegnì*” (Codex Atlanticus, 86 r. a).

“Experience, interpreter between the nature made with artifice and the human species, teaches us what this nature does among mortals constrained by necessity, so that on does not act otherwise and that the reasoning, its rudder, teaches to it to act”.

Therefore, in the Leonardo view, experience is intermediary between man and nature: its role is to approach man to nature, but, due to the “infinite causes that have never occurred in experience”, the full understanding of nature is not achievable by man. The truth represented by the circle is not attainable by the man, which uses experience, mathematics and reasoning to reach it, formulating theories that remain confined into the square. The measurement process, aimed to find a correlation among the physical quantities and to justify it through a theory, is not definitive, but recursive and under continuous improvement and never concluded: for this reason the man inscribed in the square remains always shifted with respect to the man inscribed in the circle.

The figurative representation of the impossibility of reaching the truth by the man is the known problem of the squaring of the circle. In approaching this problem, which is strictly connected to the Vitruvian Man, Leonardo shows his genius in extremely sophisticated drawings of “lunule” (lunes) and mathematical calculations. The Codex Atlanticus (see 45 v. a, 455) contains several dense pages full of detailed, intertwined and complex geometrical drawings realized by the renowned graphic mastery of Leonardo, testifying the obsessive research of Leonardo in the squaring of lunes, moving from the first studies of Hippocrates of Chios on lunes related to the isosceles rectangle triangle, i.e. “lunule” (Proclus 1873). In these pages, Leonardo states that in the *De ludo geometrico* he describes the protocol for squaring the circle:

“*Avendo io finite li contro vari metodi di quadrare li circoli, cioè dare quadrati di capacità equali alla capacità del circolo e date le regole di procedere in infinito, al presente comincio il libro de ludo geometrico e dò ancora modo di processi infiniti*” (Codex Atlanticus, 45 v. a).

“Having ended up various methods of squaring the circles, that is, giving squares of capacity equal to the capacity of the circle and given the rules of proceeding indefinitely, now I begin the book de ludo geometrico and I give still way of infinite processes”.

Despite the Leonardo sentence: “*Finito addi 7 di luglio, a ore 23, a Belvedere nello studio fattomi dal Magnifico, 1514 (42)*” (Codex Atlanticus, 90 v. a) (“Ended the 7th of July, at 23, in Belvedere, in the office gave to me by Magnifico, 1514 (42)”), the *De ludo geometrico* book have been never written as well as the squaring of the circle has been not described by Leonardo in his notebooks, except for some reference to it as:

“*La quadratura del cerchio di Archimede è ben detta e male data. E ben detta è dove lui dice il cerchio essere eguale a uno ortogonio fatto della linea circonferenziale e del semidiametro d’un cerchio dato; ed è mal data dove lui quadra una figura laterata di 96 lati, alla quale viene a mancare 96 porzione spiccate d’essi 96 lati: e questa in nessun modo è da esser detta quadratura del cerchio, ma invero per tali regole è impossibile a fare altrimenti*” (Codex Atlanticus, 85 r. a).

“The squaring of the circle of Archimedes is well-defined and badly given. And it is well-defined where he says that the circle is equal to an orthogonium made of the circumferential line and of the semidiameter of a given circle; and it is badly given where he squares a figure of 96 sides, which is lacking of 96 marked portions of these 96 sides: and in no way this is to be called squaring of the circle, but indeed for such rules it is impossible to do otherwise”.

“Li animali motori delli charri senplicitis simamente cian dimostrato a quadratura del cierchio che anno le rote di tal carro che mediante ilue stigio della circhunferentia dital rote chessi fa retti linie” (Ms G, 58 r).

“The motor animals of the chariots simply have shown to us a squaring of the circle that the wheels of this chariot have by means of the trace of the circumference of these wheels which is straight”.

These sentences make reference to a linearization of a circle rather than to the squaring of the circle and then they are not a clear demonstration that Leonardo was convinced about the true possibility to square the circle. As it is well known (Marinoni 1982), the squaring of the circle is a problem whose solution requires an irrational number; therefore, it is not unreasonable to hypothesize that Leonardo was aware that a circle cannot be squared even using a very high number of sides of the polygon exactly as he knew that the truth cannot be reached, so confirming that he could have given to his Vitruvian Man the meaning of paradigm of his scientific method.

