TECHNIQUE AND FORMAL EXPRESSION IN ARCHITECTURE

THEORY IN ARCHITECTURAL TECHNOLOGY FROM THE RENAISSANCE TO THE AGE OF REASON

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ABSTRACT

The thesis addresses the relationship between theory and practice in the production of architecture. Placed within an in-between condition, as determined by the dichotomy of theoretical constructs versus physical construction, the thesis is founded on the assumption that theory and practice are inherently connected and interdependent. Herein lies the intention to bridge theoretical and practical undertakings in establishing possible modes of relationship between thought and action within the making of architecture. Since architecture as an expression of human culture depends on the context of technical matters, architecture assumes a position in which thought and action converge. The interest in developing such connections represents the attempt to establish models conceived by individuals within different historical periods for the production of architecture. This framework, identified as the *structure of making* in architecture, determines possible or actual systems of relation between theory and practice. Theory, as determined by the order of conceptual thought, and practice, as made manifest by technical execution, permit to discern specific structures of interrelationship. These structures disclose the forms of correlative dependencies between thought and action and contribute to architecture in its formal manifestation.

The order inherent within the relation between theory and practice is made visible and expressed in two distinct areas of architectural production. The first is that of the specific techniques, methods and procedures engaged in the processes of making. The second is constituted by the formal expression of the architectural product. Both form and technique reflect in their relationship the dichotomy between product and process. During the course of history different emphases have been given to formal and technical considerations; Renaissance theory gave priority to form, while within the Enlightenment greater attention was given to questions of technique. Such differing positions disclose the order between thought and action as perceived within different historical periods. Form and technique physically expose the relation between theory and practice. Ultimately, the analysis of systems of relation in the production of architecture constitutes a theoretical approach towards the formulation of a theory of architectural technology.

The early modern era, defined within the field of philosophy as the phase from the Renaissance to the Age of Reason, has been chosen as the specific field of analysis. This period was marked by the gradual introduction of modern science into the system of human knowledge. This thesis stems from the development of technology as a science. Although technical activity originates from the earliest periods of human evolution, the formalization of a generalized structure for establishing a framework of technological undertaking is at base a phenomenon of the modern era. The beginning of this period, that being the sixteenth and seventeenth centuries, is marked by an increasingly rational approach to thought which dominated science, philosophy, and human action in general. From such a perspective, technology was viewed as a body of knowledge which constituted an overall framework for the understanding of technical matters. In addressing the realm of ideas and conceptions of technology, this thesis is in essence based on the foundations of the modern era in structuring *technology* as a system of knowledge. Technology, in this sense, provides models of thought addressing the relation between theory and practice and is of significance for establishing an understanding of contemporary architectural technology.

TECHNIK UND FORM IN DER ARCHITEKTUR

THEORIE DER TECHNOLOGIE IN DER ARCHITEKTUR VON DER RENAISSANCE BIS ZUR AUFKLÄRUNG

KURZFASSUNG

Die Arbeit behandelt das Verhältnis zwischen Theorie und Praxis in der Architektur. Da Architektur sich sowohl im theoretischen Konzept wie auch im gebauten Raum manifestiert, basiert die Arbeit auf der Annahme einer engen Beziehung und einer sich gegenseitig bedingenden Abhängigkeit von Theorie und Praxis. Die Arbeit beabsichtigt Idee und Realisierung in der Architektur miteinander zu verknüpfen, indem mögliche Formen von Theorie-Praxis-Beziehungen untersucht werden. Um eine Verbindung herzustellen wird der Versuch unternommen, theoretische Modelle aus unterschiedlichen Zeitabschnitten der Architekturgeschichte nachzuweisen. Die Auseinandersetzung mit solchen Modellen erlaubt einerseits die möglichen oder tatsächlichen Beziehungen zwischen Theorie und Praxis zu bestimmen und trägt andererseits zum Verständnis des formalen Ausdrucks der Architektur bei.

Die Untersuchung der Beziehung zwischen Theorie und Praxis weist auf zwei charakteristische Formen der Architekturproduktion hin. Die erste ergibt sich aus den spezifischen Techniken, Methoden und Arbeitsabläufen, welche den Realisierungsprozess der Architektur bestimmen. Die zweite ist im formalen Ausdruck des architektonischen Produktes konstituiert. Beide, Form und Technik reflektieren in ihrem Verhältnis die Beziehung zwischen Produkt und Prozess.

Innerhalb des geschichtlichen Ablaufs können verschiedene Wichtungen zwischen formalen und technischen Überlegungen beobachtet werden. Die Theorie der Renaissance gab formalen Überlegungen Priorität; im Zeitalter der Aufklärung wurde andererseits größere Aufmerksamkeit den Fragen der Technik gegeben. Solche gegensätzlichen Positionen weisen auf spezifische Beziehungen zwischen Gedanke und Durchführung während unterschiedlicher Perioden der Geschichte hin. In der Architekturform und Technik wird das Verhältnis von Theorie und Praxis sichtbar. Die Analyse von Modellen, die die Beziehungen zwischen Gedanke und Ausführung behandeln, erlaubt schließlich einen Ansatz zur Formulierung einer Theorie der Technologie der Architektur.

Die Zeit der frühen Moderne, welche innerhalb der Philosophie als die Zeit von der Renaissance bis zur Aufklärung aufgrund der allmählichen Einführung der modernen Wissenschaft definiert ist, wurde als Untersuchungsgebiet gewählt. Demzufolge wird in der Arbeit von der Entwicklung der Technologie als Wissenschaft ausgegangen. Obwohl technische Entwicklungen die Menschheitsgeschichte zu allen Zeiten prägten, ist der Anspruch eine generelle Theorie der Technologie zu formulieren, ein Phänomen der modernen Zeit. Diese geschichtliche Phase nahm im sechzehnten und siebzehnten Jahrhundert ihren Anfang. Rationales Denken bildete die Grundlage von Wissenschaft, Philosophie und praktischen Tätigkeiten im allgemeinen. Indem Ideen und Konzeptionen der Technologie behandelt werden, ist diese Arbeit grundsätzlich auf den Fundamenten der modernen Ära aufgebaut. Technologie in diesem Sinne liefert Gedankenmodelle, welche sich mit dem Verhältnis zwischen Theorie und Praxis auseinandersetzt; diese werden so von essenzieller Bedeutung für ein Verständnis der heutigen Technologie der Architektur.

INTRODUCTION

In Search of a Definition of Architectural Technology

"...that architects who have aimed at acquiring manual skill without scholarship have never been able to reach a position of authority to correspond to their pains, while those who relied only upon theories and scholarship were obviously hunting the shadow, not the substance. But those who have a thorough knowledge of both, like men armed at all points, have the sooner attained their object and carried authority with them."
Vitruvius, *The Ten Books on Architecture* [1]

Technology in View of History, Theory, and Philosophy

I) Fundamental Considerations, Sources, and Assumptions

One of the primary tasks for an investigation of the nature of architectural technology is to formulate a definition of technology and then to delimit that definition to the particular case of architecture. Definitions, in general, allow the systematic exploration of a subject matter as developed from the structure of specific concepts.[2] Since such a point of departure is marked by the position from which definitions are determined, it is important to develop an understanding of their underlying historical and theoretical contexts.

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1 Vitruvius, "The Education of the Architect," *The Ten Books on Architecture*, translated by Morris H. Morgan, Dover Publications Inc. (New York), 1960, p. 5.

2 The question concerning definitions of technology in general and their specific application to the field of architecture is raised by Peter McCleary in an essay entitled "History of Technology." McCleary emphasizes the necessity for definitions, for they reveal the conceptual structures underlying any systematic exploration of a given subject. P. McCleary, "History of Technology," *Architectural Research*, edited by James C. Snyder, Hutchinson Ross Pub. Co. (New York), 1982, pp. 81-91.

Consequently, an analysis of technology is to be addressed in reference to ideas, allowing understanding in relation to man's system of knowledge. Identified in reference to systems of thought, definitions of technology must be considered in view of historical, theoretical, and philosophical questions. This investigation, therefore, does not advocate a specific theory of architectural technology but rather identifies different approaches to the field, which are to be seen as essential for understanding attitudes towards the making of architecture.

Systems of thought are seen in relation to the physical, material reality of architecture as well as understood in connection with techniques involved in the processes of architectural production. This duality between mental constructs on the one hand and physical construction on the other constitutes the fundamental theme and point of departure for definitions of technology. The word *technology*, a binomial expression formed by the terms *techné* and *logos*, implies a twofold reference to the realm of human activity. *Techné* pertains to the work of the maker in the creation of artifacts and recognizes the predominantly operative quality of his processes of production.[3] *Logos* addresses the realm of thought and recalls the reflective nature of human activity. In this sense, while belonging to both domains of man's system of

[3] The Greek *techné*, commonly translated as "art," "craft," or "skill," is rooted in the Indo-European *tekn-*, approximately meaning "woodwork" or "carpentry." It is similar to the Greek *tékton* and Sanskrit *táksan*, meaning "carpenter" or "builder" as well as the Sanskrit *táksati*, "he forms," "constructs," or "builds."

thought and action, the field of *technology* reveals itself to be mutually concerned with questions of theory and practice.[4]

Martin Heidegger asserts in his essay "The Question Concerning Technology" that the relationship between thought processes and technical production implied by the term *technology* raises a number of questions which must be addressed within a philosophical framework.[5] To explore the sources and meaning of technology is to consider the pragmatics, the basic rules and principles, as well as the methods of technical undertaking. Simultaneously, an analysis of the phenomenon *technology* must be founded, according to Heidegger, on a critical approach which offers the possibility for searching, revealing, and questioning in a very general sense. This duality within analysis allows on the one hand considerations purely within a technical framework, that is, dealing with technological problems which require technical solutions. Analysis, on the

[4] For Plato the word *techné* not only pertains to particular activities but also addresses knowledge. In his writings, the terms *techné* and *episteme*, art and systematic knowledge, are closely associated. In the *Gorgias*, for example, Socrates argues that every *techné* is involved with *logoi* (words, speech) bearing upon the specific subject matter of the arts (450b). Plato, however, did not join the two terms, *techné* and *logos*, to form one expression. It was Aristotle who probably used the word *technologia* for the first time in his writing on rhetoric. Aristotle's use of the term addresses the role of "speech concerning art" or "words about *techné* " (*Rhetoric* I, I; 1354b17, 1354b27, 1355a19, and I, 2; 1356a11). Yet, the meaning of the word does not directly correspond to contemporary definitions of the term *technology;* Aristotle understands the art of rhetoric as a *techné* or 'means' of speech. In this sense, *technology* is understood as the science addressing the techniques of a particular art. For a detailed analysis of the etymology of the word *technology* and its various applications see, Carl Mitcham, "Philosophy and the History of Technology", in *The History and Philosophy of Technology,* edited by George Bugliarello and Dean B. Doner, University of Illinois Press (Chicago),1973, pp.171-189.

[5] Martin Heidegger, "The Question Concerning Technology," in *Basic Writings,* edited by David Farrell Krell, Harper & Row (New York), 1976. The essay was published in German under the title "Die Technik und die Kehre," in *Vorträge und Aufsätze*, Günther Neske Verlag (Pfullingen), 1954. "The Question Concerning Technology" was presented for the first time as a lecture to the Bremen Club in 1949 under the title "The Enframing."

other hand, also suggests an investigation of technology's essential meaning and purpose, that of exposing the realm of technical considerations to a philosophical inquiry. In this sense, Heidegger's differentiation of "technical technological" problems versus "technical philosophical" questions offers a framework for understanding technology as being inherently connected to the realms of theoretical and practical considerations.

A similar distinction between the instrumental aspects of technology and its theoretical implications is made by Carl Mitcham and Robert Mackey in their introduction to a compilation of essays entitled *Philosophy and Technology, Readings in the Philosophical Problems of Technology.*[6] It is necessary, according to the authors, to recognize technology as a philosophical problem. A philosophical approach to the question of technology, like philosophy itself, they write, "is concerned with what have been called second-order questions," as opposed to "first-order questions."[7]

The current and prevailing understanding of technology as a means of problem solving is primarily conceived in view of "first order questions," implying an inherently instrumental definition of technology. It is this definition which is commonly applied to architectural technology. The manufacture and utilization of equipment, tools, machines, as well as materials and industrialized products for the building process,

[6] Carl Mitcham & Robert Mackey, "Introduction: Technology as a Philosophical Problem," in *Philosophy and Technology, Readings in the Philosophical Problems of Technology,* edited with an introduction by C. Mitcham & R. Mackey, The Free Press (New York), 1972, pp. 1-30.

[7] Ibid., p. 1.

and the manufactured and used objects themselves all belong to what technology is in instrumental terms. In architectural technology, "first-order questions" are determined by the directness of operational concerns. Typical questions are such as: What are the most appropriate materials with which to construct an architectural artifact? What are the specific qualities and properties of building products? What are the methods and techniques to be applied for achieving most efficient construction procedures?

In contrast, an approach to technology in view of philosophical considerations is concerned with "second-order questions" which raise fundamental issues about the nature and meaning of technology. Within such an inquiry, technology is addressed in reference to man's system of knowledge. In this sense, conceptions of technology are to be understood in connection to specific models of thought as they are formed within given cultural and social contexts. Architectural technology considered as a "technical philosophical" problem can thus be exposed to "second order questions" allowing, for example, concerns of the following nature to be raised: Is architectural technology merely of the applied sciences; does it involve theories of the material sciences or theories of architecture as fine art? What are the metaphysical justifications underlying formal intentions and how do they relate to technical exigencies? What is the meaning of progress, how can it be understood in reference to technical development, and how does it inform the form of building?

The interrelationship between "first-order questions," which primarily relate to empirical phenomena, and "second-order questions," which depend on reason and understanding, constitutes the fundamental point of concern within an analysis of technology. Consequently, the search for a definition of technology allows philosophical understandings of technical undertaking. Only from addressing the philosophical as well as the technical realms will a meaningful approach result to a complete understanding of technology. The integration of thought processes in the making of artifacts will therefore constitute a first point of analysis within this thesis. In that, an attempt will be made to identify conceptual frameworks ordering the making of architecture. An initial concern will focus on the role of theories which structure the physical act of production. These theories constitute the body of intellectual constructs invested in the technical means for the production of things. For establishing an understanding of the relation between theories of technology and the processes of making, it is important to describe and analyze the way in which man has perceived of his ability to create artifacts throughout history.

The formation of *history,* rather than considered as being *a priori* given, can be understood as a human conception; similarly, technical achievements as well as the understanding of technology result from human activity. In these terms, history in general and the history of technology specifically can be considered constructs of the mind. Giambattista Vico (1668-1744) and Georg Wilhelm Friedrich Hegel (1770-1831) both made history the object of their sciences, their philosophical positions being guided by an understanding of history as a primary factor of human knowledge. A parallel interest can be observed in the propositions of Francis Bacon (1561-1626) and Denis Diderot (1713-84). Their works suggested the necessity for establishing a historical awareness of technical development. They offered an understanding of technology as a discipline inherently connected within the whole system of human knowledge. Bacon advocated at the beginning of the seventeenth century that a history of the mechanical arts must be written, for the future progress of civilization would require an understanding of the technical developments of the past.[8] This idea found its realization with the publication of the *Great Encyclopedia*, compiled by Diderot and his collaborators during the mid eighteenth century. Their interest was directed towards the arts and crafts; the *Encyclopédie*, while offering descriptions of the specific instruments and methods of production, disclosed the prevailing efforts within society to order the knowledge of the advancement of technique.[9]

Such emphasis on the notion of the idea of history *per se* reflects man's attempt to assert his state of being. Technology similarly affirms man's self-consciousness in providing him with the means to overcome his natural condition. Both history

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[8] The writing of a "history mechanical" was strongly advocated by Francis Bacon in *The Advancement of Learning*, 1605; in *Francis Bacon, The Advancement of Learning and New Atlantis*, edited by Arthur Johnson, Clarendon Press (Oxford), 1974.

[9] The significant role of technical development within the system of human knowledge was stated in Denis Diderot's "Prospectus de l'Encyclopédie" as well as in Jean Le Rond D'Alembert's "Preliminary Discourse." "Prospectus de l'Encyclopédie," in *Diderot Oeuvres Complètes*, Hermann (Paris), 1976, vol. V, pp. 84-130. "Preliminary Discourse," in *Denis Diderot's Encyclopedia*, edited and translated by Stephens J. Gendzier, Harper & Row (NewYork), 1967.

and technology assume a liberating role for the development of the human mind in its ability to reflect upon itself. In this, the conceptions of history and technology as autonomous disciplines were given significant emphasis within the modern era. The development of this period, defined by the gradual introduction of modern science, led to the understanding of such fields as history and technology as clearly identified disciplines. In an essay entitled "Philosophy and the History of Technology" Carl Mitcham emphasizes the very idea of the autonomy of such fields; he asserts that the concepts of history and technology, while affirming the human condition, are essentially expressions of the modern era.[10] He writes:

..., history and technology are both somehow characteristic of modernity. The modern period has been called the 'age of technology'; it has also been called the 'age of historical consciousness'. These views are both grounded in modern man's affirmation of himself. [11]

As the concepts of history and technology are both indicative of modernity, Mitcham concludes, then an approach to the history of technology unites the historical awareness of the modern era with its emphasis on technological development.[12] Technology, like other disciplines, stands in relation to its past; it is in this reference to its history that technology's changing conditions can be understood. An analysis of

10 Carl Mitcham, "Philosophy and the History of Technology", op. cit., pp. 163-201.

11 Ibid., p. 166.

12 "*Technology is designed to give ... modern man his rightful power of nature; history is the study of ... man's life independent of nature. The history of technology unites these two aspects of modernity in a paradigmatic fashion.*" Ibid., p. 167.

technology must consequently address how it has been perceived within history. Different methods of historical analysis are identified; these reveal certain attitudes towards history as given by underlying models of thought disclosing views, although sometimes contradictory, of history. In accordance with Mitcham, an attempt to define a typology for histories of technology offers the following three categories for consideration[13]:

The first is a *technological history*, that is, the history of man-made products, objects, tools, and artifacts. This view includes also the processes of manufacturing, how artifacts are made and produced.

The second approach to the history of technology is directed towards the implications of technological development on man and his social organizations. This approach has been called the *social history* of technology.

The third category addresses the way in which man conceives of technology and is part of the history of ideas. This type of history is concerned with the changing perceptions and understandings of man's activity in the making of artifacts. An evaluation of ideas about technology as defined within different periods is the initial point of concern for this third approach.

The most common understanding of the history of technology is largely preoccupied with the enumeration of historical facts.

[13] Ibid.

As defined by the first category, *technological history* commonly traces a chronology as marked by technical progress and achievements. The second approach to the history of technology, which focuses on the relation of technical evolution to social conditions, has been widely addressed in the recent historiography of the subject. The third category, however, has not sufficiently been surveyed. The history of ideas of technology remains to be investigated. It is the aim of this thesis to research the field of ideas within technology as pertaining to the relation between theory and practice. The making of architecture has been chosen as the specific field of analysis. Since architecture represents all the qualities of an art depending on the *de facto* context of technical matters, a unique position is assumed in which thought and action converge. This study of ideas about the making of architecture represents the attempt to establish a structure of how individuals within different periods have conceived of the production of architecture. Technology, in these terms, is understood as the field addressing the *thinking* about *making*.

