Everything comes from everything, and everything is made out of everything, and everything returns into everything: Leonardo's analogical (re)search

Aliki Economides

School of Architecture, McGill University, Montreal

March 2002

A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfilment of the requirements of the degree of Master of Architecture.

National Library
of Canada

Acquisitions and
Bibliographic Services

395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque nationale
du Canada

Acquisisitons et
services bibliographiques

395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence
ISBN: 0-612-85910-X
Our file Notre référence
ISBN: 0-612-85910-X

Table of Contents

Thesis Abstract

This thesis explores the foundations of the complex and multifaceted work of Leonardo da Vinci as a whole. What underscores the universality of his research and transcends the artificial divisions of his vast body of work into modern categories of specialization, is the operation of analogy, which is grounded in a mimetic imagination. Leonardo's search is ultimately one of understanding the underlying causes that animate the universe and through analogy, his work and his world hold together. Central to my investigation of the continuity of Leonardo's analogical mode of thinking and making, are questions pertaining to the body, architecture and representation. I put forth that only by appreciating the analogical nature of Leonardo's (re)search, can one access the meaning and value of his efforts and contribution.

Résumé de Thèse

Cette thèse explore les fondements de l'oeuvre complexe et facettée de Leonardo da Vinci. C'est l'opération de l'analogie, prenant racine dans l'imagination mimétique, qui met l'universalité de sa recherche en évidence et transcende la division artificielle de ses innombrables travaux selon les catégories modernes liées à la spécialisation. Fondamentalement, Leonardo cherche à comprendre les causes profondes qui animent l'univers; par le biais de l'analogie, son oeuvre et son monde s'unifient. Au coeur de mon investigation de la continuité des modes analogiques de pensée et de fabrication chez Leonardo, se trouvent des questions qui concernent le corps, l'architecture et la représentation. De plus, je soutiens que seule l'appréciation de la nature analogique de la recherche de Leonardo permet d'aborder de façon significative la valeur de ses efforts et de sa contribution.

Acknowledgements

The process that generated this product of deep personal significance involved a long gestation period full of fascinating discovery and personal anguish; sharp pangs signalling my long-awaited readiness to write; and a messy but welcomed birth. Since the realization of this undertaking was by no means a solitary endeavour, I wish to gratefully acknowledge the many individuals who were of tremendous help to me, at different times and in various ways. To the following people I owe many thanks:

To Alberto Pérez-Gómez, for his guidance, trust and compassion. His inspiration has touched me deeply and the enrichment I have received through exposure to his wisdom is a gift that I will enjoy in perpetuity.

To the guests and in-house critics Louis Brillant, Gregory Caicco, Marco Frascari, David Leatherbarrow, Stephen Parcell, Louise Pelletier, and Helene Stub, all of whom sent me looking in fruitful directions that helped me develop my ideas from self-directed studio project into what has become a written thesis.

To my classmates and colleagues in the architectural history and theory graduate program at McGill University, for sharing their thoughts and research and for contributing to a stimulating creative and intellectual environment. I also wish to thank the students in the professional degree program for their interest and encouragement, and for having the patience to listen to my thoughts crystallize during lectures and design critiques.

To Kathleen Innes-Prévost for her kindness, concern and unfailing willingness to be of administrative assistance even when she could little afford the time, and to Anne Bordeleau for generously offering her skills in translation.

To the powers that be at McGill University for awarding me two Graduate Fellowships and, more precious to me than the material support, for granting me sufficient time to complete this thesis.

To Philip Beesley, Heather Cameron, Ze'ev Friedman, Lloyd Gerson and Hans Lücke, teachers who had a formative influence on my learning during my undergraduate studies in architecture and philosophy at the University of Toronto. By exposing me to ways of approaching architecture that I have integrated as my own, and to questions that I will spend my life asking, they have contributed to the journey that has brought me to the present work.

To Beth Allen, Pierre Bélanger, Jennifer Carter, Ricardo Castro, Ralph Ghoche, Narly Golestani, Linda Graif, Ali Hatami, Ruth Krongold, Regal Leftwich, Panos Leventis, Sophie Lorenzo, Lori Merriott, Yelda Nasifoglu, and Annie Potter, who have enriched my life as well as this particular undertaking with their emotional support, insightful feedback and generous friendship.

To my parents, aunts, uncles, cousins and godparents who consistently offer me their love and affirmations of their belief in me, especially when I have neglected to extend these kindnesses to myself. Without the support of my family the realization of this work would not have been possible.

And finally, I wish to express my tremendous gratitude for the unconditional love of my furry companion, Zeus, and my sister, Georgia, neither of whom ever left my side.

For our parents
Irene and Alekos Economides

Preface

To comment on the work of Leonardo da Vinci (1452 – 1519) is a daunting proposition, partly due to the enormous quantity of work Leonardo, one of the most well-known figures of the Italian Renaissance, left behind, as well as to the abundant scholarship that already exists on him. While a text limited to the scope of a Masters thesis cannot do justice to the quantity and richness of Leonardo's legacy, my ambition is to shed light on what I perceive to be some important aspects of his work as a whole, in a manner and with an emphasis that has not already been exhausted by Leonardo scholarship. In view of some of my personal questions that are a part of the discipline of architecture, I wish also to explore in the work of Leonardo, some of the connections architecture has to the body, both in terms of its ideation and its representation.

The dissemination of Leonardo's notebooks and the history of their organization (and in some cases recompilation) by the various hands that claimed them; their dispersal and loss; and their subsequent, albeit partial, retrieval, is a lengthy story in its own right. Important to know is that no treatise of Leonardo's was published during the course of his own life, although he made numerous notations to himself pertaining to how he should organize his collected material for various intended treatises. From his notations, it is possible to glean that some of the works he intended to gather and make public were to be called "On the Human Body", "Treatise on the Flight of Birds", "Treatise on Light and Shadow", "Elements of Machines", and "On Transformation", to name a few. The first attempt to collect and publish any of Leonardo's work was carried out by his student and companion Francesco Melzi. Consulting the disparate notations and sketches in his master's notebooks which were bequeathed to him in Leonardo's will, Melzi copied out the passages pertaining to painting, and published them in 1651 under Leonardo's name, as the *Treatise on Painting*.[1] Following the death of Melzi, the manuscripts exchanged many hands in many countries

---

1 Many of the original folios that Melzi consulted in order to compile the treatise are now lost. It has been estimated "that out of 1,008 headings only 235 are traceable in the surviving documents." Ladislao Reti and Bern Dibner, *Leonardo da Vinci Technologist; Three essays on some designs and projects of the Florentine master in adapting machinery and technology to the problems in art, industry and war* (Norwalk, Connecticut: Burndy Library, 1969) 63. Elsewhere it is stated that 225 out of the 944 paragraphs are identical to passages in the extant manuscripts. Edward MacCurdy, *The Notebooks of Leonardo da Vinci* (New York: Reynal & Hitchcock, 1939) 53. Suffice it to say that in the surviving manuscripts, approximately only one quarter of the contents of the *Treatise on Painting* can be found. From the original folios against which the treatise may be compared, it has been agreed that Melzi's compilation is a faithful and reliable one. The fact that Melzi gave priority to the work pertaining to painting over Leonardo's other studies indicates how important this area of research was to Leonardo within his oeuvre.

over several centuries, and have only been made available to scholars since the late 19th century. Jean Paul Richter was the first to collect and translate Leonardo's writings which he published as *The Literary Works of Leonardo da Vinci.*[2] Subsequently, many of Leonardo's manuscripts were published in facsimile editions in the late 19th and early 20th centuries, making the work more widely available.[3]

The nature of the work we have inherited is what, by present day terminology, may be referred to as 'interdisciplinary'. It has been calculated that we have inherited over 100,000 sketches, drawn by Leonardo on over 5,000 pages of his known sketchbooks.[4] By noting references he makes to works which we do not have and are therefore assumed lost or destroyed, it has been concluded that the bounty of Leonardo material that has come down to us is in fact probably only one third of what had constituted his entire life's work.[5] Considering the prolific quantity of work which we have inherited, it is doubly astounding to imagine that this likely constitutes less than half of what he accomplished in his 67-year life span. Of the works that have come down to us intact, the majority of sketches pertain to Leonardo's study of the human body.[6] This is quite astounding given the scarcity of specimens available for dissection and the taboo associated with cutting the body at the time. Unlike other artists of his time who dabbled in dissection largely for the sake of improving their art by better understanding the superficial muscle structures of the body, Leonardo probed deeper, analyzing the human figure in unprecedented detail. This suggests that he was interested in exploring the human body for more reasons that improving his painterly technique.[7]

After the collection of anatomical drawings, the second largest thematic group is that of his drawings of numerous inventions and strategies pertaining to military engineering.[8] The

---

2 *The Notebooks of Leonardo da Vinci*, 2 vols, ed. Jean Paul Richter, 1883 (New York: Dover Publications, 1970). Since its original publication the work has undergone several revisions, including changes to the title.

3 The following manuscripts are the earliest to have been published in facsimile. Six volumes of the manuscripts at the Institut de France (1880-91); Codex Trivulziano (1892); Codex Atlanticus (1894-1904); the anatomical drawings at Windsor Castle (1898 and 1911-16); and the Leicester Codex (1909). The dates are taken from MacCurdy, 47-52.

4 André Chastel, "The Problems of Leonardo's Architecture in the Context of his Scientific Theories," *Leonardo da Vinci; Engineer and Architect* (Montreal: Montreal Museum of Fine Arts, c. 1987) 193. Leonardo worked mostly on loose sheets of paper, hence the difficulty in establishing a chronology of his work.

5 Kenneth Keele, *Leonardo da Vinci's Elements of the Science of Man* (New York: Academic Press, 1983) 4.

6 It is estimated that there are well over 200 sheets of anatomical drawings collected from the folios at Windsor Castle and the pages in the Codex Atlanticus. See Pietro Marani, "Leonardo, Fortified Architecture and its Structural Problems," *Leonardo da Vinci; Engineer and Architect* (Montreal: Montreal Museum of Fine Arts, c. 1987) 303, fn, 329.

7 In subsequent chapters I will discuss how the body for Leonardo is in fact central vehicle to his understanding of all other branches of his research.

8 Marani., 303. Leonardo's surviving drawings of fortifications total close to 600 sketches collected on at least 200 sheets of paper.

abundance of these studies is understandable due to the many decades he was in the service of the rulers Ludovico Sforza and Cesare Borgia. Less extensive thematic groupings of drawings include studies pertaining to the movement of water, the flight of birds, light and shadow, mechanics and geometry. The bounty of Leonardo material is overwhelming and in its totality is challenging to grasp, however, it must be remembered that these fragments - our primary texts - while being representative of his thought, are nevertheless a small sample of it. Therefore even the most comprehensive examination of the work of Leonardo that we posses is but a partial study.

There is no one who has examined the material, who has not been taken by Leonardo's vast range of interests and talent. Every writer on Leonardo, from those scholars who have devoted their lives to the study of Vinciana, to those who write about him out of a more amateurish interest have been amazed by his diversity. In fact Leonardo's 'universality' has become a commonplace recognition, if not the most-known fact about his work. The difference between being genuinely 'universal' and being merely 'eclectic' is that universality implies that beneath the surface of the diverse tangents of thought and multifaceted explorations is an essential and underlying unity to the work; a coherent and sustained investigation. By contrast and likely guided by the desire to offer points of entry to his work that cater to different interests, numerous publications have been put out on Leonardo that aim to focus on separate aspects of his work, such as his art, his anatomy, or his architecture. On the one hand, this tendency to tackle one aspect of the work and bracket out the rest is completely understandable, given the variety and overwhelming quantity of Leonardo's research. However, despite its convenience and its affinity with our understanding of things according to their placement under identifiable subject categories, this dismemberment of the whole into parts undermines an understanding of the very universal nature of his work.

I must confess that I initially came to the work of Leonardo out of a fascination with his anatomical drawings. I was immediately captivated by the unique sophistication of his drawing techniques, noting the clarity with which they describe the human figure from multiple vantage points, and the depth with which they probe the hidden depths of the body. Drawn in by his anatomical studies I eagerly sought out his architectural work, expecting to find a clear, visual translation of his innovative methods of representation of the body to that of buildings. I did not find such an obvious correspondence, and at first I was quite disappointed by what I perceived to be

the fragmentary and undeveloped nature of his architectural drawings. His small sketches drawn from a bird's-eye view seemed to lack the rigour and depth of his drawings of the body, and many of his other hastily drawn or incomplete architectural investigations lacked the sophistication of his anatomical explorations. Out of this discrepancy it seemed fruitful to speculate on how he may have understood architecture, in contrast to and/or through his understanding of the body. My efforts then focused on finding whether there exists a bridge or network of thoughts between his work in anatomy and architecture, that is mutually informing, thus allowing the findings in one domain to flow toward the other, and vice versa. However, I soon came to realize that a true understanding of any one area of these supposed 'specialized' domains of Leonardo's inquiry necessitates a conscientious approach to the whole multifaceted exploration of his vast research, despite, and in fact *with* all of its attendant inconsistencies. It became apparent to me that commenting meaningfully on the work of Leonardo, depends upon going beyond the convenient fragmentation of his work into separate topics, and instead probing the underlying issues and concerns that connect any one of his investigations to all others. That is, to explore how the 'thematic' parts inform and enrich the whole and how the whole is therefore far more than the sum of its parts, as a weave is more than the sum of its coloured threads.

Selected Chronology

1452 Leonardo is born (April 15) near Florence

Florence (*c.*1464 – 83)

c. 1466-76 is taken into the studio-workshop of Andrea del Verrocchio
1472 becomes a member of the Guild of Florentine painters (la Compagnia di San Luca)
1473 ink drawing of the Arno valley (August 5). This is his earliest dated drawing that has come down to us.
1478 likely met Ludovico Sforza
1481 works on two studies for the *Adoration of the Magi* (commissioned by the Monastery of San Donato)

Milan (1483-99)

c. 1482 writes a letter to Sforza enumerating his talents and capabilities, and offering his services
c. 1482 enters the service of Ludovico Sforza (il Moro); transfers his activities to Milan
1483-6 paints the *Virgin of the Rocks* (commissioned by the Confraternity of the Immaculate Conception)
1487 the earliest anatomical drawings we have are from this period; draws the "Vitruvian Man"
1486-90 earliest sketches for the proposed bronze Sforza equestrian monument
1487-90 works on a model of the Milan Cathedral dome and experiments with designs for centralized churches
1489 articulated his project for the (unrealized) treatise "On the Human Body"; drawings of skulls at this time
c. 1490 is called to Pavia with Francesco di Giorgio to give advice on the construction of the cathedral
1493 enormous clay model of Sforza horse exhibited under the triumphal arch in the Piazza of the Castello
1495-7 paints *Last Supper* in the Refectory of Santa Maria delle Grazie, Milan
1496 meets Luca Pacioli
1498 draws the figures of the 5 "Platonic bodies" for Pacioli's *Divina Proportione* (not published until 1509)
1498-9 draws cartoon for *Virgin and Child with St. Anne*
1499 writes on movement and weight; around this time does coitus drawing
1499 leaves Milan with Luca Pacioli; travels to Mantua and Venice before returning to Florence

Florence (1500-6)

1502-3 in the service of Cesare Borgia, inspecting the fortifications of Romagna; likely visits Rome
1502 draws map of Imola
1503-5 paints the *Mona Lisa* (the suggested dates of this work range from 1502-6)
1503-6 works on cartoon and mural painting for *Battle of Anghiari*, Florence
1504 visits Piombino and Rome
1504-9 does composite drawings of human and animal materials [*OHB*, 22]
1505 works on *On the Flight of Birds* and *On Transformation*; probably constructs of his "Flying Machine"

Milan (1506-13) under French rule

1506 enters service of Charles d'Amboise, Vice-regent of Louis XII and Governor of Milan
1506 draws study for the *Leda*
1507-8 two trips to Florence; returns to Milan and is in the service of King Louis XII
1510 meets the anatomist Marcantonio della Torre (who died in 1511)
1513 leaves Milan with Francesco Melzi and others

Rome (1513-16)

1513-16 has his studio in the Belvedere of the Vatican; travels to Florence, Civitavecchia, Parma
1513 continues anatomical studies (especially intensive study of the heart) and studies in optics
1513-16 paints *St. John the Baptist*
c. 1514 draws the *Deluge* series
1516 is poorly treated by the Pope; leaves Rome upon an invitation from François I to come to France

France (1516-19)

1517 is a guest (with Melzi) of King François I at the Château of Cloux; travels to Romorantin
is visited at Cloux by the Cardinal Luis d'Aragon and his secretary (October); shows them his work including his anatomical drawings, the *Mona Lisa, St. John*, and the *Madonna with St. Anne*
1519 Leonardo dies (May 2); buried in Amboise

List of Abbreviations

Manuscript	Abbreviation	Date of Work
Windsor Drawings in the Royal Library, Windsor Castle	W with inventory number	1478-1518
The Anatomical Studies by Leonardo da Vinci. The Queen's Collection at Windsor Castle. 3 vols. Keele and Pedretti.	K/P with folio number	
Ashburnham Codices		
Also known as BN 2037, formerly part of MS. B, Paris.	Ash. I	*c.* 1487-1490
Also known as BN 2038, formerly part of MS. B, Paris.	Ash. II	*c.* 1492
Codex Arundel 263 in the British Museum The British Library, London	Arundel	1480-1518
Codex Atlanticus Biblioteca Ambrosiana, Milan	C.A.	1478-1518 (this has also been assigned the dates 1483-1518)
Codex On the Flight of Birds Biblioteca Reale, Turin	Sul. Vol.	1505
Forster Manuscripts. 3 vols. Trustees of the Victoria and Albert Museum, London	Forster I Forster II Forster III	1487-90, 1505 1495-7 *c.* 1493-6
Codex Hammer (formerly the Codex Leicester) Collection of Bill Gates, Seattle, Washington	Leic.	*c.* 1506-1510
The Madrid Codices I, II Biblioteca Nacional, Madrid	Madrid I Madrid II	1493-1500 1503-5
Manuscripts A,B,C,D,E,F,G,H,I,K,L,M Bibliothèque de l'Institut de France, Paris	MS. A MS. B MS. C MS. D Ms. E MS. F MS. G MS. H MS. I MS. K_1 & K_2 (folios 1-80) MS. K_3 (folios 81-128) MS. L MS. M	*c.* 1490-92 *c.* 1487-90 1490-1 1508-9 1513-14 1508 1510-15 1493-4 1497-9 *c.* 1503-5 *c.* 1506-8 *c.* 1497-1504 *c.* 1495-1500

MS Bibliothèque Nationale (BN 2038) This MS had been included as part of MS. A by the Reale Commissione Vinciana. It runs from A 81r to A 114v, corresponding to BN 1r to BN 34v. See Ashburnham Codices.	BN 2038	
Codex Trivulziano Castello Sforzesco, Biblioteca Trivulziana, Milan	Triv.	*c.* 1487-1490
Treatise on Painting Translated by Philip McMahon (1956)	TP with paragraph number	1651(originally published)
Codex Urbinas and Libro A Compiled by Francesco Melzi from various manuscripts including Libro A of c. 1508	Urb.	

Introduction to a Body of Research

In this Introduction I will briefly sketch out some significant aspects of the Renaissance world-view in which Leonardo is immersed and the more important influences that are evident in his thought. In general terms I will introduce the ways in which Leonardo works, and in subsequent chapters I will elaborate on all of these themes through specific examples in his oeuvre. Through this thesis I am attempting to read Leonardo's work, to the best of my abilities, in terms that are as free as possible from the prejudices that I have observed in some aspects of Leonardo scholarship. It is my opinion that the depth and implications of Leonardo's investigations cannot be grasped by perusing isolated branches of his work. Furthermore, a fragmentation of Leonardo's research into modern categories of specialization (for instance his 'engineering' versus his 'architecture', or his 'science' as distinct from his 'art'), encourage misreadings of his cultural context and the nature of his work. Therefore, to borrow from hermeneutics, it is my intention to understand Leonardo's contribution within the *world of the work* in order to make informed conjectures.[1] Martin Kemp justifiably contends that "[t]he existing scholarship on Leonardo is so vast that it has embraced almost all the extremes of historical writing: from poetic insight to novelettish sloppiness; from myopic scholarship to insupportable generalization; from brilliance to stupidity. But unified visions of Leonardo's achievements have been few and far between."[2] My aim is to present the various aspects of Leonardo's research through what *unifies* them, thus reading him in a more appropriate way.[3]

I put forth that analogical thought underpins all of Leonardo's diverse areas of research and therefore holds the key to understanding a significant component of how he understood himself, his

---

1 Where relevant, I will also comment briefly on how, in my opinion, aspects of Leonardo's work have been misconstrued. Through this I seek to unravel some of the basic prejudices that hinder our understanding of his legacy. My aim is to bring to the surface certain aspects of our world-view that colour the reading of Leonardo in his own context and therefore lead to unfortunate misconceptions, or at best limited readings of his work. Rather than construct a polemic around the scholarship of any particular Leonardo scholar, I will approach the problems of interpretation by raising general misconceptions that seem to be generally perpetuated.

2 Martin Kemp, *Leonardo da Vinci; the Marvellous Works of Nature and Man* (Cambridge, MA: Harvard University Press, 1981) 18. Kemp also argues that "[t]hose authors who have written that Leonardo began by studying things as an artist but increasingly investigated things for their own sakes have missed the point entirely." Kemp, 124.

3 The challenges of aspiring to an informed interpretation are best articulated by Gadamer who writes: "The idea of a definitive interpretation seems intrinsically contradictory. Interpretation is always on the way." He also states that "[t]he first guiding insight [into hermeneutics] is to admit of the endlessness of the task." Hans-Georg Gadamer, *Reason in the Age of Science*, trans. Frederick Lawrence, 1981 (Cambridge, MA; London: The MIT Press, 1989) 105 and 108.

work and his world.[4] Thus, I am tracing a thread that is integral to his vast body of work, but one that appears and fades from the surface, as it weaves through his research, connecting his ideas and informing his findings. My ambition to look at his work as a whole (albeit with particular attention to his architectural and anatomical studies) is by definition broad, and because of this there will be many aspects of the work that I will not have the space to address. Within the parameters of this thesis it is of course not possible to offer an exhaustive, extensive or even coverage of Leonardo's interests, pursuits and discoveries, or to elaborate on every instance of analogy as it plays itself out in his oeuvre. However, I make this choice to paint in broad strokes because I feel it is more worthwhile to explore the connective tissue that unifies his multifaceted investigation. Due to this choice, I will make selections that I think illuminate my argument best and exemplify the typical operation of Leonardo's methods and findings.

Problems of interpretation invariably arise from conflating terms, concepts and values of our own with what those may have been for our predecessors. For instance, it is problematic to assume that the designation of distinct professional fields existed then much the way that they do now. While technical categories, general distinctions, and even tensions did exist between the various crafts in the Renaissance, the categories and 'professions' were not the same as we may be inclined to conceive the from our current perspective. For instance, architecture at the time was not an established profession in the modern sense.[5] The work that fell under the purview of the 'architect' went beyond the construction of buildings, and extended to other inventive realms such as those concerned with engines of war, mechanical devices, and theatrical machines for festivals.[6] In this context, Leonardo's letter to the duke Ludovico Sforza in which he boasts extensively about his numerous talents and the services he can deliver, is not a list of radically separate activities and professional titles, but facets of a broad base of theoretical and practical expertise.[7] Rossi states: "In the early years of the [16th] century, sculptors and architects in

---

4 My emphasis on analogy is an attempt to comprehend how Leonardo may have understood his world in his own terms. Through the course of my research, I have come to the conclusion that the operation of analogy is one of the most integral if not completely obvious aspects of Leonardo's work. Yet surprisingly, commentaries focusing on, or deliberately treating the issue of analogy are not common in Leonardo scholarship.

5 For a discussion on the history of the term 'architect' until the 15th century, see Nicholas Pevsner, "The Term 'Architect' in the Middle Ages", *Speculum, A Journal of Mediaeval Studies* 17.4 (October 1942): 549-562.

6 Paolo Rossi, *Philosophy, Technology and the Arts in the Early Modern Era*, trans. Salvatore Attanasio, (New York: Harper and Row, 1970), 22.

7 In a draft of this letter to Sforza dated *c.* 1482, Leonardo expounds extensively on his capacities in the areas of military strategy (such as in the construction of bridges, ladders and other scaling equipment, and designs for cannons and other machines of war). At the end of his lengthy list he adds that in times of peace he can provide architecture, conduct water from place to place, and execute sculpture and painting. C.A. 391 r-a. See MacCurdy, 1152-3.

Florence were members of the minor guild of masons and carpenters while painters were classed as associates of the major guild of doctors and druggists, together with subordinate house painters and color grinders."[8] Thus it must be remembered that during the Renaissance the barber also served as the surgeon, and painters and apothecaries belonged to the same Guild, for through the mixing of compounds, powders and other ingredients, both medicines and pigments could be concocted. At this time in some Florentine studio-workshops (such as that of Andrea del Verrocchio, with whom Leonardo apprenticed for approximately ten years) a fusion between technical (manual) and theoretical (scientific) activities had been effected.[9] For instance, in such an environment the otherwise 'unlettered' apprenticing artist would have had exposure to such areas of learning as rudimentary anatomy, optics, perspective, and geometry, alongside their training in the arts of painting, sculpture, stone-cutting and pouring bronze.[10]

Leonardo is considered to be the quintessential "Renaissance man," largely for having engaged everything of interest to him and in the process, for overcoming the opposition posed between the 'lofty' liberal arts and the less valourized mechanical arts. Leonardo often cites 'experience' as imminently valuable to learning.[11] That which he advocates, which is also clear in his the way he works, is a profound engagement with the stuff of the world. Learning happens through the mediation of making, not through book-learning, for books full of words are less competent at revealing true knowledge than is observing the phenomena directly. For Leonardo, the ultimate search is to approach the mind of Nature and this is achievable by imitating her works through making.[12] Human action (*vita activa*), in contrast to contemplation (*vita contemplativa*) becomes important because it is man's responsibility as *participant* to bring things together within this world so that they may connect, unify and align with the cosmological order.[13] Interesting to

---

8 Rossi, 21.

9 Rossi, 22.

10 Rossi, 23.

11 David Summers asserts that the notion of the 'man of experience' was formed by the early 13th century. David Summers, *The Judgement of Sense; Renaissance Naturalism and the Rise of Aesthetics* (Cambridge: Cambridge University Press, 1987), 263. Hereafter references to this source will be cited as Summers, *JS* with the page number. Rossi mentions others in the 16th century who demanded knowledge "in which the observation of phenomena, attention to operations, and empirical research would have a superior status vis-à-vis rhetorical evasions, verbal accommodations, logical subtleties, and *a priori* constructions." Rossi, 7.

12 Judging from his prolific output, Leonardo seems to have worked incessantly until the end of his life. Relevant to bear in mind is that since some (and perhaps much) of his research was undertaken where there was little or no assured financial incentive for its execution, he must have invested so deeply into his research – especially that of the human body - because there was something very important at stake.