4 The Vitruvian Man of Leonardo as a Representation of the Operational Approach

In the Leonardo’s Vitruvian Man, unlike the man in the circle, the man in the square shows some signs on wrists, arms, hands, knees, pubis, shoulders, and all along the chest, as highlighted in Fig. 9.

These signs refer to the proportions described by Leonardo in the text at the top of the drawing: the proportions of the human body, where each part is a fraction of another part, are represented and explained by Leonardo. Leonardo aims to relate the structure of the human body to the structure of the physical world:

“L’uomo è il modello del mondo” (Codex Arundel, 156 v).

“Man is the model of the world”.

The general concept of harmony, although it can today seem lyrical and romantic, is nevertheless founded on precise quantities and measures, or, in other terms, on quantities governed by arithmetic and geometric laws.

The idea of an “aesthetic” purpose at the basis of the mathematical laws of proportion will be present even in the work of Isaac Newton (Rykwert 1996). However, finding the “numbers” that preside over the generation of proportions capable to produce harmony in the human body as in a musical instrument is already a concern of Augustine, Father of the Church (DCD, 22. 24. 4 (Augustine of Hippo 1925), found also in one of the sources of the genius of Leonardo (Kemp 2004; Pedretti 1988).

To understand the importance that the notion of “quantity” had for Leonardo it is sufficient to think that in the Codex Atlanticus he expressed the intention to compose a treaty on continuous quantities (Codex Atlanticus, 167 r). This treaty should have been

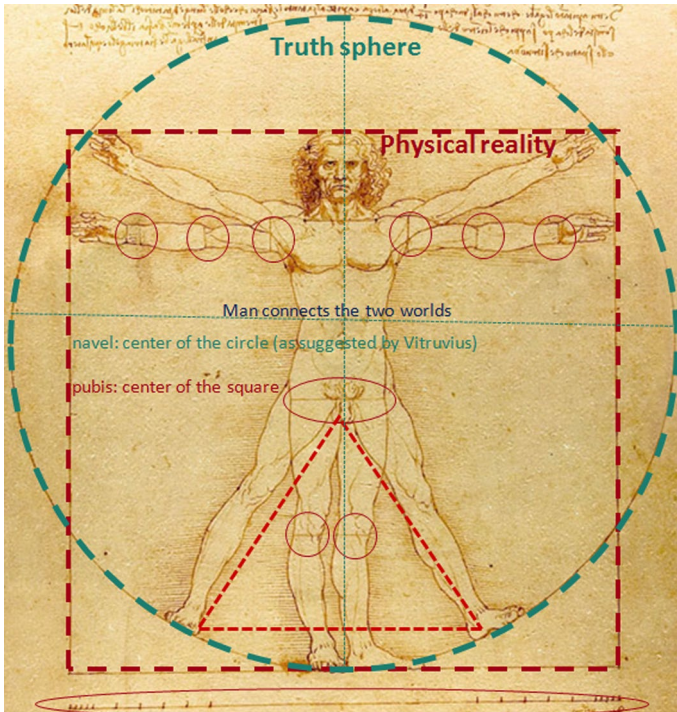


Fig. 9 The measure units marked by signs in the Vitruvian Man

referred to geometry, as a discipline addressed to the study of the “continuous” quantities, which has to be added to arithmetic which is addressed to the study of the “discontinuity” of the numerical quantities.

The constant purpose of Leonardo was certainly to find an “order” in the fascinating chaos of natural manifestations (Kemp 2004).

On that score, Leonardo used the severe analytical attitude with which the philosophers tried to snatch to Nature the secret *ratio* with which it operated.

For Leonardo “measuring” the Nature means:

- (i) Investigating the *arithmoi*, i.e. the numbers, but also the “rhythms” of aggregation and expansion, of contraction and relaxation (as, for example, in the anatomical questions of *increasing* and *decreasing* muscles) (Keele and Pedretti 1979).
- (ii) Observing the tendency to produce symmetrical arrangements and proportional relationships among the parties;
- (iii) Organizing, in numerical patterns, the manifold manifestations of the world and of the human body (for example, for Leonardo the *uffici* of the eye are 10 (Ms A, 102 v), the movements of the tongue are 7 (Ms B, 31 v), the ways in which *violence* is exerted are 4 (Ms A, 35 r), and so on).
- (iv) Tracing, within the investigated numerical patterns, recursions, correspondences and analogies.