An investigation into the theoretical foundations of technology cannot be considered independent of its *technological* and *social histories* as previously defined. An approach to the theories of technology suggests that a historical understanding of technical development and its influence on social organizations should not be exclusively viewed in terms of "first order questions," but also exposed to "second order questions," the latter of which allows the various histories of technology to be addressed within the framework of philosophical questions.

II) Technological History

When considered in relation to "second order questions," *technological history* offers the possibility for providing an analytical and conceptual approach to technology. Historical facts are structured according to specific conceptual models from which theoretical positions can be derived. Whether focusing on specific events or continuous lines of development, such analysis addresses history in order to assemble and order information in view of specific themes. Significant within this approach is the classification of periods leading to a conception of technology's history as formed by clearly identified phases, such as proposed in Lewis Mumford's book *Technics and Civilization* in which the distinction between "eotechnic," paleotechnic," and "neotechnic" phases is made.[14] A similar type of classification is suggested by José Ortega y Gasset in an essay entitled "Man the Technician" proposing a division of periods according to the technologies of "chance,"

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14 "*Looking back over the last thousand years, one can divide the development of the machine and the machine civilization into three successive but* over-lapping and interpenetrating phases: *eotechnic, paleotechnic, neotechnic. ... While each of these phases roughly represents a period of human history, it is characterized even more significantly by the fact that it forms a technological complex. Each phase, that is, has its origin in certain definite regions and tends to employ certain special resources and raw materials. Each phase has its specific means of utilizing and generating energy, and its special forms of production. Finally, each phase brings into existence particular types of workers, trains them in particular ways, develops certain aptitudes and discourage others, and draws upon and further develops certain aspects of the social heritage.* " Lewis Mumford, *Technics and Civilization*, Harcourt Brace & World (New York & London), 1934; edition of 1963, pp. 109, 110. See also Peter McCleary, op. cit., p. 84.

the "craftsman," and the "technician."[15] Categorizations of this kind provide fundamental conceptual structures for the understanding of technology.

Within the field of architectural technology such a conception of history is primarily marked by an interest in case studies of specific events, such as the emergence of new inventions, the achievement of long-span structures erected within an efficient time frame, or the introduction of the machine in the building process. The latter, for example, was the subject matter of Siegfried Giedion's seminal study *Mechanization Takes Command* in which the role of the machine and its effects on modern civilization and architecture were examined.[16] From analyses of technical development, specific historical periods have been identified within architecture. While not necessarily coinciding with the traditional classification of formal styles, such an alternative understanding of the history of architecture suggests a chronology of subsequent phases according to the development of technical means. In this, an

[15] *"The best principle of delimiting periods in technical evolution is, to my judgment, furnished by the relation between man and technology, in other words by the conception which man in the course of history held, not of this or that particular technology but of the technical function as such. ... Taking this principle as our point of departure we come to discern three main periods in the evolution of technology: technology of chance; technology of the craftsman; technology of the technician."* José Ortega y Gasset, "Man the Technician," in *History as a System and other Essays toward a Philosophy of History*, W.W. Norton (New York), 1961 and Greenwood Press (Westport, Connecticut), 1981, pp. 141, 142 ; originally published under the title "Medictación de la técnica," in *Ensimismamient y Alteraction* (1939).

[16] Siegfried Giedion, *Mechanization Takes Command, a Contribution to Anonymous History,* Oxford University Press, 1948.

understanding of architectural technology is offered in view of technical progress.[17]

Attempts to systematize the field of architectural technology commonly focus on specific issues such as the role of the materials, tools, trades, elements, and systems of building construction.

- Classifications according to building materials offer the distinctions between timber, stone, masonry, concrete, and steel constructions. Historical analyses in view of material characteristics, as suggested by Peter McCleary, not only address the introduction of new materials and methods of production within architecture but most importantly emphasize the conceptual structures underlying their application.[18]
- A systematization of technology based on the various instruments used by man in the production of artifacts has been advocated by Lewis Mumford when suggesting the distinction between "utensils," "apparatus," "utilities," "tools," "machines," and "automatons."[19] The historical relevance given to those technical means which are used in building and

17 Such classification of historical periods has been suggested, for example, by Adolf Max Vogt in the introductory remarks "Explosion der Reichweite" to his book *19. Jahrhundert* : "*Die Geschichte der zivilisatorischen Reichweite hat ganz andere Einschnitte und Schwellen als die Kunstgeschichte mit ihren Stilphasen. Sinnvoll erscheint eine weit ausholende Einteilung in vier Stufen: 1. Stufe: Die natürliche Reichweite der Griechen ... 2. Stufe: Die künstliche Reichweite der Römer ... 3. Die künstliche Reichweite der Renaissance ... 4. Stufe: Die künstliche Reichweite des 19. Jahrhunderts ...*" Adolf Max Vogt, *19. Jahrhundert*, Belser (Stuttgart) and Kunstkreis Verlag (Luzern), pp. 9 -12.

18 "*A tentative history of the concept of the characteristics of materials might show that the earliest concept was related to visual and tactile properties; then through the experience of use are generated craftsman descriptions of the use and properties; then through experimentation comes the recognition of thermal, acoustical, strenght, tolerance, and other properties; and today our concern is with the specification of a desired performance rather than with a material's physical properties.*" Peter McCleary, op. cit., p. 85.

19 Lewis Mumford, op. cit., pp. 9 -12, 410 - 417.

manufacturing processes implies an understanding of architectural technology as an operational agent for achieving specific ends.

- Further propositions for structuring the field of technology have based their classification on the systematic differentiation between the various crafts involved with building construction. Analyses of this kind propose a conception of architecture in relation to the divisions of the building trade.[20]

- Similarly, other categories have been of significance within architectural technology proposing the understanding of constructional elements such as the column, beam, arch, truss, and frame in view of their historical developments. The essential concept underlying this approach is the understanding of the building as an assembly of distinct components formed to make entire systems. This idea supports the conception of architecture as being comprised of different interdependent systems, such as the structure, enclosure, and mechanical systems.

Whether pertaining to classifications of materials, tools, trades, building components, or systems, the principal method underlying such historical approaches is based on the systematization of compiled information. *Technological history* addresses both facts and concepts as well as the vantage points of their determination. The relationship between historical

[20] Such classification based on the different building trades was proposed, for example, byAndré Félibien in his treatise *Des Principes de l'Architecture, de la Scupture, de la Peinture* (1676). Similarly, Denis Diderot's *Encyclopédie* approached the sections on the mechanical arts and crafts by structuring them according to the division of trades (1750-1777).

facts and the formulation of conceptual structures is straightforward and inherently pragmatic. It is basically founded on the attempt to directly relate conceptual ideas to the reality of observed phenomena allowing the definitions of concepts to be based on the facts as they are determined by historical survey.

Technological history is therefore marked by the relative aims of specific conceptual definitions. Although assuming an objective position, such an approach to the history of technology is not value free. On the contrary, the formulation of conceptual structures, as observed by Mitcham, are most often carried by ideological belief:

Insofar as narrative interpretation and causal explanations are constructed, while technological history is easily construed as linear and progressive in a way that the history of art, for instance, never could be, the norms for such a history do not need to be imported from outside; the historical actors, that is the technologists themselves, seem to share a univocal ideal of technical efficiency which can be used to judge technological development.[21]

The belief in technological progress as a constant force for the development of man's condition is understood as being *a priori* given. This understanding is marked by an optimistic attitude towards technical progress and is assumed to be value neutral. At one extreme such historical assessments imply the separation between technology and man. Technology is nothing

[21] Carl Mitcham, op. cit., p. 168.

else than an operational tool at man's disposal and represents in this an objective entity. Technological progress, at the other extreme, is considered a determining factor for civilisatory development contributing to the potential realization of the human condition. The latter concept, while in reference to man's social organization, offers an approach to technology in view of its *social history.*

III) Social History of Technology

The *social history* of technology in view of "second order" questions addresses the fundamental interdependence between technical development and society. As the French sociologist Jacques Ellul advocates in his book *The Technological Society,* technique cannot be considered an "isolated fact" but must be understood as a "sociological phenomenon" relating to every aspect "in the life of modern man."[22] This opinion, which asserts that technology is fundamentally connected to the human condition, is shared by Mitcham when comparing the differences between *social* to *technological* history:

> *..., with regard to the social history itself, it is much more complex than technological history. Not only are more complex causal factors involved in relating technology and society, but the interpretation which turns the chronicle of technological history into the narrative of social history inevitably brings into play human values and questions about the nature of man.* [23]

22 Jacques Ellul, *The Technological Society,* translated from *La Technique ou l'enjeu du siècle* (1954) by John Wilkinson , Vintage Books (New York), 1964, p. xxvi.

23 Carl Mitcham, op. cit., p. 168.

In addressing socio-cultural values in relation to technological development, two reciprocal forms of interdependence can be identified. One focuses on the social consequences resulting from the forces of man's technological enterprise; the other shows that the forms of technical undertaking are derived from the effects of society. The former position is supported by the view that technical development determines the progressive realization of human nature. The latter understands technology as a result of man's pursuit for self-realization. In both cases, the attempt to establish correspondences between technology and society imply a direct equation between technical and human progress.

The relation between technology and society, as based on the assumption that technical development primarily defines the program of social evolution, is again inherently optimistic in nature. In these terms, the *social history* of technology meets the demands set forth by the understanding that the historical progressive realization of the human condition is achieved through technical development. Such interdependence between technology and man was a primary idea of Francis Bacon's and Denis Diderot's philosophical positions advocating that the mechanical arts and their technological advances were historically significant in their contribution to the development of human knowledge. With the increasing advances of methods and techniques of production during the seventeenth and eighteenth centuries, man's social structures could not be considered independent of technology. This idea, while also offering a new approach to architectural technology, essentially contributed to the foundation of the modern era.

During the nineteenth century the conception underlying the social significance of technical development evolved as one of the guiding tenets of Karl Marx's understanding of technology.[24] Marx, "the man who proposed to turn Hegel 'rightside up' - to replace the phenomenology of spirit with what can be called a phenomenology of technology," gave primary emphasis to the concept of labor as the sole source of human value.[25] Hegel's idealist dialectic is here substituted with Marx's materialist dialectic. Hegel's concept of the history of ideas as the progressive actualization of the mind connects philosophy to history. Similarly, Marx's optimistic vision of "technical development as the progressive realization of human nature" addresses the history of technology within the context of philosophical inquiry.[26] In agreement with Hegel regarding the interdependence of history and philosophy, with history itself the embodiment of progressively developing reason, Marx placed technical development at the center of the argument. His view, while disclosing an interest in man's system of productive forces, is primarily embedded in a

24 The "technology-culture" or "technology-society" relationships are significant concepts within the Marxist tradition, "according to which changes in the technology of production are inevitably and univocally determinative of culture and social structure." Emmanuel G. Mesthene, "How Technology Will Shape the Future," in *Philosophy and Technology*, edited by Carl Mitcham and Robert Mackey, The Free Press (N.Y.),p.116.

25 Carl Mitcham, op. cit., p. 164. See also Sanford A. Lakoff, "Socialim from Antiquity to Marx," in *Dictionary of the History of Ideas*, edited by Philip P. Wiener, Charles Scribner's Sons (N.Y.), vol.IV, p.292.

26 Carl Mitcham, op. cit., p. 164.

historical presentation of the triumph of *homo faber,* man the maker.[27]

This rather optimistic concept of technology, understood as the developing realization of man's system of thought and action, is shared by capitalist ideologies. These are best expressed in the positivistic approach to the phenomenon of technological progress. However, the relation between technology and society, whether defined within Marxist or Positivist ideologies, does not necessarily imply being seen in positive terms. Mitcham writes that "Marx, too, can be turned 'rightside up'."[28] The historical development of technology has increasingly during the twentieth century been understood as the "progressive dehumanization rather than the humanization of man."[29] The expansion of technology into every aspect of daily life is described by such authors as Mumford and Ellul as having a critical impact on man and society. This pessimistic, anti-technological position places technology in its *social history* with the progressive destruction of man by technological means. Such views, however, still equate technical development with social evolution, whereby the notion of technical progress is criticized.

The *social history* of technology, furthermore, offers for consideration another form of relationship between society and technology. As founded on the notion that social development

27 For the basic tenets of Marxist philosophy of technology see, Karl Marx, "Machines and Modern Industry," in *Das Kapital,* vol.I, chapter 15. See also Karl Marx, "The Labour Process and Alienation in Machinery and Science," in *The Grundrisse* , translated by David McLellan, Harper and Row (New York), 1971, chapter 18.

28 Ibid.

29 Ibid.

determines the program of technical progress, this approach propagates the idea that different societies develop different types of technologies. This view is suggested by José Ortega y Gasset in his essay "Man the Technician." Ortega stresses the historical differences between technologies as determined by different social groups. He compares, for example, the technology of Tibetan society with the technology of Western society. Tibetan technology follows the ideals set forth by Buddhism, whereas Western technology exemplifies the ideals of the bourgeoisie. Both are described as being inherently connected to the structure of their social organizations. Most important are not the specific differences found between one form of technology to another but the common system of interdependence between society and technology. Based on this idea, Ortega proposed the following definition for understanding the fundamental connection between man and his technical means of production. "Technology," he writes, "is the system of activities through which man endeavors to realize the extranatural program that is himself... ."[30] Technology is here defined as the totality of actions resulting from the human pursuit for self-realization and mirrors the development of social evolution. Technical development is, again, placed at the center of a historical view, with history itself embodying the progressive realization of human nature.

Whether the *social history* of technology analyzes the effects of technology on society, or visa versa, it primarily raises questions about the relation between man and technology in very general terms. In order to address these fundamental issues, a

[30] José Ortega y Gasset, "Man the Technician," op. cit., pp. 122, 123.

social history of technology must contain inherent philosophical views, that is, theories about the nature and meaning of technology, models about technology and human action, and concepts about the relation between technology and science as well as between technology and art. The reference to such themes points to the history of ideas about technology and its implications for understanding the relation between man's systems of thought and action, i.e. between theoretical and practical constructs.

IV) Technology in the History of Ideas

The meaning of the term *technology*, as its etymological roots indicate, pertains to the theories of practice. A full understanding of technology can therefore only be derived from the history of ideas, the analysis of models of thought, and historically proposed attitudes about technology. Mitcham identifies this mode of investigation as an Aristotelian approach. Aristotle's method surveyed the history of opinions in order to identify the basic problems of ethics and metaphysics. Similarly, an approach to technology must address the history of ideas about man's applications and understandings of technique.[31] The method entails the reference to existing histories of technology and is specifically based on the relation between theory and practice. The framework of this thesis follows with architectural technology considered in reference to concepts addressing the interdependence between theoretical propositions and practical execution.

[31] Carl Mitcham, op. cit., pp. 164, 165.

The production of architecture is not the result of some precise accumulation of technical knowledge; the processes of making are conditioned not only by social needs and values but also, and perhaps more significantly, by systems of thought. The development of architectural technology should be viewed as proceeding within intellectual frameworks. Consequently, the thesis offers an approach to building involving systems of knowledge from a pluralistic rather than from a singular perspective. Architectural technology will specifically be addressed in reference to the concepts of art and science, for historically changes of their understandings inevitably implied a different form of relation between practice and theory.

Before the modern era, the art of architecture referred to the practical skill of building, and the science of architecture addressed the theory of the discipline. Knowledge of artifacts united two distinct understandings of making, one being *art*, the skill requiring practical knowledge, and the other being *science*, the skill requiring theoretical knowledge. Technology was considered to have embraced both art and science. With the beginning of the modern era, an increasing differentiation was made between skills requiring practice, or art, and those requiring primarily theoretical knowledge, or science. The distinction, furthermore, between pure and applied science propagated the difference between scientist and technician; similarly, the division between fine arts and applied arts led to the separation between artist and artisan. From such developments, differing conceptions of technology evolved along with changing understandings of architectural production.

As given by the categorizations of art and science, the interdependence between practice and theory within architecture is most clearly revealed in the relation between technique and form. On the one hand, technique can be analyzed in reference to the formal expression of its material manifestation. Such a view considers form a resultant of technical causes. A reciprocal relation, on the other hand, must be addressed where formal intention as the primary architectural motivation relies on technical means as tools for its material realization. The influence of a preconceived formal vocabulary determining the investment of specific techniques has been a major influence in the historical development of building construction. This latter relationship between technique and formal expression has led to an understanding of construction as a language form. A vocabulary of constructional elements, originally derived from technical procedures, periodically throughout history has been used as a formal canon of autonomous forms divorced from their technical origin. This transfer from the *real* to the *implied* characterizes what shall be called a *representational* structure between technique and architectural expression. It is in this attempt to organize technique according to the logic of symbolic form that a synthesis of form and technique resulted within the Classical tradition of architecture.

The *representational* structure between form and technique will further be seen in opposition to an *ontological* mode of creation in the production of architecture. Rather than addressing referential form, as with the representational approach, the ontological mode derives formal expression from tectonic qualities whereby the manifestation of technical means and material properties becomes the guiding principle within architectural appearance.[32] Form is then based on truth of expression. This concept evolved historically from the search of modern science for revealing the essential structures underlying natural phenomena. As applied to the production of man-made objects, the search for truthful conditions required an understanding of those considerations which contributed to the physical formation of human artifacts. Consequently, this approach gave emphasis to questions of utility addressing such issues as function, material and structural performances, and manufacturing techniques. From this historical development evolves an understanding of architectural conception based on the parameters of building construction. The conceptual framework is formed by the belief that the internal order of technique generates all qualities of formal expression. The structure of appearance, consequently, is constituted by the order underlying technical production. Architecture is essentially considered to be derived from a truthful act, that which reveals the exigencies and methods of production.

Viewed within the framework of "second order" questions, a history of ideas of technology ultimately approaches the metaphysical grounds underlying architectural production. Historically, both the *representational* and *ontological* structures of form and technique suggested a search for identifying architecture's truthful foundation. Whether

[32] Within this context, the meaning of the term *tectonic* is used in reference to its etymological origins. Derived from the Greek *téktón*, meaning carpenter, the word *tektonikós* can be translated as "pertaining to building or construction." *The Oxford Dictionary of English Etymology*, Clarendon Press (Oxford), 1966. See Eduard F. Sekler, "Structure, Construction, Tectonics," in *Structure in Art and in Science*, edited by Gyorgy Kepes, George Braziller (New York), 1965, pp. 89-95.

emphasizing form or technique, this search for truth transcended the physical creation of a material reality, thereby justifying the metaphysical condition of architecture.