13 Since antiquity, the term *scientia* meant philosophy, not an activity devoted to instrumental ends as the positivistic sciences became. Originally 'philosophy' and 'science' were one, for *philosophia* named every type of theoretic

note is that at the same time that Leonardo seeks to valourize the 'practical applications' of the mechanical arts, he is also asserting a polemic against pure empiricism.[14] In essence Leonardo is advocating an integrated relationship between theory and practice, and his own revealing notations on the necessity of *theoria* for *praxis* are articulated in the form of analogies. He states: "Those who are enamoured of practice without science are like a pilot who goes into a ship without rudder or compass and never has any certainty where he is going. Practice should always be based upon a sound knowledge of theory, of which perspective is the guide and gateway, and without it nothing can be done well in any kind of painting."[15] Elsewhere he states more succinctly: "Science is the captain, practice the soldiers."[16] Rossi comments that "Leonardo's awareness of the nexus that had to be established between theoretical knowledge, practical activity, and experience was born from an artisan's familiarity with the characteristics of materials and the possibilities opened up by processing them."[17] Since Leonardo's prolific making is so close to philosophical concerns, this *praxis* which is a kind of practical wisdom, may be understood as *theoria.*[18] Conversely, his *theoria* does not call for a withdrawal into intellectual speculation but depends upon direct engagement with the world, and is therefore a kind of *praxis.*[19]

In this reciprocal process between Leonardo's contemplating and making, analogy figures prominently. In fact, it is the substratum that supports and propels the dynamic thrust of his varied research. The Greek word *analogia* (αναλογία), in its primary and most general definition means 'a relation', and in its secondary definition has to do with mathematical proportion and ratios. Both nuances of the definition concern themselves with naming a correspondence between things that is

---

knowledge. The birth of philosophy took place when reasoned thought replaced mythology in giving an account for the world around us. A 'philosopher' was then a 'natural scientist' and old science, with its metaphysical orientation, had the capacity to provide orientation in the world through a unifying interpretation of experience.

14 Rossi, 25.

15 MS. G. 8r. Cited in MacCurdy, 910.

16 MS. I. 130, 82 r. Cited in MacCurdy, 72.

17 Rossi, 25.

18 Note that in naming Leonardo's theory 'practical' it should not be assumed to be practical in the sense of a modern conception of 'pragmatism' that has efficiency, functionalism and instrumentality as its ultimate aims. His knowledge is 'practical' in the sense that his theoretical speculations demand testing and examining through making. In other words, the implication in Leonardo's position is that humans can only truly *know* that which we make. Gadamer informs us that "[t]he classical opposition [between theory and practice] ultimately was a contrast within knowledge, not an opposition between science and its application." Gadamer, 89.

19 This discussion recalls the debate during the extended process of constructing the Milan Cathedral beginning with the laying of its foundations in 1386. Essentially the aims of the Milanese clashed with the practical and aesthetic agenda of the northerners. The famous saying by the northerners, "Ars sine scientia nihil est" or 'Craft/skill without knowledge/contemplation is nothing', was turned around by the Milanese to say "Scientia sine ars nihil est" or "Knowledge/contemplation without craft/skill is nothing." For the history of this lengthy debate, see James Ackerman,

rooted in similitude. In the subsequent chapters, the manner in which Leonardo works within both the broadly relational and the mathematically proportional modes of analogical speculation will be discussed. Suffice it to state here that for Leonardo, analogical thought is not an abstract epistemological schema, but a framework that figures as both an unselfconscious outgrowth of the world-view of his time and his sense of connection to the world around him.[20] Through analogy in general and in Leonardo's work in particular, imaginative thought is enabled to leap scales and transcend superficial differences to find hidden and fruitful connections amongst things. Analogy enables us to locate the realm of human affairs within the cosmological, more-than-human framework in which it sits and by which it is supported, and through this it becomes possible to more readily perceive an implicit unity or wholeness in the world.[21] Unity, however, does not imply homogeneity. Rather, through analogy, the abundant diversity of phenomena of the world can coexist, interact, and mutually inform. Analogy opens us up to being receptive to the possibility that even seemingly diverse things may have much in common.[22] Max Jammer suggests that the role of analogy is important to the project of expanding knowledge because through it, cognition becomes recognition.[23] According to Foucault, the protoscience of Leonardo's time was based on similarities, for during the Renaissance, resemblance was a category of knowledge.[24]

"*Ars Sine Scientia Nihil Est*; Gothic Theory of Architecture at the Cathedral of Milan," *The Art Bulletin* 31 (1949): 84-111.

[20] The predominant relationship that was omnipresent and therefore largely taken as a given in the Renaissance was the correspondence between macrocosm and microcosm. C.f. Chapter 1.

[21] When we make the leap outside of the boundaries we presume to encircle a thing, we are faced with a potential for connections, relationships, and therefore too, of expanded meaning. Analogy maps out networks of possibility by tracing the visible lines connecting things by similitude as well as the implicit or invisible connective tissues that persist despite differences that vision may perceive.

[22] Leonard Barkan comments: "All imaginative thought attempts to bridge the gap between man and what is outside him. One method of bridging this gap is to see these two points of reference as fundamentally similar." Leonard Barkan, *Nature's Work of Art: The Human Body as Image of the World* (New Haven: Yale UP, 1975) 3.

[23] Max Jammer, *Concepts of Force; a Study in the Foundations of Dynamics*, 1957 (Mineola, NY: Dover Publications, Inc., 1999) 16.

[24] Foucault writes: "Up to the end of the sixteenth century, resemblance played a constructive role in the knowledge of Western culture. It was resemblance that largely guided exegesis and the interpretation of texts; it was resemblance that organized the play of symbols, made possible knowledge of things visible and invisible, and controlled the art of representing them. The universe was folded in upon itself: the earth echoing the sky, faces seeing themselves reflected in the stars, and plants holding within their stems the secrets that were of use to man. Painting imitated space. And representation [...] was posited as a form of repetition." Michel Foucault, *The Order of Things; an archaeology of the human sciences*, 1966 (New York: Vintage Books, 1994), 17. Barkan also addresses this issue. See Barkan, 9.

Renaissance thought, with its interest in the revival of the Classics, was largely influenced by Aristotelian and Neoplatonic texts that were transmitted through medieval scholars. Generally speaking, Leonardo's approach and thought can be more readily linked to that of Aristotle, therefore I will enumerate some general Aristotelian influences that Leonardo absorbed and modified as his own.[25] One important manifestation is Leonardo's conception of art as an imitation of nature. After establishing that "action for an end is present in things which come to be and are by nature"[26] Aristotle writes:

> "Thus if a house, e.g., had been a thing made by nature, it would have been made in the same way as it is now by art; and if things made by nature were made not only by nature but also by art, they would come to be in the same way as by nature. The one, then, is for the sake of the other: and generally art in some cases completes what nature cannot bring to a finish, and in others imitates nature. If, therefore, artificial products are for the sake of an end, so clearly also are natural products. The relation of the later to the earlier items is the same in both."[27]

Aristotle's notions about the works of Nature and those of man having the same ends, and that the products of both are for the sake of the other, is highly influential in Renaissance thought. Nature is both the ideal and the norm.[28]

Leonardo articulates several key scientific principles to explain the causes of everything in the world.[29] In the natural philosophy of the Italian Renaissance, heat is deemed to be the origin of life and motion, while cold induces rest and rigidity.[30] Aristotelian physics is the science of *physis*, that is, the examination of the phenomena of growth and becoming. In Aristotle's schema there is no

---

25 Unlike the Platonists who subscribed to a geometrical order above, Aristotle was more concrete, believing that what manifests in world is what *is*, and that the real is not a world of ideas that is immaterial and elsewhere. Leonardo, operating in a largely Aristotelian mind-set, is also inclined to confront the things themselves because it is through the visible that he thinks he can find everything. Summers maintains that Aristotle was 'in the world' the sense of his dependence on the senses for apprehension of the world. Summers, *JS*, 2.Gadamer writes: "For Aristotle *theoria* itself is a practice." 90. As has already been discussed, such is also the case for Leonardo.

26 Aristotle, *Physics*, Book 2, part 8, 199a 7-8.

27 Aristotle, *Physics*, Book 2, part 8, 199a 12-19. In another passage he records, "But if on the other hand art imitates nature, and it is the part of the same discipline to know the form and the matter up to a point (e.g. the doctor has a knowledge of health and also of bile and phlegm, in which health is realized and the builder both of the form of the house and of the matter, namely that it is bricks and beams, and so forth): if this is so, it would be the part of natural science to know nature in both its senses." Aristotle, *Physics*, Book 2, part 2, 194a 21-22.

28 Leonardo's understanding of the imitation of Nature is taken up in detail in Chapter 2.

29 Here I will not treat in depth Leonardo's adoption of the Aristotelian notion of 'action' being 'equal to reaction'; his ideas about movement in waves; and his pyramidal law. For a comprehensive explication of Leonardo's scientific principles, see Kenneth Keele, *Leonardo da Vinci's Elements of the Science of Man.*

30 Jammer, *Force*, 77.

distinction made between organic and inorganic matter,[31] and neither is there for Leonardo. Aristotle writes: "This then is one account of nature, namely that it is the primary underlying matter of things which have in themselves a principle of motion or change."[32] Thinkers of the Renaissance associated 'spirit' or 'soul' with life, and an overriding Aristotelian concept that is inherited by Leonardo is the notion that *physis* is alive. In a universe understood to be wholly animate, the world is perceived to be 'ensouled.'[33] Everything, therefore, including the inventions of the human imagination, is endowed with some sort of soul, which causes it to be active, moving.[34]

Leonardo records, "The soul desires to dwell in the body because without the members of that body it can neither act nor feel."[35] In Leonardo's formulation, the soul relies on a corporeal entity as a vehicle for it to act. However, at the same time, the soul desires to flee from the body and return to its source. He writes:

> "Now you see that the hope and the desire of returning to the first state of chaos, is like the moth to the light..... But this desire is the very quintessence, the spirit of the elements, which finding itself imprisoned with the soul is ever longing to return from the human body to its giver."[36]

Influential in Leonardo's understanding of natural processes (that stretch from the minutest particles to the scales of geology and cosmology), is Aristotle's notion that each element has its "natural place" within the strata of the elements. Therefore each element constantly struggles to get back to its proper region in space, when it has been dislocated by some force or activity. Thus when something is destabilized and moved out of its appropriate 'spot', it desires to return there. This as true for the soul as it is for the four elements. Leonardo cites, "Aristotle says that everything desires to keep its own nature."[37] Working against a thing's innate inclination to remain itself,

---

31 Max Jammer, *Concepts of Mass in Classical and Modern Physics,* 1961 (Mineola, NY: Dover Publications, Inc., 1997) 19.

32 Aristotle, *Physics*, Book 2, part 1, 193a 28-29.

33 Summers, *JS*, 10. On the animism of the universe in Renaissance thought, Jonathan Sawday notes that the universe is understood as corporeal in nature. Jonathan Sawday, *The Body Emblazoned; Dissection and the Human Body in Renaissance Culture,* 1995 (London; New York: Routledge, 1996) 92. Given this world-view of an animistic universe, certain correspondences and cosmological significations were collectively held and they allowed for a sense of coherence in the world, as well as a means for humans to understand their place within this order. The power of architecture to *mean*, directly benefited from this.

34 For Aristotle, this internal principle of motion is the first hallmark of the natural. See Lorraine Daston and Katharine Park, *Wonders and the Order of Nature* (New York: Zone Books, 1998) 281.

35 C.A. 59 r-b. Cited in MacCurdy, 61.

36 Richter, *Literary Works*, 2:242.

37 C.A. 123r-a. Cited in MacCurdy, 88.

however, is the power of movement through which things in nature interact, mingle and change.[38]

Hence, Leonardo's schema of the places proper to the four elements in the sublunar realm, places the heaviest of the elements, earth, resting at the centre of this elemental arrangement. Around earth is a ring of water (which scoured and carved the earth into the terrain that we now find. Had there been more water encircling the earth, he imagines the whole as a perfect sphere). Next, encircling water is the realm of air, for air always struggles to rise above water.[39] Next, and occupying the outermost ring in the strata of elements is fire, because it possesses the greatest amount of motion. When movement occurs, combinations of elements occur. Water and air may mix as water cascades downward, but the air, being predisposed to release itself from this forceful disequilibrium, will always move upward to return to its natural level (between water and fire) in the cosmological scheme of things. This is what is meant by elements moving towards their home.[40]

Figure 1: How water contains the body of the earth without the destruction of the sphericity of its surface (MS. F. 62v)

Experiment: Leonardo submerges a cube of lead into a drop of water and notes that "the drop [does] not lose any of its roundness although it is increased in size equal to that of the cube enclosed in it."

What is made visible through the configuration of the four elements of earth, air, fire and water and their struggle to return to their 'natural place', are the effects of what Leonardo names the four powers (*potenze)* of Nature; the causes of all transformation in the world. These four factors or 'powers' are movement, weight, force and percussion. For Leonardo, movement is the parent of the other powers because "[it] is the cause of all life."[41] In animistic interpretations of 'force', it is considered to be a 'tendency' or 'striving', with one force having the capacity to 'overcome' another.[42] Rossi maintains that in Leonardo's physics, which is formulated with vague terminology, his concept of force is linked more to the "theme of universal animism than to rational mechanics."[43] Hence, one aspect of this is the notion that forces hasten (furiously) towards a state of rest. In an extended definition of force Leonardo writes:

> "Force (*forza*) is complete and whole throughout itself and in every part of it. Force is a non-material (*spirituale*) power, an invisible potency which is imparted

---

38 Gombrich, 45. Another way of describing this is to say that all things tend towards rest in their proper place. The world is in constant flux and therefore it is full of transformation. Thus, nothing in the world is totally stable.

39 Note that Leonardo was clear on the differences between steam, which is water transformed into vapour, and air proper.

40 Gombrich, 44.

41 MS. H. 141, 2v, r. Cited in MacCurdy, 72.

42 Jammer, *Force*, viii.

43 Rossi, 28.

> by accidental violence from without to all bodies out of their natural inclination.... by animated bodies to inanimate bodies, giving to these the semblance of life.... it speeds in fury to its undoing, retardation strengthens and speed weakens it. It lives by violence and dies through liberty.... great power gives it great desire for death. It drives away in its fury everything that stands in the way of its ruin.... it inhabits the bodies placed outside their natural course and usage..... nothing moves without it.... no sound or voice is heard without it."[44]

Leonardo's notion of force contrasts his understanding of weight, which is characterized as "eternal", "material", and that which continually seeks "stability and permanence."[45] And about percussion he states: "For all the elements when removed from their natural position desire to return to it, especially fire, water and earth; and the shorter the line along which this return is made, the straighter its course, and the straighter its course the greater the percussion upon whatever opposes it."[46] The interaction, movement and transformation of the elements through the agency of the four powers is summarized in a statement that echoes the thoughts of Anaxagoras. Leonardo articulates his understanding of the fluid connection between all things in the following manner: "Everything comes from everything, and everything is made out of everything, and everything returns into everything, because whatever exists in the elements is made out of these elements."[47] Ultimately Leonardo is interested in the qualities or powers that all things partake of.

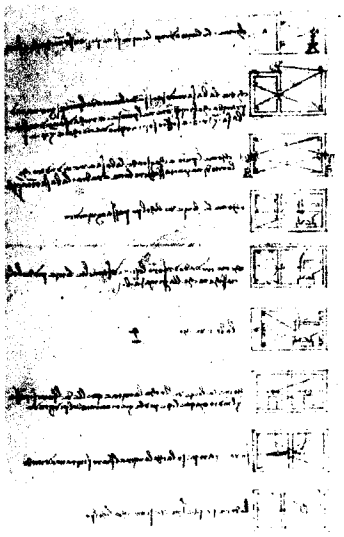


Figure 2: Similar patterns of transmission of the forces of light, sound, magnetism and smell, all of which percuss objects. (C.A. 126r-a)

It has been documented mostly through Leonardo's notations that he was an "unlettered man" and therefore was not the recipient of a classical education featuring Greek and Latin. His formal

---

44 C.A. 302-a, and a related passage in MS. A. 34r. Richter 1113B. Cited in Gombrich, 51. Kemp translates Leonardo's Italian as "[...] an immaterial power (*virtù spirituale*), an invisible potency which is created and infused by animated bodies in inanimate ones through acquired violence, giving to these bodies the appearance of life; this life is of marvellous efficiency compelling and transmuting all created things from their places. It rushes with fury to its destruction and continues changing in accordance with the causes. [...] It always desires to weaken and extinguish itself." Kemp, 138. In another passage Leonardo writes: "Every action done by nature is done in the shortest way." B.M. 85v. Cited in MacCurdy, 73.

45 Kemp, 138.

46 MS. C. 26v. Cited in MacCurdy, 667. Gombrich comments that movement happens and is observable because the elements experience violence that pushes them out of their proper place and causes them to return to a state of rest. E. H. Gombrich, *The Heritage of Apelles; Studies in the Art of the Renaissance* (Oxford: Phaidon Press Ltd., 1976) 52.

47 C.A. 385 v-c. Cited in MacCurdy, 89.

education was likely elementary, and by his own admission, Leonardo claims that he is discriminated against because "[he] cannot cite the authorities."[48] Leonardo writes all of his thoughts in the 'vulgar tongue', making him the first major intellect since antiquity to use the vernacular as the primary means of structuring and articulating his investigations and expositions in natural philosophy.[49] He had no command of Latin until his forties when he begins to study it on his own, and while it is plausible that he could have understood parts of conversations in Latin, it is unlikely that he would have been able to read any sources by himself. This puts him on the periphery of the humanist circles, although clearly, he is influenced by the ideas that are 'in the air' around him.

Most scholars conclude that Leonardo absorbed general philosophical knowledge more through conversation than from diligent study.[50] Leonardo's sources and the works that most influence his thought are difficult to trace with any definitive assurance, however, some are more certain than others. In addition to instances where he paraphrases Aristotle, he also instructs himself to "[s]ee Aristotle 'De Coelo' [sic] and 'De Mundo'."[51] Furthermore, in the Codex Atlanticus, there are lists of manuscripts that were either in his possession, authors and titles he had heard of and wished to remember, or simply sources that he intended to consult. Among the sources, he lists Pliny, Aesop, Ovid, Albertus Magnus, Petrarch, Vitruvius, Archimedes, Avicenna, Archimedes, and Euclid, as well as several libraries.[52] Through his service to the duke Ludovico Sforza he was also permitted to visit the library at Pavia and make use of its resources.

Many of his influences are traceable to his contacts thereby attributing in part to the ways Aristotlelian notions may manifest themselves in Leonardo's scientific principles. For instance, his friendship with Luca Pacioli undoubtedly exposes him to geometry in general, and in particular, to Euclid's *Elements*. In fact in one memo to himself he records, "Learn multiplication from the root from Maestro Luca."[53] His surviving work reflects an elementary knowledge of the *Elements* and

---

48 Giorgio De Santillana, "Man Without Letters," in *Leonardo da Vinci: Aspects of the Renaissance Genius*, ed. Morris Philipson (New York: George Braziller, Inc., 1966) 204.

49 Kemp, 105. De Santillana makes the disparaging remark that Leonardo writes like a peasant, which is probably also the way he spoke. De Santillana, 191. Leonardo's use of language in his notations is rarely poetic although he sometimes develops allegories. Mostly he is in conversation with himself, giving directives and stating plans and intentions for further work. He plainly states what he sees in the world.

50 De Santillana, 193. I am also inclined to believe that he read relatively little and overheard much.

51 C.A. 97v-a. De Santillana also asserts that there is an undeniable influence of Cusanus in Leonardo's work. De Santillana, 195.

52 MacCurdy, 1163-73. There were in existence Italian translations of all the classical works mentioned, and any of these may have been in Leonardo's possession. See MacCurdy, 1164.

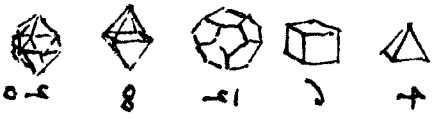
53 C.A. 120r-d. Cited in MacCurdy, 1163.

no knowledge of algebra. Even had he had an education in algebra, it is doubtful that it would have held his interest the way geometry did because algebra is abstract and not so readily perceived through experience. The chronological dating of his notebooks also reflects that the folios bearing the most intensive geometrical speculations occur after he meets Pacioli in Milan in 1490.

Through collaboration with Pacioli, he also draws the five regular Platonic bodies, for Pacioli's book, showing the polygons in their transparent and solid forms. Through the process of drawing the figures and perhaps also preparing the woodcuts for the book, he would have been exposed to the contents of Plato's *Timaeus* and the Platonic distinction between the realm of Forms and their compromised, imperfect instantiations in earthly matter. It is interesting to note that Leonardo compared the ordering (or nestling) of the elements in the Platonic model and took issue with some of Plato's designations of geometrical shape to element. In particular, he objected to the cube being used to represent the earth. He states:

> "They say that the earth is [...] cubical, that is to say a body with six bases, and they prove this by saying that there is not among regular bodies a body of less movement or more stable than the earth; for this reason they attribute the pyramid to fire and the cube to the earth. Now if one had to consider the stability of the pyramidal body and to compare it with that of the cube, this cube is without any comparison more capable of movement than the pyramid.[54]

The way he establishes a proof for this assertion is by demonstrating that the cube is more adapted to circumvolution than the pyramid.



4 tetracedon ——
6 evsacedron
12 duodecedron
8 ottocedron
20 icocedron

4 Tetrahedron
6 Hexahedron
12 Dodecahedron
8 Octahedron
20 Icosahedron

Figure 3: The five regular polygons of Plato. (MS. F. 27v)

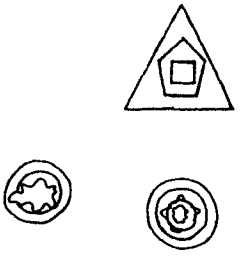


Figure 4: The Platonic configuration of the elements and the 'true' configuration. (Diagram based on MS. F. 27r)

[54] MS. F. 27v. Cited in MacCurdy, 617. The passage in Plato to which he is referring is Plato. *Timaeus and Critias*. trans. Desmond Lee. 1965 (London: Penguin Books Ltd., 1977) 73-79.

Being a friend of Francesco di Giorgio (who cited Aristotle abundantly) also expands his exposure to a broader knowledge base and has a formative influence on Leonardo's thought. His contact with Francesco di Giorgio is traceable to at least as early as 1480s when they were both called to offer consultation on the Milan Cathedral.[55] Also, what is referred to as Leonardo's Ashburnham Codex is in fact a copy of Francesco di Giorgio's *Trattato*, which Leonardo annotated, therefore it can be safely assumed that he was well acquainted with di Giorgio's thought.

On a few occasions he cites the inherited anatomical knowledge of Mondinus and Avicenna, which he likely learned through word of mouth.[56] Leonardo also works for a short time with the anatomist Marcantonio della Torre until della Torre's untimely death from the plague in 1511. He certainly would have added to Leonardo's understanding of Galen. However, in general, Leonardo revises and contradicts his own thoughts frequently, which makes it difficult to assess his final opinion.[57] The jumble of influences and patchy sources also make it challenging to establish in certain terms when Leonardo is making an original observation, or when he is framing in his own words, something that he heard. It seems that he formulates many of his ideas through dialogue with himself and others.

Leonardo's sketches, drawings, paintings, sculptural undertakings, mechanical investigations, and architectural intentions constitute a body of research that takes as an implicit point of departure, the interconnectedness of all the things of the cosmos. What we have inherited is a portion of the understanding that Leonardo constructed; the lasting traces of his fleeting and flowing observations and interpretations. His drawings are dialogical in that he constantly records directives or notes to himself, reminders of what else to investigate and instructions for how to organize future material. The pages of his notebooks are also internally dialogical as the articulation of his findings happens in words and in sketches. By drawing he is not simply illustrating what he passively observes. Rather he is reasoning out his thoughts and findings, trying to reconcile these discoveries with what he thinks he knows and making comparisons or

---

In MS. F 27r, Leonardo takes issue with Plato's configuration of the elements. See MacCurdy, 69.

55 Martin Kemp puts forth that Leonardo's contact with Francesco di Giorgio and his work in the mid to late 1480s pertaining to the Milan Cathedral were of vital significance in shaping his understanding of the relationship between the works of man in relation to nature. Kemp, 107.

56 See MacCurdy, 106-7. For Leonardo's medical influences and achievements see Leonardo da Vinci, *Leonardo on the Human Body,* trans. C. O'Malley and J. B. de C. M. Saunders, 1952 (New York: Dover Publications, 1983) 13-35. From this point forward, this work will be cited as OHB with the page number.

57 George Sarton, "Art and Science," in *Leonardo da Vinci: Aspects of the Renaissance Genius*, ed. Morris Philipson (New York: George Braziller, Inc., 1966) 160.

extrapolations from this new observation outwards to everything else.[58] Like Aristotle, Leonardo moves from the particular to the universal; he proceeds from what is close to that which is far. Through his work he images his thought process, and in so doing, maps out relations for himself to understand. His drawings are tracings of these observations and interpretations. His drawings pose questions.[59]

Often on any given page of his drawings there is what appears to modern eyes a cluttered jumble of unrelated topics. In some instances it is very clear (mostly from his accompanying annotations) that what may be perceived as unrelated material sketched on one page, is in fact different aspects and moments of a single analogical train of thought. In other cases, since he uses every piece of paper that he has,[60] he works on blank portions of sheets that he has drawn on even up to several years prior. Therefore the content of any given folio does not always contain contemporaneous investigations. It has been surmised also that Leonardo filled pages haphazardly and sometimes started at the end of a set of blank pages and worked backward.[61] In addition, more than half of his surviving material is on loose sheets.[62] He also has the habit, due to the fragmentary character of his writings, of rapidly jotting down an idea, thereby leaving a mass of

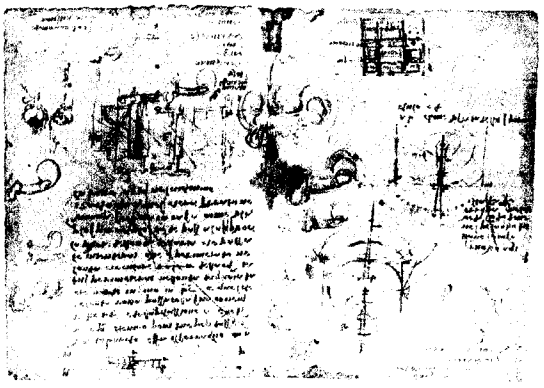


Figure 5: genito-urinary system: coition, waves, house plan. *c.* 1503 (W 19106v)

Figure 6: comparative anatomy: bird's wing, architecture. *c.* 1513 (W 19107v)

58 It is evident that Leonardo reasoned out many of his assertions, not only from the content of his notations to himself, but also in the fact that he could not possibly have observed and measured everything about which he speculates.

59 Gombrich, 43.

60 Marioni, 59-60.

61 Maria Vittoria Brugnoli, "Il Cavallo", *The Unknown Leonardo,* ed. Ladislao Reti (New York; Toronto: McGraw-Hill Book Company, 1974) 104.