The Vitruvian Man is then a paradigmatic example of the quantitative investigation that Leonardo used to trace details and “measures”. In investigating the proportions of the human body, Leonardo used both the mathematical fractions and the tool of the analogy (Ciocci 2016):

“La proportione no[n] solamente nelli numeri e nelle misure fia ritrovata, ma etiam nelli suoni, pesi, per tempi e siti e qualunque potenza” (Ms K, 49r.).

“The proportion not only in numbers and measures is found, but also in sounds, weights, for times and places and any power”.

In the unbalanced comparison with the “invisible” world of the non-quantity, i.e. of the Infinity of Nicholas of Cusa, the scientist’s only certainty is that the world of quantity is not only a “visible” world, but also a “divisible” world, since only “*where there is no quantity there is no division*” (Codex Atlanticus, 200 r. b.). A “visible” world is consequently “measurable”.

For Leonardo, who was used to criticize the traditional distinction between mechanical and scientific arts of his time, the primacy of the experience on the abstraction of the *mental sciences* is not only a guaranty of a “correct” approach, but also the paradoxical prelude to a sort of “ecstatic” perception of the truths of science.

The *eternal silence* and the *peace* invoked by Leonardo do not appear far from the Pythagorean conception of an *arithmon arretion*, i.e. of a number which cannot be expressed in words. Regarding the experimental knowledge, Leonardo in fact points out:

“Qui non si arguirà che due tre facciano più o men che sei, né che un triangolo abbia i suoi angoli minori di due angoli retti, ma con eterno silenzio resta distrutta ogni arguizione, e con pace sono fruite dai loro devoti, il che far non possono le bugiarde scienze mentali” (Ms A, 50 r.).

“Here it will not be inferred that two three give more or less than six, neither that a triangle has its corners smaller than two right angles, but with eternal silence every inference is destroyed, and with peace they are enjoyed by their devotees, what that cannot be done by the lying mental sciences”.

For Leonardo, then, the circle will be the emblem of a world to which the mathematical point, invisible and indivisible, belongs; this is opposed to the visible world of the square, to which the mechanical point, which he defines as “divisible”, although divisible ad infinitum (Codex Atlanticus, 200 r. b), is referred.

In such a context, an element of novelty introduced by Leonardo, with respect to Vitruvius, is the equilateral triangle that Leonardo mentions to describe the distance between the legs of the man inscribed in the circle (see Fig. 9). A similar element, together with the reduction of 1/14 of the height of the man who spreads the legs, is present in the representation of the criterion made by Agrippa Von Nettesheim in his *De occulta philosophia* (Fig. 10) (Zöllner 1985; Agrippa 1533), where each diagonal of the pentagon defined by the five human extremities divides the geometric representation in Golden section.

At this point it should be stressed that Vitruvius offers a “ruler” to his interpreters. In antiquity, the measurement practice was anthropomorphic, i.e. it envisaged a measurement system that had, as its basic quantity, the length of the limbs of the human body as prescribed by Greek metrology (Zöllner 1995). In particular, Vitruvius, as also Leonardo, adopts, as a reference quantity, the “step” (*fathom*), i.e. the dimension of the man’s height. All the proportions provided by Vitruvius are therefore defined as fractions of the total length of this standard measure (Zöllner 1995).