The making of artifacts, the manufacturing of tools and machines, and the production of architecture, in general, man's ability to create is to be viewed within man's epistemological context. Only from such a vantage point will the search for definitions of technology reveal the essential constructs underlying technical activity. The search for definitions must include the facts of an analytical history of technology. The search must integrate in its analysis the cultural implications of social history. But most importantly, the approach must be considered in relation to systems of thought and propositions for definitions of technology. Inherent to the exposition of definitions is the quest to reveal the essence of technology, as proposed by Aristotle:

The essence of each thing is that which it is said to be per se. ... *Hence essence belongs to all things the account of which is a definition.*[33]

33 *καὶ πρῶτον εἴπωμεν ἔνια περὶ αὐτοῦ λογικῶς, ὅτι ἐστὶ τὸ τί ἦν εἶναι ἑκάστου ὃ λέγεται καθ' αὑτό. ... ὥστε τὸ τί ἦν εἶναί ἐστιν ὅσων ὁ λόγος ἐστὶν ὁρισμός.*
Aristotle, *Metaphysics,* Book VII; translated by Hugh Tredennick, The Loeb Classical Library, William Heinemann (London), 1933, pp. 320-323.
Peter McCleary uses the same quote from another translation of Aristotle's *Metaphysics* in the conclusion of his article "History of Technology": "In the quest for an agreement on an explicit formal logic for technology, the recommendation here is to search again (re-search) for an exposition derived from the knowledge that 'the essence of a thing is what it is said to be in its very self... so essence is composed of those things, the enumeration of which makes a definition'." Peter McCleary, op. cit., p. 90.

1. Chapter

TECHNOLOGY, TECHNIQUE AND THE CHANGING CONCEPTS OF SCIENCE

TECHNOLOGY, TECHNIQUE AND THE CHANGING CONCEPTS OF SCIENCE

"*If science is not to degenerate into a medley of ad hoc hypotheses, it must become philosophical and must enter upon a thorough criticism of its own foundations.*"
A.N.Whitehead, Lowell Lectures 1925[1]

Science-Technology

The emergence of modern science in the sixteenth and seventeenth centuries suggested a new mentality based on a changing view of the world derived from the structure of scientific thought. An historical understanding of this mentality is essential for comprehending the profound impact of technology on the modern era. Directed by the occurrence of scientific reasoning, the metaphysical presuppositions and imaginative contents of man's epistemological context changed greatly. Within the field of architecture, fundamental restructuring occurred of traditional understandings. Of major importance was the change in attitude towards the making of objects, implying a redefinition of the structure of approach and a precise re-evaluation of the specific techniques involved in production.

Technology and *technical* evolve from the word technique, which in turn is a descendent of the Greek term *techné,* meaning the art, craft, or skill invested by man in his processes of making the artifacts of the human environment. Technique currently has

[1] Alfred North Whitehead, *Science and the Modern World* (1925), The Free Press (NewYork), 1967, p.17.

two definitions, one general and the other leading toward the scientific. The first definition, derived from its etymological Greek root, understands technique as the manner and ability with which an artist, writer, dancer, athlete, or the like employs the technical skills of his particular art or field of endeavor. The second meaning of the term defines technique as the body of specialized procedures and methods used in a specific field.[2] Technical activity in the former general sense has accompanied the earliest activities of man's existence. Technical undertaking in the latter sense, however, has a history of development pertaining to the emergence of scientific thought. Prior to the rise of modern science, technical skill constituted the means by which man created artifacts from natural products. Technique was symbolically understood as the connector between nature and man. In determining the physical materialization of the man made reality, technique simultaneously addressed the realm of mythical thought. Technique incorporated the physical with the metaphysical by uniting the material existence of things with the sphere of meta-physical thought. As history evolved, an increasingly rational view dominated science, philosophy, and human action in general, with technique primarily understood as a body of knowledge, increasingly divorced from its mythical origin. Rational thought constituted the guiding force in determining man's system of thought and action, altering every aspect of civilization. Technique became understood as an instrument or neutral tool for carrying the tasks of scientific work. This understanding spread into every domain of human

2 The two definitions are given in *The Random House Dictionary of the English Language,* 1969.

action. It can be seen that within architecture the development of rational thought strongly affected the methods and techniques of making.

Technique within the field of architecture is commonly referred to in two differing meanings of the term, as based on the distinction proposed by the two previous definitions given. The first identifies technique as the ability with which the architect, builder, craftsman, or maker employs the skills of his particular art. The second meaning of the term is considered as the body of specialized procedures and methods used within the field of architectural production. The former definition is direct and active engaging the maker with his means of production. The latter is distanced and general assuming a certain objectivity for the systematization of the field. In the production of architecture, both definitions of technique must be addressed. Architectural production requires the specific technical skills for the art of building construction as well as necessitating a general framework or a structured field of knowledge determined by the science of building technology. With the development of modern science, the field of architectural technology became primarily determined by the understanding of technique as a system of methods and procedure, conceptually ordered and rationally invested. Technique as skill was subordinated to the structure of scientific thought. This development had a major impact on the production of architecture; it affected the specific methods of the building process as well as the products of architecture in their expression as built form. Scientific reasoning in its structure of thought provided an order to technique; science and technique became considered as inseparable entities.

The relation between science and technique can be considered as twofold. On one hand technique figures as the point of contact between material reality and scientific structure. Technique in these terms is an application of abstract scientific principles. On the other hand, science depends on technique for realizing its program, and at its most extreme, technique constitutes the very substance of scientific thought. Technology historically came to be viewed as a body of knowledge which formed an overall framework for the understanding of technical matters. Technology developed as a science addressing the specific field of its own discipline. Although technical activity originates from the earliest periods of human evolution, the formalization of a generalized structure for establishing a framework of technological undertaking is at base a phenomenon of the modern era. The beginning of this period is marked by the introduction of modern science.

Modern science is built upon the foundations of Greek science; without the theoretical base of Euclid, Archimedes, and Pappus, Newton's achievements would not have been possible. Yet modern science differs from its Greek origin. Science is persistently referred to as "modern," often coupled with the term "technology," in the hyphenated form "science-technology," as if referring to a unitary phenomenon. It is in the understanding of technique as exemplifying an application of science that modern science developed apart from its early beginnings. The rapid development of technological achievement and scientific determinism placed technique as the connector between physical reality and the rational structure of scientific thought. In this link between science and technology lies the radical transformation of human reason itself, explicit in the transformation of man's thought and action. Technology embodies the physical manifestations of scientific thought when science sets up its own conditions as a measure of nature. The new science is in its essence technological.

Material and Magical Technique

Technical activity in the general sense has been considered one of the earliest expressions of human existence. There are the techniques of hunting, fishing, food gathering, later the fabrication of weapons, the manufacturing of clothing, and the construction of shelter or building. Historically, technique preceded science. As described by Lewis Mumford in his book *Technics and Civilization,* early human history was marked by the integration of technique in daily life.[3] Technique existed as tradition and was constituted by the transmission of inherited processes that slowly developed through repeated experience and empiricism. This very concrete notion of technique has been called material technique, the technique of *homo faber,* man the maker. But there is also another pre-scientific understanding of technique evolving along another path of a more or less spiritual order, that is, the notion of technique as magic.[4] Magic is defined as the art of producing a

[3] Lewis Mumford, *Technics and Civilization* (1934), Harcourt, Brace & World, Inc. (New York), 1963, pp. 60-65.

[4] Jacques Ellul, *The Technological Society,* originally published in French under the title *La Technique* and the subtitle *L'enjeu du siècle* (1954), Vintage Books (New York), 1964, pp. 23-27.

desired result through the use of various processes assuring control of the supernatural and the mystical forces of nature. Magic developed as an expression of man's will to obtain certain results of a spiritual order. Magic displays all the characteristics of technique in operating as a mediator between man and the "higher powers" just as material technique mediates between man and the environment. In his struggle to survive man interposes the processes of technique as intermediary agencies between himself and the environment as a means of protection and as an attempt to tame his surroundings. Through technique, man is able to utilize to his benefit powers which are perceived to be alien or hostile; thus, man establishes a situation of balance between human kind and nature. As discussed in *The Technological Society* by Jacques Ellul:

These characteristics of material technique correspond to the characteristics of magical technique . There, also, man is in conflict with external forces, with the world of mystery, spiritual powers, and mystical currents.[5]

Man, according to Ellul, attempts to tame these spiritual forces through the intervention of magical technique; by virtue of magical formulae man mediates his condition of being with what is perceived to be hostile to his state of existence.

The material and magical aspects of technique, although based on similar characteristics, incorporate different aspects for understanding man's system of thought and action. Magical technique is based on imagination emphasizing mystical

[5] Ibid., p. 25.

symbolism whereas material technique operates on rationality oriented towards technical "know-how." Both knowledge based on imagination as well as knowledge derived from reason as deduced from experience are of significance for understanding the early beginnings of science and technology. The gradual developments from magic to science, empiricism to systematic experimentalism, alchemy to chemistry, and astrology to astronomy, were indicative of the fundamental changes within man's system of knowledge.[6] This phase in history coincides with the transition from the culture of the Middle Ages through the Renaissance to the Age of Reason.[7]

Magical and material technique evolved into science and technology. Material technique developed from craftsmanship and the experience of the artisan to mechanical art furthering discovery and invention. Magical technique developed into the natural sciences engaging in the explanation and study of natural phenomenon. This evolutionary process is described by Paolo Rossi in his research on Francis Bacon, published under the title: *Francis Bacon, from Magic to Science.* Rossi identifies the work of Francis Bacon (1561-1626) as being deeply rooted in the magical tradition. Bacon expressed his reservations about the speculative aspect of magic and alchemy but was in favor of the experimental nature of their inquiries,

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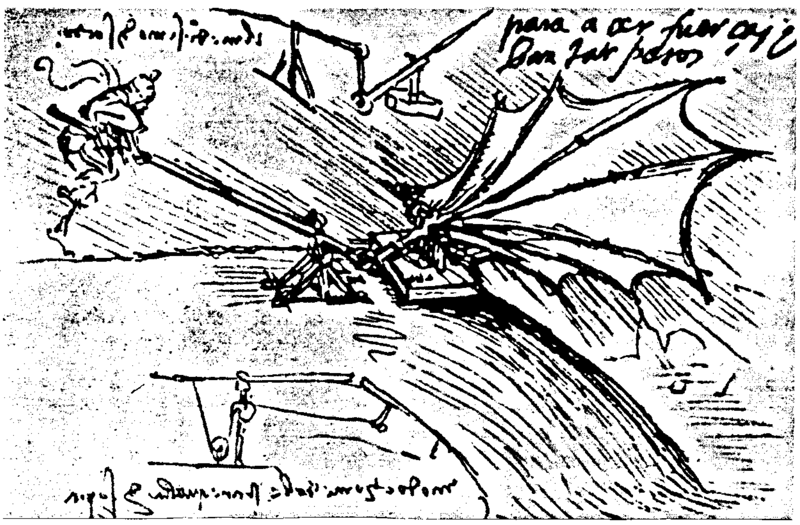
6 In a eight-volume work entitled *The History of Magic and Experimental Science,* Thorndike discusses the importance of many techniques of magical and alchemical practices for the development of technology and experimental science. Lynn Thorndike, *The History of Magic and Experimental Science,* Columbia University Press (New York), 1923-58.

7 The first phase of this development from magic to science as a transition from black magic to white magic is described in: Jacob Bronowski, *Magic, Science, and Civilization,* Columbia University Press (New York), 1978, pp. 19-37.



Sketch by Leonardo da Vinci,
wing-testing device for an ornithopter, 1486-90.

for the idea of an inventive science was basic to his own method:

The aim of magic is to recall natural philosophy from the vanity of speculations to the importance of experiments. Alchemy aims at separating and extracting the heterogeneous elements latent and implicit in natural substances, purifying what is polluted, releasing what is obstructed and bringing to maturation the unripe.[8]

This view was shared by other writers of the time, such as Corlelius Agrippa and G.B. Della Porta who placed magical technique within the field of natural science. Agrippa stated that the so-called miracles of magic are not, like the miracles of saints, a violation of natural laws but instead are the results of developing natural powers. G.B. Della Porta valued the practical nature of magical operations as the ultimate manifestation of natural philosophy.[9] It was in this modification of the inherent meaning of magical technique that historically the procedures of modern science were gradually introduced, with a loss in imaginative forces.

The fantastic and mystical element of imaginary thought, although removed from magical tradition, remained intact in fables, legends, and above all, in religious belief. The disregard of the mystical component of thought from technical

[8] Francis Bacon, *De dignitate et augumentis scientarum*. Paolo Rossi, *Francis Bacon, From Magic to Science*, translated from *Francesco Bacone: Dalla magia alla Scienza* (1957), Routledge & Kegan Paul (London), 1968, p. 22.

[9] Cornelius Agrippa from *De incertitudine et vanitate scientiarum*, G.B. Della Porta from *Della chirofisionomia*, see Paolo Rossi, *Francis Bacon, From Magic to Science*, op. cit., p.19.

considerations meant the elimination of a significant aspect of human existence from science and technology. Imagination had always acted as the bridge that united fantasy with early technology. Recalling, for instance, man's dream of flying, one of the fantastic human desires, one has to consider the power that such a vision had on those who technically attempted to engage in the enterprise. On the one hand are the stories of Daedalus among the Greeks, Ayar Katsi, the flying man among the Peruvian Indians, the flying carpet of *Thousand and One Nights*, and the legend of Wieland, the German smith, who made feather clothes for flight. On the other hand we have the undertaking to realize human flight with technical means, such as Leonardo da Vinci's attempts to reproduce the motion of bird's wings. Da Vinci's sketches, dated 1485, show various forms of aeronautical machinery such as ornithopters, helicopter models and measuring devices for determining the lifting capacity of wings.[10] Those investigations indicate the strong impact the vision of human flight had on technical development anticipating the achievements of modern science and technology.

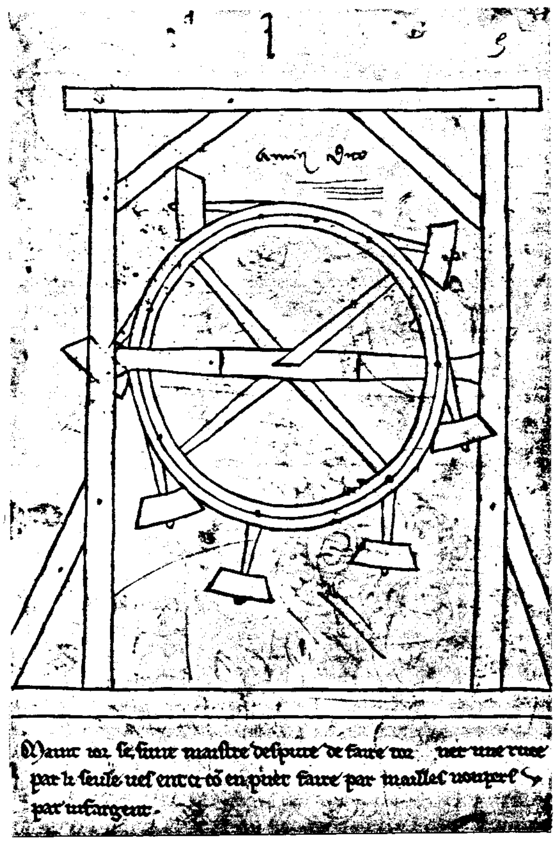
Architectural Technique in the Transfer from Practice to Theory

In architecture during the Middle Ages the fantastic and mystical component of thought provided the spiritual structure of material technique. One of the major mythical expressions of the Medival period was deeply anchored in religious belief. The imaginary realm of Christianity was one in which a fabulous heavenly world, filled with gods, saints, devils, demons, angels, and archangels provided the spiritual content of

[10] C. H. Gibbs-Smith, *Leonardo da Vinci's Aeronautics*, published by Her Majesty's Stationery Office (London), 1967.

material technique. The construction of Gothic cathedrals as well as Medieval treatises on arts demonstrate a synthesis of the heavenly world in unison with the reality of an earthly existence. For the construction of cathedrals, the irrational component of imaginative thought was conveyed by the material realization of fantastic structures of constructional ingenuity and the application of a sculptural decorum derived from the legends and fables of mythical tradition. The visible order signified as symbolic manifestation the belief in an eternal world. At the same time the methods employed by the builders of Gothic cathedrals were based on artisan empiricism which existed at the level of practice. If medieval treatises on arts as well as the Lodge Books of the Middle Ages are considered, it is discovered that they primarily cover specifications on procedures of the manufacturing process of things. Detailed instructions on the methods of production are given in terms of rules, recipes, and precepts. These were often put in connection with fantastic constructions of the imagination. The Lodge Books, or *Bauhüttenbücher,* used as to inform the builders of the construction methods, or sketchbooks such as that by the Frenchman Villard de Honnecourt, reflect the union of the magical with the material aspect of technique.

Lodge Books provided examples of ground floor plans, elevations, structural details, and ornament selected partially from existing monuments and partly invented by the authors



A perpetual motion machine from the sketchbook of Villard de Honnecourt. The legend below reads: *Often have experts striven to make a wheel turn of its own accord. Here is a way to do it with an uneven number of mallets and quicksilver.* (To which a later hand has added: *I say Amen.*)

themselves.[11] Villard de Honnecourt's sketchbook, dating from about 1235, demonstrates the extensive field of work of the thirteenth century master craftsman, architect, and engineer.[12] The book contains geometrical constructions, surveying methods, and specification of mechanical apparatus in addition to architectural designs. In reaching into the field of mechanical art, the architect's work of the Middle Ages demonstrated an affinity to Vitruvius's definition of the 'departments' of architecture. This definition includes not only the art of building but also the manufacture of clocks (time-pieces), the construction of cranes, military machinery and other technical devices.[13] Villard de Honnecourt's work, while in agreement with the Vitruvian 'departments', addresses also the realm of imaginary creations. Of interest are drawings of fantastic pieces such as an angel whose finger always points to the sun or a proposition for a *perpetuum mobile,* a wheel with an uneven number of moveable hammers which was to generate its own constant motion. Such mechanical inventions were of symbolic quality and referred to a spiritual level of understanding. As well as being of technical value, medieval documents of this

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11 See *Architector, the Lodge Books and Sketchbooks of Medieval Architects* by François Bucher, a compendium of illustrations and commentary of the notebooks of medieval architects; this compilation and analysis of Lodge Books represent a remarkable source of information on medieval architectural theory and methods of construction. François Bucher, *Architector*, Abaris Books (New York), 1979.

12 The following two facsimile editions of Villard de Honnecourt's Sketchbook were consulted by the author: *Villard de Honnecourt, Kritische Gesamtausgabe des Bauhüttenbuch*, Hans R. Hahnloser, Verlag von Anton (Wien), 1935; *Sketch-book of Wilars de Honecort*, with commentaries by M. J. Lassus, M. J. Quicherat, Rev. R. Willis, Henry & Parker (London), 1959.

13 "*There are three departments of architecture: the art of building, the making of time-pieces, and the construction of machinery.*" Vitruvius, *The Ten Books on Architecture*, translated by Morris Hicky Morgan, Dover Publications, Inc. (New York), 1960, Book I, Chapter III, pp. 16, 17.

type referred to the realm of the imagination allowing human fantasy to develop within technical propositions.

Technical writings of the time, however, made no attempt to explain to the reader why specific techniques were to be performed in a particular way. No systems of general concepts were provided by which problems could be addressed. These treatises were devoid of theory or any attempt to derive technical rules from general principles based on a totality of verifiable facts.[14] It was in the Renaissance that an analytical method was appropriated; treatises of the *quattrocento* and the *cinquecento* attempted to formulate *a priori* theories for the disciplines they addressed. Leone Battista Alberti (1404-72), in basing his writing on that of Vitruvius, derived his propositions on architecture from general principles. Alberti explicitly structured the field of architecture by identifying different classes of tasks. These formed a coherent and unifying system; similarly, technical problems of building construction were approached from the vantage point of conceptual frameworks.