62 Sherwin Nuland, *Leonardo da Vinci* (New York: A Lipper/Viking book, 2000) 102, 114-117.

provisional notes to be developed later.[63] Also, he revises his ideas, leaving contradictory statements in his manuscripts, without leaving a clear indication of which ideas were discarded.[64] All of this has made determining chronologies to the work very challenging. Yet, while it cannot be automatically assumed that sketches on the same page are contemporaneous and/or intentionally co-present, the material can be compared even if it is separated by many years, due to the operation of analogy which is at work in his thought throughout his life, and which allows him to unearth and express the interconnection of, and recurrent principles in, all things in the world.

With Leonardo's work we have to 'suffer' indeterminacy not only within the stream of his investigations but also in the implications of the scope of that which he probes. As guardians of his legacy we have to surrender to the absence of closure. He works from what he discovers, and each new finding connects to many others, so each discovery has wide repercussions. What is perhaps the most admirable about Leonardo (if not too the most enviable) is that he is fully immersed in and deeply intrigued by the stuff of the world. He searches the nature of nature and so builds up a body of understanding. Leonardo enjoys the world. He finds it endlessly fascinating, wonder-*full*.

---

63 Brugnoli, 82.
64 Reti and Dibner, 63.

I Man is a 'Little World'

The most prevalent analogy of the Renaissance, which infused the entirety of human thought and action, was the connection between the macrocosm and the microcosm[1]. Essentially, the collectively-held belief was that the order of things on earth has a correspondence to the larger order of the celestial bodies. However, unlike the perfect and predictable rhythm of the heavens, humans who are mortal and subject to terrestrial flux, fall short of this cosmic perfection.[2] While humans are imperfect, they nevertheless embody aspects of the higher order, albeit in a compromised manner. This relationship was articulated in the common understanding of man as a small world (*piccolo mondo)* or microcosm, meaning that the structure of man reflects the structure of the world in miniature.[3]

This ancient analogy inherited and elaborated by the Renaissance espoused the notion that between earthly matter and the divine there exits an ascending scale whereby all things find their proper place. All natural things are composed of the four elements, and were classified hierarchically in accordance with their motive properties. At the bottom of the ladder were minerals, which do not have the capacity to move of their own accord. Above minerals came plants, which grow and change, and therefore exhibit that they possess some kind of soul. Still higher were ranked animals, which have greater powers of movement and reproduction than plants. And at the top of the list was placed man, who possesses an intellective soul. Man therefore, is not only an admixture of the four elements, but contains within him the qualities of the things in nature that are ontologically below him.[4] This notion is elaborated by Francesco di Giorgio in his comments pertaining to the principles governing the first builders of cities. He writes:

---

1 David Summers writes: "The ancient idea that man is a microcosm, a little world, is considered one of the representative ideas of the Renaissance, symbolizing, like the image of the Vitruvian man, the centrality of human values for the age. The idea, by no means peculiar to the Renaissance, had an ancient history and had received especially exuberant definition in the late Middle Ages. As one might expect the *piccolo mondo* appears frequently in Renaissance art theoretical treatises." David Summers, *Michelangelo and the Language of Art* (Princeton, NJ: Princeton University Press, 1981) 291-292. Hereafter this source will be cited as Summers, *MLA* with page number. See also M. Tuzet for a discussion about how the correspondence between God and man "becomes a *participation*, a deep substantial unity, an organic relation, in which man is not subordinated; he is the bond, the core of the world." M. Tuzet, *Le Cosmos et L'Imagination* (Paris: Librairie Jose Corti, 1965) 284.

2 Barkan, 133.

3 Richard Turner, *Inventing Leonardo*, 1992 (Berkeley; Los Angeles: University of California Press, 1994) 179. This comment needs to be qualified, for by 'structure' what is meant is more than the physical composition of both, but rather similitude in essence.

4 Summers, *MLA*, 293.

> "It ought to be understood that man, called little world (*piccolo mondo*) contains in himself all the general perfections of the whole world, because he shares being (*essere*) with the elements and metals; in feeding and generating himself he is like the plants; he shares sensory knowledge with the brute animals and finally, through understanding (*intendere*) he is like the angels and immaterial substances, so that in him shines similitude with all creatures. Also, because more works (*operazioni*) proceed from him than from any other creature, he has more instruments than the other corporeal natures, and so the parts of his body are more symmetrical (*correspondenti*) than those of other animals. Whence with great reason the human artist (*artifice*) ought to take whatever work he does from the human body, as from his exemplar, taking the form of those things that may be in any way likened to it."[5]

From this shared cosmological picture articulated by di Giorgio, profound meaning was guaranteed through the assurance that both what we are and what we make (especially architecture) connect to something larger and more noble. His argument states that humans are privileged among all earthly creatures because we *make* and that this capacity is reflected in how we are *made* by the Creator. This implies that aspects of the divine are evident in our body, thus the human body is the ultimate model for all human invention, particularly for architecture.

In the architectural drawings of Francesco di Giorgio and Antonio Averlino (known also as il Filarete), it is most evident how the Renaissance humanists presupposed such a *literal* microcosm.[6] These architects used the micro-macro analogy to directly inform architecture by superimposing the human body onto plans and elevations of buildings, as well as onto the schematic diagrams of cities. Through this inscription, they imply an exact correspondence between the parts of the human body and those of the corporeal entity of civic space and order. In these drawings hierarchies in program and location are directly attributed to the hierarchies of bodily parts, which underscores the dependence of human-made works on the microcosmic modules of the human body.[7]

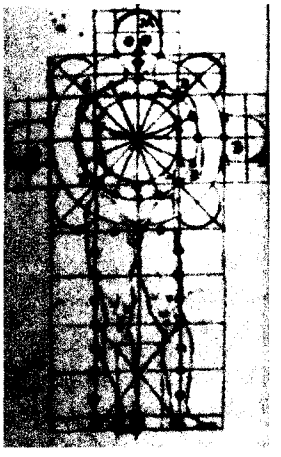


Figure 7: Proportioning in the design of a temple with a longitudinal plan. Francesco di Giorgio Martini.

---

5 Francesco di Giorgio Martini, *Trattati di Architettura Ingegneria e Arte Militare*, Tome II, ed. and transcribed by Corrado Maltese and L. Maltese (Degrassi. Milano: Il Polifilo, 1967) 361.

6 Barkan, 28. Barkan discusses the differences between a *figurative* and a *literal* microcosm. He puts forth that in the former, man is viewed "as a précis of all creation and seeks in that perception a spiritual or intellectual truth," whereas in the latter, an equivalence is posited between the human body and the cosmos, and this is relied upon as a key to understanding the nature of man and the world.

7 Kemp, 115.

Leonardo is not so concrete in his approach and 'application' of the microcosm-macrocosm analogy. His particular incorporation and understanding of this over-riding analogy manifests itself in his various written statements about the relationship between man and world. He expresses his ideas both about how humans and the earth are made of the same four elements, and how the visible phenomena in the world are analogous in essence and function to aspects, processes and phenomena extant in the human body. While very different in appearance and scale, the body and the world are nonetheless kindred in his view. He writes:

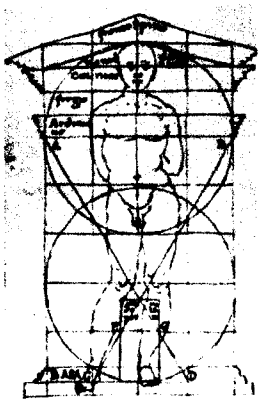


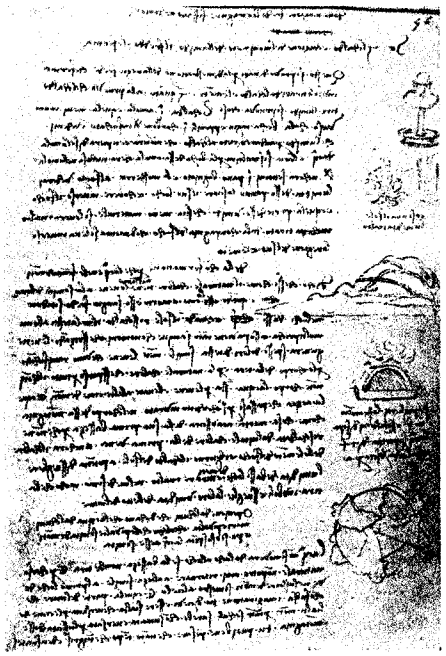
Figure 8: Proportioning scheme of the façade of a temple with longitudinal plan. Francesco di Giorgio Martini.

> "Man has been called by the ancients a lesser world, and indeed the term is rightly applied, seeing that if a man is compounded of earth, water, air and fire, this body of the earth is the same; and as man has within him bones as a stay and framework for the flesh, so the world has the rocks which are the supports of the earth; as man has within him a pool of blood wherein the lungs as he breathes expand and contract, so the body of the earth has its ocean, which also rises and falls every six hours with the breathing of the world; as from the said pool of blood proceed the veins which spread their branches through the human body, in just the same manner the ocean fills the body of the earth with an infinite number of veins of water. In this body of the earth there is lacking, however, the sinews, and these are absent because sinews are created for the purpose of movement, and as the world is perpetually stable within itself no movement ever takes place there, and in the absence of any movement the sinews are not necessary; but in all other things man and the world show a great resemblance."[8]

One aspect in this passage that is very interesting to note is that even though Leonardo observes some discrepancies in the workings of the human and earthly bodies, the absence of an exact correspondence did not contradict or deny the fundamental sense that he had of their underlying

---

[8] MacCurdy, 654. This passage is found on MS. A. 55v, and is datable to *c.* 1492. It was intended as the introduction to his (unrealized) "Treatise on Water," yet it could have served just as appropriately as the introduction to his planned book on anatomy. See Kemp, 119. "Lesser world" is translated as "a world in miniature" in Mark Kidel and Susan Rowe-Leete, "Mapping the Body," *Fragments for a History of the Human Body; Part Three*, eds. Michel Feher, Romana Naddaff and Nadia Tazi, 1989 (New York: Zone, 1990) 454. The portion of the passage pertaining to the elemental composition of man is translated by Martin Kemp as "[...] in that man is composed of water, earth, air and fire, his body is an *analogue* for the world." Kemp, 117 (italics mine). Martin Kemp also uses the term "nerves" instead of "sinews". Kemp, 118.



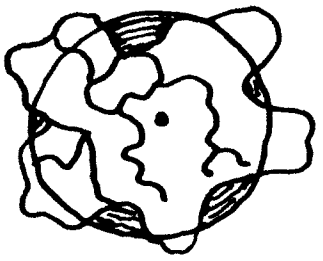


Figure 9: Cross-section of the Earth with the sphere of water. (Diagram based on Leic. 31r)
The annotation from this folio reads, "Here it is imagined that the earth is sectioned through the middle, showing the altitudes of the sea and earth; the veins arise from the beds of the seas and intersect the world and ascend to the mountains and travel back again to the rivers and return to the sea."

Figure 10: How the heat of the sun raises water vapour, and how the Earth grows through the seas. (MS. A. 56r)

affinity.[9] Leonardo's analogical framework, is broad, encompassing, and central enough to his thought that it can support imprecise correspondences between earth and man. This flexibility or 'tolerance' with respect to the micro-macro correspondence held for most of his life.

For Leonardo, the world is therefore visibly and invisibly reflected in man and vice versa because humans are made of the basic elements that are found in nature, *and* because in the world there are structures and processes that are broadly analogous to those of the human body. Therefore, whereas his contemporaries rely on the body to establish formal considerations that can be applied proportionally to the making of human artifacts, in a fairly straightforward manner, Leonardo's meditation on the microcosm-macrocosm analogy serves to articulate the dynamic processes animating the bodies of man and world. For instance, he observes how both the human body and the body of the earth experience growth and renewal. In an extended passage he records:

> "Nothing grows in a spot where there is neither sentient, fibrous nor rational life. The feathers grow upon birds and change every year; hair grows upon animals and changes every year, except a part such as the hair of the beard in lions and cats and creature like these. The grass grows in the fields, the leaves upon the

[9] See Kemp, 261. Since analogy is fundamentally oriented towards resemblances between particular aspects of things that are otherwise distinct, it privileges the aspects that things have in common over the differences that hold them apart. Despite the discrepancies that may interfere with understanding that beings, objects, substances, etc., have something in common, analogy retains its resilient capacity to name a meaningful relationship between the things.

> trees, and every year these are renewed in great part. So then we may say that the Earth has a spirit of growth, and that its flesh is the soil; its bonds are the successive strata of the rocks which form the mountains; its cartilage is the tufa stone; its blood the springs of its waters. The lake of blood that lies about the heart is the ocean. Its breathing, the ebb and flow of the blood in its pulses, is the ebb and flow of the sea in the Earth. And the vital heat of the world is fire, which is spread throughout the Earth; and the dwelling place of its creative spirit is in the fires, which in divers parts of the Earth are breathed out in baths and sulphur mines, and in the volcanoes, such as Mount Etna in Sicily, and in many other places."[10]

Here the pulse of the body is paralleled to the ebb and flow of the Earth's seas, and human blood is compared to the Earth's waters. The body's vital heat (which is what distinguishes a living body from a corpse) is associated with the fires burning in the depths of the Earth, and flesh is likened to soil. Leonardo makes these comparisons in order to grasp the processes of the world within human terms, and through this analogical structure, he perceives homologies between these bodies despite their vast differences in scale and form. It is noteworthy that in both of these lengthy passages, the human body is Leonardo's referent for everything that is outside of it. Thus, in articulating his version of the microcosm-macrocosm analogy, Leonardo starts from the familiar ground of the body and from it, pivots into the unknown. Comparisons to the body are therefore central to his understanding of the world.[11] Through his embodied understanding of his own flesh, he describes the *flesh of the world*.[12]

---

[10] Leic. 34r, cited in Kemp, 261. Also in MacCurdy, 86. In this same Codex he writes: "If a man has a lake of blood in him whereby the lungs expand and contract in breathing, the earth's body has its oceanic sea which likewise expands and contracts every six hours as the earth breathes." Leonardo goes on to associate underground springs with veins. Citation from James Ackerman, "Leonardo da Vinci: Art in Science," *Daedalus; Journal of the American Academy of Arts and Sciences*, Winter (1998), 213. The Leicester Codex has been dated to 1507-10, meaning that Leonardo's speculations about the relationship between the earth and body extended to within the last decade of his life. Martin Kemp states that the microcosm-macrocosm analogy, manifesting itself most clearly through Leonardo's speculations on 'the body of the earth,' took on particular intensity from 1506-9. Kemp, 261.

[11] In other words, "Leonardo's anatomical investigations [play] a central role in determining his attitude towards the formative principles of the universe." Kemp, 286.

[12] I borrow this term from the phenomenologist Maurice Merleau-Ponty. On the reciprocity between the flesh of our body and that of the world, philosopher and ecologist David Abram writes: "To touch the coarse skin of a tree is thus, at the same time, to experience one's own tactility, to feel oneself touched *by* the tree. And to see the world is also, at the same time, to experience oneself as visible, to feel oneself *seen*. Clearly, a wholly immaterial mind could neither see things nor touch things – indeed, could not experience anything at all. *We* can experience things – can touch, hear, and taste things – only because, as bodies, we are ourselves included in the sensible field, and have our own textures, sounds, and tastes. [...] We might as well say that we are organs of this world, flesh of its flesh, and that the world is perceiving itself *through* us." David Abram, *The Spell of the Sensuous; perception and language in a more-than-human world*, 1996 (New York, NY: Vintage Books, 1997) 68.

Figure 11: Embryology: fetus in utero.
c. 1510-12 (W 19102r)

Figure 12: Fetus in 'cosmic' utero. Aliki Economides.

Using Leonardo's drawing(s) of the fetus in utero as a reference, this (re)drawing interprets the microcosm-macrocosm analogy. Here the layers of the uterine wall are treated as a celestial globe recording the days of the year, the phases of the moon, and the signs of the zodiac. The sun – the giver of vital heat – is simultaneously an orb of fire in the galaxy and the ovum penetrated by sperm at the instant of conception. In contrast to the immutable celestial rhythms, humans dwell in the flux of the terrestrial realm. During the traumatic passage of birth, we wriggle, blood-soaked and screaming into our mortal, earth-bound predicament.

In addition to the notion that the four elements constitute all bodies from the human to the earthly, there is also evidence of Leonardo's adoption of the ancient Galenic theory of the four humours which were believed to move through the body in a motion of ebb and flow. An inherited awareness of humoural medicine was then a commonplace and this is especially clear when he describes water as "the vital humour of the arid earth."[13] Elsewhere he records, "[t]he water which arises in the mountains is the blood which maintains the mountains in life,"[14] and "The ramification of the veins of water in the earth are all joined together as are those of the blood in animals, and they are all in continual revolution for the vivification of it, always consuming the places in which they move, both within and without the earth."[15] The body is nourished by the blood carried to its parts via veins, as the veins of water carry nourishment throughout the earth. These comments reveal that for Leonardo, the basis for life of any body is the circulation of fluids.[16]

In the Renaissance, the notion that things return to their origin is based on a conception of matter moving in a loosely circular motion, but this is not 'circulation' in the modern sense of pulmonary circulation.[17] For Leonardo, references to 'circulation' imply an irregular ebb and flow movement of liquids and vapours, governed by the interpenetration of earth, air, water and fire, and the nature of all elements to return to their state of rest. Although this rather vague formulation of circulation would be deemed inaccurate and untenable by modern science, nonetheless it is inherently fertile and valuable.[18] In Leonardo's understanding of 'circulation' reciprocity and continuity exit between the body and the world that sustains it. By contrast, through the mechanistic values that emerged in the 17th century, the inclusive and encompassing potential implicit in the pre-modern notion of circulation, to a great extent became limited to the consideration of self-contained entities. That is, that the continuity of the bodily system in the

---

13 Arundel 236v.

14 MS. H. 29r, cited in Kemp, 117. The passage continues: "If one of its veins be open either internally or at the side, nature, which assists its organisms, abounding in increased desire to overcome the scarcity of moisture thus poured out its prodigal there in diligent aid, as also happens with the place at which a man has received a blow. For one sees then how as help comes the blood increases under the skin in the form of a swelling in order to open the infected part. Similarly life being severed at the topmost extremity (of the mountain) nature sends her fluid from its lowest foundations up to the greatest height of the severed passage, and as this is poured out there it does not leave it bereft of vital fluid down to the end of its life." MS. H. 29r, cited in MacCurdy, 71.

15 Leic. 28r, cited in Kemp, 261.

16 See Kemp, 261.

17 The modern notion of the double-circulation of the heart was formally stated by William Harvey in 1628, and by the end of the 17th century, it was generally accepted by medical science. Ivan Illich, *H_2O and the Waters of Forgetfulness* (London: Marion Boyars Publishers, 1986) 42.

18 Ivan Illich suggests that the concept of the "circulation of matter" is one of the very few major scientific generalizations on which we continue to build. Illich, 43.

mechanistic understanding of the body - largely as a functional system of pumps, valves, conduits and filters - is continuous only within its own perimeter.[19]

Figure 13: Mountain: geological strata. Aliki Economides

For Leonardo, the correspondence between macrocosm and microcosm serves as the large 'umbrella' analogy under which all of his other analogies are nested, and it is that which guides the numerous tangents of his research until near the end of his life when he calls it into serious question. [20] In the last decade of his life he begins to doubt whether mountain springs are in fact caused by a circulatory process such as that stimulating the movement of blood in animals and the sap in plants. The unsettling discrepancy he observes is that while the veins in the human body dry out with age, thereby becoming straighter and narrower, the 'veins' of the earth become enlarged over time through the erosion caused by the continual passage of water.[21] This leads him to abandon the micro-macro analogy in the terms in which he had relied on it up until then and instead to explore the correspondences between man and earth in terms how they partake of universal law. Thus he continues his research into the analogical connections between man and the world by examining how all of the various bodies found in nature are perfectly created to fulfill their various functions.[22] Therefore, he switches his emphasis to the fundamental causes that bear on all things, seeking out the analogous functions that necessitate analogous effects.[23] In the final analysis, although his original formulation of the relationship between the bodies of man and earth has to be abandoned, his mature realization does not in any way cancel out his search for an understanding that is fundamentally rooted in

---

[19] Illich, 42. To this it may be added that a mechanistic understanding of the world's processes, limits our appreciation of the flow of connection from the self, to the other, to the world, and back to the self. Flow understood in mechanistic terms is only continuous within a given entity's isolated perimeter. It therefore hinders an understanding of the complex interweaving and interdependence of all things in the world by implying their autonomy as closed systems within its conceptual schema. The mechanistic framework we have inherited since the Scientific Revolution is limiting because it compromises the potential of analogy to unearth meaningful connections and imposes boundaries between things that have an implicit, if not profound relationship to each other.

[20] Gombrich, 53.

[21] He records these observations on MS. F 1r. See Kemp, 316-17. This notion was formulated most explicitly after he dissected an old man who had died a peaceful death, and noted the state of his straight and dehydrated veins. However, the observation is also clearly informed by the Aristotelian notion that dryness is death and moistness indicates life.

[22] His conviction about the perfection of Nature's creations is articulated in a note from the Windsor folios where he says, "in [Nature's] inventions nothing is lacking and nothing is superfluous." W. 19115r.

[23] See Kemp, 317.

analogical correspondences between all things. The implications of this 'parent' analogy persist throughout all of his work.

Figure 14: Identity. Aliki Economides

In spite of its limitations, there is in Leonardo's articulations of the micro-macro analogy, a periscoping set of relations, where each organ or part within the microcosm carries connections to vastly different scales of things in the macrocosm. The relations are not univocal or fixed but rather open up the imaginative field for speculation into how we are in the world and how the world is in us. In this regard his extended analogies enable the cultivation of a formal and dynamic understanding of the inherent connections between all things, thereby making the world more coherent, accessible and indeed, hospitable.[24]

[24] The central assumption governing the macro-micro analogy is that the universe as cosmos has an intelligible order, and this is reflected in man. We no longer understand the universe as a cosmos, therefore it is challenging for us to understand the implications of man as a 'little world'. For more on this see Summers, *MLA*, 293. The destruction or dismantling of the classical notion of the universe as (finite) cosmos was a characteristic of the Scientific Revolution of the 17th century. See Alexandre Koyré, *From the Closed World to the Infinite Universe*, 1957 (Baltimore: John Hopkins Press, 1968). Unfortunately, we no longer have a shared cosmological picture from which to draw universal significations and guarantees of meaning and this particularly impacts on architecture's capacity to provide existential orientation; to facilitate *dwelling* in the Heideggerian sense.

II Drawing from Nature and the Nature of Drawing

As has already been discussed, Leonardo did not receive a classical education, as did many of his contemporaries who were well versed in Latin and Greek, which enabled them to consult the ancient texts directly. In contrast to the Humanists who scorn manual investigations through experimentation, Leonardo cites "experience" as far more valuable than book learning, because for him it is only through exposure to the world as it appears to our senses - especially through vision- that access to true knowledge is possible.[1] He expounds his conviction that "Nature, [is] the mother of all good authors"[2] and states, "[t]he grandest of all books, I mean the Universe, stands open before our eyes."[3] It is through direct engagement with the world around him that he investigates the causes of things and speculates on their interrelationships. Nature, offering him a bounty of phenomena to study, draw and emulate, is his ideal teacher. Leonardo's life-long area of research is one that *searches* the works of nature.

He also states that Nature produces things masterfully and does not create anything that is unnecessary, and that while human craft should seek to model itself as conscientiously on an understanding of Nature's universal laws, human works will never surpass her creations. He writes, "[a]lthough human ingenuity makes various inventions, corresponding by means of various machines to the same end, it will never discover any inventions more beautiful, more appropriate or more direct than nature, because in her inventions nothing is lacking and nothing is superfluous."[4] This observation reveals a strikingly Aristotelian tone. Compare Aristotle's praise of Nature in his *Parts of Animals* wherein he contends, "Every realm of nature is wonderful. Absence of haphazard and conduciveness of everything to an end are to be found in nature's works in the highest degree,

Figure 15: Landscape. 1473. (Galleria degli Uffizi, Firenze)
This ink drawing is the earliest dated work of Leonardo's that has survived.

---

1 In upholding the value of 'experience', Leonardo's thesis is that thought does not (and in fact should not) call for a withdrawal into the mind. On the contrary, that which is to be known is out there in Nature. Unlike the philosophers who deem vision to be a distraction to thought, Leonardo urges us to see that which is around us; to engage Nature through our senses so that our judgement will not fall into error from having begun and ended in the mind. See Giovanni Gentile, "The Thought of Leonardo", *Leonardo da Vinci* (New York: Reynal & Company, 1956) 168-9.

2 Nuland, 7.

3 Nuland, 63. Leonardo also states, "The eye, which is called the window of the soul, is the principal way through which the mind can most copiously and magnificently consider the infinite works of nature." TP 30. See Keele, 43-77.

and the end for which those works are put together and produced is a form of the beautiful."[5] What Leonardo shares with Aristotle is a firm grounding in the phenomena of the world. He is not a Platonist in the sense that he does not assume meaning to be elsewhere. For him as for Aristotle, the concrete conditions constitute reality; they are *it*. Nature speaks through the phenomena, and her effects accord with an end defined by an earth-bound cause. Therefore, what is never called into question or even conceived, is that there could exist another possible or better world than the one we inhabit. Further, while Leonardo is highly inventive, his work is never the rival of nature, but rather her humble pupil. The mimetic imagination keeps human activity in check.

Figure 16: Trees (W 12431r)

For Leonardo the best way to explore the phenomena is to cultivate 'science' (i.e., philosophy) by synthesizing intellectual and creative processes through corporeal engagement. Painting, for him is the supreme art, the supreme end of knowledge, precisely because it is an "imitator of Nature – a child of Nature and an instrument of philosophy."[6] He devotes much attention to comparisons between painting and the other arts, namely sculpture and poetry, both of which in his estimation lack the more encompassing descriptive potential that painting possesses. Painting, according to Leonardo, is more powerful and revealing than other arts because apprehension of it is instantaneous and it contains everything within itself, whereas sculpture depends on conditions external to it such as light and shadow.[7] Similarly, poetry is deficient due to the fact that its images, narratives and meaning are not revealed all at once as in painting. Furthermore, poetry is apprehended through hearing, which is deemed to be a less noble sense than vision. He states, "[p]oetry places things before the imagination in words, while painting really places the objects before the eye, and the eye accepts the likenesses as though they were real. Poetry offers itself

---

4 W. 19115r. Cited in Kemp, 286.

5 Aristotle. *Parts of Animals*. 1.5, 645a17-25.

6 Ash. II 20r; MS. A. 100r. Cited in Keele, 44.

7 "If sculpture is lighted from below, it will seem monstrous and strange, but this does not happen with painting which carries all its elements within itself." TP 46. In a related passage, he cites his experience as a sculptor to assert his authority to judge these matters. He writes, "Applying myself no less to sculpture than to painting, and practicing both in the same degree, it seems to me that with little change of bias I can judge which demands more of the mind, and which presents greater difficulty and is more perfect than the other." TP,32.

without this likeness and therefore does not make an impression by way of visual impact as does painting."[8] Through these arguments Leonardo defends that painting is more powerful than words.[9]

Language is a receptacle of shared meaning, and expressing oneself is an act of constructing a path from the self to the other; of forging a link. Although Leonardo makes copious notations beside his sketches, his preferred language is that of drawing.[10] In several instances he asserts the superiority of graphic means over wordy descriptions. For example, in the context of how to best communicate his anatomical findings he states:

> "And you who think to reveal the figure of man in words, with his limbs arranged in all their different attitudes, banish the idea from you, for the more minute your description the more you will confuse the mind of the reader and the more you will lead him away from the knowledge of the thing described. It is necessary therefore for you to represent and describe."[11]

Through this mode of research that emphasizes the graphic, he is enabled to truly see what is there and to communicate his findings eloquently. In his words:

> "That science is most useful the results of which are most communicable, and, conversely, that is less useful which is less communicable. Painting makes its end result communicable to all the generations of the world, because it depends on the visual faculty [...] Thus painting does not have need of interpreters for different languages as does literature and at once satisfies mankind, no differently than do those things produced by nature."[12]

Drawing (or painting) is therefore a means of understanding, and also, of sharing. Only when Leonardo draws does he internalize deeply that which he sees, and this mode of engagement with

---

8 TP 21. In a different passage he states: "the ear is second to [the eye], becoming noble through hearing about things that the eye has beheld. If you historians, poets, or mathematicians had not seen these things with the eye, you would hardly be able to report them in writing. And if you, poet, represent a narrative with a painting of the pen, the painter with a brush will more easily make it satisfying and less tedious to comprehend." TP 30.