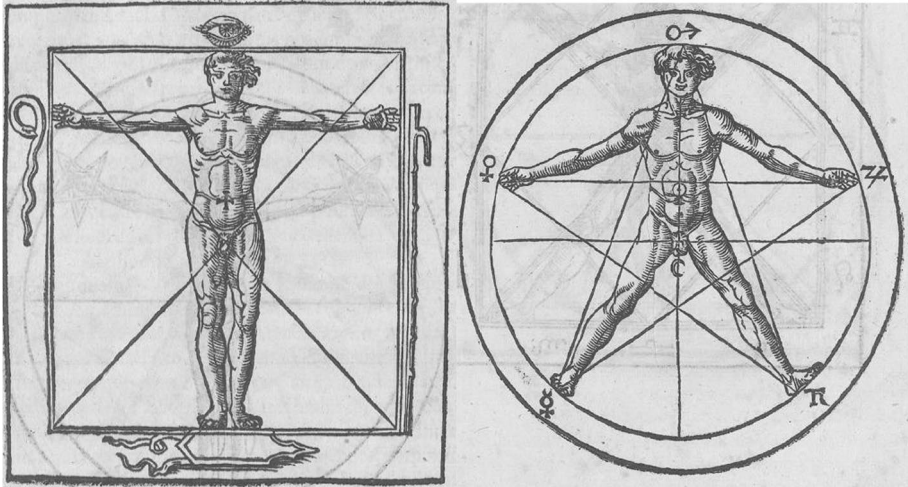


Fig. 10 Representation of the criterion made by Agrippa Von Nettesheim in his *De occulta philosophia*: Homo quadratus and Homo circularis (Henrici Cornelii Agrippae *De occulta philosophia libri tres*, Johannes Soter, Köln 1533)

Here it will be not superfluous to observe that a graduated ruler, like the one proposed by the Vitruvian criterion, is a scale and that, at the time of Leonardo, the scale is present in the philosophical speculation through different representations:

- (i) The representation of the Pythagorean lambdoma divided into steps in the *De Harmonia Mundi* by Franciscus Georgius Venetus (Fig. 11) (Giorgi 1525);
- (ii) The representation of the Universe in the form of a graded succession of several worlds, as in the *De coniecturis* of Nicholas of Cusa (Fig. 12) (de Cusa 1972; Roob 2014);
- (iii) The quaternary scale of the elements of the *De occulta philosophia* of Agrippa (Agrippa 1533) where the quaternary division of the *mores* of the human complexions, distinkted in *impetus—alacritas—tarditas—inertia*, is present (Fig. 13).

Fig. 11 The pithagorean lambdoma in Francisci Giorgii Veneti *De harmonia mundi totius cantica tria, in aedibus Bernardini de Vitalibus calchographi, Venetiis* 1525

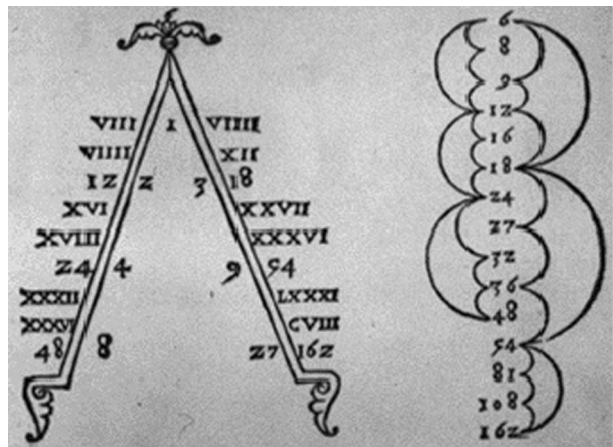
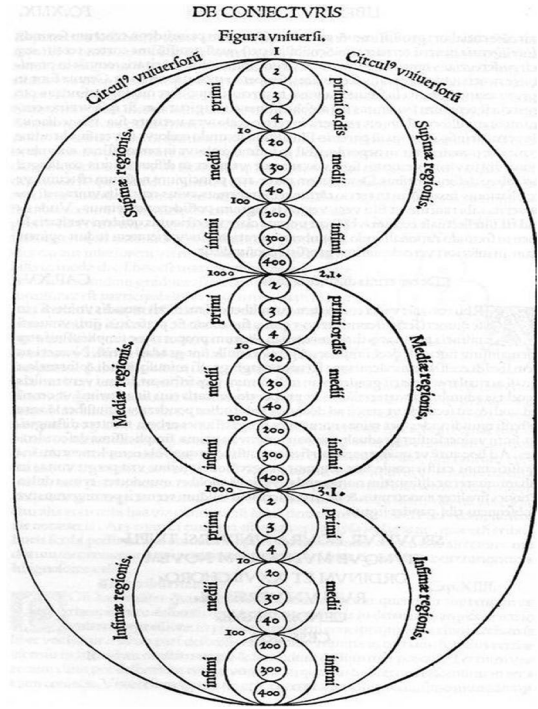