Traditionally, techniques of building were primarily a matter of practice. During the Renaissance, as the work of Filippo Brunelleschi (1377-1446) demonstrates, the methods of architectural construction requiring an understanding of specific technical solutions became increasingly founded on theoretical assumptions. Frank D. Prager's seminal study on Brunelleschi's contribution to the construction of Santa Maria

[14] Paolo Rossi, *Philosophy, Technology and the Arts in the Early Modern Era*, translated from *I Filosofi e le Macchine* (1962) by Salvator Attanasio, Harper & Row (New York), 1970, p. 33.

del Fiore in Florence describes the development of a series of technical inventions clearly discerning the significance of a conceptual approach to problems of building.[15] Regarding the construction of the dome structure, Prager addresses three of Brunelleschi's contributions: the "system of chains" as structural reinforcement, the method of "vaulting without armature," and the use of "hoisting machines" during the construction process.[16] The realization of such inventions necessitated a conceptual understanding of building practice.

The structure of the *Duomo* 's cupola consists of a combination of vertical ribs as primary load bearing elements and concentric rings which act as Gothic ribs laid in a horizontal plane. Brunelleschi's experience in Gothic construction provided him with the necessary base for understanding the complexity required for building the cupola. From the knowledge of traditional building methods, he was able to develop new construction techniques. In order to reinforce the structure, stone and wooden "chains" were integrated within the masonry shell tying the primary structural ribs together. While the stone chains substituted for the need for external buttressing, the wooden chains were left exposed so as to be an instrument for reading the stresses occurring during construction. With the system of wooden chains, Brunelleschi provided a method by

[15] Frank D. Prager, "Brunelleschi's Inventions and the 'Renewal of Roman Masonry Work'," in *Osiris*, edited by Georgius Sarton, Volume IX, 1950, pp. 457-554. See also Frank D. Prager and Gustina Scaglia, *Brunelleschi, Studies of his Technology and Inventions*, MIT Press (Cambridge, Massachusetts), 1970. The significance of Prager's work was pointed out by Bates Lowry in a "Letter to the Editor," *The Art Bulletin*, Vol. XXXV, June 1953, No. 2, pp. 175-177.

[16] Prager, op. cit., pp. 483-525.

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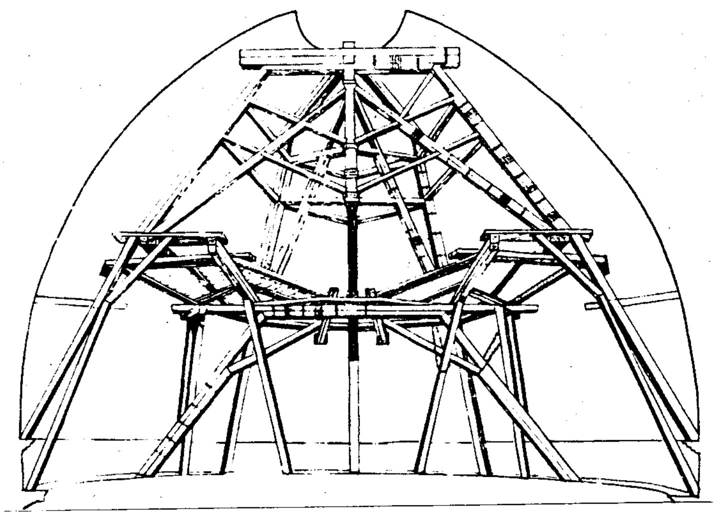


Scaffold designed by Brunelleschi
for the construction of the cupola of
Santa Maria del Fiore in Florence.
The proposed construction method did
not require a formwork for building
the spheroidal vault of the dome.

which to asses the condition and performance of structural properties.

In the construction of the cupola, furthermore, Brunelleschi abandoned the medieval system of wooden scaffolding supporting the temporary frames on which the vaulted work was constructed and which simultaneously delineated the sectional configuration of the form to be built. Brunelleschi proposed to omit a complete formwork; that is, to build the dual spheroidal vault of the cupola without using a provisional wooden structure to describe the geometry of the dome. This was achieved by using a method of layered construction in which horizontal concentric layers were placed on one another. This presupposed two things: "an admirable artisan expertise and the capacity to prearrange the development of the work in terms of an abstract view of the form."[17] It was necessary to determine through geometry and calculation the inclination and curvature of the masonry shells. This conceptual understanding of the form as well as the precise arrangement of ribs and chains imply the knowledge of structural laws and their methodical application to the building process.[18] Such an approach was based on speculation as there was at the time no possibility of quantitative verification.

A further indication of Brunelleschi's understanding of structural logic was the use of a double rather than the traditional single shell within the cupola. This allowed a

[17] Paolo Rossi, *Philosophy, Technology and the Arts*, op cit., p. 34.

[18] Prager writes that Brunelleschi "had obtained, ..., a knowledge of basic, qualitative laws of stress analysis which was centuries ahead of the understanding of his contemporaries." Prager, op. cit., p.493.

maximum weight saving and provided an outer shell as weather protection for the inner one. Brunelleschi might have also considered the additional stiffness that a double dome would provide, for an interest in identifying the most efficient means of construction guided his work. The aspect of efficiency was not limited to structural considerations but was also applied to the organization of the building process, such as the development of hoisting machines for saving time and labor. From Brunelleschi's understanding of traditional construction procedures and his knowledge of mechanics, he was able to derive new techniques which were applied to the production of architecture. In all, Brunelleschi's various contributions reveal an exposition of pragmatic considerations to the structure of rational thought whereby suggesting an understanding of building practice in view of conceptual frameworks.

With such conceptual as well as built works, architecture gradually passed from a phase of mystical and empirical technique to an age of reason and mathematical speculation.[19] The builder of the Middle Ages had been an artisan; his counterpart in the Renaissance was an intellectual. In the construction of the cupola of Santa Maria del Fiore, for perhaps the first time a fusion can be found between the technical and the scientific, or between manual labor and theory. Renaissance thought propagated the unification of fields forming coherent unifying systems, such as architecture understood as a discipline. Propositions or solutions to specific problems were derived from general principles which in

[19] Ibid.

turn were justified by facts. The union between fact and principle was the determining factor for the understanding of the development of the scientific and technological modern mind. It was this union of direct interest in detailed, clearly identifiable facts with equal reference to abstract generalization which formed the methodological base of scientific thought as applied to technique.

A Matter of Facts

The influence of modern science on human knowledge has evolved since Renaissance as a central theme of philosophical investigation. The origins of modern science have been addressed in depth by Alfred North Whitehead in his philosophical work *Science and the Modern World.* Whitehead, while agreeing with the unity of fact and principle in forming scientific thought, emphasized the dominance of the element of fact for the origins of modern science and technology. In doing so, he challenged the common belief that the modern period began when men turned from the faith of the Middle Ages to a reliance on reason. Whitehead states that the Middle Ages was characterized by a "sweeping and unbridled" rationalism, as supported by the church, which propagated the conception of a definite cosmological order and justified the detailed way in which the world should function. According to Whitehead the modern period begins as a revolt against such rationalism, and turns instead to the "irreducible and stubborn" facts of experience. He writes:

It is a great mistake to conceive this historical revolt as an appeal to reason. On the contrary, it was through and through *an anti-intellectualist movement. It was the return to the contemplation of brute fact; and it was based on a recoil from the inflexible rationality of medieval thought.*[20]

The dichotomy between the rationalism of the Middle Ages and the scientific interest in the factual reality of experience, as discussed by Whitehead, constituted the central element of disagreement in the historically known dispute between Galileo and the Catholic Church. Galileo Galilei (1564-1642) and his adversaries held inherently opposed positions. Galileo insisted on "irreducible" facts as derived from the observation of nature. Simplicius, his opponent, based his argument on reason as the justifying element of the *status quo*, the accepted order of the world system. Galileo's interest was clearly directed towards *how* things happen, whereas his adversaries referred to a complete theory as to *why* things happen. These two opposed world views reflected the schism between modern science and philosophy, the former dealing with *how* the world functions and the latter with the explanation of the *why* of its condition of being.

Based on the hypothesis that an interest in facts dominated scientific thought, Whitehead speculated that science, although based on rational maxims, has never shaken off the imprint of its origin in the historical revolt of the later Renaissance. Science, according to Whitehead, has remained predominantly an anti-philosophical movement, based on naïve faith for facts and a consistent rationality. Science has accepted this faith but

[20] Alfred North Whitehead, *Science and the Modern World*, 1925; The Free Press (New York), 1967, p. 8.

has not cared to integrate in its procedures the explanation of its meaning.[21] In view of such a contradiction in scientific thought, it is of importance to consider the *a priori* role of faith for an understanding of science. This form of faithful belief is based on the instinctive conviction in the existence of an order of things, and, in particular, of an order of nature. The formation of a general idea, such as the concept of natural order, resides in the belief that nature as an *a priori* given determines the absolute working of things. The Greek view of nature was essentially dramatic. It conceived of nature as articulated in the way of a dramatic art, as the exemplification of general ideas converging to an end. Nature was differentiated so as to provide its proper conclusion for each event; nature was a drama in which each element played its part. This inevitability is what pervades scientific thought in its foundation. In other words, the laws of nature were seen as the decrees of fate. The observation of nature became essential, and natural occurrences had to be studied and analyzed. Consequently, specific techniques for measuring and recording experienced occurrences were developed.

During the Renaissance a revolution in the conception of space took place, whereas space as a hierarchy of values was replaced by space as a system of magnitudes. One of the indications of this orientation was the closer study of the relations of objects in space through the discovery of the laws of perspective allowing the systematic organization of pictures within a frame fixed by foreground, horizon and vanishing points. Perspective was seen as a method by which to

21 Ibid., p.16.

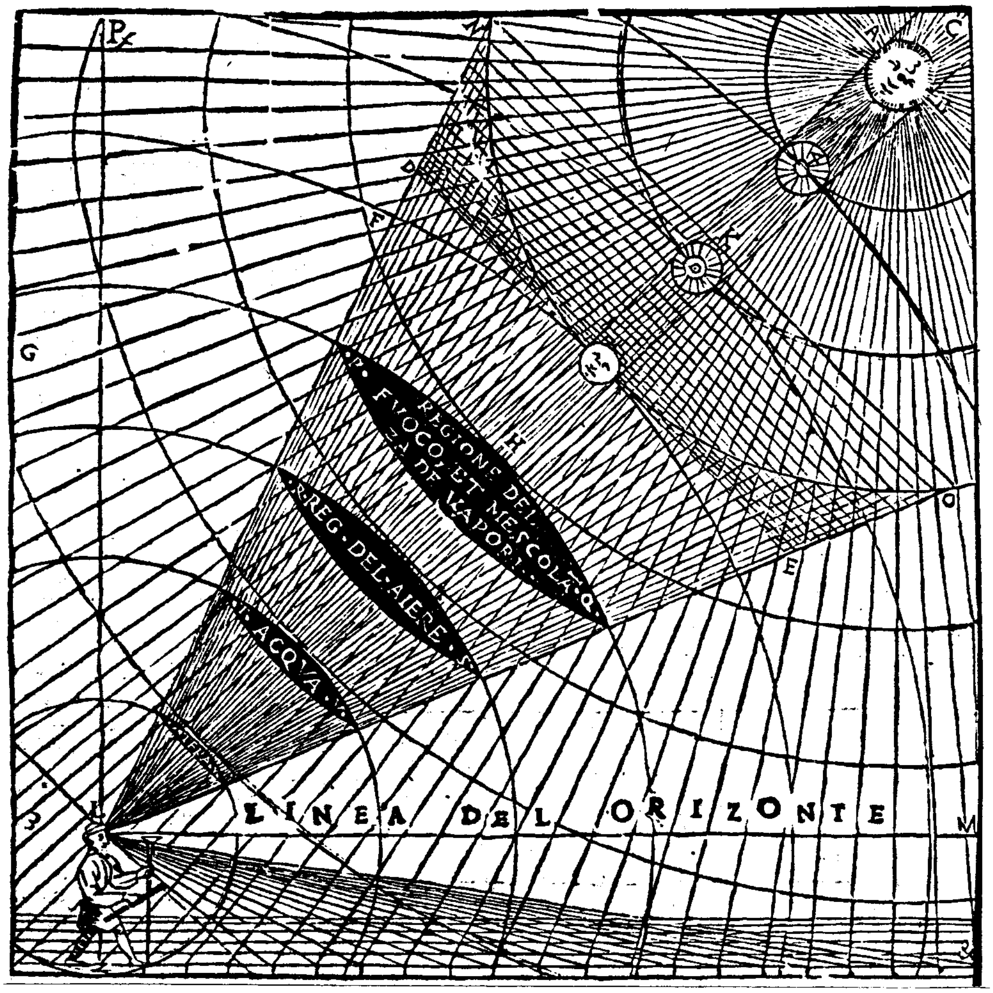
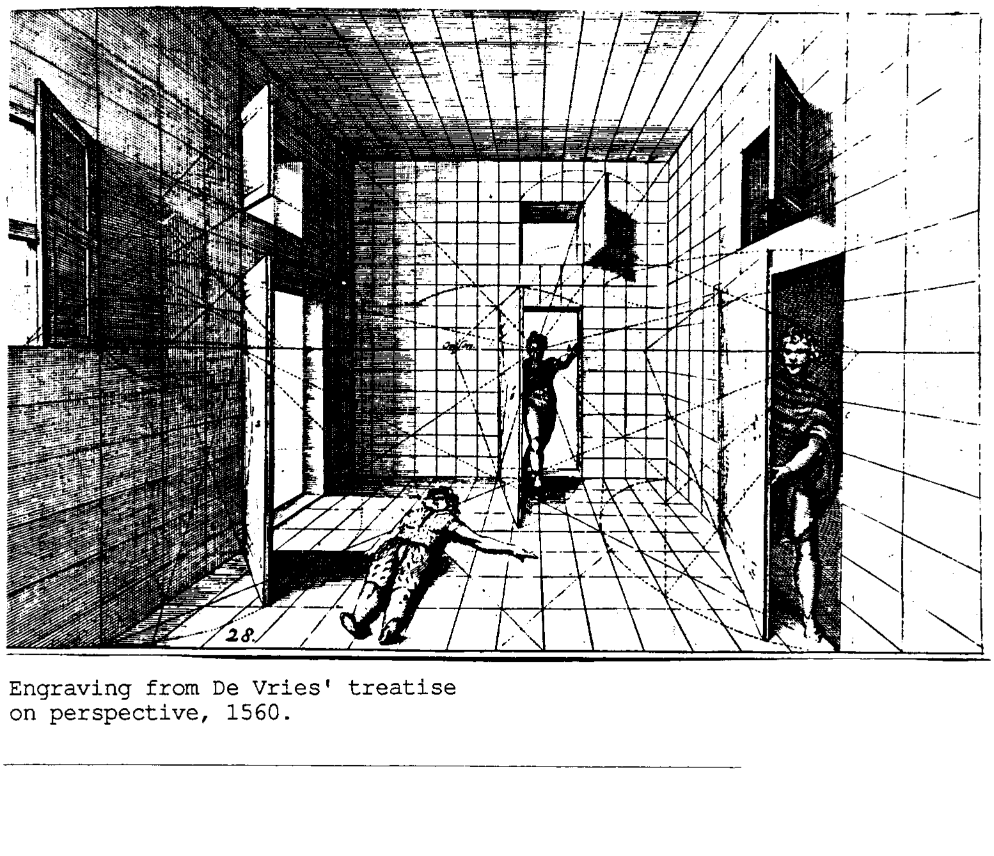


Illustration from Gianbattista Caporali's edition of Vitruvius' *Ten Books*, 1536.



Engraving from De Vries' treatise on perspective, 1560.

technically construct space and was a device with which to portray an accurate representation of space within the process of conceiving architecture. Perspective turned the medieval concept of a symbolic relation of objects into an understanding of visual relation, which in turn was determined by quantitative entities. Geometry and number, divorced from their mythical order, became instruments for the technical control of practical operations. Size meant not divine importance but rather measurable entity. Objects were perceived in terms of their accurate representation based on a point-by-point correspondence between picture and image. The division of the drawing board into squares, as demonstrated in Dürer's treatise on perspective[22], indicates a new technique for the scientist, painter, or architect by which to order his ideas through scientifically accurate representation.[23] Various other treatises on perspective followed supporting the interest in developing procedures for the creation of a representation of space as based on perspectival construction.

Perspective was a technical device to view and understand the entire world system. Gianbattista Caporali's edition of Vitruvius's *Ten Books on Architecture* (1536) includes an illustration on man's view of the universe, perceived and organized as a perspective construction. A system of lines

[22] See Hans Schuritz, *Die Perspektive in der Kunst Albrecht Dürers,* Heinrich Keller (Frankfurt), 1919. The illustration "Der Zeichner des liegenden Weibes" by Albrecht Dürer was added to the *Unterweisung der Messung* (1525) after Dürer's death in 1538.

[23] Alberto Pérez-Gómez, *Architecture and the Crisis of Modern Science,* MIT Press (Cambridge, Massachusetts) 1983. Pérez-Gómez traces the process by which the mystical and numerological grounds for the use of number and geometry in building gave way to those more functional and technical which prevail in architectural theory and practice today.

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Illustration from Cesare di Lorenzo
Cesariano's edition of Vitruvius' *Ten Books*, 1521.

extend from the human eye by which to organize space, the surface of the earth, as well as the position of sun and planets. The world system was conceived as a measurable entity organized along geometric lines. An illustration from Cesare di Lorenzo's edition of Vitruvius's *Ten Books* (1521), in contrast, shows a Medieval perception of the cosmos based on the animistic belief that natural phenomena possess souls. Here the image of the world is primarily based on symbolic representation. Spatial relations, which during the Middle Ages tended to be organized as symbols and values, were during the Renaissance described by geometry and number divorced from their mythical order. Geometry and number became instruments for the technical control of practical operations.

The interest in facts combined with the instrumentality of technique were the primary elements of a model for man to use in understanding as well as in creating his environment. Scientific inquiry aided the development of material technique which became significant factors of civilizatory progress. The fantastic and imaginary power of magical technique was lost and replaced by a faith in technological evolution. Technological development, as foreseen by Francis Bacon in the early seventeenth century, was to become world-wide.

Bacon, in respect of the new achievements in science-technology, proposed in his *Novum Organum* a new type of knowledge derived from the observation of natural phenomena independent of transcendental causes. The history of science was regarded by Bacon as progress, an accumulation of valuable experience derived from the past for the future development of society. Knowledge, in these terms quantifiable, thus evolved as a collective task capable of being shared and transmitted. The result would be a single scientific tradition, a product of necessity, and the only true knowledge in contrast with the long-standing conflict among philosophical systems.[24] This description of an utopian model concerning a new system of knowledge coincides clearly with the reality of technology as perceived today.