9 "[....] Painting presents the works of nature to the senses with more truth and certainty than do words or letters. But letters present words with greater truth than does painting." TP 17.

10 I will use 'painting' and 'drawing' interchangeably since Leonardo considered drawing to be 'fast painting.'

11 MacCurdy, 100-1. In a different passage Leonardo comments extensively on the capacity of drawing to describe things better than words: "With what words O writer can you with a like perfection describe the whole arrangement of that of which the design is here? For lack of due knowledge you describe it so confusedly as to convey but little perception of the true shapes of things [...] I counsel you not to cumber yourself with words unless you are speaking to the blind. [...] How in words can you describe this heart without filling a whole book? Yet the more detail you write concerning it the more you will confuse the mind of the hearer...." W. Anatomia I, 1r. Cited in MacCurdy, 166-7.

12 TP 17. The weighty assertion that Leonardo makes here is that painting is able to *speak* to us in the same way and with the same clarity that Nature's products do.

the phenomena of the world is both the catalyst and the fuel of his wonderment. For Leonardo who privileges experience over book learning, sight is the most direct route to contemplation.[13]

What emerges as crucial in Leonardo's approach is that the imagination of the artist - or for that matter, of any maker including the architect - is *mimetic*.[14] Martin Kemp has commented that, "[a]rtistic creation [...] takes its place in the natural order of microcosmic things; the universal creative force of nature generates all species of things, and man produces his works in a broadly analogous manner."[15] Human endeavour is ennobled (if not assured meaning) by modeling itself on an understanding of Nature's laws. Creation in nature is mimetically re-created in human terms through invention. In this context, invention (*invenzione*) which comes from the Latin verb *invenire* meaning 'to find', describes the capacity of humans to build from the things that are already present in the world, waiting to be noticed or *found* and reconfigured. Invention, in its truest sense is therefore not the creation of

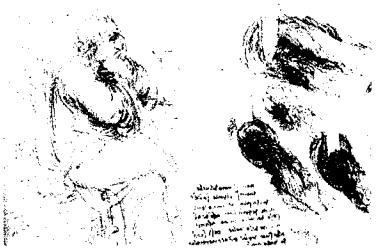


Figure 17: Profile of contemplative man and studies of water moving around obstacles, *c.* 1513 (W12579r)

Figure 18: Storm breaking over a town in the Alpine valley. (W 12409)

---

[13] The notion that philosophy began in wonder and wonder began in vision, was clearly articulated by the Greeks. In *Theatetus*, Socrates says, "I mean, this feeling – a sense of wonder – is perfectly proper to a philosopher: philosophy has no other foundation, in fact." Plato, *Theatetus*, trans. Robin Waterfield (London: Penguin Books, 1987) 155d, 37. In the *Timeaus*, it is explained how wonder began in vision. Plato, *Timaeus*, 47a, 65. The ability to observe phenomena coupled with an intention to better understand the world and humanity's place in it is an act of selection that relies upon an interested (i.e., *wonder-struck*) gaze, and the intellectual operation of interpretation to make sense of what has been seen. Vision has always been our primary mode of perception, and from its Pre-Socratic roots, Western philosophic thought has been tied to the authority of sight. The intimate relationship between vision and discourse is made explicit in the Greek word *theoria* [*θεωρία*] which not only means 'contemplation, reflection' – a process or activity which cannot occur outside of language - but it also means 'a looking at (something), viewing, beholding.' On this subject Marco Frascari has written: "The very notion of *theoria* is connected to the primacy of seeing. According to one etymological hypothesis, the word theory derives from the fusion of *thea* (seeing) and *hora* (care). Theory is then measured on careful seeing [...]." See Marco Frascari, "A Secret Semiotic Skiagraphy: the Corporeal Theatre of Meanings in Vincenzo Scamozzi's *Idea* of Architecture," *VIA II; Shadow; Journal of the Graduate School of Fine Arts University of Pennsylvania* (New York: Rizzoli International Publications Inc., 1990) 35.

[14] Leonardo asserts, "This benign nature so provides that over all the world you find something to imitate." MacCurdy, 897. Richard Kearney has noted that it is not until after the Renaissance that the mimetic imagination transformed into a productive imagination. See Richard Kearney, *The Wake of Imagination; Toward a Postmodern Culture*, 1988 (London: Routledge, 1994). Productive imagination sees itself as autonomous from the world, whereas Leonardo and his contemporaries do not.

[15] Martin Kemp, "From *Mimesis* to *Fantasia*: the Quatrocento Vocabulary of Creation, Inspiration and Genius in the Visual Arts," *Viator* 8 (1977): 382. Note that in subsequent citations this article will be listed as Kemp, "*Mimesis to Fantasia*" with the page number, whereas references to his book will continue simply as Kemp with the page number.

something out of nothing, i.e., *ex nihilo*. In the Renaissance, therefore, the human capacity for invention is readily harmonized with *mimesis* for where nature finishes man begins.[16] Thus, "[t]he human race in its marvellous and varied works seems to reveal itself as a second nature in this world."[17] Human creations are a 'second nature' in that they follow through a mimetic faculty the very life flow, the *physis,* of the natural world and transform this very same *first order* or original impulse to life into their human creations. However, in this imitation, the original impulses of Nature find themselves *in their wholeness* as the source of the human artifice. That is, the inventiveness that is proper to man does not come out of some internal human 'ego', but rather out of Nature's own inventive, creative and fertile basis. And yet there is also a distance in this *second nature* creativity. It is a distance that would seem to imply a particular self-consciousness in the act of making, but not a self-consciousness about the artifice in a modern sense. This distance, in the Renaissance was enacted as man's capacity to reconnect to nature, and was therefore an active participation *within* the existing cosmological order, not outside of it.

To fulfill the mandates of painting as Leonardo defines them, the painter must be 'universal.'[18] In this way the artist's mind is transformed into the mind of Nature. Therefore, through the human capacity for invention, the inventor/maker approaches the divine mind. Leonardo puts forth that "[the] natural desire of good men is knowledge."[19] For him, painting leads to true knowledge of the most important things. Painting is noble because it "...embraces and contains within itself all the things which nature produces or which result from the fortuitous actions of men, and in short whatever can be comprehended by the eyes."[20] These comments not only reflect the workings of the mimetic imagination, but also reveal Leonardo's interest in elevating painting from a 'mere' mechanical art to a source of true knowledge. In his time, the mechanical arts were excluded from the epistemological branches of classical education.[21] The gaze of the mediaeval person did not stop at the work of art or architecture, but looked through it at the reality beyond and thus the visual arts and architecture were regarded as mere craft. Leonardo's aim is to raise painting to the intellectual status of *scientia* and discover an order that stands in direct alignment with the

---

16 Kemp, 348.
17 Arundel MS. 151v.
18 See TP 94 –97.
19 C.A. 119 v.a. Cited in MacCurdy, 88.
20 MacCurdy, 880.
21 Rossi notes that Leonardo's polemic is not concerned with overcoming the opposition extant between the liberal and mechanical arts, but justifying the elevation of painting to a liberal art. Rossi, 29.

intelligible sphere of the cosmos. Thus it is also on these grounds that Leonardo devoted much effort to arguing for the supremacy of painting. He writes:

> "If you say that sciences which are not mechanical are of the mind, I say that painting is of the mind, for, as music and geometry treat of the proportions of continuous quantities, while arithmetic treats of the discontinuous, painting treats of all continuous quantities as well as the proportions of shadow and light, and the variations of distance in perspective."[22]

Through his attitude toward painting, Leonardo reveals his thoughts pertaining to the implicit and mutually informing relationship between thinking and making, which are never separate for him. However, Nature does not reveal herself entirely. In every visible fibre of the world's flesh that Leonardo examines through drawing, he also theorizes about that which is not visible.[23] In order to do this he must excavate beneath the surface of things, and he does so through drawing.

The nature of Leonardo's drawings is such that they gather in visible evidence onto the surface of a page, the secrets of nature. The drawings expose both that which is apparent to the gaze as well as what is not so easily perceived. His drawings are 'demonstrations of the world' and to call them thus means that they reveal and open up hidden realms. The drawings are not facile or neutral didactic instruments, for they disclose an order. Through drawing Leonardo meditates on what is, he gathers what he perceives, and he builds up what he finds. In other words, he re-collects Being. His drawings therefore, are not merely the realistically recorded observations of a keen eye, but a visualization of Nature's reason that is both visible and invisible.[24]

---

[22] TP 16. Leonardo devotes much effort to defending the intellectual potential and cultural dignity of painting, therefore it seems pertinent to include more of his arguments here. In TP 19, he states, "That knowledge, they say, is mechanical which is born of experience, and that is scientific which is born and ends in the mind, and that is semi-mechanical which is born of science and ends in manual activity. But to me it seems that those sciences are vain and full of errors which are not born of experience, mother of all certainty, and which do not end in recorded experience, that is, where the origin, or middle, or end is not made known to any of the five senses." In TP 25, he continues, "Since writers have not had any knowledge of the science of painting, they have been unable to describe its degrees and parts, and since painting itself does not display its achievements in words, through ignorance it has been left behind the sciences already mentioned, but it is not on that account lacking in divinity. Truly, it is with reason that they have not ennobled it, because it ennobles itself without the help of others' tongues, just as the wonders of nature do." It is also relevant to note his argument for the 'divinity' of painting: "If you disparage painting, which alone can portray faithfully all the visible works of nature, you certainly disparage a discovery which considers all manner of forms with subtle and philosophic attention: the sea, places on land, plants, animals, grass, flowers, all of which are surrounded by shadow and light. Truly this is a science and the legitimate daughter of nature, since painting is born of nature. To speak more accurately, we would say the grandchild of nature, for all visible things are born of nature, and painting is born of these. Therefore, we rightly call painting the grandchild of nature and related to God." TP 6.

[23] Leonardo states: "Nature is full of infinite causes which were never set forth in experience." MS. I. 18r. Cited in MacCurdy, 72.

[24] Summers comments that in Leonardo's work we do "not simply [see] an image of what putatively strikes the eye," but observations filtered through the artist's judgement. Summers, 6.

His drawings, especially those of the human body, are *demonstrations* of interiority's mysterious depths, and as such are inventions not illustrations. Of his intended treatise on the body he writes to his future readers that they will see before them a representation as telling as real life. He states:

> "This my configuration of the human body will be demonstrated to you just as if you had the natural man before you. The reason is that if you want to know thoroughly the anatomical parts of man you must either turn him or your eye in order to examine him from different aspects [...] Therefore through my plan you will come to know every part and every whole through the demonstration [...] just as though you had the very same part in your hand and went on turning it round bit by bit until you had obtained full knowledge of what you want to know."[25]

By developing techniques of representation that best suit his ambition to allow him to reveal what he discovers in his anatomical research, Leonardo makes tremendous innovations in modes of graphic representation. It is his stated intention to show the body from several aspects to reveal its three-dimensionality. Within the space of the page, therefore, the body moves.[26] One key example of this is seen in how he places the body part in space by casting shadows, which is very clear in his studies of the human skull. Another is his technique of the 'exploded view' to describe

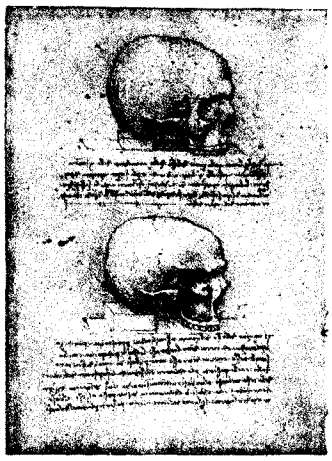


Figure 19: The skull: lateral views, *c.* 1489 (W 19057v)

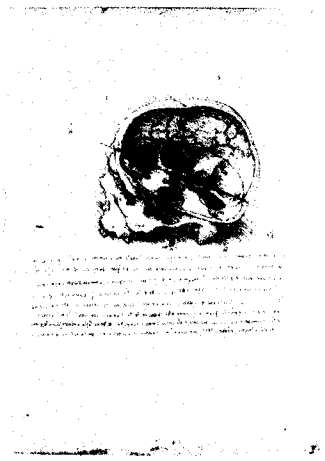


Figure 20: The skull: interior view, *c.* 1489 (W 19058r)

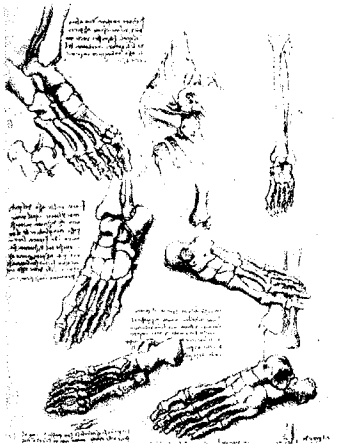


Figure 21: The lower extremity: bones of the foot, *c.* 1510 (W 19011r)

---

25 W 19061 r. Cited in Keele, 196-7. Elsewhere he also states: "The true knowledge of the shape of any body will be arrived at by seeing it from different aspects. Consequently in order to convey a notion of the true shape of any limb of man who ranks among the animals as first of the beasts I will observe the aforesaid rule, making four demonstrations for the four sides of each limb, and for the bones I will make five, cutting them in half and showing the hollow of each of them, one being full of marrow the other spongy or empty or solid." MacCurdy, 94.

26 Fundamentally what Leonardo freezes on the two-dimensional surfaces of his drawings, is movement. While he necessarily cuts and examines *dead* bodies, it is the *living* body that he is interested in. What he tries to find in the decaying tissue he is probing, are the effects of what had animated the body. This is evident in his mechanical studies of the body in motion, his efforts to map the confluence of the senses in the skull, and his dissections of the vital organs.

simultaneously an individual part and how it fits into the whole, which is obvious in his drawings of the foot and shoulder. Of this innovation he instructs himself to "[s]how the bones separated and somewhat out of position so that it may be possible to distinguish better the shape of each bone by itself. And afterwards join them together in such a way that they do not diverge from the first demonstration except in the part which is concealed by their contact."[27] His use of thin lines connecting the removed part to the spot from which it was pulled, indicates how the viewer's imagination should recompose the whole, and in this way involves the viewer in a dynamic process of the simultaneous coming together and holding apart of the body.

Another striking innovation in representation is his development of the technique to render the elevation of a body transparent, which allows him to reveal the inside workings of the body while showing them in their context. The drawing allows us to overcome our perceptual limitations by granting us a view through a surface that we know to be factually opaque. His drawing of a female figure is most exemplary of this, for in this drawing he is demonstrating the respiratory, circulatory, and urino-genital systems within an outline of the body which allows the viewer to readily understand the spatial setting of the parts. To describe this in architectural terms, it could be said that the programmatic pieces are 'fleshed out' within the context of their site. In his own words:

Figure 22: Female torso with internal organs, or 'Transparent Woman', c. 1510 (W 12281r)

> "You will draw accurate outlines [around the dissected area] so that the shape of the limb which you describe will not remain a monstrous thing from having its parts taken away. Additionally there follows a greater knowledge of the whole, because after the part is removed you will see the true shape overall."[28]

The impressive skill in depicting objects realistically which he achieves through drawing, has a further extraordinary dimension to it and that is that his modes of drawing, especially in the realm of his anatomical dissections, were unprecedented innovations.[29] Essentially he developed the mode of drawing that would best facilitate his communication with the viewer. Hence, conventions that are commonplace now especially in architectural representation, such as sections, sectional

---

27 W 19018r. Cited in Kemp, 289.

28 W 19027r; W 19035r. Cited in Kemp, 349.

29 Rossi observes, "Leonardo truly made a decisive contribution to the invention of a precise method for the representation of reality." Rossi, 28.

elevations, depictions of an edifice from multiple vantage points, and the 'exploded view', were not already common or even extant conventions.[30] Not only the content but also his mode of drawing is inventive.

The culmination of his inventiveness in representation is perhaps instantiated in his theoretical vivisection of a copulating couple.[31] Historians of medicine have commented that the drawing is poor in terms of its accuracy in describing the male and female body, however its true value, I argue, is not in its claims to anatomical accuracy. What is fascinating about this drawing in addition to the fact that it attempts to reconcile the conflicting traditional notions of Galen and Avicenna pertaining to the generative act, is that Leonardo is capturing the moment when a theoretical couple is conceiving its offspring. This drawing is concerned with the living, moving, procreating body at the moment when it is actualizing its potential to create new life; to add, like Nature, the only 'simple' that it is capable of making. Thus another reason why Leonardo devotes so much attention to the body is because while it is divinely created, it is a divine creation that humans can (re)produce as well. He writes:

Figure 23: Coition, *c.* 1510
(W 19097v - detail)
Below the figure is written: "Here two creatures are cut through the middle and the remains are described."

> "Nature is concerned only with the production [*produtione*] of elementary things [*semplici*] but man from these elementary things [*semplici*] produces an infinite number of compounds, though he has no power to create [*creare*] any elementary thing except another like himself, that is his children."[32]

The artist begets the work, as the person begets the offspring. Interestingly, the vocabulary Leonardo uses in relation to the production of art involves verbs that carry biological associations.

---

30 This statement must be qualified because while it is true that within the history of art Leonardo's drawings have been described as the earliest elevational and perspectival cross sections, it was Filarete who is credited with inventing the perspective cross section. See George Hersey, *Pythagorean Palaces; Magic and Architecture in the Italian Renaissance* (Ithaca; London: Cornell University Press, 1976) 145-6. Leonardo's innovation lies in the degree to which he developed the techniques and in his main application of these conventions to the representation of the human body.

31 Kenneth Clark estimated that the coitus drawing was done *c.* 1493, which would make it one of the very few anatomical drawings from this period of Leonardo's life. It has also been suggested that the drawing dates from *c.* 1500. OHB 460. Martin Kemp notes that "his early anatomies generally show what ought to be there instead of what is." The majority of Leonardo's anatomies from his Milanese period (i.e., 1483-99) were designed more in accordance with his understanding of underlying causes than by what he actually encountered through empirical investigation. His inventiveness is manifested here in his tendency to "devis[e] inner forms according to their supposed functions in the context of microcosmic law." Kemp, 137.

32 Windsor 19045r. ca. 1510.

Martin Kemp puts forth that before Leonardo, the verb 'to create' was barely used in any artistic context. The standard verb employed to discuss the production of the work of art was *fare* (make), and this was applied equally to art as to any production, even the most mundane.[33] It can be inferred from this that Leonardo sees the creation of human works as analogous to giving birth; as having primal status.

Like an architect, Leonardo sees in section not in surface. His gaze cuts. Cuts are openings and openings reveal that which is normally concealed.[34] This penetration of the surface is both actual and metaphorical, for only by getting past the superficial layers of things can meaning be unearthed. Leonardo cuts with a knife in order to recompose with a pen; he opens up the body in order to fit it back together in a graphic demonstration. This is a very important motion in dissection, and by extension, in architectural representation. The fact that one has to cut the body up into parts, thereby damaging it irreparably, is a necessary deconstruction of the body in order to construct an understanding of it.[35] The process involves the careful removal of anatomical layers; astuteness in recognizing which programmatic part connects to what; and the patience of an archaeologist. Therefore only through a sensitive *unmaking* of the body, can knowledge of it's God-given arrangement be *made*. His partitioning of the body into dismembered segments is not reductive, leading to the isolation of autonomous parts, but additive as his probing allows him to refigure a more deeply understood whole. Leonardo is cutting to better understand causes and therefore to find the conduits of this agency. Similarly, he wants to see the animating principle in rocks, people and in all life of the world. He probes the visible to better understand the invisible.

However, what must be qualified is that Leonardo's is not a modern section in the sense of a cut through the cone of vision that is coordinated with a plan and elevation. The coordinated plan and section or elevation only becomes common in the 16th century, and was 'institutionalized' in architectural theory through the work of Andrea Palladio. Leonardo's architectural drawings are not coordinated in the modern sense, although they are internally consistent. The nature of Leonardo's contribution to architecture is therefore significant, but not in terms of built works. Rather, in the form of inventions in representation that have become standard conventions in

---

33 Kemp, "*Mimesis* to *Fantasia*", 397.

34 On a page with a sectional '*in congressu*', he records: "I reveal to men the origin of their second – first or perhaps second – cause of existence. [...] Division of the spiritual from the material parts." W. Anatomia III, 3v. Cited in MacCurdy 172.

35 It is important to observe, that in his search of the body, he is never looking for the invisible inscriptions of the zodiac and this further characterizes him as more Aristotelian than some of his contemporaries.

representations of space. Perhaps what is most profound about his contributions to anatomical dissection, is that the modes of representation he developed to depict the body, have become commonplace conventions in architectural representation, if not also the main tools of architectural ideation. While Leonardo's graphic techniques are not clearly and consistently transferred to his own architectural designs and speculations, there is a discernible relationship between his animistic understanding of the body and that of architecture.

His existing architectural drawings are, to a large extent, a collection of sketches drawn from an aerial vantage point. He also draws in plan, but this seems mostly to determine the geometrical arrangement that will generate the building's form. In his architectural studies he did not pursue an investigation of the building's 'body' with the same systematic rigour as he did the human body.[36] Ironically, Leonardo is most architectural when he is exploring the body. His representation of each part of the body from several vantage points in space is fundamentally an architectural survey. The architecture of the human body is spatially the most complex. The obvious implications of this are that our present modes of understanding, communicating and conceiving architecture have their origins in the conception and representation of what we are. Both by cutting a section of the body to reveal its inner organs and processes, and by drawing a building without some of its walls to show the system of staircases within, Leonardo is revealing interiority in an unprecedented way.[37] This is more than a logical cross-over of modes of representation. It admits to a profound kinship between our bodies and what we make.

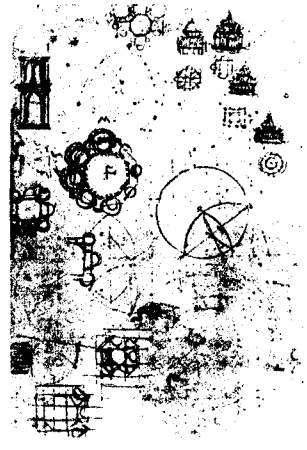


Figure 24: Diagrams of building with a centralized plan. (C.A. 1010v / 362v-b)

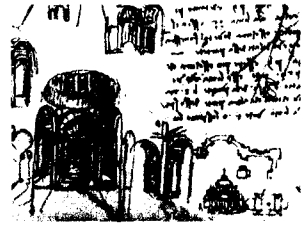


Figure 25: Interior views of a cross-shaped church. (C.A. 104r / 37r-a – detail)

---

[36] Judging from the nature of his architectural studies and the fact that architecture is not mentioned in his *Paragone* of the arts in which he speaks so extensively and favourably about painting, it may be interpreted that he did not see in architecture the same rich potential for cultivating true knowledge of Nature, as he did in painting. Rossi elaborates on the widespread polemics in the sixteenth century, over the comparison between the status of painting and architecture. He states: "The thesis that maintains architecture superior to painting is linked to the prominence given the 'mathematical' foundations of the former and the 'manual' character of the latter." Rossi, 30. While we only possess clear textual evidence regarding Leonardo's opinion of painting, and given that his notations pertaining to architecture are mostly of a pragmatic nature, it may be maintained that Leonardo's position regarding the status of painting vis-à-vis architecture inverts the hierarchies of this main-stream opinion.

[37] George Hersey observes that "Leonardo was rendering the cutaway parts of the building transparent, and showing the remainder in perspective. In this sense the cutaway perspective rendering is a variation of the corpo transparente." Hersey, 145-6.