Fig. 12 Representation of the Universe in the form of a graded succession of several worlds (Nicholas of Cusa, *De coniecturis*, Meiner Verlag, Hamburg 1972)



| | | | | |
|----------------------------------|----------|-----------|------------|-------------|
| Quatuor humani corporis elementa | Spiritus | Caro | Humores | Ossa |
| Quadruplex spiritus | Animalis | Vitalis | Gignitivus | Naturalis |
| Quatuor humores | Cholera | Sanguis | Pituita | Melancholia |
| Quatuor complexio num mores | Impetus | Alacritas | Inertia | Tarditas |

Fig. 13 The quaternary scale of the elements in the *De occulta philosophia* of Agrippa (detail) (Henrici Cornelii Agrippae *De occulta philosophia libri tres*, Johannes Soter, Köln 1533)

As it is evident, in the Vitruvian criterion adopted by Leonardo the reference pattern is based on the number 4. The importance of the number four is fundamental in the Pythagorean mathematics that made this number the descriptive matrix of a non-three-dimensional Universe, i.e. of a Universe at four figures, composed of point, line, triangle and tetrahedron (Burkert 1972).

The Pythagorean *tetraktys*, which is composed of the first four numbers and which gives 10, in the decusse representation (X cross) furnishes the iconic value of two (the two axes intersecting in the center) and of four (the four segments that can be obtained from the intersection).

The recursion of the number 4 in the Leonardo's writings is easily observed. For example, for Leonardo the principles of the painting science are 4, and concern the point, the line, the surface and the body (Codex Atlanticus, 271 v. a.); the accidental powers

(*potentie accidentali*) are 4 (Codex Arundel, P 12v: 151v); the man's universal stories, that he wanted to deal in a "*libro titolato de la figura umana*", "book titled of the human figure" (Windsor RL, 19037v), are 4.

The importance of the number 4 for the human figure is reflected also with its multiples. The Leonardo's Vitruvian Man is composed by 24 palms and, consequently, by 96 *digiti*, and the symbolic value of these multiples should not be underestimated.

We observe, for example, that the 24 letters of the alphabet have been identified by the Greeks with 24 parts of the man's body; the 24 h of the day have determined the division of the earth's body within a geometry applied to geography; finally, the number 24, which is a submultiple of 96, was involved in the complex measurement of the distance of the earth from the sun, in the calculation of the zodiacal belt, in the inclination of the ecliptic at the times of Vitruvius, and even much earlier (Stirling 1981), and we know how important was the consideration of the movements of the sun at the times of Leonardo, as pointed out in Fig. 14.

It is therefore clear how the Leonardo's Vitruvian man can be interpreted as a measure system, with a meaning conceptually different from that of the Renaissance rediscovery of ancient "man as a measure of all things" concept (Sholarin et al. 2015). The Renaissance man as a measure of all things is in fact not to be identified with just an ideological principle that justifies the prominence of man within the realm of Nature. Conversely, man as a "measure" is a sort of prototype, an operational and scientific instrument beyond every generic and simple metaphor. The human body as a measure system allows to approach the world knowledge by means of the quantitative and analytic observation of the physical world. Therefore, the Leonardo's Vitruvian man symbolizes an operational approach to knowledge which is based on the scrupulous observation of the physical world; it is noteworthy to recall that Leonardo very often used the graphic representation to describe the phenomenological world, using his extraordinary abilities as a painter for representing Nature. More specifically, although in many relatively simple cases, he was able to formulate quantitative phenomenological laws and to make predictions for the investigated system behaviours, in other more complex cases, both for the mathematical tools and for the precision of the instrumental devices available at that time, he did not succeed in quantitatively describing the systems and the phenomena he observed: especially in such cases, he has drawn the phenomena with the mastery and details that everyone knows, used images

Fig. 14 Solar noon crossing the S. John baptistery of Florence on summer solstice (source: Museo Galileo—Laboratorio multimediale IMSS—Florence)



in the place of words or numbers, used art for science (Kemp 2006; Pedretti 2003; Capra 2013). In conclusion, in his approach to scientific knowledge, Leonardo extended the concept of “operational definition” to the concept of “operational representation”, which finds an excellent expression in the Vitruvian Man.

Compliance with Ethical Standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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