The predominant criteria determining the daily field of operation of contemporary architectural technology is based on the specific propositions of modern science. The decision-making process in building construction is in direct correspondence with an unlimited faith in facts. The main concern becomes how to build in an efficient and economical manner while avoiding questions related to why one builds and whether such activity can be justified under the given conditions. The rise of positivism in the physical and human sciences has without doubt accelerated that tendency towards the functionalization of architecture as is manifested in the material determinism inherent within the processes of the making of things.

A Matter of Principle

The reference to general principles within scientific thought constituted a second and parallel development within modern science. William Barrett, in his book *The Illusion of Technique*, proposes that the immediate bond between observer

[24] Paolo Rossi, *Philosophy, Technology and the Arts*, op. cit., pp. 80 - 87.

and nature, as had been maintained in Greek science, has been drastically altered by modern scientific thought. He asserts that scientists such as Copernicus (1473-1543) and Kepler (1571-1630) did not primarily address "stubborn and irreducible" facts, as Whitehead would argue; instead, intellectual models were constructed in contradiction to facts as they disclosed themselves in immediate experience. Barrett writes:

Consider the theories of Copernicus and Kepler, for example. They are as revolutionary as any theories can be, for they change the whole picture of the universe in which men live. The earth is no longer the center of the cosmos, and the heavenly bodies do not move in the patterns that our immediate perception discloses. If you are a persistent stargazer, reader, you will know that natural and congenial sense of the heavenly bodies - sun, moon, stars, and planets - wheeling in their circle around you as center. Walking in the summer night, you become accustomed to that movement almost as an extension of the axes of your own body, as it takes its direction from them.[25]

Barrett suggests that modern science challenged the system of relationships between man and nature as had been propagated in Greek science. The expression *Sozein ta Phainomena*, to preserve things as they show themselves to be, explicitly describes the understanding of the traditional structure of scientific thought that congruence is preserved between natural objects

[25] William Barrett, *The Illusion of Technique*, Anchor Books (New York), 1979, p.200.

and the direct perception of them.[26] Scientists such as Copernicus and Kepler, rather then addressing factual reality, based their understanding of the world on abstract concepts removed from immediate experience. The phenomenological congruence between man and nature was broken.

William Barrett provides a further example in addressing Galileo's contribution to the concept of inertia as a fundamental characteristic of moving bodies. Barrett writes that Galileo set up a concept that could never be realized in actual fact: "Imagine, he says, a perfectly smooth and frictionless plane; set a ball rolling upon this plane, and it will roll on to infinity unless another body and force interpose to stop it."[27] Of importance here is that experience never presents man with perfectly frictionless surfaces nor with planes infinite in extension. Nevertheless, Galileo's presuppositions, according to Barrett, supplied to the science of mechanics a concept of inertia more fruitful for theory than any that could be directly derived from direct observation. In the "new science" of Galileo visible reality lost importance in order to come to terms with a world of abstraction, relations, and equations. "Rationalism," Barrett asserts, did not "surrender itself to ... facts;" rather, rationalism set "itself over facts" by creating conceptual constructs which were seen as being *a priori* given.[28] Such concepts led to the formulation of general principles which formed the rules within a specific field. Scientific inquiry, although establishing

[26] Ibid.
[27] Ibid., p.201.
[28] Ibid.

"conditions contrary to fact," proceeded "to measure the facts in the light of these contrafactual conditions."[29]

Since the Age of Reason an approach to architecture from such a perspective allowed the processes of problem solving to occur on the basis of general principles. These were conceived in reference to an understanding of technology as a system of knowledge. Technique, in this regard, followed the predetermined structure and logic of given rules for the processes of construction. Furthermore, the union of science and technology was seen in terms of the acceptance of true principles and their establishment within technical production. Technology in general and architectural technology specifically constituted the theoretical base for the application of those general concepts in physical reality.

René Descartes (1596-1650) was one of the first thinkers of the modern period who attempted to transfer the procedures of science into philosophy. He proposed a universal and distinct method which was to be extended to all aspects of human thought. Descates's method, furthermore, indicated the priority of rationality over existing reality. In his *Discourse on the Method of Properly Conducting One's Reason and of Seeking the Truth in the Sciences* Descartes established four rules of method which he presented as valid for the study of all sciences.

The first was never to accept anything as true that I did not know to be evidently so: that is to say, carefully to avoid

[29] Ibid.

precipitancy and prejudice, and to include in my judgement nothing more than what presented itself so clearly and so distinctly to my mind that I might have no occasion to place it in doubt.

The second, to divide each of the difficulties that I was examining into as many parts as might be possible and necessary in order best to solve it.

The third, to conduct my thoughts in an orderly way, beginning with the simplest objects and the easiest to know, in order to climb gradually, as by degrees, as far as the knowledge of the most complex, and even supposing some order among those objects which do not precede each other naturally.

And the last, everywhere to make such complete enumerations and such general reviews that I would be sure to have omitted nothing.[30]

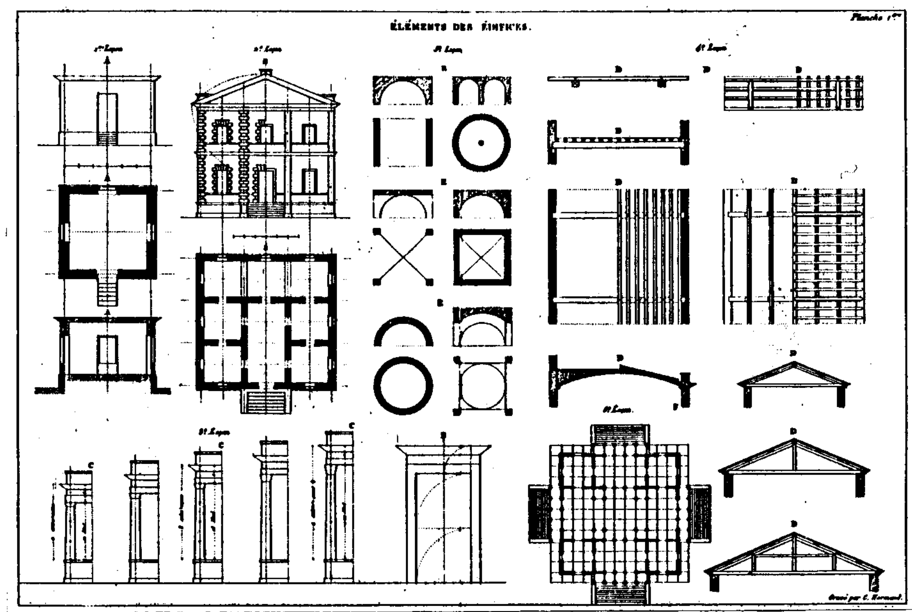
Descartes's method departs from intuition. The first principle implies the operation which Descartes identifies as intuitive reasoning, that is the use of the "pure light of the mind as opposed to the evidence of the senses."[31] It is by 'intuition' that man knows that he thinks and therefore that he is. This first rule may be paraphrased that in the study of any problem, one shall start by approaching 'intuitively' the fundamental truths of which there can be no doubt. The second methodological step, often known as the rule of analysis, proposes the decomposition of complex problems into

[30] René Descartes, "Discourse on the Method of Properly Conducting One's Reason and of Seeking the Truth in the Sciences" (1637), in *Descartes, Discourse on Method and the Meditations*, translated with an introduction by F. E. Sutcliffe, Penguin Classics (Harmondsworth, Middlesex, England), 1968, p. 41.

[31] F. E. Sutcliffe, "Introduction," in *Descartes, Discourse on Method and the Meditations*, ibid, p. 16.

identifiable parts. In other words, the process of problem-solving is suggested to follow a structured analysis, through a step-by-step approach, leading from complex phenomena to simple configurations. The third rule is known as the rule of synthesis, and is applied to the truths reached by the two preceding methodological steps. Descartes's method proposes an ordering structure starting with the simplest revelations reached through a process of analysis and followed by the truths deducted from them, going from the simple to the more complex. The third rule can be understood as a direct application of the principles inherent within the formation of equations in mathematics. The proposition to operate from the simple to the complex can be compared with the movement from equations of the first degree to those of a higher degree. Lastly, the fourth rule takes account of the fact that deduction, unlike intuition, depends to some extent on the complete enumeration of all parameters in view of all possibilities. With this rule the attempt is made to demonstrate for deductive reasoning the link between the first principles and their ultimate consequences.

Descartes's method illustrated the attempt to systematize the processes of scientific reasoning for establishing a new and general base of philosophical thought to be applied to all disciplines. Cartesian philosophy became the general model of reference of Western culture for the succeeding centuries. In architecture, the tendency towards a systematization of the field found its expression in such works as Jean-Nicolas-Louis Durand's theoretical publications: the *Recueil et Parallèle des Edifices de Tout Genre, Anciens et Modernes* (1801) and the



J.N.L. Durand, "Éléments des Édifices,"
Partie Graphique des Cours d'Architecture, 1821.

Précis des Leçons d'Architecture (1819, 1821). The *Recueil*, a collection of existing and invented buildings drawn at the same scale, propagated a conception of history as an objective science. History was viewed as a progressive and linear accumulation of data from which it was possible to derive fixed principles.[32] These rules were summarized in the *Précis des Leçons* which outlined the content of Durand's course at the *École Polytechnique*. Following Descartes's method, in the first part of the *Précis* entitled "Éléments des Édifices," building elements such as columns, walls, openings, foundations, roofs, vaults, and trusses were analyzed. Such elements, constituting the basic vocabulary of architecture, were considered in terms of their form and proportion as well as in relation to the materials used in construction. In the second part of the treatise, "De la Composition," Durand provided rules of how to combine the simple elements, which are for architecture "like words in language or notes in music," into complex structures.[33] These combinations, according to Durand, formed the essential aspect of an architect's work. Building components were to be assembled according to specific rules in order to determine individual units, which again were to be combined to form larger structures. Durand's methodology was fundamentally a rational structure by which to conceive architecture, for he believed that buildings could result from the combination of few elements as given by the *mécanisme de la composition*. The structure for combinatory procedures was

[32] Alberto Pérez-Gómez, *Architecture and the Crisis of Modern Science*, op. cit., pp. 313, 314.

[33] "*... qui sont à l'architecture ce que les mots sont au discours, les notes à la musique,...*" Jean-Nicolas-Louis Durand, *Précis des Leçons d'Architecture*, (1802-05); edition of 1819, Verlag Dr. A. Uhl (Nördlingen), 1981, p. 29.

determined by the use of a grid which allowed the placement and arrangement of the elements in plan. Columns were to be located at the intersections of grid lines, walls were to be placed on the lines, and openings marked the center of their respective modules.[34] The grid was in Durand's *mécanisme* an instrument of technical value divorced from any kind of symbolic connotation; technique was considered a neutral tool. Whether pertaining to design or construction, technique had become a system of operational devices to be objectively invested in the production of building. Architecture herein followed the procedures of scientific methods and their formalization by Cartesian philosophy.

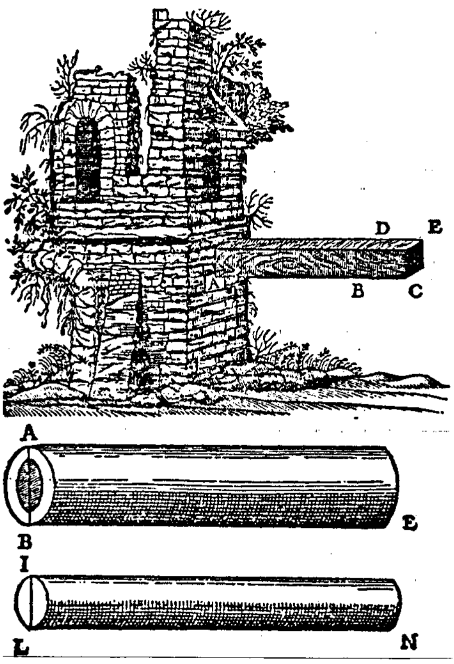
Descartes's propositions addressed the reality of physical phenomena in analogy to mathematical operations. For understanding the external world, the method, according to Descartes, allowed one to proceed with the same success as when dealing with mathematical structures. Mathematical relations were considered of the same order as those of understanding. The external world was seen as being mathematical in its structure. The hypothesis of the mathematical, and in this sense mechanical, order of nature was, however, by no means peculiar to Descartes. At the end of the seventeenth century a fully articulated philosophy of the universe had been articulated on purely mechanical lines. A mechanical *Weltbild* had come into existence. The movement of the stars, the relationship of the planets to the sun, as described by Copernicus and later by Kepler, were described in terms of the rules and principles of an abstract system. Intellectual

[34] Alberto Pérez-Gómez, op.cit., p. 304.

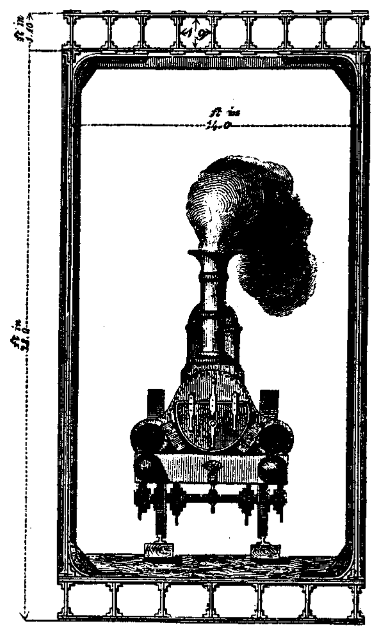
systems of thought replaced the facts of reality; the structure of the world was understood to be conceivable as an exemplification of general principles. Galileo's *Dialogues Concerning Two New Sciences* at the beginning of the seventeenth century demonstrated a clear interest in identifying general principles for a better understanding of the world.[35] The formation of principles such as that of the cantilever or the discovery that the strength of a hollow tube exceeds that of a solid cylinder made of the same material and of equal size and weight, represented attempts to structure the physical world. Such principles were considered to provide the framework towards establishing an universal system of knowledge.

The general and all encompassing magnitude of the Cartesian model led to the consideration of its applicability, through the transfer and application of principles, for scientifically structuring the various disciplines of human knowledge. An approach to architectural technology from such a perspective allowed the processes of problem solving to occur on the basis of an understanding of general principles. This development had its strongest impact on the field of structural engineering during the nineteenth century and was marked by the increasing attention given to scientific methods which were translated into practical propositions for structural design. The construction of the Britannia and Conway bridges, built from 1845-1850 in Wales, England, for example, represented a

[35] Galileo Galilei, *Dialogues Concerning Two New Sciences*, translated by Henry Crew & Alfonso de Salvio (1914), Dover Publications, Inc. (New York), 1954, p.150; see also *Dialogue Concerning the Two Chief World Systems - Ptolemaic & Copernican*, translation by Stillman Drake, foreword by Albert Einstein, University of California Press (Los Angeles), 1967.



Illustrations from Galileo's *Dialogues Concerning Two New Sciences* referring to the principle of the cantilever and the propositions on the structural behaviour of tubes.



The Britannia Bridge in Northern Wales, built in 1845-1850 under the supervision of the engineers William Fairbank & Robert Stephenson and the mathematician Eaton Hodkinson.

conceptual application of Galileo's theory on the structural performance of hollow tubes. Based on elaborate calculations and experiments, the Britannia and Conway bridges were conceived as horizontally posited tubes or hollow beams. The problems occurring during the planning and construction phase of the Britania Bridge necessitated various experiments with models to determine the quantitative and qualitative performance of material and structure.[36] The mathematician Eaton Hodgkinson in collaboration with the two engineers in charge of the project, Robert Stephenson and William Fairbank, developed the structural system of the bridge from theoretical assumptions followed by mathematical analysis and verified by empirical experiments. Within the field of architectural technology, principles supported by mathematical formulas were applied to practice through a process of analytically determining the forms and dimensions of structures. Construction techniques were not any longer determined solely by previous experience but were derived from the results of scientific methods.

The union of science and technique was seen in terms of the acceptance of scientific principles and their establishment within the field of technology. What Galileo had done for the physical sciences was considered by Descartes as the starting point for a philosophy rooted in science. Important for the understanding of Cartesian philosophy is that the *method*, which supported deductive science, was primarily conceived as a model of thought. The mere distinct idea of an object, for example,

[36] Tom F. Peters, "Die Britannia- und Conwaybrücke," in *Time is Money, die Entwicklung des modernen Bauwesens,* Julius Hoffmann Verlag (Stuttgart), 1981, pp. 103-115.

established no guarantee of the real existence of the object itself. Aristotle had started from the given world in all its complexity and with all the qualities perceivable to human senses. Descartes, on the other hand, rejected the validity of the evidence of the senses. Material objects were only to be understood in regard of various established schemes of abstraction, for example in mathematical terms: an object had height, depth, and width and was identified through the universality of geometrical principles. Aristotle's philosophy departed from the complexity of the real world in order to define unifying principles; Descartes proceeded instead from the abstract idea to the particular. But the idea did not necessarily entail the existence of its physical manifestation; Descartes had no assurance that the real was not, in fact, irrational and obscure. Science, following Descartes, incorporated the will to eliminate chance and the irrational, allowing for control of the environment and the potential for human supremacy. Descartes transferred the procedures with which science had already embarked into philosophy, and he proposed that these be extended to all domains of human inquiry. When Galileo set up his concept of inertia he had not passively reproduced facts as taken from nature; he had created instead an artificial concept, one that was a construct of the mind, and he had set this up over nature as the measure of it. Descartes recognized the intellectual consequences of scientific propositions suggesting that all things were conceivable as exemplifications of general principles which reigned throughout the natural order. The mind of its own power provided its own reality.

Reason became "legislative of experience" - this being the decisive point that Immanuel Kant (1724-1804) perceived as the real revolution of science. In his *Critique of Pure Reason*, Kant clearly established the distinction between "*a priori* knowledge" and "empirical knowledge." Knowledge *a priori* was considered absolutely independent of all experience and was therefore entitled as pure. Reason, or pure reason, was understood as the faculty which supplies the principles of *a priori* knowledge. In contrast, empirical knowledge was defined as *a posteriory* knowledge that in experience "is made up of what we receive through impressions."[37] *A priori* principles, according to Kant, establish universal rules which in themselves are absolutely independent of experience, but indispensable for the possibility of experience. In other words, *a priori* knowledge was considered absolute. Kant's *Critique of Pure Reason* represented an attempt to understand the meaning of the 'new science,' which at his time had existed for more than a century. In this regard, his philosophical investigation did not primarily attempt to set up a system of idealistic philosophy but rather was directed towards assimilating the mentality proposed by the 'new science.' *The Critique* is primarily a treatise on method engaging in the investigation of speculative reason rather than a system of science itself. Kant's writing is entitled *transcendental*, that is, dealing neither directly with objects nor with things, but instead with the mode of man's knowledge of objects. Kant described the world from the structures of human consciousness; if the world in itself should be different from those

[37] Immanuel Kant, *Critique of Pure Reason* (first edition 1781 and second edition 1787),translated by Norman Kemp Smith, St Martin's Press (New York), 1965, pp. 41- 62.

structures, then, according to Kant, we would not be able to think it. In that regard, there is no intrinsic difference between the idea of a thing as mere possibility and the idea of the same thing as actually existing. The reality of things, so far as judgment is concerned, proceeds from the act of will that establishes these things as real.