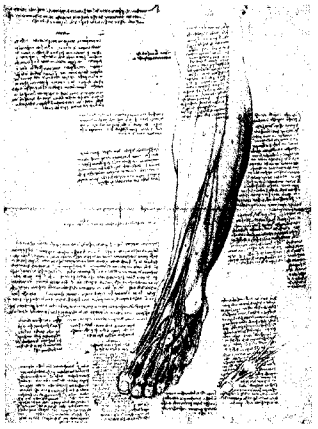


Figure 26: Study of the superficial anatomy of the foot and lower leg. 1510 (W 19017r)

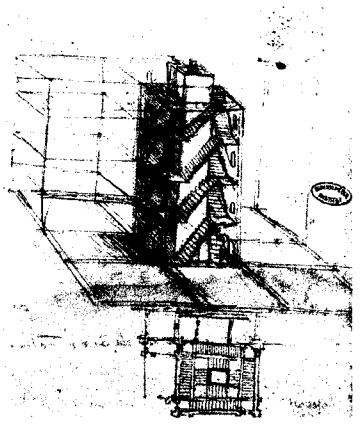


Figure 27: Quadruple staircase in the middle of a square tower (MS. B. 47r)

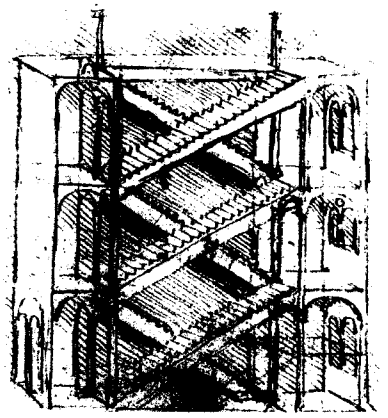


Figure 28: X-shaped staircase (MS. B. 68v – detail)

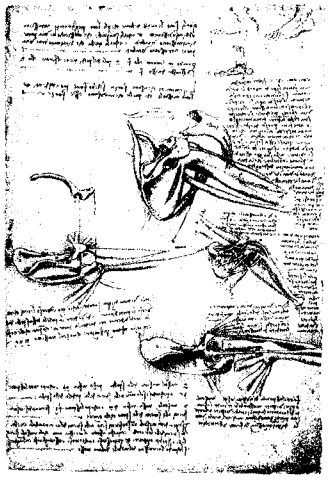


Figure 29: Myology of the shoulder region: exploded views, *c.* 1510-13 (W 19001r)

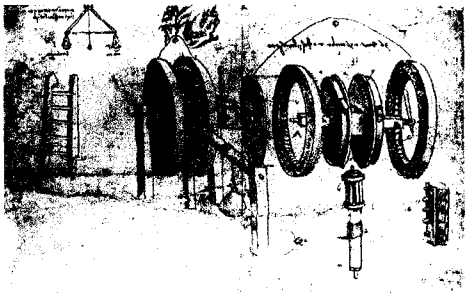


Figure 30: General and exploded view of a hoist (C.A. 30v / 8 v-b)

Leonardo also understands the machine animistically. Looking at Leonardo's drawings of machines, especially those demonstrated through the technique of the 'exploded view', one can imagine these mechanical inventions recomposed into a whole.[38] Leonardo brings his understanding of the body and his modes of anatomical representation to drawings of mechanical equipment, displaying the individual parts pulled apart with thin connecting lines indicating the path one's imagination would follow to put the body of the machine back together again. He shows the anatomy of the mechanical parts that are subjected to the same 'powers' as the human body and everything else in nature. "Every one of his mechanical devices [is] in a sense a new kind of 'body'

[38] In addition to its architectural application, the 'exploded view' is a technique that has become a standard mode of graphic communication in present day technical illustration. Leonardo's drawings of machines, in a sense, are 'doubly' inventive in that not only is the device that is depicted an invention of his, but so too is the mode of representing it.

springing into life when activated by force."[39]

The closeness of the machine to the body is very clearly expressed in his notation to himself, where he states: "Do not forget that the book on the elements of machines with its beneficial functions should precede proofs relating to the motion and power of man and other animals; then on their basis, you will be able to verify your propositions."[40] Leonardo intended to precede his book on anatomy by his book on machines. This projected book was to present the 'anatomical' elements of mechanical devices such as pulleys, joints, levers, gears, springs, screws, ball bearings, etc.[41] Martin Kemp comments, "[thus] the invented bodies of machines and the created bodies of nature were comparably conceived to operate in infallible harmony with the universal laws of dynamics. The actual forms of machines and organic systems were not, of course, identical [...] because mechanical inventions were often conceived to achieve different effects, but the design principles were the same in every instance. In some cases, the analogies were so close that the products of the engineer and nature seemed to merge inseparably."[42]

For Leonardo, painting is the means to knowing. The implications of this for any epistemological inquiry, but in particular for architectural ideation, are substantial. What he is intimating is that we can only truly *know* something, when we internalize it through a synthesis of our senses and our imagination. Only when we overcome our detachment as spectators of that which is outside of ourselves, and engage it through our imagination, our embodiment and our capacity as intellective, inventive beings, in order to *make* something with it, can meaning appear. Without stating it in these terms (for in the context of his own world-view, the crisis of an absent alignment between human-made works and nature was nonexistent), Leonardo has exposed a critical strategy for us today. It entails connecting with the process by trusting that through it, meaning will appear, and therefore permitting ourselves to work from what we are discovering through making, rather than determining from the outset, where our investigation will take us. This approach contrasts the currently favoured instrumental modes of working that prize efficiency and seek the shortest path to achieving a product. This is very much the case in contemporary architectural practice and because of this, the possibility for genuine discovery is greatly short-changed.

---

39 Kemp, 120-122.
40 MS. A. 10r. Cited in Kemp, 119.
41 Kemp, 119.
42 Ibid., 122. Leonardo's work in mechanics is never divorced from the organic. See Kemp, 146.

III Drawing an Analogy is like Building a Bridge

As discussed in the previous chapter, Leonardo advocates the superiority of painting and places his confidence in the power of painting (and drawing) over words to attain true knowledge of Nature. The word 'drawing' functions as both a noun and a verb. In addition to its obvious artistic significations, 'to draw' in its general sense, means to gather disparate things and to bring them into proximity with one another, hence the phrase 'to draw together.' It also denotes the capacity to identify and extract something from the findings, that is, 'to draw out' (information, meaning, truth) through careful contemplation. Leonardo actively draws together his observations of the phenomena of the world onto the pages of his notebooks. By graphically committing to paper (i.e., 'drawing' in the artistic sense) the undulating stream of his thoughts and observations, he is able to discover both expected and sometimes unexpected connections between things. That is, he is enabled to draw out meaning.[1] His drawings, the 'product' of this gathering, are maps of the process of his transforming thoughts. Leonardo's drawings are the tangible evidence of his active, life-long search. Since each sheet that is full of his observations and speculations contributes to a body of research that is much larger than the contents and investigation(s) hosted by any given page, all of his drawings may be considered 'works in progress'. Neither Nature, nor his work that seeks to comprehend her, remains static.

If I have not already expounded too pedantically on the centrality of drawing in Leonardo's research, I wish to illuminate one more nuance, which carries with it a bit of irony. In the specific context of Leonardo's work, the expression *to draw an analogy* exposes a pun. More than a figure of speech, drawing analogies with pen, graphite or charcoal on paper, names one of his most steadfast modes of research. His drawings are the bridge which help him to construct analogical relationships. The drawings allow the observed phenomena to be gathered and brought into visible comparison and therefore tested through experience. For instance, through his explorations of the human skull, he observes that "[i]f you cut an onion down the centre you will be able to see and count all the coatings or rinds which form the concentric circles round the centre of this onion. Similarly if you cut a man's head down the centre you will cut through the hair first, then the skin and the muscular flesh and the pericranium, then the cranium and within the dura mater again and

---

1 I am indebted to the discussions I have had with my colleague, Michael Carroll, which stimulated my reflections on the multiple nuances of 'drawing.'

the rete mirabile and the bone which is the foundation of these."[2] Since he places more confidence in the drawings' ability to convey ideas effectively with an economy of means, he not only says, "the skull is like an onion" but he also sketches it, thereby *drawing the analogy*. Another example of this is found in his anatomical drawings of the upper spinal chord and the sinews, tendons and chords that connect to the head and attach the spine to the shoulders. Beside his drawing he records, "You will first make the cervical spine, without the skull, with its cords like the mast of a ship with its stays; then make the skull with its cords which give it the motion upon its axis."[3] On these pages he explores the similarities between the structural features of the body, which simultaneously allow for movement and stability, and the rigging of a ship's mast which fulfills the same needs. The body resolves its tensions for it contains within it everything that will ensure its stability as well as its flexibility for movement. Thus humans are wise to model their artifacts on its truths. The body appears in nature and nature is reflected in the works of man.

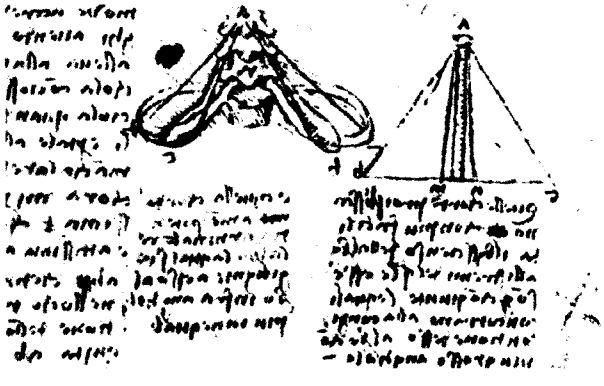


Figure 31: Skull as onion: central nervous system and cranial nerves, *c.* 1490. (W 12603r)

Figure 32: Studies of the spinal column as mast, *c.* 1513. (W 19075v)

Figure 33: Myology of trunk: spine and ship's mast, schematic detail, *c.* 1510. (W 19015v - detail)

2 W. 12603r, c. 1490. OHB 330. Text cited also in MacCurdy, 193.

Leonardo also uses analogy to develop an argument and state a proof. In a passage in his notebooks in which he is refuting the Galenic proposition that the liver is the vital organ in the generation of the vascular system, he puts forth instead that it is in fact from the heart that the tree of vessels in the body originates. He states, "If you should say that the veins arise in the protuberances of the liver.... just as the roots of the plants arise from the earth, the reply to this analogy is that plants do not have their origin in the roots but .... the whole plant has its origin in its thickest part, and in consequence the veins have their origin in the heart where is the greatest thickness.... and the example of this is to be seen in the growth of the peach which proceeds from its stone as is shown above."[4] Therefore, to reason out his argument he takes issue with the assumption that the roots of plants rise from the earth, and points out from what he has observed in nature, which is that the roots originate from the thickest part of the plant, namely the seed. By drawing the analogy to a peach, he is able to defend his position against the assumed correlation between the growth patterns of plants and the liver.

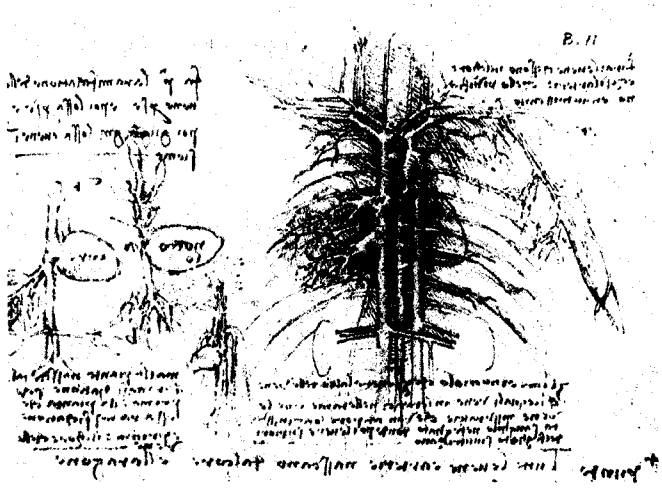


Figure 34: The heart likened to a seed or nut producing roots and branches. (W 19028r; K/P 70r)

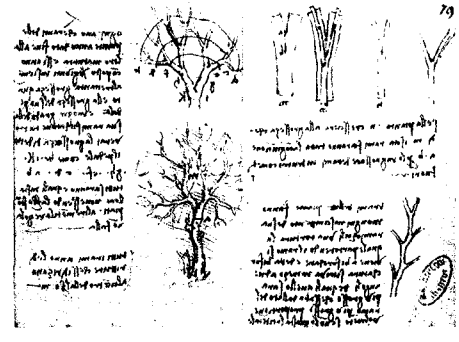


Figure 35: Studies on the growth of plants, *c.* 1495-1500 (MS. M. 78v – 79r)

On a different folio Leonardo writes: "All the branches of trees at every stage of their height, united together, are equal to the thickness of their trunk. All the ramifications of the waters at every stage of their length being of equal movement are equal to the size of their parent stream. (MS. I. 12v)

From his dissection of an old man, who passed away painlessly and without disease, Leonardo observes that the veins appeared to be dried out and withered, unlike the wavy, juice-filled veins of

---

3 W 19075v, c. 1513. OHB 76.
4 W 19028r. Cited in Kemp, 260.

the young.[5] He deduces, then, that the old man's death was likely due to the deprivation of nutrients carried by the blood to the regions of the body. From this he extrapolates that "the very old have skin the colour of wood or dried chestnut because skin is almost completely deprived of sustenance. And the network of vessels behaves in man as in oranges, in which the peel becomes tougher and the pulp diminishes the older they become."[6] This assessment is very consistent with Aristotelian thought, for Aristotle too discusses the living creature as being warm and moist by nature, and that old age brings cold and dryness, as in that which has died. As we age, our bodies dry up. Life is therefore understood as intimately connected to vital liquid, which diminishes over time.[7]

Figure 36: Cardiovascular system: veins of young and old, *c.* 1504-6. (W 19027r)

To these clearly stated analogies there is not much to add. In these examples Leonardo sketches and annotates a drawing and in it he names the analogies that he pieces together. Text and drawing collaborate to expose his findings. However, the analogical workings of his approach can be traced also beyond these obvious examples. For instance, his studies of the movement of water, the growth of plants and the waves in hair, indicate an analogical mode of thought at work. In the way that he studies and presents these phenomena to himself through his drawings, it can be inferred that even when he does not expound the point explicitly, he sees a profound underlying analogical connection between diverse phenomena. His studies of the movement of water are numerous, and perhaps one of his most captivating drawings is that which demonstrates the behaviour of water as it cascades downward into a pool. As the water drops into the pool below,

---

5 Leonardo recorded, "The old man, a few hours before his death told me that he had lived a hundred years and that he felt nothing wrong with his body other than weakness. And thus [...] without any movement or other sign of any mishap he passed out of this life. And I made an anatomy of him in order to see the cause of so sweet a death. This I found to be a fainting away through lack of blood to the artery which nourishes the heart, and other parts below it, which I found very dry, thin and withered." W 19027v. Cited in Keele, 37.

6 W 19027v. Cited in Kemp, 257.

7 Aristotle. *On Length and Shortness of Life*, 466a, 19ff; and *Generation of Animals*, 784a, 34. See also Richard Broxton Onians, *The Origins of European Thought about the Body, the Mind, the Soul, the World, Time, and Fate.*

Figure 37: Studies of hydrodynamic turbulence, *c.* 1508-9. (W 12660v)

Figure 38: Study for the Star of Bethlehem (Omithogalum umbellatum) and other plants, *c.* 1506. (W 12424)

Figure 39: Study of coiffure for *Leda*, *c.* 1507-8. (W 12516)

spreading in circular waves, bubbles are formed as the air trapped in the descent, gurgles upward 'struggling to reach its own element'. In the process, the visual effect created appears as a 'bouquet' of waves. Similarly, not only in form but also in essence, are his contemporaneous drawings of the plant named the Star of Bethlehem and his studies for the coiffure of a woman for his painting *Leda*. In these investigations an underlying similitude exists that goes beyond the seeming differences between curls in hair, waves in water and blossoming foliage. All of these manifestations of Nature respond to the same powers and they reveal their effects in visibly similar ways. Observation of one informs his understanding of another. He writes:

> "Observe the motion of the surface of water, which resembles that of hair, which has two motions, one of which depends on the weight of the hair, the other on the direction of the curls; thus the water forms turning eddies, on of which follows the impetus of the main course, while the other follows that of incidence and reflection."[8]

Interesting to note is that although air and water are contrasting elements and differ radically in that the former can be compressed while the latter cannot, Leonardo nevertheless perceives a deep affinity between. He perceives similar transmutations in their movements and states that movement

---

1951 (Cambridge: Cambridge University Press, 1988) 215.

[8] Richter 389. Cited in Gombrich, 46. Gombrich has noted that this analogy exposes two main factors evident in the movement of water, namely, forward pull of the flowing river and the spiraling movement of the vortex. In MS. F. 87, Leonardo records his observations about the similar patterns that exist in waves in water, currents in air, and the patterns that are visible as wind passes over a cornfield.

through air and swimming in water are analogous processes. "Swimming on water teaches men how birds do up in the air."[9] In the same line of thought he states, "Swimming illustrates the method of flying, and shows that the widest weight finds most resistance in the air."[10] He derives an analogy between the hand of a swimmer and the wing of a bird, stating, "When two forces percuss each other it is always the swiftest which leaps back. So it is with the hand of the swimmer when it strikes and presses on the water and makes his body glide forward in a contrary movement. So it is with the wing of a bird."[11] His interest in pursuing these correspondences has to do in part with his speculation that the space which is displaced in front of a moving body, is always replaced by the closing in of space behind a moving object, which propels it forward. As an extension of this, he probes the relationships between the shapes of fish and that of boats.[12]

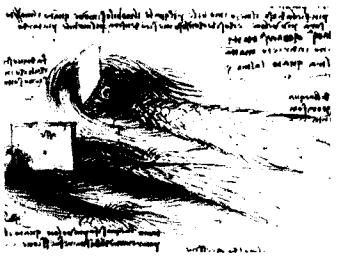


Figure 40: The movement of flowing water around obstacles. (W 12660r)

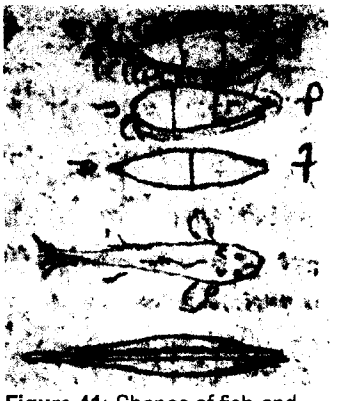


Figure 41: Shapes of fish and boats. 1510-15. (MS. G. 50v)

For Leonardo, water and air share some fundamental properties, and therefore the exploration of one element reveals clues about the nature of the other. He states, "[a]ir moves like a river and carries the clouds with it just as running water carries all the things that float on it,"[13] and late in life he reaches the conclusion that "[i]n order to give the true science of birds in the air it is necessary first to give the science of the winds and this we shall test through the movement of water."[14] Through Leonardo's studies of the wave patterns in water he speculates on similar patterns occurring in air. This leads him to research patterns of bird flight with, through and against these wave patterns, considering the pressure under their wings and the birds' shifting centre of gravity. He compares birds to other flying creatures such as butterflies, bats and even flying fish, and this

---

9 C.A. 66rb. Cited in Keele, 184.

10 MS. M. 83r. Cited in Keele, 183.

11 MS. F. 41v. Cited in Keele, 183.

12 On this plate he writes, "Three ships of uniform breadth, length and depth, when propelled by equal powers, will have different speeds of movement; for the ship which presents its widest part in front is swifter, and it resembles the shape of birds and fishes such as the mullet. And this ship opens with its sides and in front of it a great quantity of water which afterwards with its revolution presses against the last two-thirds of the ship. The ship *dc* does the opposite, and *fe* has a movement midway between the two above." MS. G. 50v.

13 MS.G. 10r. Cited in Keele, 88.

14 MS. E. 54r. Cited in Keele, 88.

leads him to speculate on the flight of man. For Leonardo, the Great Bird, as he called his invention, was modeled so closely on its analogical counterpart, that for Leonardo, it became *a bird* (*uccello*) itself.[15] He devotes much attention to the wing structures and flight patterns of birds. The bird is an adaptive creature that attunes itself to its environment. It adjusts its wings and tail in response to changes in air currents and shifts its centre of "natural gravity" to achieve ascent or descent so that this centre will be in front or behind its "centre of resistance."[16] Since air can be compressed, Leonardo surmised that this compressed air under the flapping wings of a bird is what provides the spring-like lift and that this enables flight.[17] His scheme for the flying machine offers what is perhaps his closest analogy between a product of Nature and that of an inventor. His invention for human aviation relies upon, and in fact is inseparable from, an imitative strategy of the wing structures and flight patterns of birds. By basing his invention so faithfully on nature's creation, he feels assured that man would be able to perform the same motions.[18] He writes:

> "The same force is made by an object encountering the air as the air against the object. See how the percussion of the wings against the air is able to support the heavy eagle in the rarefied* air close to the element of fire [the outer sphere of the atmosphere containing the earth]. Also see the air moving over the sea and repercussing in the swelling sails to transport burdens in heavy ships. Thus from these demonstration and their appropriate causes man may learn, with large wings attached to him, to draw power from the resistance of the air, being victoriously able to overcome the air, raising himself upon it."[19]

Human invention is that which allows us to compensate for what we were not naturally given by Nature. Leonardo's mimetic imagination inspires in him a deep faith that a correct alignment with nature allows even man to fly.

It is unknown exactly how far Leonardo went in his construction of the Great Bird, but it is known that he did not succeed in achieving human-powered flight.[20] However, the relevant issue is not whether his analogies would stand up to the scrutiny of modern science as valid truth claims. Whether his analogies were 'accurate' is incidental to the discovery, for accuracy can only be

---

15 See Kemp, 122-123. Since Leonardo did not consider his flying machine merely to be 'like' a bird, but for him it *is* a bird, his analogical exploration in this instance developed to the level of metaphor.

16 Sul. Vol. 18v.

17 Gombrich, 53.

18 "The bird is an instrument operating through mathematical laws, which instrument is in the capacity of man to be able to make with all its motions." C.A. 161ra. Cited in Kemp, 122.

19 C.A. 381va. Cited in Kemp, 122.

* Spelled "rarefield" in the citation, which I assume to be a typographical error.

20 Kemp, 123-4

determined in hindsight. The relevant issue is that he probed the contents of the world to find links between things, and through this lens, found a profound coherence in the phenomena around him.

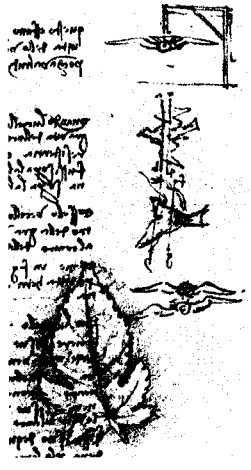


Figure 42: The centre of gravity of a bird. (Sul. Vol. 15v – detail)

Figure 43: The course of birds in rising flight. (C.A. 308 r-b)

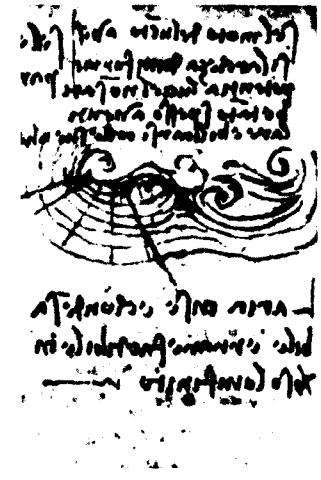


Figure 44: Eddies and bending of the wing-tips in a flying bird. 1513-14 (MS. E. 47v – detail)

This sketch shows Leonardo's (mis)conception of the compression of air under birds' wings.

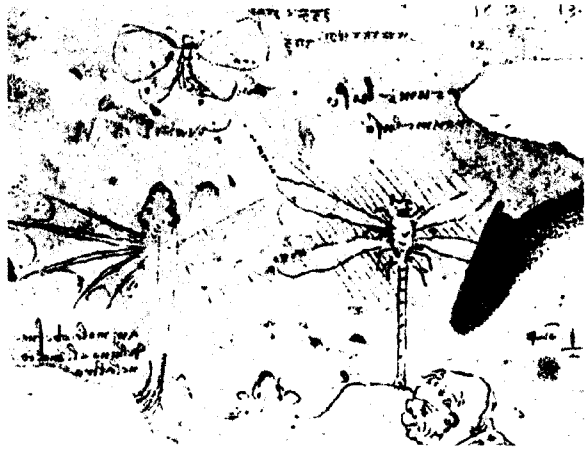


Figure 45: The moving parts of the butterfly, dragonfly, bat and flying fish. (MS. B. 100v)

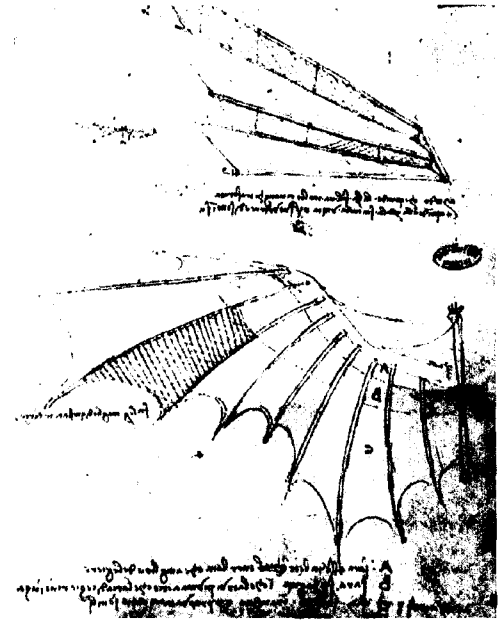


Figure 46: Armature for the wing of the flying machine, the Great Bird. (MS. B. 74r)

His comparative studies of flying creatures extend to investigating the homologies between man and beasts. Analogy is a correspondence in function between anatomical parts of different structure and origin, and one aspect of his analogical mode concerns itself with the uncovering of correspondences between mammals. On these homologies Leonardo writes:

> "It is an easy matter for anyone to acquire universality in this, because all terrestrial animals have a similar structure, that is similar muscles, nerves and bones, and their only variation is in their length or thickness as will be demonstrated in the Anatomy. The only exception is the aquatic creatures, of which there are a great variety. I shall not try to persuade the painter to make up a rule for them, for they are of almost infinite variety; and the same applies to insects."[21]

In comparing terrestrial animals Leonardo is searching for the underlying principles that unite them despite their obvious differences. When he draws the profiles of man, horse and lion in an expression of ferocious rage, he is looking at the expressions common to beasts and man. As Gombrich comments, "[f]ar from believing that there were 'lion men' and 'horse men', Leonardo was out to demonstrate that essential unity of all expression in vertebrates."[22] He also seeks evidence of unity in his comparisons of the skeleton and musculature of the leg of a man with that of a horse, as well as in the mechanics of pulling in the arms of a monkey and of a man.[23] In these examples his aim is to better inform his understanding of one through the other and vice versa. Similarly, he seeks to derive exact correspondences between the reproductive organs of man and woman since both male and female contribute to reproducing more of their own kind.[24]

Figure 47: Studies of fury in man and animals for the *Battle of Anghiari*. 1503-4 (W 12326r – detail)

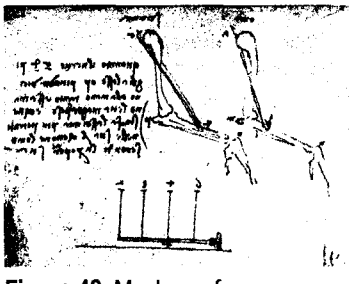


Figure 48: Myology of upper extremity: leverage in man and monkey. c. 1504-6 (W 19026v – detail)

---

21 Richter, no. 505. Cited in Gombrich, 61

22 Gombrich, 61.

23 On a different folio Leonardo records the following instruction: "For this comparison you should represent the legs of frogs, for these have a great resemblance to the legs of the man, both in the bones and in the muscles; you should afterwards follow this with the hind legs of the hare, for these are very muscular and the muscles are well defined because they are not hampered by fat." W. Anatomia V, 23r. Cited in MacCurdy, 194.

24 He states his conviction that the testes and ovaries have a similar function and make a similar contribution to the fetus, i.e., that the mother's 'seed' has an equal influence on the offspring as the father's. This is a departure from the Aristotelian view of generation. OHB 454-456.

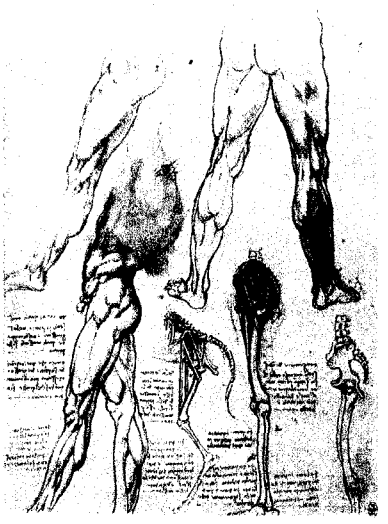


Figure 49: The superficial muscles of the leg: comparison of the leg of a man with that of a horse (W 12625r)

Figure 50: Comparative anatomy: the foot of a bear on the left leg of a human. *c.* 1490-3 (W 12372r)

Figure 51: Genito-urinary system: homologies of male and female generative organs. *c.* 1503 (W 19095v)

In his speculations he may at times be mistaken, and his attempts to bring these chosen pairs into comparison with one another may indeed pose many factual problems and logical inconsistencies, but the important issue is that he makes the comparisons in the first place. Working within a mindset that understands everything in the world to be connected, he likely appreciates the differences and discrepancies but chooses to privilege the similarities because for him they are far more important and more revealing. In this way he is able to dissect a bovine heart and have it stand in the place of a human one, because mammals share fundamental similarities.[25] These comparisons not only intimate his conviction that crucial correspondences exist between creatures, but that the interconnectedness of all things in the world is also discernible. For Leonardo, the human realm is never divorced from nature and in this alignment is ingrained a deep and intuitive ethics.