The Science of Imagination

With the gradual development of modern science from the seventeenth to the nineteenth centuries, human thought and action became increasingly dominated by rational constructs. The power of rational determination evolved to such an extent that the mind created its own reality. Kant determined that the reality of the world corresponds to the structure of the human mind. Consequently, reality as perceived by man could be understood as a construct of the human imagination. The question was raised by David Hume (1711-1776) in his *Enquiry Concerning Human Understanding* as to whether the rational propositions of modern science were not to be considered pure results of arbitrary and imaginary thinking. Hume accepted the fact that science in general is knowledge as founded on the relation of cause and effect. He was of the conviction that the human mind could never possibly find the effect in a supposed cause, even when proceeding by most accurate examination. It follows, according to Hume, that the human mind must invent or imagine some event which it ascribes to the cause as its effect. He wrote:

In a word, then, every effect is a distinct event from its cause. It could not, therefore, be discovered in the cause, and *the first invention or conception of it, a priori, must be entirely arbitrary.*[38]

If, according to Hume, the definitions of scientific propositions can be considered arbitrary, it follows that science as a totally rational endeavor is impossible except in the sense of establishing "entirely arbitrary" connections. Scientific thought in this regard, when not directly based on experience, must be founded in the realm of pure imagination.

The concept of modern science, viewed from such a vantage point, offered the possibility for reconsidering the spiritual and symbolic aspect of technique in order to incorporate the notion of the irrational and mythical moment of human understanding. Giambattista Vico (1668-1744), at the beginning of the eighteenth century, was one of the first Western philosophers to speak up for the primordial knowledge that stemmed not from reason but from imagination. Western philosophical thought was dominated by reason with thought processes grounded on the idea of reason coming to terms with the concreteness of experience as perceived. Vico broke with that tradition and proposed for science the reconciliation between rational structure and mythical sphere which lies in human imagination. Vico assigned what he called *fantasia* to the imagination which played a primary role in the act of making wherein the meaning of things is created through poetic

[38] David Hume, *Enquiries concerning Human Understanding and concerning the Principles of Moral*, reprinted from the 1777 edition with introduction by L. A. Selby-Bigge, third edition with revised text and notes by P. N. Nidditch, Oxford University Press (Oxford, England), 1975, p. 30.

Frontispiece to Giambattista Vico's
New Science, 1730/1740.

thought.[39] Imagination, according to Vico, is the power of understanding something from the inner perspective of its existence and is inherent within the poetic act which holds human thought and action together. Technique in this sense was considered to unify the poetic component of mystical thought with the structure of rational thought embodying, therefore, the rational-irrational moment within making.

Donald Philip Verene in *Vico's Science of Imagination* views Vico's propositions in juxtaposition to traditional philosophy.[40] While not founded on the concept of reason, Vichian philosophy stands outside the Western tradition of thought and proposes other foundations for human understanding:

It begins instead with the imagination, with fantasia, *as an original and independent power of mind. In Vico's thought, images are not images of something; they are themselves manifestations of original power of spirit which gives fundamental form to mind and life. Images or* universali

[39] See Donald Phillip Verene, "Vico's Philosophical Originality" and Leon Pompa, "Imagination in Vico," in *Vico: Past and Present*, edited by Ciorgio Tagliacozzo Humanities Press (Atlantic Highlands, N.J.), 1981, pp. 127 - 143 and pp. 162 - 170.

[40] According to Verene, Western philosophy developed along two major traditions of thought. The foremost tradition was dominated by the notion of reason. Rational thought constituted the means by which philosophy could come to terms with the concreteness of experience. He writes that Plato's problem with poetic imagery and Aristotle's concern to conceive man as rational are, each in its own way, evidence that conceptual reasoning as supported by rational thought was a predominant concern of Western philosophy. This philosophical tradition constituted the philosophy *des Geistes*, the philosophy of mind. The second tradition within Western thought directed its interest towards the question of Being and substituted the philosophy *des Geistes* with a philosophy *des Lebens*, of life and existence. Vico, according to Verene, stands outside both Western traditions; his propositions proceed neither from the notion of *Geist* nor from the concept of *Leben;* instead, Verne writes, Vichian philosophy offers another possibility of understanding. See Donald Philip Verene, *Vico's Science of Imagination,* Cornell University Press (Ithaca, New York), 1981, pp. 32, 33.

fantastici *are not, in Vico's terms, simply concepts in poetic cloaks. The image is not to be understood in relation to the concept. The image is to be understood on its own terms.*[41]

The importance of imagery, of metaphor, and of symbolic meaning in Vichian philosophy is best expressed in the frontispiece to Vico's *New Science.*[42] The world is here represented not as a system of magnitudes and geometrical order but as a field of relationships between images of symbolic quality. God appears in the sky as an eye within a triangle, reflecting his vision onto the breast of a female figure symbolizing the science of metaphysics. She stands on a globe representing the world of nature. Illuminated by a ray reflected from her breast is a statue of Homer, the first poet of Western tradition, surrounded by various man-made objects of the world of human civilization. The opening paragraph of the *New Science* is an explanation of the frontispiece's intention. The frontispiece, which constitutes the point of departure for the reader, depicts itself as an origin alluding to the images, metaphors, and symbols of the philosophical *oeuvre.*[43]

Vico's conception of the imagination was centered on poetic thought through which image and rational idea are understood. Memory plays an important role in Vico's propositions; it is

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41 Ibid., p. 33.

42 Giambattista Vico, *The New Science of Giambattista Vico,* unabridged translation of the third edition (1744) by Thomas Goddard Bergin and Max Harold Fisch, Cornell University Press (Ithaca, New York), 1961 and 1968; paperback edition 1984.

43 For further descriptions of the frontispiece see: Giambattista Vico, "Explanation of the Picture placed as Frontispiece to serve as Introduction to the Work," in *The New Science,* ibid., p. 3. See also Donald Phillip Verene, *Vico's Science of Imagination,* op. cit., pp. 17, 18.

the means by which to recall original thought and to revoke the fantastic creations of mythical thought. Those constitute the base of imaginative universals, of *fantasia* as a way of thinking and acting. Vico's ideas generated philosophical understanding from the image rather than from rational categorization. Memory and imagination were considered powers providing man with an inner perspective. Within the development of modern science, memory and imagination, according to Vico, permitted man to overcome the externality of the world and to enter the original immediacy of the human mind.

Fantasia was considered a way of making things, occurrences, and events intelligible as can be seen, for example, in Villard de Honnecourt's fantastic creations, Leonardo da Vinci's sketches for aeronautical machines, and the seventeenth century proposals for a diving apparatus by G. A. Borelli.[44] The power of the imagination brought together with the structures of conceptual thought led to the development of innovative techniques within the fields of architecture and engineering. The determining role of *fantasia* on technique was essential to the development of such contributions as Brunelleschi's inventions for the dome structure in Florence as well as Stephenson's and Fairbank's approaches to the construction of the Britannia and Conway bridges. A more recent example in which the imagination was merged with technical considerations is to be found in the work of Antonio Gaudí. His experimental models for the *Colonia Güell*, for instance, are a manifestation

[44] See Friedrich Klemm, *A History of Western Technology*, translated from *Technik: eine Geschichte ihrer Probleme* (1954) by Dorothea Waley Singer, MIT Press (Cambridge, Massachusetts), 1964; paperback edition 1970, pp. 182-185.

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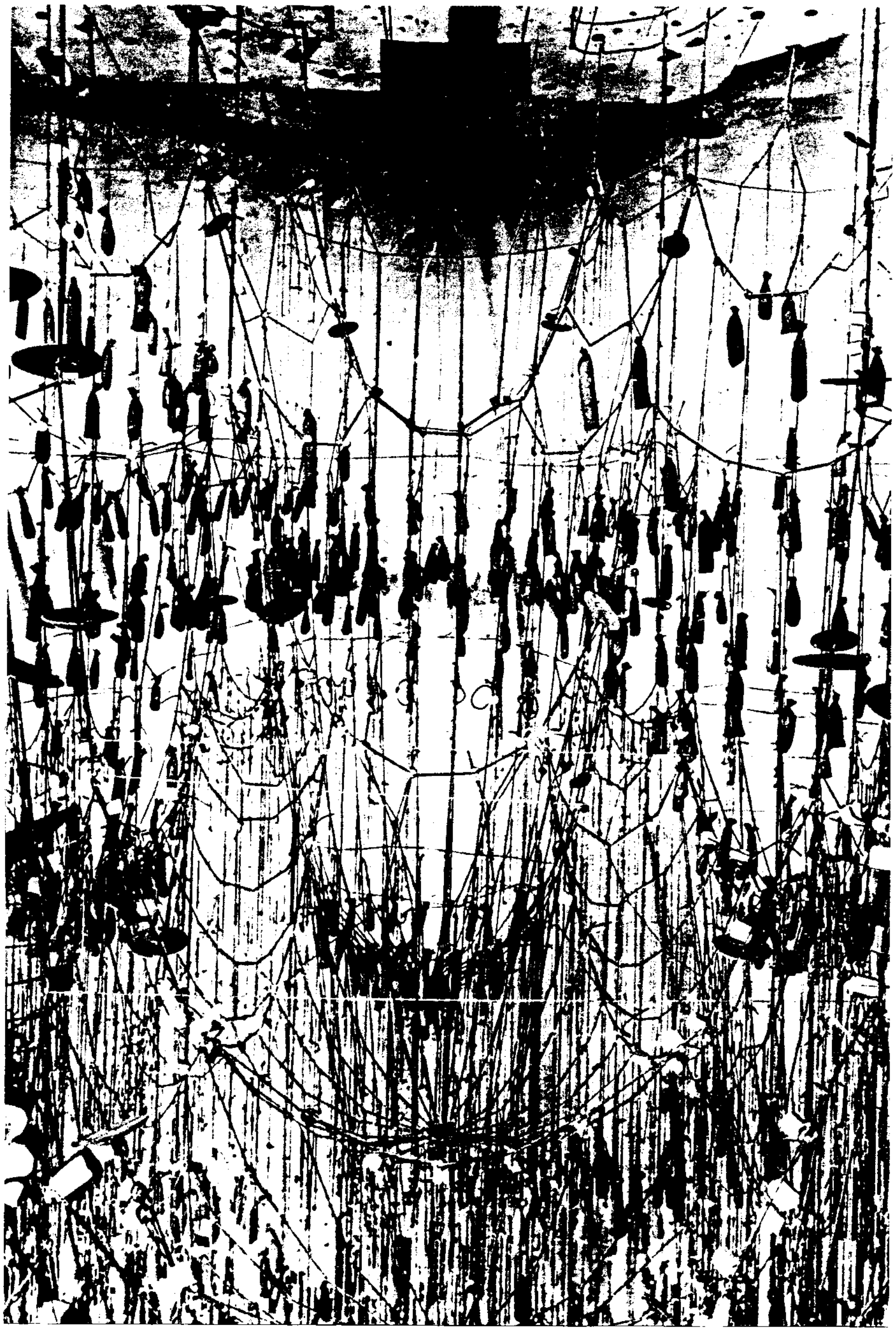

Antonio Gaudi, model for the church of the *Colonia Güell*, 1898-1914.

of creative fantasy united with technical knowledge. The highly elaborate preparatory studies and funicular models by which Gaudí experimented with loads to determine structural systems indicate the clarity of Gaudí's vision as well as his ingenuity concerning technical considerations.[45] *Fantasia,* in those terms, is a conception of how knowledge is created. The mind's power of *fantasia,* as Vico asserted, is the means by which the world is understood. Instead of basing knowledge exclusively on generic concepts, Vico's philosophical orientation engaged the imagination by uniting the image with the concept, and myth with fact.

Vico's understanding of science is best described in the distinction he made between the terms *scientia* and *conscientia.* This initial distinction is based on the difference between *scientia,* standing for knowledge or science, and *conscientia,* meaning consciousness or conscience. *Scientia* pertains to the true and truthful; that is, it addresses the search for universal principles. *Conscientia* has as its object the certain, facts, events, and occurrences as derived from careful observation. In the introduction to the *New Science* (edition 1961) Max Harold Fisch proposes a definition of Vico's understanding of science as based on the synthesis of both terms.[46] Scientific knowledge within Vichian philosophy, he writes, unites fact and principle.

[45] Robert Descharnes & Clovis Prévost, *Gaudí, the Visionary,* The Viking Press (New York), 1971, pp. 128, 129.

[46] "*The pursuit of coscienza of the certain is philology or history; the pursuit of scienza of the true or the common is philosophy. Thus far, scienza in the narrow sense. But it is in a wider sense that the term scienza is used in the title of Vico's work, and in that wider sense it embraces both philology and philosophy.*"
Max Harold Fisch, "Introduction," in *The New Science of Giambattista Vico,* op. cit., p. xxx.

Fisch points out that the connection between the true, *il vero,* and the certain, *il certo,* is defined in Vichian theory as the *verum-certum* principle, standing for the mutual involvement of the true and the certain in the *New Science.* The certainties of the human world are 'made' in human action; they constitute the truths of human choice. And visa versa, "human truth" directs man's actions in his attempt to 'make' the certainties of the world.[47] The *verum-certum* relationship discloses to be herein imbedded within man's ability to make and produce.

Fisch, furthermore, explains that the second term besides *certum* which Vico associates with *verum* is *factum,* standing for making. The term *fact* has its etymological roots in the Latin word *facere* , meaning *to make* or *do.* The identity and convertibility of the true and the made is stated in Vico's *verum-factum* principle: what is made is known and intelligible to the maker and therefore is true to him. Man as the maker of the human world is the knower of it, and has a science of its truth.[48]

Vico had developed a theory of knowledge according to which man knows, or has science of, only what he himself makes and

[47] The term *human truth* is used within Vichian philosophy to identify the universal principles to which man refers for understanding and creating the man made environment; the term is opposed to the concept of *divine truth.*

[48] The *verum-factum* principle, according to Fisch, is based within Vichian philosophy on the medieval doctrine of God the Maker, the creator of the world. Human truth is made comprehensible in relation to divine making. The divine is in internal relationship to what it makes, to the product of its creation, namely nature. Man on the other hand can only stand in external relationship to divine creation; his world is based on the images of his truths, those of his imagination. To his making man develops an internal relation in his attempt to approximate the truth of his activity with the divine.

conceives. Science of nature, in the strict sense, is reserved for God, who made it. But science of the human world is possible for man because he has made it and its principles or causes, Vico writes, "are therefore to be found within the modifications of our own human mind."[49] Man, in his ability to know through the act of making, must therefore master his techniques for making the world. To be good at making means to know how to make it, and "know-how" is technical knowledge.

Science, according to Vico, means "to know," knowing is to make, and making embodies truth. This sequence of identities is placed within *fantasia* which constitutes the element of poetic thought in the act of creation. As the source of imaginary thought *fantasia* forms the base for knowledge and scientific thought, for technique and human making. Herein lies the key to Vico's *New Science* : the act of making, man's attempt to create his world, derives its essence, and its symbolic and meaningful base from the poetic element of imaginary thought. Vico describes the founders of civilization and the human world as poets in the Greek sense of the word, as makers or creators:

In such fashion the first men of the gentile nations, children of nascent mankind, created things according to their own ideas. But this creation was infinitely different from that of God. For God , in his purest intelligence, knows things, and , by knowing them, creates them; but they, in their most robust ignorance, did it by virtue of a wholly corporeal imagination. And because it was quite corporeal, they did it with marvelous sublimity; a sublimity such and so great that it excessively

[49] Giambattista Vico, *The New Science,* op. cit., p. 96, (331).

perturbed the very persons who by imagining did the creating, for which they were called 'poets,' which is Greek for 'creators'.[50]

Imagination within Science and Art

Man's faculty to create and produce within Vichian philosophy originates from his ability to recall the metaphors of his imagination. Historically those were rooted in fables, myths, and fantastic creations of the mind. Vico saw a primary base of educational value in imagination and memory. He argued that an early training in logic was unnatural; instead education must address the sensibilities, feelings, metaphors, and memories upon which human culture was founded. Reason could than develop on the foundations of imagination, allowing a fruitful interaction between mythical sphere and rational structure. Vico believed that conceptual reasoning as understood in modern science could only develop on the foundations of imaginative thought. Descartes's philosophy, for instance, required at base to be founded on imagination. In Vico's view the ingenuity Descartes sought in his fourfold method of truth presupposed the ingenuity of the mind trained in metaphor to produce the grounds on which such a conceptual process could take place.[51]

Modern science, however, failed to maintain its bonds to the origins of imaginative thought, it became purely conceptual. Similar was the development of technology. The emphasis on rationality in scientific thought became the primary characteristic for technical understanding. Rationality, best

[50] Ibid., p. 117, (376).
[51] Donald Phillip Verene, *Vico's Science of Imagination*, op. cit., p. 42.

exemplified in systematization, division of labor, creation of standards, and production norms, led to the reduction of method to its logical dimension alone, excluding spontaneity, creativity, and imagination. Every intervention of technique became in effect a reduction of facts and principles to the schema of logic.[52] Technological order in the modern era, following the premises set by the Cartesian model of mind, was functionalized, reduced to efficient procedures, and totally devoid of poetic meaning.[53] Descartes's method was taken as a prescription for a step-by-step organization of thought and action.

Whether within the arts or sciences, technique traditionally included considerations pertaining to human imagination. Although science involves the use of imagination for the invention of new developments, it was with the formularization of scientific achievements that a loss in imaginary thought gradually occurred. During the modern era, the fantastic component of imaginary thought, as expressed in images, metaphors, and symbols was removed from the techniques of scientific procedures and exclusively considered part of the creative application of artistic techniques. With the emphasis given to rational thought, fantasy and imagination came to be associated with the arts. Correspondingly, the reference to the realm of the irrational remained a major tenet of art belonging to the processes and techniques of artistic production.

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52 Jacques Ellul, *The Technological Society,* op. cit., pp. 78,79.

53 Cartesian philosophy is not to be understood as the specific cause which led to the technological order of the modern era. It is used in this context as a metaphor for the radical change in the conception of knowledge and truth.

2. Chapter

TECHNOLOGY, TECHNIQUE AND THE CHANGING CONCEPTS OF ART

"In fact, we cannot observe the creative phenomenon independently of the form in which it is made manifest. Every formal process proceeds from a principle, and the study of this principle requires precisely what we call dogma. In other words, the need that we feel to bring order out of chaos, to extricate the straight line of our operation from the tangle of possibilities and from the indecision of vague thoughts, presupposes the necessity of some sort of dogmatism. I use the words dogma *and* dogmatic, *then, only insofar as they designate an element essential to safeguarding the integrity of art and mind, and I maintain that in this context they do not usurp their function."*

Igor Stravinsky, Charles Eliot Norton Lectures, 1939-40[1]

Natural and Artificial Creation

The concept of artificial creation has its origin in the Aristotelian understanding of creativity as the poetic act of bringing something into existence, into a state of being. The expression *ousia*, which commonly has been translated as "substance," the term used by Aristotle to identify the concrete and particular substances of the world, is in fact the noun formed from the Greek verb "to be." The act of making within creation, hence, addresses, according to Aristotelian philosophy, the question of being in its most fundamental sense, that is in relation to the substance of things. The

[1] Igor Stravinsky, *Poetics of Music in the Form of Six Lessons,* Harvard University Press (Cambridge, Massachusetts), 1942, pp. 5, 6.

meaning of the word substance is double; it includes that of which a thing consists, its material condition, as well as its essential meaning. As Aristotle asserted, both matter and meaning are brought to synthesis within the process of creative making, in the production of form. Thus, making was considered the art of bringing the essential meaning of things into existence by giving form to matter.[2]

Aristotle's philosophical propositions regarding the origins of objects are of significance as that they form the base for understanding the processes of natural and artificial creation as historically perceived within Western culture. The concept of substance, the distinction between form and matter, the theory of motion, as well as the doctrine of the four causes fundamentally marked understandings of how man conceived of his ability to create and produce artifacts. Such conceptions addressed at one extreme the role of pragmatic considerations, i.e. materials, techniques, and methods of production, while at the opposite extreme suggesting theories about the making of art.