[25] While it is true that human specimens were difficult to acquire for the purposes of dissection, and substitution of animal parts was a common practice since antiquity, I maintain that Leonardo's use of animal specimens, is not primarily an issue of convenience. Rather, his choice is first and foremost grounded in a confidence that the vital organs of terrestrial animals are inherently similar to those in humans, and therefore that they can stand in the place of human parts.

In his analogical constructs, the human body plays a central role in the comparisons and this tendency extends to his architectural studies. The body is a hinge, a familiar entity that is also full of mystery, and one that instantiates and exemplifies Nature's wisdom. Unlike his contemporaries, Leonardo's treatment and appreciation of the connection between body and architecture does not prioritize numerical proportion or geometry, but places the emphasis on essence and function. He invests so much effort investigating the mortal body's earth-bound truths rather than abstracting it into a numerical ideal because he is interested in understanding how Nature's causes are manifest through it. In this way, he is not demystifying the "machine of the body" into a mechanistic composite of functional parts, but is seeking to tap into the animism proper to a self-mover. The body is affected by the same causes in Nature that have a bearing on the realm of human artifacts, and therefore the body instantiates similar effects. Since everything in the world is subject to the same laws, so too is architecture implicated.

A very clear example of an analogical connection at work between the body and architecture is evident in his drawing showing the human figure sketched without skeleton or flesh but delineated only by its branching network of veins that carry fluids through the body. On this same page most of the sheet is devoted to sketches of stairs, i.e., to the architectural parallel to circulation and meridians of flow. In a different folio he takes this analogy to the larger scale of urban circulation. In his unrealized urban schemes for Milan, which were designed following the plague that is estimated to have claimed the lives of 50,000 people, he makes the focus of his investigation the paths of pedestrian and other urban movement, especially water channels. For Leonardo, these passages are first and foremost conduits of flow, and secondarily pragmatic constructs for efficient organization of different modes of traffic. Sanitation is a means to an end, which is unclogged movement and this has health, i.e., soundness, as its beneficial effect. His city designs in MS. B. exhibit an organic dynamism in the way distinct paths of movement overlap on different levels, forming a weave of conduits, which facilitate the movement of the

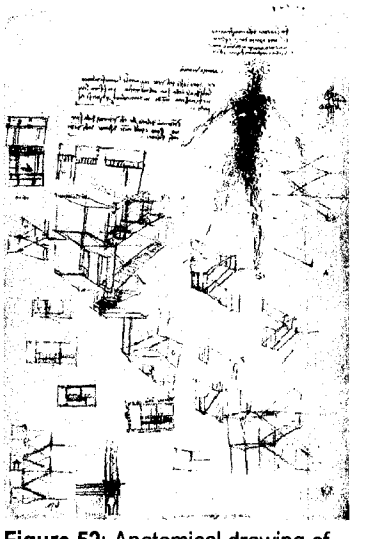


Figure 52: Anatomical drawing of network of veins and staircases. (W 12592r)

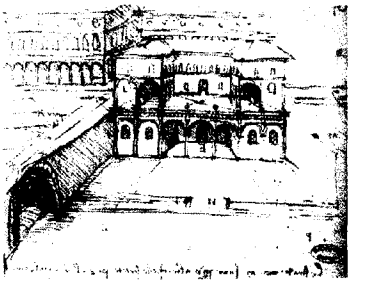


Figure 53: Study for an urban development project in Milan. (MS. B 16r – detail)

urban 'vital fluids' and thereby ensure good health for the civic body.

The network of vessels in the body through which fluids migrate, carrying nutrients to all regions of the body in order to sustain it, is paralleled to stairs and criss-crossing paths through the body of a building, which at a larger scale, are reflected in the intricate patterns and various densities of movement in cities. The movement of the people through the spaces of a building or through a city, and the movement of fluids within the body all condense and expand instantaneously in his imagination.[26] Thus, Leonardo's contemplation and proposals for a healthy city, are directly informed by his notions of what constitutes a healthy body. By possessing an understanding the body, the architect can be to the building or to the city, what the doctor is to the patient. The analogy of the doctor-architect was widely understood and appropriated by Renaissance theorists. The comparison of an architect with a doctor implies that the building, like the body is alive and needs to be cared for. It also places the responsibility of the architect to be a healer who knows well the body of the building well and is able to care for its needs. Adopting a nurturing role, the architect like the physician, tends to the vulnerabilities of a mortal body. Leonardo writes, "Medicine is the restoration of elements out of equilibrium; illness is the discord of elements infused into the living body."[27]

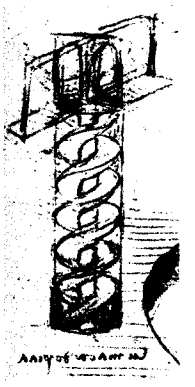


Figure 55:Ten spiral staircases around a tower (MS. B. 47v – detail)

Figure 54: Double newel staircase (MS. B. 69r – detail)

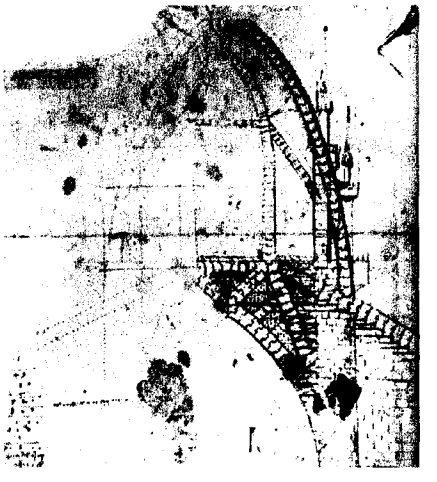


Figure 56: Milan Cathedral: section of the crossing piers and projection of a double dome above. (C.A. 850r / 310r-b)

During his time in Milan, Leonardo was recruited to consult on the structural problem of the domed crossing (*tiburio*) of the Milan Cathedral. His studies for this date from 1487-90, and his architectural preoccupation at this

---

[26] The nature of analogy is such is that it produces webs of meaning. In Leonardo's epistemological schema, from each thing connective tissues branch out to touch many things. Leonardo did not think in straight lines. In this regard, the staircase speaks of and is spoken of not merely by the body, but also with the mechanical element of the screw. The screw and the stairwell share formal similarities especially the circular stairs or those where multiple staircases are twisted around one cylindrical core like twine. In this way analogy permits the crossing of scales and programmes to allow for the mutually enhancing merger of meanings.

[27] Triv. 4r. This formulation can be traced to classical medical theory. See Kemp, 107. For a discussion on architectural equilibrium being analogous to bodily equilibrium, see Kemp, 146.

time is the interplay of forces that will result in stability of the building. It has been suggested that in 1488, he likely submitted the following text to the Cathedral authorities along with his wooden model a section of the dome.[28] It states:

> "Doctors, teachers and those who nurse the sick should be aware what sort of thing is man, what is life, what is health and in what manner a parity and concordance of the elements maintains it; while a discordance of these elements ruins and destroys it; and one with a good knowledge of the nature of the things mentioned above will be better also to repair it than one who lacks knowledge of them..... the same is necessary for the ailing cathedral, in that a doctor-architect understands what kind of thing is a building and from what rules a correct building derives and whence these rules originate and into how many parts they may be divided and what are the causes which hold the building together and make it permanent, and what is the nature of weight and what is the potential of force, and in what manner they may be conjoined and interrelated, and what effect they will produce combined. He who has true knowledge of the things listed above will present the work satisfactorily to your understanding."[29]

The doctor-architect comparison had already been made by Alberti, Francesco di Giorgio and Filarete, but Leonardo took it further by defining the building as a natural organism. For a building to be healthy and sound, it requires nurturing care. Martin Kemp has made the astute observation that:

> "The proportional relationship of the parts reflects universal design. And a 'medical' equilibrium of elements ensures a stable structure. These qualities are thus shared equally by God's creation of the human body and the human being's own production of a good building. In the late 1480s, this theme of the artistic microcosm emerged as one of the great unifying principles of his thought. This architectural application is not the end of the matter, however; it only represents the beginning of a concept which had a literally universal application. Not only is man a 'lesser world' in structure and beauty, but also in terms of the dynamic processes of nature."[30]

To summarize, Leonardo's analogies are not always assembled on the same page or diligently cross-referenced to other studies, but even in the instances where an overt explication of the correspondences is lacking, what is traceable in his work is an implicit mode of gathering and contextualizing any one thing with and against others. We may assume from the many instances of analogy in his work that any one phenomenon he examined was never perceived as an isolated

---

28 Kemp, 107.
29 C.A. 270r-c. Cited in Kemp, 107.
30 Kemp, 117.

entity, but was integrated into the vast network of his research. Each finding was not only meaningful in its own right but more so for what it could say about others, since no one thing has the capacity to tell the complete story of itself. In this way each phenomenon, body part, mechanical object, and architectural sketch, is imbued with the power to speak about more than just itself. Implicitly all things point to aspects and hidden dimensions of others, and in this open-ended process Leonardo expands and enriches his understanding and his appreciation of the world. Meaning, even if it is not upheld as strictly accurate or verifiable by later assessment, is nevertheless uncovered.

IV Circles and Squares return Everything to Everything

Geometry, a topic of great interest to Leonardo, is a form of analogy because it identifies relations between things based on a certain set of rules. Analogy in general operates on and is sustained by a principle of continuity and therefore has as its secondary definition, mathematical proportion. Identifying proportions and through this exercise, deriving the relationship of one thing to another, is an analogical process. Leonardo states, "Proportion is not only found in numbers and measurements but also in sounds, weights, times, positions, and in whatsoever power there may be."[1] While proportion is discernible in various things, of all mathematical proportion, the geometric variety most engages him. He responds more readily to 'continuous quantity' (i.e., the arithmetically inexpressible relations between geometric forms) than to 'discontinuous quantity' (i.e., the magic of number).[2] This is probably due to the fact that he can relate to geometrical figures as physical bodies, and perceived as such, they present themselves as possessing a certain earth-bound concreteness. His explorations into geometry are aided if not characterized by his ability to visualize geometric forms in physical, spatial terms.[3] His tendency toward geometric speculation over and above any other mathematical inquiry has far more to do with the predominance of analogy in his thought to which geometry is more conducive, than to his lack of formal education in arithmetic and algebra.

Geometry is visible in things. Consider for example the sphere of the human head which can be analyzed geometrically, as well as the patterns produced by the opening and closing of the valves of the heart, which easily offer themselves to geometrical speculation. Leonardo's mathematical studies are never abstract musings, but are always connected to the sensual world.[4] In fact geometrical proportions are derived from the world, not imposed back onto it as a human-designed form of order. Due to this, the geometrical problems he undertakes always have some

---

1 MS. K 49 (48 and 15) r. Cited in MacCurdy, 622.

2 Kemp, 250.

3 Ibid., 252.

4 "Leonardo saw nature as weaving an infinite variety of elusive patterns on the basic warp and woof of mathematical perfection." Ibid., 307. That is to say that true knowledge comes from being able to demonstrate things mathematically, and this is done through painting and drawing. He writes, "Oh students, study mathematics and do not build without foundations." W. Anatomia I, 7r. Cited in MacCurdy, 82. As part of his project to elevate painting from a mechanical art to the status of science, Leonardo cites the necessity of experience to be able to provide mathematical demonstrations, which are the tests of scientific certainty. He asserts: "No human investigation can be termed true science if it is not capable of mathematical demonstration. If you say that the sciences which begin and end in the mind are true, this is not conceded, but is denied for many reasons, and foremost among these is the fact that the test of experience is absent from these exercises of the mind, and without these there is no assurance of certainty." TP 1.

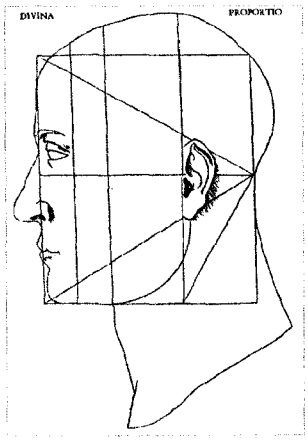


Figure 57: The proportions of the human head based on the triangle. From Luca Pacioli's *Divina Proportione*.

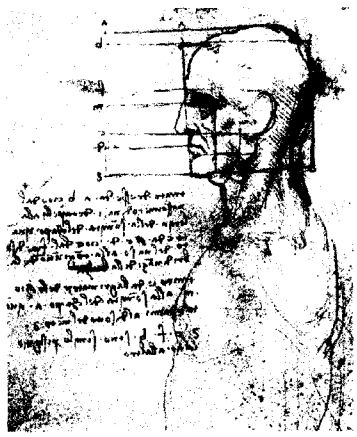


Figure 58: Proportional head. *c.* 1488 (W 12601 – detail)

Figure 59: Studies of the skull. (W 19057r; K/P 43v)

Here Leonardo investigates the intersecting lines in the skull which locate the *senso comune*.

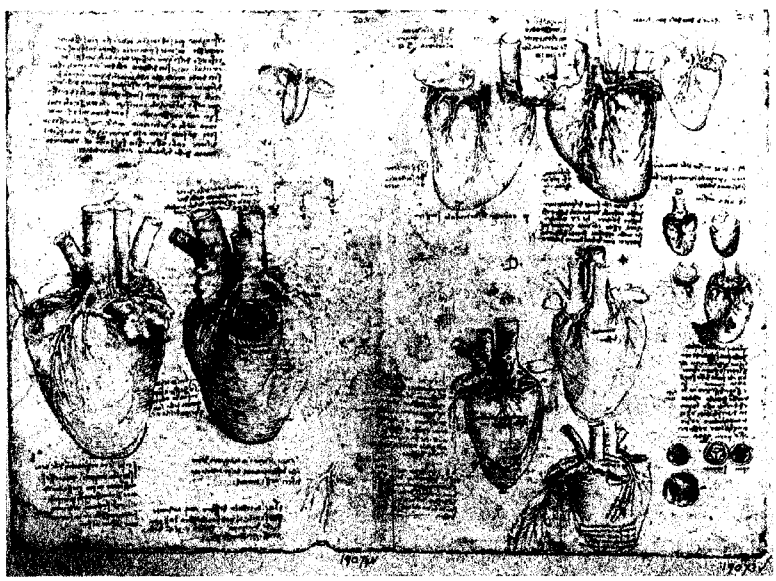


Figure 60: Studies of the heart (of an ox or bull?). 1513-14 (W 19073v-4v)

In the lower right-hand portion of this folio showing drawings of the heart, Leonardo investigates the geometric patterns formed by the aortic pulmonary valve.

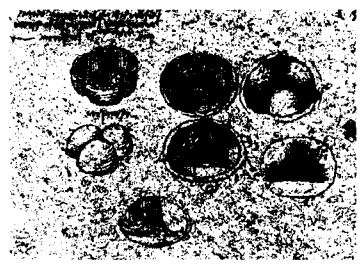


Figure 61: The cusps of the aortic pulmonary valve. (W 19079v; K/P 169v)

link to potential forms in the physical universe. This is noticeable in the fact that he shades his diagrams of geometric shapes as though they are real objects in space.[5] Therefore for Leonardo, geometry is not an imposed order but a palpable part of things, and although geometrical relationships are not always apparent on the surface, nevertheless, they are graspable. He seeks to expose the geometry that is inscribed in the visible "like filigree", to borrow from Merleau-Ponty who says this about the invisible.[6] In other words, the workings of geometry can be witnessed and the harmonies and relationships it makes present are discernible in human terms. Through study of mathematical proportions, mortals are granted a glimpse into the mysterious divine workings of a larger, macrocosmic order.

Leonardo devotes much attention to the transformation of geometrical solids. His study of these proportional relationships is ultimately the voice of analogy spoken through shapes. Leonardo's preoccupation with the ancient exercise of "squaring the circle" is one such manifestation of his desire to discover the truths latent in geometry, and its ability to transform. The problem concerns itself with constructing a square precisely equivalent to a given circle. Leonardo takes up this problem as early as

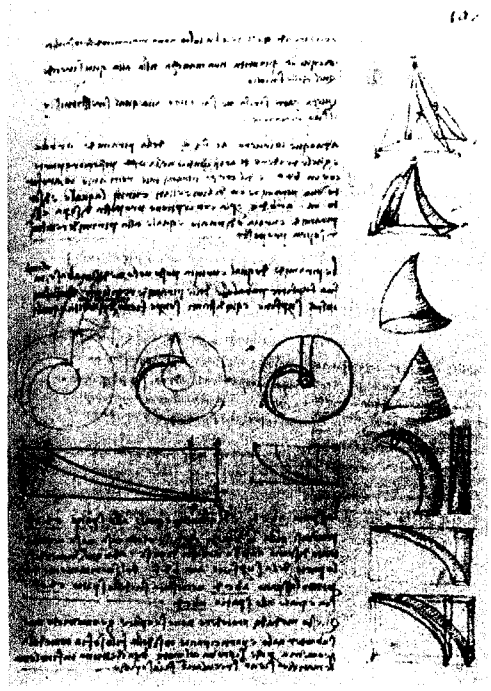


Figure 62: Transformation of solid rectilinear pyramids into curved pyramids and other forms. (Madrid II 107r)

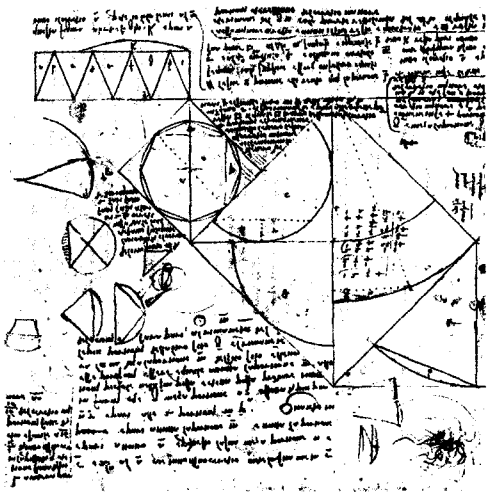


Figure 63: Geometrical studies of squaring the circle. *c.* 1509 (W 12700v – detail)

5 Kemp, 253.

6 Maurice Merleau-Ponty, *The Visible and the Invisible*, trans. Alphonso Lingis, 1964 (Evanston, IL: Northwestern University Press, 1968). In a working note dated November 1959, Merleau-Ponty specifically states: "Meaning is *invisible*, but the invisible is not the contradictory of the visible: the visible itself has an invisible inner framework and the in-visible is the secret counterpart of the visible, it appears only within it.... It is *in the line* of the visible, it is its virtual focus, it is inscribed within it (in filigree)– ".

1492,[7] but his more consistent efforts devoted to this problem come approximately ten years later.[8] Although his efforts at making the precise quadrature are unsuccessful, it is significant that through this problem of transformation the square retains its lineage to the circle, its birth mother, and thus its meaning is compounded, enhanced, enriched. While this is a theoretical exercise for Leonardo, it reflects the imagination's capacity to set things in motion. In his work, two-dimensional and three-dimensional geometric bodies are endowed with the capacity to transform. In these investigations, he is most interested in changes to shapes that do not entail a loss or accretion in area or volume. This is achievable, he argues, because things take up as much space as they leave behind.[9] Therefore by taking what is displaced and attaching it to a different part of the geometrical body, the figure is altered in its shape, but retains similarity to the original body in essence and size. From these numerous investigations it is clear that Leonardo is interested in how identity or sameness can persist through change. Through these geometrical experiments he seeks to resolve multiplicity into unity, which is fundamentally a medieval notion. On a sheet of geometrical studies in the Codex Atlanticus he arranges 180 diagrams with annotations that describe the relative proportions of the shaded and unshaded areas in relation to each other and to

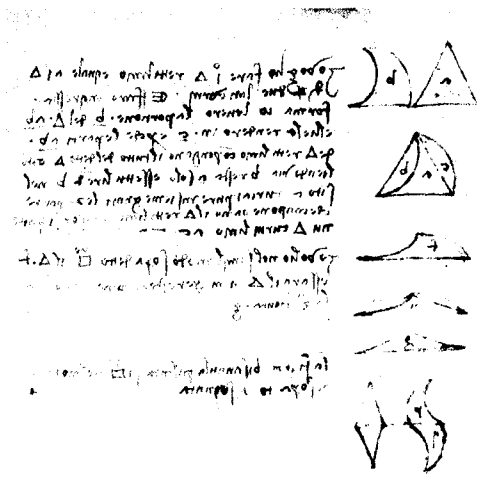


Figure 64: Transformation of a rectilinear triangle into a falcate. (Madrid II 111v)

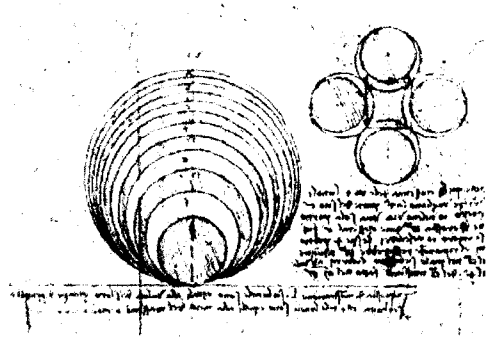


Figure 65: Mathematical proportion of twelve concentric circles. (C.A. 221v-b)

7 This is documented in Ash. I, 9v.

8 Leonardo's attempts at solving this problem display his tendency to make associations with phenomena in the physical world. His first attempt at squaring the circle is very concrete. He physically cuts a circle into radial sections and unrolls the circumference, which he then is able to square. From this he derives the formula that the circumference of the circle multiplied by one-quarter of its diameter yields its square. Another method he attempts relies upon equivalences in area, slicing circles in a way that reduces them to rectilinear figures. The removed 'slices' are juxtaposed and squared and added to the square of the remainder. See Kemp, 253-4.

9 Here, there is an obvious carry-over from his speculations pertaining to movement through water and the propulsion action that he assumes occurs as space/water/air close in to fill the vacant spot left by the moving body.

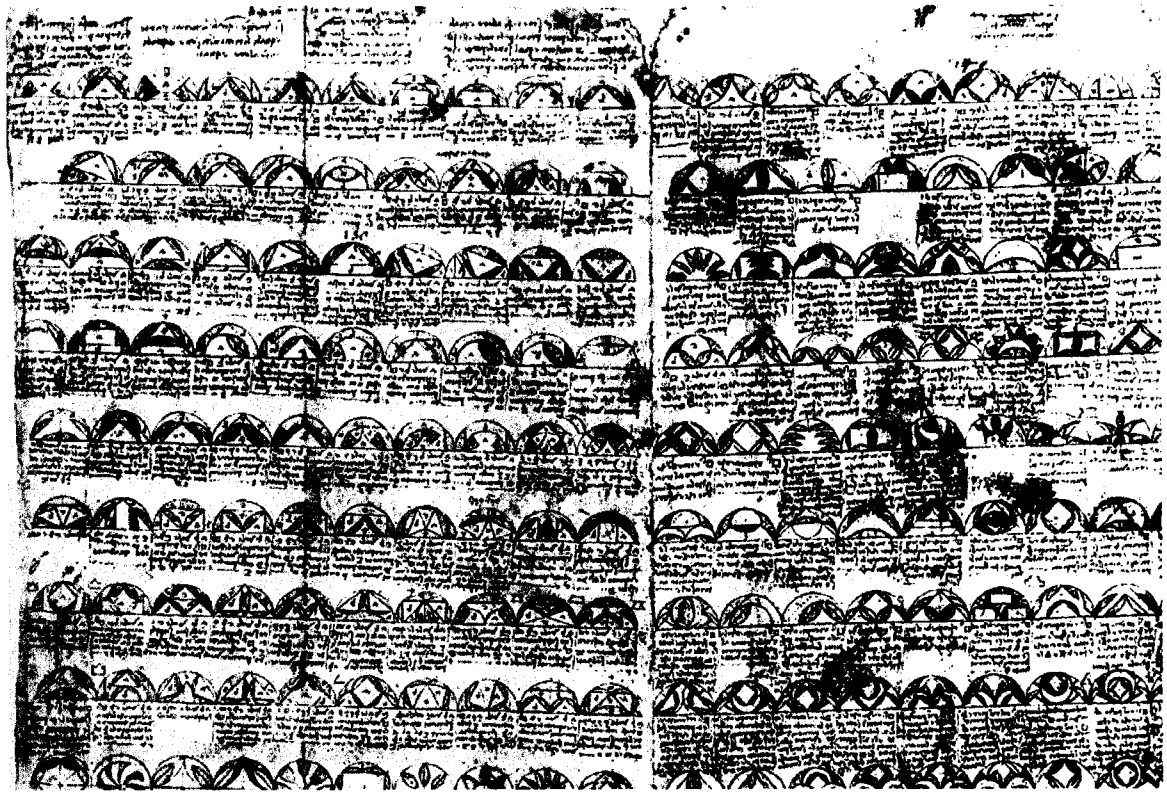


Figure 66: An exercise in geometrical transformations. (C.A. 167r-ab)

the whole.[10] The visual effect of these explorations is a subtle filigree of decorative patterns, but its significance for him is clearly not in the prettiness of the flowering patterns. Leonardo is fundamentally interested in determining unity within diversity and by drawing out how the essences of things persist through their transformations, he explains to himself a process that can account for the bountiful variety in Nature.[11] On the continuity implicit in geometry and the origins of its principles he writes:

> "[... A] continuous quantity, that is, the science of geometry, beginning with the surface of bodies, is found to have an origin in line, which is the boundary of surface. We are not satisfied with this because we know that the line ends in the point, and the point is that than which nothing can be smaller. Therefore, the point is the first principle of geometry, and nothing in nature or the human mind can be the origin of the point."[12]

Additionally, Reti has noted that Leonardo's exercises in the transformation of solids into other solids of equal volume were carried out at the same time as his notes on the flight of birds. Reti, "Technologist", 26.

10 C.A. 167ra-b, *c.*1513 .

11 Interestingly and perhaps oddly, Leonardo himself does not think his work has anything to do with the preoccupations of the alchemists. In fact he is quite scornful of alchemy.

12 TP 1.

This comment refers to a central feature of Leonardo's geometrical understanding, namely the generative potential of a moving point. Stirred into activity the point, the smallest of all quantities, is that which generates lines, plane surfaces and indeed all physical bodies. In Leonardo's conception, while the point is the procreator, or seed, of all other material things, it itself is immaterial. He maintains that the point inhabits space but it itself does not take up any space.[13] The point is therefore wholly present and emanating its activating potency, and yet it is immaterial (*spirituale*). Leonardo explains how a point participates in the matrix of time and space. He states:

> "A line is made by the movement of a point; a surface is made by the movement of a line which travels in straight lines; the point in time is to be compared to an instant, and the line represents time with a length"[14]

Leonardo makes a distinction between a mathematical point, which is immaterial, and a mechanical point, which is the instantiation of mathematics in the physical world.[15]

Leonardo's analogical thought was continually occupied by the nature and effects of movement. In his articulation of the four powers (*potenze*) of nature, which underlie and activate the four elements, he asserts that weight, force and percussion are all produced by movement. In one passage he instructs himself to "[s]peak first of movement, then of weight because it originates from movement, then of force which arises from weight and movement, then of percussion which springs from weight, movement and often from force."[16] Movement comes into being from disequilibrium and is the cause of all change. Movement disturbs stillness, thereby both indicating and activating life. This disturbance is a constant condition of life for when everything is completely balanced there is *statis*, and in this stillness, there is perceptible a sort of death. Motion indicates that the world is alive, and in the case of self-movers such as humans and animals, it evidences the existence of a soul. The living body, then, is that which moves and it appears in the world through its actions. Movement is ultimately about transformation.