Animate and inanimate objects were described as a particular combination of matter and form as was discussed by Aristotle in Book VII of his *Metaphysics.* Matter consisted of the four primary elements, or *roots* : earth, water, air, and fire, which determined the substance of things. Form delineated the shape

[2] Werner Jaeger repeatedly emphasized in *Aristoteles, Grundlegung einer Geschichte seiner Entwicklung* (1923) that the distinction between matter and form was one of the primary tenets of Aristotles philosophical foundation. Werner Jaeger, *Aristotle, Fundamentals of the History of his Development*, translated by Richard Robinson, Oxford University Press (Oxford, England), pp. 13, 167, 296, 301, & 382.

of objects. And both matter and form in unison constituted the mundane and living objects of the world.

The substratum is that of which everything else is asserted; it is not itself asserted of anything. So we must first of all determine its nature, for it is the primary substratum that is most of all thought of as being substance. In one sense, matter is talked of as the substratum; in another sense, the shape; in yet a third, the product of the two. (By matter I mean, for instance, bronze; by shape, the pattern of the form; and by the product of the two, the statue, the combined whole.) [3]

An object was thus characterized by the requirement of a union between form and matter. When an object was created, it was the form that was created. When the object perished, only the form disappeared, not the matter.

Aristotle developed his model on substance from two differing processes of creation. He wrote: "Of the things that come to be, some do so by nature, others through art, ..."[4] Natural creation united form and matter to create stars, stones and living beings. Nature was guided by divine power. The formation of the world was subject to the will of the Creator. The making of every plant and every animal was, to a certain degree, a unique event and was seen in analogy to the creation of objects by man. We find in Plato's *Timaeus* one of the first

[3] Aristotle, *Metaphysics*, Book VII, in *The Philosophy of Aristotle*, translation by A. E. Wardman and J. L. Creed, New American Library (New York), 1963, p. 82.

[4] Ibid., p. 89. The Aristotelian distinction between natural and artificial creation is discussed by Werner Jaeger in *Aristotle, Fundamentals of the History of his Development*, op. cit., pp. 74-76

Miniature from a French mid-13th century Bible
showing God as the architect of the universe.
(Österreichische Nationalbibliothek, Vienna)

descriptions of the formation of the world as the work of a craftsman. God was considered to be the Architect or Sculptor of the world, for nature was His art. Both Plato and Aristotle expressed their belief in the design of the universe from the images of artificial production. Their account of the details of creation was full of images drawn from carpentry, weaving, modeling, metallurgy, and agricultural technology.[5] This argument addressing the idea of the creation of the world in reference to the processes of art constituted for centuries the base for understanding the conception of nature and man.

The image of God as artificer gained importance with the integration of Aristotelian philosophy into medieval Christianity. Saint Albertus Magnus (ca.1193-1280) and his pupil Saint Thomas Aquinas (ca.1225-74) merged Aristotle's concept of natural creation with Christian thought, and thus attained a single world-picture, embracing natural knowledge, with God at the summit of all.[6] The concept of God as the Maker of the world is perhaps best expressed in a French mid-13th century Bible illustration showing God with a compass tracing the limits of the universe. The miniature is a careful depiction of the First Book of Genesis: "In the beginning God created the heaven and the earth, and the earth was without form and void, ..." (exemplified by the shapeless mass in the

[5] References to the relation between artificial and natural creation in Aristotelian texts can be understood as being of pedagogic intention. In order to facilitate understanding of natural processes, which were less comprehensible to man, Aristotle described them in comparison with the more familiar procedures of art. Aristotle's unmoved mover, unlike Plato's Craftsman, was a final, not an efficient cause; but Aristotle too believed that final causes were at work in natural processes, and he extensively used comparisons drawn from the arts and crafts to support his argument.

[6] Friedrich Klemm, *Technik: eine Geschichte ihrer Probleme* (1954), *A History of Western Technology*, translated by Dorothea Waley Singer MIT Press (Cambridge), 1964, p. 56.

middle of the circle). "And God said, 'Let there be a firmament in the midst of the waters,' ... and God called the firmament heaven" (the wavy blue shape representing "the waters which were above the firmament"). "And God made two great lights, the greater light so to rule the day, and the lesser light to rule the night: he made the stars also."[7]

The compass used by God to delineate the world, to give form to matter, was an instrument commonly used by master-masons to transfer measurements from drawings to actual full-scale size.[8] Divine creation was described by means of a technique used by the guilds of the masons in the construction of cathedrals. Conversely, the act of making in its use of geometry addressed the realm of the spiritual and the divine. The description of natural creation in analogy to the results and activities of human production gained further significance with the gradual increase of scientific thought in the modern era.

The processes of art, particularly the concept of mechanical means of production, served as models for the understanding of nature. Kepler, for example, derived the functioning of the universe, the movements of celestial bodies, from the mechanics of the clock. Descartes compared the machines built by artisans with the structure of natural bodies. The assertion made by the major exponents of early modern science that there was no

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[7] *Genesis,* "The Creation of the World," in *The New English Bible*, Oxford University Press (New York), 1971, pp. 1, 2. See also John Harvey, "The Mason's Skill", *The Flowering of the Middle Ages*, edited by Joan Evans, (McGraw-Hill Book Company, New York, 1966), pp. 82,83.

[8] The image of God using a compass was probably inspired by Proverbs 8:27 in which it says: *"When he prepared the heavens, I was there; when he set a compass upon the face of the depth, ..."* See Eduard F. Sekler, *Proportion, a Measure of Order,* Carpenter Center for the Visual Arts, Harvard University (Cambridge, Massachusetts), 1965, p. 50.

substantial difference between the products of art and those of nature, however maintained the belief in God and divine creation.[9] William Paley (1743-1805) in his *Natural Theology*, published a few years before Darwin's *Origin of Species*, was a strong believer in the concept of a "designed" world.[10] In explanation Paley compared the making of a man-made object with the creation of living organisms.

If you find a watch, you will scarcely doubt that it was designed by a watchmaker. Similarly, if you consider a complex organism with all its purposeful organs, you cannot escape the conclusion that it was designed by the will of a Creator. For it would simply be absurd to suppose that the eye of a mammal, for example, with the precision of its optics and its geometry, could have developed by mere chance.[11]

The art of making objects through craftsmanship constituted the model of reference for describing God as the Maker of the world. Natural creation was explained by artificial creation. "Just as God was considered the artificer of nature," Vico wrote, "so was man of the things formed by art."[12]

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9 See also "The Nature-Art Relationship and the Machine of the World" by Paolo Rossi, *Philosophy and the Arts in the Early Modern Era,* (Harper & Row, New York, 1970).

10 The concept of Divine Creation for understanding the existence of different forms of living organisms, was put into question by Charles Darvin in the *Origin of Species.* In opposition to the argument from design, Darwin showed that it was possible to explain what appeared to be special creation by the chance variation of characteristics, followed by natural selection.

11 François Jacob quoting William Paley's *Natural Theology* (Charles Knight, London, 1836), in*The Possible and the Actual,* Pantheon Books (New York), 1982, p.13.

12 G. Vico, *Opere*, ed. F. Nicolini, (Milano), 1953, pp. 293, 307.

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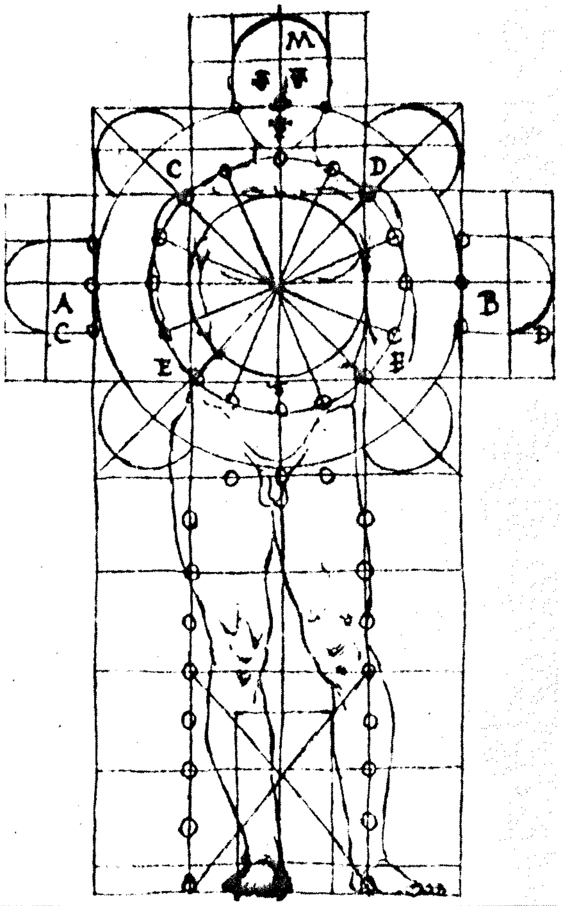

Drawing by Francesco di Giorgio Martini showing the plan of a church derived from the proportions of the human body (Florence, Bibliotheca Nazionale).

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Art as a form of production, in accordance with Aristotle's propositions on the creation of substance, was understood as the second type of making. Objects which find a state of existence through art were considered, as was the case for the objects of natural creation, a unity of form and matter. As natural creation was described in analogy to artificial creation, art was thought to imitate nature. According to Greek philosophy nature was presented as an ideal which art attempted to realize or reestablish. This concept of art as *imitatio naturae* was of great relevance for Ancient, Medieval, as well as Renaissance thought. It was maybe best expressed in the use of proportional systems, which where derived from nature's given order. Rudolf Wittkower in *Architectural Principles in the Age of Humanism* writes, in describing the accepted belief of the period, that since "...man is the image of God and the proportions of his body are produced by divine will, so the proportions in architecture have to embrace and express the cosmic order."[13] A building was to mirror the proportions of the human body as was given by nature. This was a demand which became universally accepted on Vitruvian authority. Vitruvius considered the human body as the model for symmetrical harmony which was understood to represent the proper relation between the parts of a building integrated to a whole.

For the human body is so designed by nature that the face, from the chin to the top of the forehead and the lowest roots of the hair, is a tenth part of the whole height; ... The length of the foot is one sixth of the height of the body; of the

[13] Rudolf Wittkower, *Architectural Principles in the Age of Humanism* (1949), W.W. Norton & Company, Inc. (New York), 1971, p. 101.

forearm, one fourth; and the breadth of the breast is also one fourth. The other members, too, have their own symmetrical proportions, and it was by employing them that the famous painters and sculptors of antiquity attained to great and endless renown.[14]

As was expressed in the transfer of human proportions to architecture, artificial creation followed the order of nature. Francesco di Giorgio Martini (1439-1501), for example, showed the correspondence between architecture and nature by developing anthropomorphically derived modular grids in which the proportions of the human body were used to determine plan, façade, and certain specific details of buildings.[15] By inscribing the human figure to the diagram of a church plan and façade elevation as well as by superimposing the head of a man to drawings of column capitals the connection between nature and architecture was established.[16] Hence, architecture followed the model given by nature. The making of artifacts, the design of buildings and temples were derived from an order which was analogous to the order of natural creation. *Analogia* in Greek meant proportion and was translated in Latin as *proportio*.[17] Analogy, in its broadest sense, was the mode of reasoning that depended on the recognition of a relationship of similarities and was applied to the art of building in the use of proportional systems to identify the comparison to nature.

[14] Vitruvius, *The Ten Books on Architecture,* translated by Morris Hicky Morgan, Dover Publications (New York), 1960, p.72.

[15] See Francesco di Giorgio Martini, *Trattati di Architettura Ingegneria & Arte Militare,* edited by Corrado Maltese, (Edizioni Il Polifilo, Milano, 1967), 2 vol.

[16] Henry Millon, "The Architectural Theory of Francesco di Giorgio", in *Renaissace Art,* edited by Creighton Gilbert, (Harper & Row, New York, 1970), pp. 133-147.

[17] Eduard F. Sekler, op. cit., p. 5.

Following in this line of reasoning, artificial creation derived its order from natural and divine creation.

Nature was placed at a hierarchically higher level than art. Given the action of man, art dealt with things which could be made into other things. The task of the artisan was to give new form to matter obtained from nature. Hence, art required an external agent to fulfill its operations. Natural form, on the other hand, contained within itself the principle of its creation and was therefore considered before art.[18] Aristotle wrote: "If you were to bury a bed, and the moisture that got into it as it rotted gained enough force to throw up a shoot, it would be wood and not a bed that came into being."[19] Nature, in this regard, internally contained the power of its coming into existence. The forms which art brought forth in matter were given from external action by the artisan, and were considered *artificial*.

In the production of objects a primary role was assigned to the maker; he possessed the art of giving shape to unformed matter. As mentioned by Aristotle: "...the things that come to be through art are those whose form is in the producer's soul; and by "form" I mean the essence and primary substance of each thing."[20] The maker had to have knowledge of the form prior to the processes of production. It followed that form was derived

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[18] Werner Jaeger writes: "It is a characteristically Aristotelian view that nature is purposive in a higher degree even than art, and that the purposiveness that rules in handiwork, whether art or craft, is nothing but an imitation of the purposiveness of nature." W. Jaeger, op. cit., p. 74.

[19] Aristotle, *Physics*, Book II, in *The Philosophy of Aristotle,* translated by A. E. Wardman and J. L. Creed, New American Library (New York), 1963, p. 210.

[20] Aristotle, op. cit., p. 90.

from form, "house from house," for the art of building was constituted by the essence of house. The products of artificial creation could only exist when someone possessed the art of production, and everything that was produced by art came into being from the knowledge of the thing that was to be conceived. Form, in those terms, was a cause of artistic creation, inasmuch as matter determined whether a thing would be made of brick, stone, or wood. The activity of the artisan departed from matter and form to produce within his processes of production the objects of the world. The craftsman possessed the art of making in order to produce. That is to say, the knowledge of his means and techniques of production identified the procedures in which he engaged for reaching specific ends. Those were determined by the purpose of the thing that had to be created. Whether a vase, a statue, or a building, each fulfilled a function to satisfy human needs. To know the purpose of the objects which were to be made determined in advance the way in which they were to be produced. To summarize, the act of bringing things into a state of being was understood to engage form, matter, process, and purpose as causes of production; in other words, as causes for art understood as a form of making.

The Principle of Cause and Effect

The making of artifacts, according to Aristotelian understanding, was described by the relation between cause and effect. Causation, in this sense, constituted the base for understanding art as a form of production. Any form of making, hence, resulted from the interdependencies of original causes to resulting effects. The primary causes engaged in the production of things were derived from the following questions: What is the object to be created? Of what is it made? Why is it made? And, how is it made? The answers to those questions were contained within the doctrine of the four causes in which Aristotle addressed art as making. The doctrine was a model according to which man was to understand the objects and processes of his creations. In that, Aristotle's propositions acquired significance by providing a theoretical framework for man's faculty to make. "Physics," Book II, contains the fullest continuous account of Aristotle's doctrine of the four causes:[21]

- the causa *materialis*
- the causa *formalis*
- the causa *finalis*
- the causa *efficiens*

These constituted the framework within which questions about the structure of substances were investigated. As was mentioned above, the term substance as used by Aristotle included not only products of human skill but also all natural substances. The model was most probably derived from the context of man-made artifacts and extended to natural processes by metaphor. In providing a structure for understanding the relationship between objects and the elements involved in the act of their creation the model fundamentally influenced the notion of artistic production within Western civilization. Any kind of making was inherently bound to the relation of causes to effects. In this regard it was understood that the techniques

[21] Aristotle, *Physics*, op. cit., pp. 209-245. See Werner Jaeger, op. cit., p. 173.

of the maker and the art of executing his skills were the means to achieve specific ends.

Aristotle's model can most clearly be explained by describing the causes of a particular example, such as architecture understood as a man-made artifact. A building has materiality as one of its predominant characteristics: its material condition reflects its state of being in a very direct and literal sense. A building is made of wood, stone, brick, concrete, steel or glass which constitute its matter, or *material cause.* In order to understand the concreteness of the concept, it is relevant to discover the roots of the word *matter.* On the one hand the term originates from timber, one of the most common building materials, and meaning "of which a thing is made." On the other hand the term has its source in the expression *māter*, standing for *mother*, understood as the one able to give birth.

The materials engaged in the structure of built architecture are arranged according to a definite plan and put into a definite order. In other words, "the thing is formed matter." This which identifies the shape or form is called by Aristotle the *formal cause.* Such distinguishes the finished object of architecture from any random accumulation of raw materials or any accidental aggregation of building parts. Therefore the building is not reduced to be *a priori* a function of its material condition, but reflects its indebtedness to the aspect of *architectureness* as being the factor or element of formal identification.

The third Aristotelean cause, the *causa finalis,* is responsible above all for the creation of the object and can be seen as the essential source in generating it. The *final cause* is the purpose aimed at by the entire operation. This includes the utilitarian aspect of function as well as its meaning and essence. It is what in advance confines the building to that which it will be after production. For example, both the function of architecture as physical shelter and protection as well as architecture in its fundamental meaning for man constitute the *final cause* from which the building is determined as to its matter and form.

The coalescence of the different causes is made explicit by the outline of the model, with each cause related to one another: the form in which the building materials are arranged is determined by the function and the meaning of the architectural object. The art of building is to possess the form as its precondition in order to engage in the production of architecture. Therefore, the *efficient cause* embraces both the maker and the art of the profession, the discipline of architecture, which in itself constitutes the theory of knowledge within the field. At certain points within history individual causes were regarded with special preference, establishing hierarchical relationships between the different causes. Expressions such as "Form follows Function," or "Form comes from Form" favor one cause versus another. The former expression functionalizes the structure of the model by implying its transformation into a set of operational rules, whereas the latter formula reduces the model to a self-referential system whose elements suggest to derive their meaning from themselves. Architectural production whether favoring one cause over another was primarily understood as resulting from the interdependencies of causes to effects. The importance given to the determining engagement of the four causes in the art of making fundamentally guided the notion for the production of artifacts from Antiquity to the Modern period.