---

13 He states, "A point is in a place [*sito*] without occupation of that place [*sito*]..... the point does exist in nature; points are infinite. The point is mobile together with the place [*sito*] in which it resides. The movement of the point describes an inanimate [*insensibile*] line which in itself is divisible to infinity." C.A. 289ra. Cited in Keele, 84.

14 Arundel, 190v.

15 "Mechanics is the paradise of the mathematical sciences because by means of it one comes to the fruits of mathematics." MS. E. 8v. Cited in MacCurdy, 613.

16 C.A. 155vb. Cited in Keele, 99.

The passage on the proportions of the human body in Vitruvius' *Ten Books on Architecture*, influenced many architects of the Renaissance who drew various versions of the figure described. Vitruvius states:

> "Then again, in the human body the central point is naturally the navel. For if a man be placed flat on his back, with his hands and feet extended, and a pair of compasses centred at his navel, the fingers and toes of his two hands and feet will touch the circumference of a circle described therefrom. And just as the human body yields a circular outline, so too a square figure may be found from it. For if we measure the distance from the soles of the feet to the top of the head, and then apply that measure to the outstretched arms, the breadth will be found to be the same as the height, as in the case of plane surfaces which are perfectly square."[17]

Vitruvius' universal man represents the harmonious relationship between man and nature and the human body as the echo of divine harmony.[18] The Vitruvian figure inscribed in a circle and square is understood as the mathematical sympathy between the microcosm and the macrocosm. The proportions and relations of the body to the circle and the square have to do with a belief in the body's proper physical arrangement.[19] Leonardo's drawing of the Vitruvian Man, done in 1489, is a relatively early drawing for him, executed before the majority of his anatomical investigations. This drawing is of an improbability of the body; an ideal. It discloses an order within the human fabric that although imperfect, points in the direction of the regularity and perfection of the higher spheres. In complete accord with Renaissance notions about the centrality of the human being, the body, as the measure of all things, especially architecture stands in the centre of the world.

When man is inscribed in a circle, the centre of the circle coincides with the navel, and when man is inscribed in a square, the central point is shifted to the phallus. Both of these bodily regions are charged with generative potency. The navel is the permanent trace on each of our bodies that recalls our origins inside the body of our mother. It is our first and most lasting 'wound,' and it remains on our bodies in the form of a small, lumpy, imperfect circle. Whereas the navel marks our passive role in the generative process, the phallus is charged with an active potency. These two faces of generation, the capacity to make and the condition of being made, are not only physically a part of us but are central to our mortality. In this drawing, Leonardo maps how through its pre-

---

17 Pollio Vitruvius, *The Ten Books on Architecture*, trans. Morris Hicky Morgan, 1914 (New York: Dover Publications, Inc., 1960) Book 3, Ch.1, 72-3.

18 Norman Crowe, *Nature and the Idea of a Man-made World; an Investigation into the Evolutionary Roots of Form and Order in the Built Environment*, 1995 (Cambridge, MA; London: The MIT Press, 1997) 94.

19 Rudolf Wittkower, *Architectural Principles of the Age of Humanism*, 1949 (New York: W. W. Norton & Company

given physical arrangement and its movements as a living thing, the human body *generates* geometrical shapes.

In addition to the circle and square, Leonardo's Vitruvian man reveals another aspect of generative potency for in the movement of the man's legs from closed position to open, there results a third shape: the triangle.[20] The circle, square and triangle are the basic and eternal constituents of geometry. At the same time, these fleeting shapes which are manifested as invisible formulations of the body in motion are frozen on the page, availing themselves to our perception and appreciation.[21] In his Vitruvian figure is the crystallization of co-presence and interpenetration of the human realm (the living, moving mortal body) with that of the abstract ideal of geometry. This image demonstrates how man is inscribed in the cosmological order of things and how the body as a whole, not a kit of parts, in motion creates basic geometry.[22] The fact that the human body is rendered as the measure and generator of the geometrical traces implies that we participate in the world order that encircles us. An extension of this is to say that man, through his movements or actions, effects change and therefore, is endowed with a generative potency that transcends his capacity to procreate.

Figure 67: Vitruvian Man (Canon of Proportions), Galleria dell'Accademia, Venice.

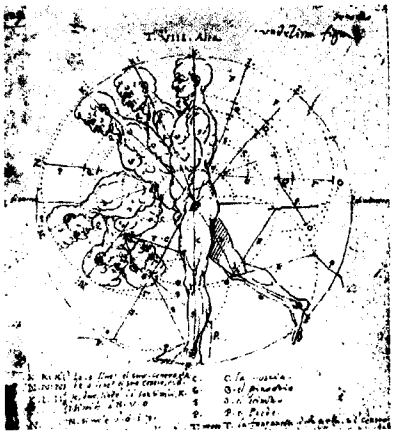


Figure 68: Rotation of the body around the hip joint. (Codex Huygens, folio 29, figure 13)

Inc., 1971) 15.

[20] Leonardo states: "If you set your legs so far apart as to take a fourteenth part from your height, and you open and raise your arms until you touch the line of the crown of the head with your middle fingers, you must know that the centre of the circle formed by the extremities of the outstretched limbs will be the navel, and the space between he legs will form an equilateral triangle." Venice Academy. Cited in MacCurdy, 213.

[21] Joseph Rykwert observes that "Leonardo show his figure-in-the-square man ruled by five equilateral triangles, a pentagon, and an octagon, whereas the figure in the circle [...] is also enclosed in a hexagon." Joseph Rykwert, *The Dancing Column; on Order in Architecture* (Cambridge, MA; London: The MIT Press, 1996) 90. The 'ideal man' defined by the Canon of Proportions generates ideal surfaces. See Hersey, 99.

[22] Regarding the cosmological inscription of the human body it is relevant to cite a portion of Leonardo's description of the order of his intended book on anatomy. He writes: "Therefore there shall be revealed to you in fifteen entire figures the cosmography of the 'minor mondo' in the same order as was used by Ptolemy before me in his Cosmography. And therefore I shall divide the members as he divided the whole, into provinces, and then I shall define the functions of the parts in every direction, placing before your eyes the perception of the whole figure and capacity of man in so far as it has local movement by means of its parts." Cited in MacCurdy, 161.

The rich significations implicit in the basic geometrical shapes, and the body's inscriptions within them, of course had a profound impact on architecture. It was generally agreed by the architects of the Italian Renaissance, particularly, Alberti, Filarete, and Francesco di Giorgio, that a centralized design yields the most beautiful form for religious edifices because the circle is a shape imbued with total unity. Although centralized designs for churches were not adopted in practice as much as the longitudinal basilica plan, it was still upheld as the most perfect form.[23]

Figure 69: Church: view and plan. (MS. B. 22r – detail)

Leonardo did many designs for centralized churches, likely for an intended mausoleum for the Sforza family. Leonardo's numerous drawings of plans and aerial perspectives for centralized churches are based on a circular plan, invariably with a square superimposed. One always inscribes the other, and smaller circles within the larger body of the building (the apses) form a ring that, at a different scale, closely resembles Leonardo's drawings of ball bearings. When ball bearings are used in a mechanical device they reduce friction, thereby enabling movement.[24] The aerial views of these temples show a proliferation of domes. These churches in all of their roundness seem imbued with a capacity to roll. Thus there is more than a formal coincidence between the mechanical component of ball bearings and Leonardo's plans for centralized churches. What they both beyond formal similarity is the movement contained in roundness. The secular and the sacred, the mechanical and the cosmological are all brought together through analogical thought. Analogy is (pro)creative: its fertile potential operates within the personal imagination bringing seemingly incompatible elements into close communion.

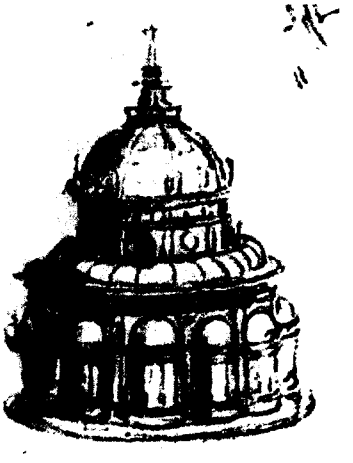


Figure 70: Church with twelve apses (MS. B. 56v – detail)

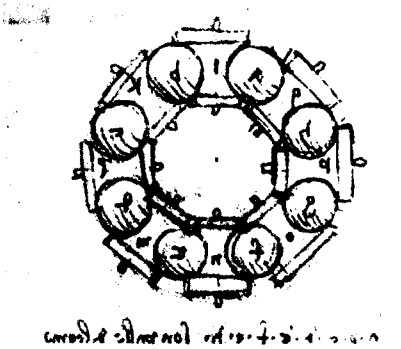


Figure 71: Ball-bearings (Madrid I 20v – detail)

---

23 Kemp, 109.

24 Leonardo considered the roller bearings to be the "marvels of mechanical genius." MS. I. 57v.

Another mechanical instance of the agile capacity for movement inherent in roundness, is found in his studies of the universal joint which allows for the greatest amount of movement in multiple planes. Being a ball in a socket, this type of joint has the advantage of being low in friction. This mechanical feature appears also in the human body as the ball and socket joints of the shoulder and hip. Here the connection between mechanical components of and body is obvious. They are both animate and they are designed in a manner that permits fexibility and fluid movement. In the same line of thought that Leonardo saw pulleys and levers in the musculature and tendons of the body, he also must have appreciated this parallel.

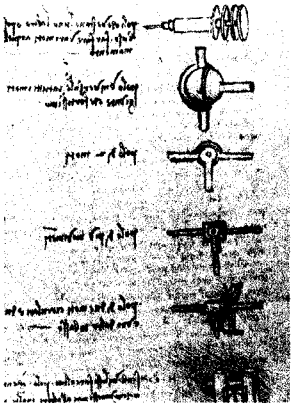


Figure 72: The universal joint (Madrid I 100v)

Figure 73: Arm joints. *c.* 1510 (W 19000v; K/P 135v)

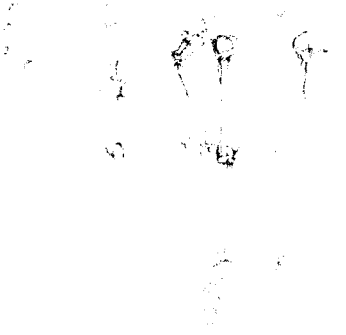


Figure 74: Joints in the thumb, elbow and shoulder. Aliki Economides.
This drawing is based on Leonardo's studies of the arm joints in folios W 19000v and W 19004r.

Leonardo also explores movement when he observes (and recreates) intense transformations such as those emotional fluctuations captured in and expressed through the human body in facial expressions and bodily gestures and postures. Emotion is one of the attributes of the soul. Its expression (i.e., the way it spreads though the body of the person in gesture and across the face) is one of the types of movement identified by Leonardo. Thus emotion is one manifestation of the four powers that affect everything in the world. Leonardo observes: "Emotions move the face of man in different ways, for one laughs, another weeps, one becomes gay, another sad, one shows anger, another pity, some are amazed, others are afraid, distracted, thoughtful or reflective. In these states the hands and the whole person should follow the expression of the face."[25] It is the movement of the body that makes apparent the movement of the soul.[26]

---

25 TP 419.

26 Summers, *JS*, 110.

In his mural of *The Last Supper,* the apostles are gesticulating against Christ's statement that one of them shall betray him. The devastating statement has fallen from the lips of Christ and what has been captured in the painting is the charged moment where we feel, as the apostles do, the impact of His words. The words are dropped into the company from the central figure of Christ and their impact spreads out in waves, affecting each of the apostles differently. The inner (invisible) sentiments of the apostles appear as external (visible) expressions. We are porous entities, constantly drawing the world inside us and projecting back outward. Humans respond instantly to the weight of words. The shock has produced a momentary stillness, but even this moment of pause is fraught with kinetic energy. In this painting the tensions created as a result of the statement of betrayal are seen in the posture, gestures of hands and facial expressions of the twelve apostles.[27] In this painted scene, Leonardo captures both the frozen instant of shock and the unfolding causal wave of resonances through each of the figures. His words are like a stone dropped in the placid surface of water.

Figure 75: Five Heads, *c.*1494 (W 12495r)

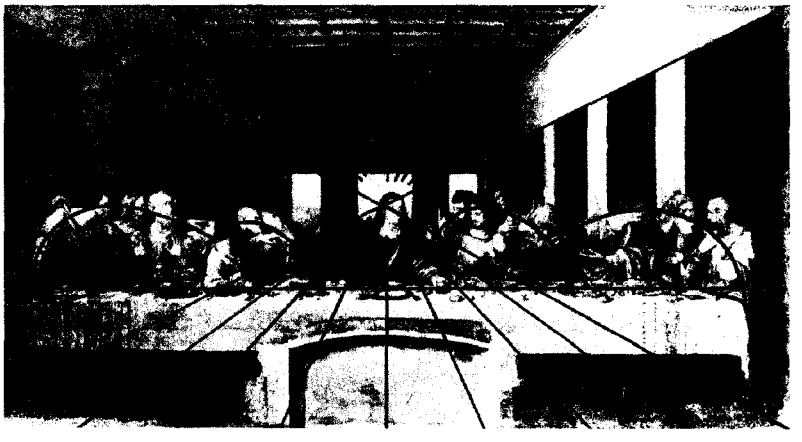


Figure 76: *The Last Supper* (with lines of perspective and waves of percussion). 1495-1498. Mural, Refectory, Santa Maria delle Grazie, Milan.

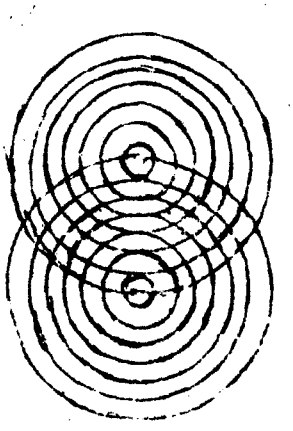


Figure 77: The spread of light in circular waves (MS. A. 61r)

Leonardo's interest in movement is not reserved only to the additive or positive aspects of transformation. He also contemplates the excess of motion, the frantic disequilibrium that leads to destruction, which is a form of creation but in the negative. In the series of 16 drawings that Leonardo did in the last years of his life, often referred to as the "Deluge" series, he depicts the

universe in the act of cataclysmic unwinding. This massive scale destruction comes about from an overabundance of the powers of nature.[28] In the drawings a sense of scale is lost, as is the horizon which adds to the disorientation. Distinctions between solid and void are obliterated and vortices of air and water are also filled with unidentifiable matter.[29] The intense collision of percussive forces creates new vortices and these waves arch and curl back on themselves. Gombrich has noted that the collapse is not simple or straightforward but orgiastic.[30] At the scale of this cosmic disaster, humans are so dwarfed by the powers of nature, that they are not even present in the unfolding drama. Human smallness is already subsumed by the larger (dis)order, rendering human affairs insignificant, if existent at all. This is a marked contrast from the centrality and potency of the Vitruvian figure.

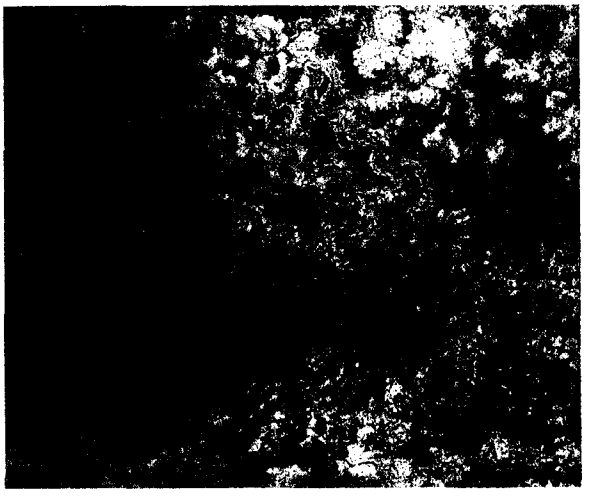


Figure 78: 'Deluge'. *c.* 1512-16 (W 12384)

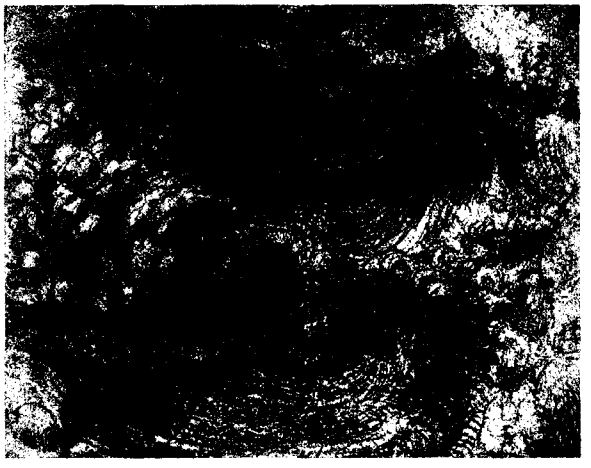


Figure 79: 'Deluge'. *c.* 1512-16 (W 12378)

His drawings and paintings display the workings of the elements and the plenitude of the universe's phenomena. Leonardo's skill is such that he is able to represent the atmosphere surrounding the 'facts' of his discoveries. His work therefore captures space in all of its qualitative impact. The death that is palpable in his "Deluge" series is a cataclysm arising from an overabundance of motion, force, weight and percussion. That is, a super-saturation of the same powers that signal and animate life. Too much life causes its own breed of imbalance, havoc. Hence we arrive at the backward turning

---

27 Turner, 194.

28 It is generally agreed that the series of 16 drawings "of unleashed and torrential energy" were done towards the end of his life. Turner, 227.

29 Ibid., 227.

30 Gombrich, 53.

of the elements towards their own undoing. Leonardo considers the cycle of generation and destruction -the continual and necessarily reciprocal dance of life and death – at the scale of the body and at the scale of the world. Transformation is a movement in which things come from and return to each other, but not identically. The weave of time and space (and everything that is contained in them) does not move in a circle perpetually identical to itself, re-inscribing in identical fashion that which came before. Instead, movement is a spiral that hosts transformation and retains sameness while pushing through the thickness of matter and allowing for differences.

The power of transformation is one that makes and unmakes. Creation and destruction, births and deaths, are all part of the fluid continuum of existence. Without one, the other could not be possible, and so they cooperate, *dance*, keeping each other in balance and therefore perpetually making and unmaking anew. Generation, destruction and re-generation, is the cycle (indeed the circle) that draws into it all the processes that we, as embodied mortals experience and witness in the world around us. Everything comes from and returns to everything. This is the way of all flesh.

Conclusion

The weave of connections and correspondences within Leonardo's body of work is kaleidoscopic and vast. Through this thesis I have endeavoured to illuminate some key issues that I feel are essential to embarking on an understanding of his life-long investigations. I have taken as my point of departure what I perceive to be his fundamental framework of analogical thought, in order to expose the underlying coherence that is present within his multifaceted research. Through this approach I seek to examine our inheritance of Leonardo's work in an appropriate way. While a comprehensive overview of his studies and research is not possible within the scope of this thesis, the vision of Leonardo presented here attempts to be a unified and unifying one.

Analogy, used as Leonardo uses it, does not flatten meanings into a facile equation of 'this equals that', which presumes that relationships cannot be construed otherwise. Rather, it opens up the possibility for uncovering veiled potential and insightful adjacencies. In so doing, instead of seeking to close things off into meanings that are rigidly fixed, analogical thought retains an openness to continual interpretation. Leonardo was deeply interested in the world around him, and in his voracious probing of the underlying causes that effect the phenomena of the world, he was truly a student of Nature.[1] However, as endearing as his fascination and perseverance is, Leonardo's animistic understanding of the cosmos and his particular analogical mode of inquiry, rooted in a mimetic imagination, is not an 'option' that can be recovered in post-modern culture. While I am in no means advocating a nostalgic return to the Renaissance world-view, I do think that where Leonardo's approach to the world and to making is informative for the present day, is in exposing a critical strategy that reveals a different approach to the cultivation of knowledge. While we are not wonder-struck by the same things that Leonardo was, a state of wonderment is an attentive fascination that entails being open and receptive to the world, and therefore is essential for the discovery of meaning.

Since analogy helps us to think laterally, it affords a means for beginning to overcome the negativity of our own present-day scientistic categories, that tend to establish boundaries, demystify phenomena and hinder the flow of wonder. Analogy thus identifies in things their similarities in meaning and essence and makes its focus the aspects that connect things to each

1 I refer to Leonardo as a 'student' in the sense of its original derivation from the Latin verb *studere*, which means "to be eager, zealous, passionately devoted (to something)."

other and to the world around them. It emphasizes what things have in common, and places less stock in the differences that hold them apart. The very mind-set that embraces and participates in this sort of speculation which resists definitive closure, is ultimately one of inclusiveness and acceptance because it is receptive to seeing the self, connected to the other. This gesturing towards the other grounds the possibility for a deeply ethical stance, and orients a more insightful awareness of what is at stake in the act of making. One aspect of this ethical stance is the resistance to positing an opposition between nature and culture, and instead to focus on how human culture participates in and is informed by the more-than-human order.

The paradox of the Renaissance, is that while the centrality of man and the belief in the power of humans to effect change was brought to the fore, it did not come at the expense of a profound respect for nature. On the contrary, the Renaissance sought to model all of its works on her perfection. Thus, the advancement of knowledge for Leonardo is not about controlling the world, but about aligning oneself with its processes. His inventiveness is tempered by a deeply ingrained respect for the world and is not fueled by any breed of opportunism to exploit its contents as 'standing reserve.' However, for all of its inspiring self-empowerment, the centrality of human affairs heralded in by the Renaissance, also marks the beginning of profound changes that have lead humanity to an almost absolute occupation of the 'centre' whereby everything is explained from this standpoint. In a sense, humanity has created his own blind spot and has banished out of view and out of its immediate concern, what does not fit into the picture it imposes on the world.

Through a close examination of Leonardo's connectedness to the world *through* his work, there is a deeper insight to be gained about what we have lost and the breaches in connection that we perpetuate and reinforce in our current modes of being and working. For all of the 'advances' and comforts technology has afforded us, our emancipation has come at the price of our self-estrangement, which is based on our ever-increasing lack of integration with the world that sustains us, despite our ever-expanding claims to scientifically verifiable knowledge.[2] Unlike Leonardo, we have journeyed far enough to have unlearned how to truly see.[3]

---

2 Gadamer,139-150.

3 In the words of Merleau-Ponty, "Synaesthetic perception is the rule, and we are unaware of it only because scientific knowledge shifts the centre of gravity of experience, so that we have unlearned how to see, hear, and generally speaking, feel, in order to deduce, from our bodily organization and the world as the physicist conceives it, what we are to see, hear and feel." *Phenomenology of Perception,* 229.

The centrality of man in the Renaissance was clearly articulated through thoughts about, and the status given to, the human body. The body is a basic if not essential component of Leonardo's analogical search of the world. It is the familiar and mysterious hinge that allows him to join thought to the more-than-human realm. Due to the fact that we cannot have an experience or even think of anything without our bodies, the body as something that readily avails itself to study and to comparison, accommodates and relates to all scales of phenomena. Through the body as metaphorical vehicle, seemingly disparate phenomena can be brought together in a unity of understanding. As was true for Leonardo, our embodiment offers itself as a locus of understanding of all other things in the world that surround us. Exploring what our embodiment offers to our appreciation of the world is inherently meaningful today, especially when brought to bear on architecture.[4]

In light of the fact that Leonardo's work was not published in his time, it has been suggested by scholars that the potential for his work to influence his contemporaries and therefore to directly contribute to the so-called "linear march of progress" was greatly thwarted. Nevertheless, his contributions to graphic representation of the human body not only unknowingly anticipated the modes of architectural representation and ideation adopted later, but have become mainstays of the discipline. The drawing conventions he invented specifically to be able to access, understand and communicate what he found in the world, serve to remind us in part of the underlying affinity between the human body and human works. Leonardo's contribution to architecture is both important and extensive, despite the fact that the most significant aspects of his contribution have not come down to us in the form of buildings. Through the body research that he built up through drawing, Leonardo's fascination and inquisitive search of nature reveals much about his world and our own.

---

4 It is of crucial significance for architecture to engage the corporeal and not merely reduce itself to an objectified image; a photogenic commodity. David Abram illuminates the important role played by the body in our current condition of technological dependence. Without explicitly naming the questions and issues that are specifically relevant to architecture, his comments are wholly pertinent to this discussion. He states that "[w]e need to know the textures, the rhythms and tastes of the *bodily world*, and to distinguish readily between such tastes and those of our own invention. Direct sensuous reality, in all its more-than-human mystery, remains the sole solid touchstone for an experiential world now inundated with electronically-generated vistas and engineered pleasures; only in regular contact with the tangible ground and sky can we learn how to orient and to navigate in the multiple dimensions that now claim us." Abram, x.

List of Illustrations

All works cited are by Leonardo da Vinci unless otherwise noted.

Figure 14: Identity. 2002 (ink on paper)
Aliki Economides

Figure 15: Landscape. 1473. (Galleria degli Uffizi, Firenze)
Reproduced in Beck, *Italian Renaissance Painting*, c. 1981 (Köln: Könemann, 1999) fig. 266, p.317.

Figure 16: Trees (W 12431r)
Reproduced in Reti, ed., *The Unknown Leonardo* (New York; Toronto: McGraw-Hill Book Company, 1974) fig. 1, p. 287.

Figure 17: Profile of contemplative man and studies of water moving around an obstacle, *c.* 1513. (W12579r)
Reproduced in *Leonardo da Vinci, Engineer and Architect* (Montreal: Montreal Museum of Fine Arts, c. 1987), Pl. XIII.

Figure 18: Storm breaking over a town in the Alpine valley. (W 12409)
Reproduced in Reti, ed., *The Unknown Leonardo* (New York; Toronto: McGraw-Hill Book Company, 1974) p. 148.

Figure 19: The skull: lateral views, *c.* 1489. (W 19057v)
Reproduced in Leonardo da Vinci, *Leonardo on the Human Body*, p. 47.

Figure 20: The skull: interior view, *c.* 1489. (W 19058r)
Reproduced in Leonardo da Vinci, *Leonardo on the Human Body*, p. 51.

Figure 21: The lower extremity: bones of the foot, *c.* 1510. (W 19011r)
Reproduced in Leonardo da Vinci, *Leonardo on the Human Body*, p. 63.

Figure 22: Female torso with internal organs, or 'Transparent Woman', *c.* 1510. (W 12281r)
Reproduced in *The Art of Invention; Leonardo and Renaissance Engineers*, p. 226.

Figure 23: Coition, *c.* 1510. (W 19097v - detail)
Reproduced in Leonardo da Vinci, *Leonardo on the Human Body*, p. 461.

Figure 24: Diagrams of building with a centralized plan. (C.A. 1010v / 362v-b)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 197, p. 203.

Figure 25: Interior views of a cross-shaped church. (C.A. 104r / 37r-a – detail)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 255, p. 235.

Figure 26: Study of the superficial anatomy of the foot and lower leg. 1510. (W 19017r)
Reproduced in Kemp, *Leonardo da Vinci. The Marvellous Works of Nature and Man*, pl. 79, p. 287.

Figure 27: Quadruple staircase in the middle of a square tower (MS. B. 47r)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 304, p. 263.

Figure 28: X-shaped staircase (MS. B. 68v – detail)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 302, p. 262.

Figure 29: Myology of the shoulder region: exploded views, *c.* 1510-13. (W 19001r)
Reproduced in Leonardo da Vinci, *Leonardo on the Human Body*, p. 141.

Figure 30: General and exploded view of a hoist (C.A. 30v / 8 v-b)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 103, p. 100.

Figure 31: Skull as onion: central nervous system and cranial nerves, *c.* 1490. (W 12603r)
Reproduced in Leonardo da Vinci, *Leonardo on the Human Body*, p. 331.

Figure 32: Studies of the spinal column as mast, *c.* 1513. (W 19075v)
Reproduced in *The Art of Invention; Leonardo and Renaissance Engineers*, fig.III.3.I, p. 231.

Figure 33: Myology of trunk: spine and ship's mast, schematic detail, *c.* 1510. (W 19015v -detail)
Reproduced in Leonardo da Vinci, *Leonardo on the Human Body*, p. 75.

Figure 34: The heart likened to a seed or nut producing roots and branches. (W 19028r; K/P 70r)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig. 15.4, p. 302.

Figure 35: Studies on the growth of plants, *c.* 1495-1500. (MS. M. 78v – 79r)
Reproduced in *The Art of Invention; Leonardo and Renaissance Engineers*, fig.III.1.m, p. 190.

Figure 36: Cardiovascular system: veins of young and old, *c.* 1504-6. (W 19027r)
Reproduced in Leonardo da Vinci, *Leonardo on the Human Body*, p. 299.

Figure 37: Studies of hydrodynamic turbulence, *c.* 1508-9. (W 12660v)
Reproduced in *The Art of Invention; Leonardo and Renaissance Engineers*, p. 236.

Figure 38: Study for the Star of Bethlehem (Omithogalum umbellatum) and other plants, *c.* 1506. (W 12424)
Reproduced in Kemp, *Leonardo da Vinci. The Marvellous Works of Nature and Man*, pl. 74, p. 274.

Figure 39: Study of coiffure for *Leda*, *c.* 1507-8. (W 12516)
Reproduced in Kemp, *Leonardo da Vinci. The Marvellous Works of Nature and Man*, pl. 75, p. 276.

Figure 40: The movement of flowing water around obstacles. (W 12660r)
Reproduced in Reti, ed., *The Unknown Leonardo*, p. 192.

Figure 41: Shapes of fish and boats. 1510-15. (MS. G. 50v)
Reproduced in Gombrich, *The Heritage of Apelles; Studies in the Art of the Renaissance*, fig. 101.

Figure 42: The centre of gravity of a bird. (Sul. Vol. 15v – detail)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig 4.19b, p. 107.

Figure 43: The course of birds in rising flight. (C.A. 308 r-b)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig 6.35, p. 190.

Figure 44: Eddies and bending of the wing-tips in a flying bird. 1513-14. (MS. E. 47v – detail)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig 6.37a, p. 191.

Figure 45: The moving parts of the butterfly, dragonfly, bat and flying fish. (MS. B. 100v)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig. 6.14, p. 173.

Figure 46: Armature for the wing of the flying machine, the Great Bird. (MS. B. 74r)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 149, p. 140.

Figure 47: Studies of fury in man and animals for the *Battle of Anghiari*. 1503-4. (W 12326r – detail)
Reproduced in Gombrich, *The Heritage of Apelles; Studies in the Art of the Renaissance*, fig. 117.

Figure 48: Myology of upper extremity: leverage in man and monkey. *c.* 1504-6. (W 19026v – detail)
Reproduced in Leonardo da Vinci, *Leonardo on the Human Body*, p. 151.

Figure 49: The superficial muscles of the leg: comparison of the leg of a man with that of a horse (W 12625r)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig. 13.14, p. 283.

Figure 50: Comparative anatomy: the foot of a bear on the left leg of a human. *c.* 1490-3. (W 12372r)
Reproduced in Leonardo da Vinci, *Leonardo on the Human Body*, p. 205.

Figure 51: Genito-urinary system: homologies of male and female generative organs. *c.* 1503. (W 19095v)
Reproduced in Leonardo da Vinci, *Leonardo on the Human Body*, p. 455.

Figure 52: Anatomical drawing of network of veins and staircases. (W 12592r)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, pl. XXI.

Figure 53: Study for an urban development project in Milan. (MS. B 16r – detail)
Reproduced in *The Art of Invention; Leonardo and Renaissance Engineers*, fig. 59, p. 62.

Figure 54: Double newel staircase (MS. B. 69r – detail)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 303, p. 263.

Figure 55: Ten spiral staircases around a tower (MS. B. 47v – detail)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 307, p. 263.

Figure 56: Milan Cathedral: section of the crossing piers and projection of a double dome above. (C.A. 850r / 310r-b)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 207, p. 212.

Figure 57: The proportions of the human head based on the triangle.
From Luca Pacioli's *Divina Proportione*.
Reproduced in Pérez-Gómez, "The Glass Architecture of Fra Luca Pacioli", fig. 19, p. 176.

Figure 58: Proportional head. *c.* 1488. (W 12601 – detail)
Reproduced in Gombrich, *The Heritage of Apelles; Studies in the Art of the Renaissance*, fig. 176.

Figure 59: Studies of the skull. (W 19057r; K/P 43v)
Reproduced in *The Art of Invention; Leonardo and Renaissance Engineers*, fig. III.3.q², p. 233.

Figure 60: Studies of the heart (of an ox or bull?). 1513-14. (W 19073v-4v)
Reproduced in Kemp, *Leonardo da Vinci. The Marvellous Works of Nature and Man.*

Figure 61: The cusps of the aortic pulmonary valve. (W 19079v; K/P 169v)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig. 15.18, p.315.

Figure 62: Transformation of solid rectilinear pyramids into curved pyramids and other forms. (Madrid II 107r)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig. 5.21, p. 148.

Figure 63: Geometrical studies of squaring the circle. *c.* 1509. (W 12700v – detail)
Reproduced in Kemp, *Leonardo da Vinci. The Marvellous Works of Nature and Man*, pl. 77, p. 282.

Figure 64: Transformation of a rectilinear triangle into a falcate. (Madrid II 111v)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig. 5.20, p. 146.

Figure 65: Mathematical proportion of twelve concentric circles. (C.A. 221v-b)
Reproduced in Reti, ed., *The Unknown Leonardo*, fig. 3, p. 77.

Figure 66: An exercise in geometrical transformations. (C.A. 167r-ab)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig. 5.34, p. 157.

Figure 67: Vitruvian Man (Canon of Proportions), Galleria dell'Accademia, Venice.
Reproduced in Millon and Lampugnani, eds., *The Renaissance from Brunelleschi to Michelangelo; the Representation of Architecture*, p. 306.

Figure 68: Rotation of the body around the hip joint. (Codex Huygens, folio 29, figure 13)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig. 12.14, p. 264.

Figure 69: Church: view and plan. (MS. B. 22r – detail)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 239, p. 230.

Figure 70: Church with twelve apses (MS. B. 56v – detail)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 262, p. 238.

Figure 71: Ball-bearings (Madrid I 20v – detail)
Reproduced in *Leonardo da Vinci, Engineer and Architect*, fig. 199, p. 205.

Figure 72: The universal joint (Madrid I 100v)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig. 4.16, p.104.

Figure 73: Arm joints. *c.* 1510. (W 19000v; K/P 135v)
Reproduced in *The Art of Invention; Leonardo and Renaissance Engineers*, fig. III.3.b, p. 227.

Figure 74: Joints in the thumb, elbow and shoulder. 1999 (graphite on paper, panel detail)
Aliki Economides.

Figure 75: Five Heads, *c.* 1494. (W 12495r)
Reproduced in Gombrich, *The Heritage of Apelles; Studies in the Art of the Renaissance*, fig. 183.

Figure 76: *The Last Supper* (with lines of perspective and waves of percussion). 1495-1498. Mural, Refectory, Santa Maria delle Grazie, Milan.
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, p. 24.

Figure 77: The spread of light in circular waves (MS. A. 61r)
Reproduced in Keele, *Leonardo da Vinci's Elements of the Science of Man*, fig. 2.18, p. 58.

Figure 78: 'Deluge'. *c.* 1512-16. (W 12384)
Reproduced in Gombrich, *The Heritage of Apelles; Studies in the Art of the Renaissance*, fig. 83.

Figure 79: 'Deluge'. *c.* 1512-16. (W 12378)
Reproduced in Gombrich, *The Heritage of Apelles; Studies in the Art of the Renaissance*, fig. 107.

Bibliography

Primary Sources:

Alberti, Leon Battista. *On the Art of Building in Ten Books*. Trans. Joseph Rykwert, Neil Leach, Robert Tavernor. Cambridge, MA; London: The MIT Press, 1994.

Artistotle. *The Complete Works of Aristotle: the revised Oxford translation*. 2 vols. Ed. Jonathan Barnes. Princeton, NJ: Princeton University Press, 1984.

Leonardo da Vinci. *Leonardo on the Human Body.* Trans. C. O'Malley and J. B. de C. M. Saunders. 1952. New York: Dover Publications, 1983.

_____. *The Notebooks of Leonardo da Vinci.* Trans. Edward MacCurdy. New York: Reynal & Hitchcock, 1939.

_____. *The Notebooks of Leonardo da Vinci.* 2 vols. Ed. Jean Paul Richter. 1883. New York: Dover Publications, 1970.

_____. *Treatise on Painting (Codex Urbinas Latinas 1270).* Trans. and Ed. A. Philip McMahon. vol. 1. Princeton: Princeton University Press, 1956.

Martini, Francesco di Giorgio. *Trattati di Architettura Ingegneria e Arte Militare*. 2 vols. Ed. and transcribed by Corrado Maltese and L. Maltese Degrassi. Milano: Il Polifilo, 1967.

Pacioli, Luca. *Divine Proportione.* Paris: Librairies du Campagnonnage, 1980.

Plato. *Theatetus*. Trans. Robin Waterfield. London: Penguin Books, 1987.

_____. *Timaeus and Critias*. Trans. Desmond Lee. 1965. London: Penguin Books Ltd., 1977.

Vitruvius, Pollio. *The Ten Books of Architecture*. Trans. Morris Hicky Morgan. 1914. New York: Dover Publications, Inc., 1960.

Secondary Sources:

Abram, David. *The Spell of the Sensuous; perception and language in a more-than-human world.* 1996. New York: Vintage Books, 1997.

Ackerman, James. "*Ars Sine Scientia Nihil Est*; Gothic Theory of Architecture at the Cathedral of Milan." *The Art Bulletin* 31 (1949): 84-111.

_____. "Leonardo da Vinci: Art in Science." *Daedalus; Journal of the American Academy of Arts and Sciences* 127.1 (1998): 207-224.

Bachelard, Gaston. *The Poetics of Reverie; Childhood, Language and the Cosmos*. Trans. Daniel Russel. 1960 (Boston: Beacon Press, 1971).

Barasch, Frances. *The Grotesque; A Study in Meanings.* The Hague; Paris: Mouton, 1971.

Barkan, Leonard. *Nature's Work of Art: The Human Body as Image of the World.* New Haven: Yale University Press, 1975.

Beasley, Gerald, ed. *Meditations on Piero: Sculptures by Geoffrey Smedley.* Montreal: Canadian Centre for Architecture, 2001.

Beck, James. *Italian Renaissance Painting.* c. 1981. Köln: Könemann, 1999.

Belt, Elmer. "Leonardo the Anatomist." *Logan Glendening Lectures on the History and Philosophy of Medicine.* Series 4 (1955). Kansas: University of Kansas Press, 1956.

Calder, Ritchie. *Leonardo and the Age of the Eye.* New York: Simon and Schuster, 1970.

Carson, Anne. *Eros the Bittersweet; an Essay.* Princeton; New Jersey: Princeton University Press, 1986.

Cassirer, Ernst. et al. ed. *The Renaissance Philosophy of Man.* 1948. Chicago: The University of Chicago Press, 1956.

Cassirer, Ernst. *The Individual and the Cosmos in Renaissance Philosophy.* Trans. Mario Domandi. New York: Harper & Row, Publishers, 1963.

Castiglioni, Arturo. *The Renaissance of Medicine in Italy.* Baltimore: The John Hopkins Press, 1934.

Chupin, Jean-Pierre. "Hermes' Laugh: Philibert de l'Orme's Imagery as a Case of Analogical Edification." *Chora 2: Intervals in the Philosophy of Architecture.* Alberto Pérez-Gómez and Stephen Parcell, eds. Montréal; Kingston: McGill-Queen's University Press, 1996. 37-68.

Clark, Kenneth. "On the Relation Between Leonardo's Science and his Art." *Leonardo da Vinci: Aspects of the Renaissance Genius.* Ed. Morris Philipson. New York: George Braziller, Inc., 1966. 209-221.

_____. *Leonardo da Vinci; an account of his development as an artist.* 1939. London: Viking, 1988.

Couliano, Ioan. *Eros and Magic in the Renaissance.* Trans. Margaret Cook. Chicago: The University of Chicago Press, 1987.

Crane, Gregory R., ed. *The Perseus Project.* <http://www.perseus.tufts.edu> last accessed March 2002.

Crowe, Norman. *Nature and the Idea of a Man-made World; an Investigation into the Evolutionary Roots of Form and Order in the Built Environment.* 1995. Cambridge, MA; London: The MIT Press, 1997.

Dampier, Sir William C. *A History of Science and its Relations with Philosophy and Religion.* 1929. Cambridge: Cambridge University Press, 1989.

Dannenfeldt, Karl H, ed. *The Renaissance: Basic Interpretations.* 1959. Lexington MA; Toronto: D.C. Heath and Company, 1974.

Daston, Lorraine and Katharine Park. *Wonders and the Order of Nature.* New York: Zone Books, 1998.

Del Maestro, Rolando, ed. *Leonardo da Vinci, the Search for the Soul Exhibition.* <http://www.mni.mcgill.ca/btrc/delmaestro/exhibitions/leoframe.html> last accessed March 2002.

De Santillana, Giorgio. "Man Without Letters." *Leonardo da Vinci: Aspects of the Renaissance Genius.* Ed. Morris Philipson. New York: George Braziller, Inc., 1966. 188-208.

Dunne, Carrin. "The Roots of Memory." *Spring* (1988): 113-128.

Field, J. V. and Frank James, eds. *Renaissance and Revolution; Humanists, Scholars, Craftsmen and Natural Philosophers in Early Modern Europe.* 1993. Cambridge: Cambridge University Press, 1997.

Fisher, Philip. *Wonder, the Rainbow, and the Aesthetics of Rare Experiences.* Cambridge, MA; London: Harvard University Press, 1998.

Frascari, Marco. "A Secret Semiotic Skiagraphy: the Corporeal Theatre of Meanings in Vincenzo Scamozzi's Idea of Architecture." *VIA II; Shadow; Journal of the Graduate School of Fine Arts University of Pennsylvania.* New York: Rizzoli International Publications Inc., 1990: 32-51.

_____. *Monsters of Architecture: Anthropomorphism in Architectural Theory.* Maryland: Rowman & Littlefield Publishers, Inc., 1991.

Foucault, Michel. *The Order of Things; an archaeology of the human sciences.* 1966. New York: Vintage Books, 1994.

Gadamer, Hans-Georg. *Reason in the Age of Science.* Trans. Frederick Lawrence. 1981. Cambridge, MA; London: The MIT Press, 1989.

Gimpel, Jean. *The Medieval Machine.* New York: Holt, Rinehart and Winston, 1976.

Goldstein, Thomas. *Dawn of Modern Science. From the Arabs to Leonardo da Vinci.* Boston: Houghton Mifflin Company, 1980.

Gombrich, E. H. *The Heritage of Apelles; Studies in the Art of the Renaissance.* Oxford: Phaidon Press Ltd., 1976.

Gray, Henry. *Anatomy, Descriptive and Surgical.* 1901. Philadelphia: Running Press, 1974.

Heath, Louise Robinson. *The Concept of Time.* Chicago: The University of Chicago Press, 1936.

Heidegger, Martin. *Poetry, Language, Thought.* Trans. Albert Hofstadter. 1971. New York: Harper & Row, Publishers, Inc.,1975.

_____. *Early Greek Thinking*. Trans. David Farrell Krell and Frank Capuzzi. 1975. San Francisco: Harper & Row, Publishers, Inc.,1984.

_____. *Basic Writings*. Ed. David Farrell Krell. 1977. San Francisco: Harper & Row, Publishers, Inc.,1993.

Héritier-Augé, Françoise. "Semen and Blood: Some Ancient Theories Concerning their Genesisand Relationship." Trans. Tina Jolas. *Fragments for a History of the Human Body; Part Three*. Eds. Michel Feher, Romana Naddaff and Nadia Tazi. 1989. New York: Zone, 1990. 158-175.

Hersey, George. *The Lost Meaning of Classical Architecture; Speculations on Ornament from Vitruvius to Venturi*. Cambridge: MIT Press, 1988.

_____. *Pythagorean Palaces; Magic and Architecture in the Italian Renaissance*. Ithaca; London: Cornell University Press, 1976.

Hillman, David and Carla Mazio, eds. *The Body in Parts; Fantasies of Corporeality in Early Modern Europe*. New York; London: Routledge, 1997.

Illich, Ivan. *H_2O and the Waters of Forgetfulness*. London: Marion Boyars Publishers, 1986.

Jammer, Max. *Concepts of Space; the History of Theories of Space in Physics*. 1954. New York: Dover Publications, Inc., 1993.

_____. *Concepts of Force; a Study in the Foundations of Dynamics*. 1957. Mineola, NY: Dover Publications, Inc., 1999.

_____. *Concepts of Mass in Classical and Modern Physics*. 1961. Mineola, NY: Dover Publications, Inc., 1997.

Jones, Caroline, and Peter Galison, eds. *Picturing Science Producing Art*. New York; London: Routledge, 1998.

Karvouni, Maria. "*Demas*: The Human Body as Tectonic Construct." *Chora 3: Intervals in the Philosophy of Architecture*. Alberto Pérez-Gómez and Stephen Parcell, eds. Montréal; Kingston: McGill-Queen's University Press, 1999. 103-124.

Kearney, Richard. *The Wake of Imagination; Toward a Postmodern Culture*. 1988. London: Routledge, 1994.

Keele, Kenneth D. *Leonardo da Vinci's Elements of the Science of Man*. New York; Toronto: Academic Press, 1983.

Kemp, Martin. "From *Mimesis* to *Fantasia*: the Quatrocento Vocabulary of Creation, Inspiration and Genius in the Visual Arts." *Viator* 8 (1977): 347-398.

_____. *Leonardo da Vinci. The Marvellous Works of Nature and Man*. Cambridge, MA: Harvard University Press, 1981.

Kidel, Mark and Susan Rowe-Leete. "Mapping the Body." *Fragments for a History of the Human Body; Part Three*. Eds. Michel Feher, Romana Naddaff and Nadia Tazi. 1989. New York: Zone, 1990. 448 –469.

Koyré, Alexandre. "The Beginnings of Modern Science." *Leonardo da Vinci: Aspects of the Renaissance Genius*. Ed. Morris Philipson. New York: George Braziller, Inc., 1966. 146-157.

_____. *From the Closed World to the Infinite Universe*. 1957. Baltimore: John Hopkins Press, 1968.

_____. *Metaphysics and Measurement, Essays in Scientific Revolution*. London: Chapman & Hall, 1968.

Laurenza, Domenico. *De Figura Umana; Fisiognomica, anatomia e arte in Leonardo*. Firenze: Leo S. Olschki, 2001.

Lawlor, Robert. *Sacred Geometry: philosophy and practice*. London: Thames & Hudson Ltd., 1982.

Leonardo da Vinci. New York: Reynal & Company, 1956.

Leonardo da Vinci, Engineer and Architect. Montreal: Montreal Museum of Fine Arts, c. 1987.

Lyons, Albert and R. J. Petrucelli. *Medicine, an Illustrated History*. 1978. New York: Abradale Press, Harry N. Abrams, Inc., Publishers, 1987.

Martin, Roger. *Fortune is a River: Leonardo da Vinci and Niccolò Machiavelli's Magnificent Dream to Change the Course of Florentine History*. New York: A Plume Book, Penguin Putnam Inc., 1999.

McKirahan, Richard, Jr. *Philosophy Before Socrates; an introduction with texts and commentary*. Indianapolis; Cambridge: Hackett Publishing Company, Inc., 1994.

Merleau-Ponty, Maurice. *The Phenomenology of Perception*. Trans. Colin Smith. 1962. London; New York: Routledge, 1996.

_____. *The Visible and the Invisible*. Trans. Alphonso Lingis. 1964. Evanston, IL: Northwestern University Press, 1968.

_____. *The Prose of the World*. Ed. Claude Lefort. Trans. John O'Neill. 1969. Evanston, IL: Northwestern University Press, 1973.

Millon, Henry and V. M. Lampugnani, eds. *The Renaissance from Brunelleschi to Michelangelo; the Representation of Architecture*. 1994. Milano: RCS Libri & Grandi Opere, 1997.

Murray, Peter. *The Architecture of the Italian Renaissance*. 1963. New York: Schocken Books, 1986.

Nietzsche, Friedrich. "On the Uses and Disadvantages of History for Life," *Untimely Meditations*. Trans. R. J. Hollingdale. 1874. Cambridge: Cambridge University Press, 1997.

Nuland, Sherwin. *Leonardo da Vinci*. New York: A Lipper/Viking book, 2000.

O'Connor, John J. and Edmund F Robertson. *The MacTutor History of Mathematics Archive.* School of Mathematics and Statistics, University of St Andrews, Scotland. <http://www.history.mcs.st-and.ac.uk/~history> last accessed March 2002.

Ong, Walter. *Orality and Literacy; the Technologizing of the Word.* London; New York: Methuen & Co., 1982.

Onians, Richard Broxton. *The Origins of European Thought about the Body, the Mind, the Soul, the World, Time, and Fate.* 1951. Cambridge: Cambridge University Press, 1988.

Pedretti, Carlo. *A Chronology of Leonardo da Vinci's Architectural Studies after 1500.* Genève: Librairie E. Droz, 1962.

_____ . *Leonardo; a Study in Chronology and Style.* 1973. New York, London: Johnson Reprint Corporation, 1982.

_____. *Leonardo, architect.* Trans. Sue Brill. 1981. New York: Rizzoli, 1985.

Pérez-Gómez, Alberto. *Architecture and the Crisis of Modern Science.* 1983. Cambridge, MA: The MIT Press, 1992.

_____. "Architecture as Science: Analogy or Disjunction?" *ANYPlace.* Ed. Cynthia Davidson. Cambridge: The MIT Press, 1995.

_____. "The Glass Architecture of Fra Luca Pacioli." *Architectura – Journal of the History of Architecture.* Karlsruhe, Germany: Institut für Baugeschichte der Universität, 1999.

Pérez-Gómez, Alberto and Louise Pelletier. *Architectural Representation and the Perspective Hinge.* Cambridge, MA: The MIT Press, 1997.

Pevsner, Nicholas. "The Term 'Architect' in the Middle Ages." *Speculum, A Journal of Mediaeval Studies* 17.4 (October 1942): 549-562.

Sarton, George. "Art and Science." *Leonardo da Vinci: Aspects of the Renaissance Genius.* Ed. Morris Philipson. New York: George Braziller, Inc., 1966. 158-187.

Reti, Ladislao and Bern Dibner. *Leonardo da Vinci Technologist; Three essays on some designs and projects of the Florentine master in adapting machinery and technology to the problems in art, industry and war.* Norwalk, Connecticut: Burndy Library, 1969.

Reti, Ladislao, ed. *The Unknown Leonardo.* New York; Toronto: McGraw-Hill Book Company, 1974.

Rossi, Paolo. *Philosophy, Technology and the Arts in the Early Modern Era.* Trans. Salvatore Attanasio. New York: Harper and Row, 1970.

Rykwert, Joseph. *The Dancing Column; on Order in Architecture.* Cambridge, MA; London: The MIT Press, 1996.

Sawday, Jonathan. *The Body Emblazoned; Dissection and the Human Body in Renaissance Culture.* 1995. London; New York: Routledge, 1996.

Scaglia, Gustina. "Drawings of Machines for Architecture from the Early Quattrocento in Italy." *Journal of the Society of Architectural Historians* 25.2 (1966): 90-114.

Schmitt, Charles and Quentin Skinner, et. al, eds. *Cambridge History of Renaissance Philosophy.* Cambridge: Cambridge University Press, 1988.

Siraisi, Nancy. *Medieval and Renaissance Medicine; an Introduction to Knowledge and Practice.* Chicago: The University of Chicago Press, 1990.

Sissa, Giulia. "Subtle Bodies." Trans. Janet Lloyd. *Fragments for a History of the Human Body; Part Three.* Eds. Michel Feher, Romana Naddaff and Nadia Tazi. 1989. New York: Zone, 1990. 132 –156.

Summers, David. *Michelangelo and the Language of Art.* Princeton, NJ: Princeton University Press, 1981.

_____. *The Judgement of Sense; Renaissance Naturalism and the Rise of Aesthetics.* Cambridge: Cambridge University Press, 1987.

The Art of Invention; Leonardo and Renaissance Engineers. Florence: Instituto e Museo di Storia della Scienza, Giunti, 1999.

The Ingenious Machine of Nature; Four Centuries of Art and Anatomy. Ottawa: National Gallery of Canada, 1996.

Thorndike, Lynn. *A History of Magic and Experimental Science; Volume V, The Sixteenth Century.* New York: Columbia University Press, 1941.

Timoshenko, Stephen. *History of Strength of Materials; with a brief account of the history of theory of elasticity and theory of structures.* 1953. New York: Dover Publications. Inc., 1983.

Turner, Richard. *Inventing Leonardo.* 1992. Berkeley; Los Angeles: University of California Press, 1994.

Tuzet, M. *Le Cosmos et L'Imagination.* Paris: Librairie Jose Corti, 1965.

Vallentin, Antonia. *Leonardo da Vinci, the Tragic Pursuit of Perfection.* Trans. E. W. Dickes. 1938. New York: Halcyon House, 1941.

Verhoeven, Corn. *The Philosophy of Wonder,* Trans. Mary Foran. New York: The Macmillan Company, 1972.

Willis, Daniel. *The Emerald City; and other essays on the architectural imagination.* New York: Princeton Architectural Press, 1999.

Wittkower, Rudolf. *Architectural Principles of the Age of Humanism.* 1949. New York: W. W. Norton & Company Inc., 1971.

Zubov. Vassili. *Leonardo da Vinci.* Trans. David Kraus. Cambridge, MA: Harvard University Press, 1968.