The Traditional Conception of Technology

Aristotle's model of the production of art in addressing and structuring the organization of the processes of work, by which man controlled the forces of nature for his own purpose, is in essence a conception of technology. The term technology commonly describes both the field of the practical arts as well as the systematic study of their products and processes.[22] Technology, in this sense, engages in the discourse between nature and man in the production of a physical and built environment. Technology considers not only the resulting products and processes but also includes the framework of thinking generated by the relationship between man and nature, i.e. "technology is both doing and the thinking about doing - the action and the reflection-in-action."[23] Aristotle's philosophical propositions on art describe the primary factors involved in the making of artifacts, but above all they constitute the attempt to provide man with a model of thought addressing human production. Herein lies the importance of

[22] Lewis Mumford, *Art and Technics,* Columbia University Press (New York), 1952, p.15.

[23] Peter McCleary, "An Interpretation of Technology" from a brochure of the Ph.D. Program in Architecture, University of Pennsylvania, 1984.

Aristotle's doctrine; in contributing to man's system of knowledge the model is a conception of technology.

The model on causality represents the undertaking to establish a very specific kind of order within man's system of thought and action. The idea that making and production proceed from the structure of causes which anticipate effects constitutes a distinct understanding of technological undertaking. The essential condition on which the doctrine of Aristotle is based is the acceptance of the principle of cause and effect, also identified as the causality principle. The term *causa* has as its etymological origin in the verb *cadere*, which means "to fall," or as a noun, it is something which brings about a specific result in a certain way. This mode of making, involving a true course of reasoning, is the base of the traditional or Aristotelian concept of technology. At the basis of this concept is the view that technology is a human arrangement of knowledge and techniques to serve and to make possible the accomplishments of civilization. In this sense technology is not an activity with an end in itself, but rather a means towards a determined end.[24]

Underlying in all of this is the distinction made by Aristotle between natural things and artificial or man-made objects. Thus within technology the maker gives form to matter obtained from nature, producing things from other things through action. Man creates from nature what he does not find in nature. Art, therefore, is man added to nature as is described in the Latin

[24] Webster F. Hood, "The Aristotelian v. the Heideggerian Approach to the Problem of Technology," in *Philosophy and Technology,* The Free Press (New York), 1972, p. 347.

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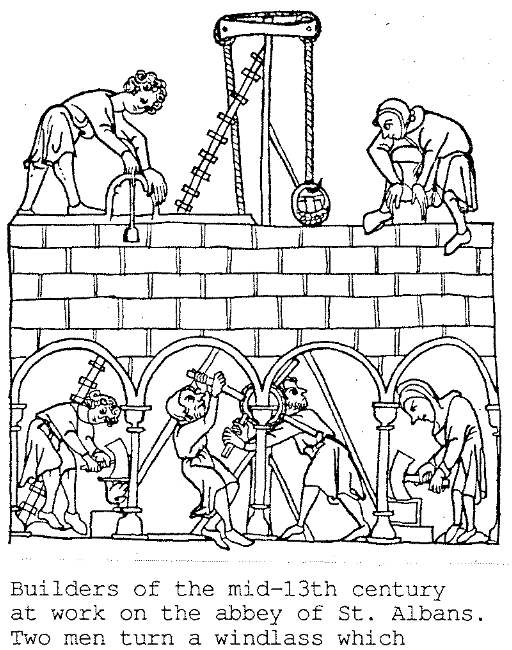


Builders of the mid-13th century at work on the abbey of St. Albans. Two men turn a windlass which raises masonry in a basket to the top of the wall; another mason uses a plumb-level to verify the horizontality of the stone layers.

expression *ars est homo additus naturae*. Technology is seen in the role of being placed between man and the given world asserting a dialogue between the built and natural environment. José Ortega y Gasset identifies man's reaction upon nature as the technological phenomenon: "It leads to the construction of a new nature, a supernature interposed between man and original nature."[25] This "supernature," or built environment, is understood as a product of technology. In other words, technology is seen as being extrinsic to nature and instrumental to man in order to overcome his natural condition. In that, technology's position in relation to man is primarily external to him, and is considered as a tool. This understanding of technology identifies the technical phenomenon as inherently artificial. Technique as art is seen in the creation of an artificial system. The means that man puts at his disposal as a function of production are artifacts determining an artificial world radically different from the natural world.[26]

Prior to the Modern era, art, in providing an artificial order to the order of nature, was considered a system of acquiring knowledge. It not only embraced the skills and experiences of the artisan but also the human ability to produce according to rules. Art was a system of methods and techniques of making as were to be found in the work of architects, sculptors,

[25] José Ortega y Gasset, "Man the Technician," *History as a System and other Essays Toward a Philosophy of History*, Greenwood Press, (Westport, Connecticut), 1981, p.95.

[26] Jacques Ellul identifies two essential characteristics of the technical phenomenon. The first assigns to technique "rationality" as is determined by the order of structured thought. The second asserts to technical matters "artificiality" as derived from man's antithetical relation to nature. *The Technological Society*, Alfred A. Knopf, Inc. and Random House (New York), 1964, pp. 78, 79.

carpenters, or weavers. Art by definition was rational and implied knowledge. This concept found expression in the work of Greek and Roman thinkers. Aristotle defined art as the "ability to execute something with apt comprehension,"[27] and some centuries later the Roman rhetorician Quintilian explained art as being based on method and order: "Art is a system of general rules" (Ars est systema praeceptorum universalium). The Middle Ages inherited the ancient concept of art and considered it as a *habitus* of practical reason. Saint Thomas Aquinas's definition described artificial creation as an "ordering of reason," and the Scottish theologian Duns Scotus (ca.1265-1308) understood art as "the ability to produce based on real principles." Production during the Medieval period was governed by fixed canons and by rules which were supported by the organization of guilds. The guild of the masons, for example, was regarded as practicing an art, not merely an useful skill, for their profession required knowledge. Methods of construction such as the use of hand-operated cranes, leveling devices, and instruments for measuring are an indication of rationally organized building procedures. But above all what was most important for the understanding of architecture as an art form was the application of mathematics[28] and geometry, which addressed the realm of true knowledge. Within the Medieval period architecture was increasingly governed by clearly defined models based on geometry. The vault-projection

[27] See also Aristotle, *Ethics*, Book VI: "*The art of building is a craft, a particular productive disposition accompanied by reason.*" Further in the text Aristotle equates *art* with *wisdom*: "*In talking about arts and crafts, we apply the term 'wisdom' as meaning 'technical mastery' to those who are most accomplished in their special skill.*"

[28] Mathematics within the Medieval period was not engaged in the precise arithmetical determination and evaluation of structures but rather was considered a discipline which in its reference to abstract relationships addressed the realm of philosophical inquiry.

method, for example, with which the masons determined the actual lengths and curvatures of complex rib and net vaults, was considered the "secret" of the architect's knowledge. With this "secret" in hand the mason had the ability to interpret the techniques developed for prefabrication of numbered ribs on the ground which when hoisted to the vault level were to fit precisely into complex configurations.[29] The application of such rules and principles, in other words the investment of knowledge to the making of things, was the true art of the maker.

The concept of making as a formation of knowledge was clearly derived from the acceptance of Aristotle's authority. To have knowledge meant to address universals, and art was considered a form of knowledge of universals which was highly respected. To have knowledge of universals was to know the causes and first principles for the creation of things. Those who possessed art derived their knowledge first from experience and then, most importantly, from the formation of all encompassing judgements. Aristotle called the knowledge of individuals "experience," whereas knowledge of universals addressed "causes." Men who had experience, or knowledge of individuals, knew how a thing was to be made, but they not necessarily had the knowledge of why an object was to be produced in a certain and specific way. From this discrepancy between *how* and *why* procedures were to be done Aristotle derived the difference between the manual worker and the master craftsman. The latter was considered

[29] François Bucher, *Architector, the Lodge Books and Sketchbooks of Medieval Architects,* Abaris Books (New York), 1979, pp. 9, 10. See also James S. Ackermann, "'Ars sine scientia nihil est,' Gothic Theory of Architecture at the Cathedral of Milan," in *The Art Bulletin*, June 1949, vol. XXI, no. 2, pp. 84-111.

"more deserving of respect, more knowledgeable, and wiser"[30] than the former. Manual workers engaged in the processes of making by habit, whereas master craftsmen derived their procedures from knowledge.[31] Although the concept of art as a form of production addressed both making and thinking, the distinction of the two disclosed a hierarchical split within the understanding of technology. The thinking, or discourse (i.e.*logos*) derived from man's action of producing, or making (i.e.*techné*) was called the *logos* of the *techné*, or technology.[32] The term technology united both terms; however, this unification was biased in favoring thought over action.

A System of Hierarchies

As was defined by the technological model of Aristotle, the understanding of the relationship between society and environment was derived from two differing points of view. One approach was determined by the act of making, addressing the realm of practical matters, or practice. The other view was drawn from the act of thinking about building, placing its emphasis on theory. This twofold aspect within technology, which was considered the theory of practice, or science of art, was to be found a major component of architecture. Vitruvius, for example, mentioned in his chapter on the education of the architect, that both theory and practice were required to successfully engage in the discipline of the field. While the Vitruvian argument asserted the unity of theory and practice, both were presented as originating from divergent positions, forming a relation of opposites. The discrepancy between theory

30 Aristotle, *Metaphysics,* Book I, op. cit., p. 41.
31 Ibid., p. 41.
32 Peter McCleary, op. cit., p. 2.

and practice was one aspect which among others formed a complex system of hierarchical relationships within art production specifically and for the systems of human knowledge in general.

The formation of knowledge was a necessity of the human condition. This Aristotelian assertion was explicitly made in the opening sentence of *Metaphysics*: "All men by nature desire to have knowledge." For understanding the human attempt to comprehend the functioning of the world four different levels of acquiring knowledge were distinguished. Man sought knowledge from one level of understanding to the next aiming towards wisdom, truth, and ultimate knowledge. In order to get acquainted with his environment man made use of his senses which enabled him to perceive the things of the world and to distinguish one thing from the other. Through sense perception man learned to know and to understand his immediate surroundings. Man's ability to memorize allowed him to further accumulate empirically derived information leading to a body of experience. The organization of experiences and their application to specific tasks, as made manifest in art production, allowed man to engage in his processes of making by referring to rules and principles. These, finally, were unified in the theoretical sciences, which constituted the highest form of expression for human knowledge. The identified levels of acquiring knowledge were, furthermore, hierarchically structured by a system of values. This was clearly expressed by Aristotle: "Thus, as we have said earlier, the man with experience is regarded as wiser than those who have just sensations, of whatever kind; the man who possesses an art as wiser than those who just have experience; the master craftsman as wiser than the manual worker; and the theoretical sciences as more important than the productive ones."[33] The hierarchical relationship between sensation, experience, art, and science was of primary significance for deriving an understanding of the way man conceived of his ability to make and produce. Most important, however, was the directness of the system and its clear hierarchical structure, placing thought over production, art over practical knowledge, and experience over sense perception. The system which originated in Antiquity was of primary influence for the formation of future models addressing the question of technology, the relation between man's systems of thought and man's systems of action.

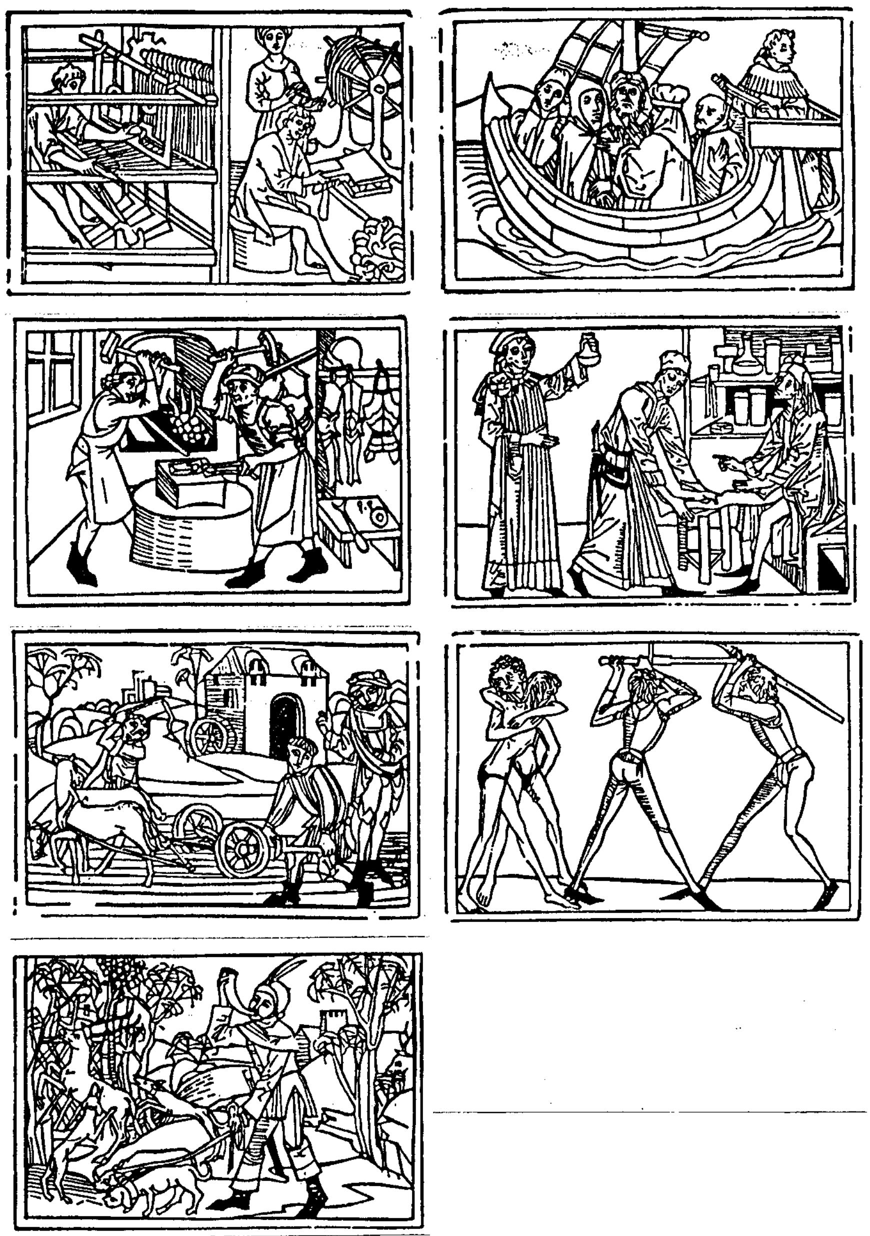
Contemporary considerations on technology have addressed the question of the integration of thought processes to the making of artifacts. Depending on the level of acquired knowledge different types of approaches to the problem of making were identified. From these prototypical approaches various models of technological knowledge were derived for establishing an understanding of how technology is placed and perceived in relation to the processes of making. The following distinctions for understanding human production have been proposed by different authors[34] within the field, with the intention to clarify the levels of conscious awareness of the technical means involved in the specific act of production. The

[33] Aristotle, *Metaphysics,* Book I, op. cit., p. 42.

[34] Carl Mitcham, "Types of Technology,", in *Research in Philosophy and Technology,* vol. I, edited by P.T. Durbin, Jai (Greenwich, Connecticut), 1980, pp. 234-235. Mario Bunge, "Toward a Philosophy of Technology," in *Philosophy and Technology,* edited by C. Mitcham & R. Mackey, The Free Press (New York), 1972, pp. 62-76. Peter McCleary, "History of Technology," in *Architectural Research,* edited by J. C.Snyder, Hutchinson Ross Pub. Co. (New York), 1984, pp. 88, 89.

classifications are without doubt an extension of Aristotle's hierarchical model, as applied to technology; however, the expression making, although in accordance with the original definition of art, does not anymore apply the term art for production in the general sense.

- The first level of making is based on an unconscious sensorimotor awareness of the forces involved in production. Intuitive learning as based on sense perception is here the guiding factor within the processes of making.
- The second level of approach is grounded on, what could be called, rules of thumb or technical maxims, which allow the act of making to be based on generalizations about experienced successful procedures. These determine the technical means and methods for the making of things, in terms of providing generalized guidelines.
- The third level of production derives rules and regulations for the making of artifacts by reference to principles and specific empirical laws as derived from experience. Technical *know how* is supported by the knowledge of causes, which the maker consciously integrates in his procedures by determining the specific means and methods of production.
- The fourth level of making is marked by the integration of theories within the processes of production. The specifics of technical means are placed in relation to broad conceptual frameworks with the intention to clarify material conditions by reference to all-encompassing models of thought. Theories and philosophies addressing man's making faculty are to be included within this mode of approach since their aim is to disclose the interdependencies of thought and action as well as of theory and practice.



The Seven Mechanical Arts by Hugo von St. Victor; woodcuts from: Rodericus Zamorensis, *Speculum Humane Vite*. Augsburg; Zainer, 1475.

The classifications of the various modes of production as based on the level of engagement of human knowledge in the act of making originated from the preference of early Greek philosophy for the activities of the mind over those of the body. Theory was considered to be of higher value than practice. The distinction was based on the fact that certain arts required physical effort whereas others were considered free of labor. This was the expression of a society which treated material needs with contempt favoring the ideal of an essentially contemplative intelligence. It was not production but other activities such as science and philosophy which in themselves perfected human nature and were thus pursued for their own sakes. This system of values was clearly reflected in the position of technology within society as was indicated by the classifications of the arts.

The Sophists distinguished two categories of art: art produced for the sake of its utility and art cultivated for the intellectual pleasure it offered. The differentiation was made between forms of art which were necessary in life and those which were a source of higher values. This most generally accepted classification divided art into a "liberal" and a "vulgar" form, known in Latin as *artes liberales* and *artes vulgares.* A further development of this dichotomy within art was further developed during the Middle Ages. Seven liberal arts were distinguished, composed of logic, rhetoric, grammar, arithmetic, geometry, astronomy, and music. These were seen in contrast to the other classification of art which was not any longer called "vulgar" but instead "mechanical." Belonging to the seven mechanical arts, as was illustrated in a woodcut of the fifteenth century, were weaving (*lanificium*), tool manufacturing and shelter production (*armatura*), agriculture (*agricultura*), hunting (*venatio*), navigation (*navigatio*), medicine (*medicina*), and acting (*theatrica*). Each of the seven mechanical arts supplied man with the things he needed to satisfy his primary needs. Clothing, shelter, food, transportation, health care, and entertainment were provided by the mechanical arts. Architecture took a interesting position of being placed between the two primary categories and was considered, as formulated in the Renaissance, an intermediate art. On the one hand architecture was considered a liberal art since it addressed the disciplines of mathematics and geometry. Building, on the other hand, requiring tools for the processes of construction and the supplying of shelter for man, belonged to the mechanical arts. Architecture united within its aegis both the practical arts with the theoretical arts. This double understanding of architectural production was an indication of the separation between technique and art within the field of architecture as was to occur with the introduction of modern science. The division, however, between art and technique as understood in the modern sense was prepared and at base pre-established by earlier historical periods. An indication for this dormant, but nevertheless existent, separation was the priority given to intellectual matters, which not only found expression in the bias for thought over action but also in a preference for the non-utilitarian over the utilitarian.

Utility and Beauty

The differentiation between utilitarian and non-utilitarian matters disclosed a further polarity within art production. A manifestation of these opposites was to be found in the dichotomy between the useful and the beautiful.

From the earliest periods of human history man was a maker, for he lived in a world in which necessity constituted the pervading and guiding force in his state of existence. Man had to invent ways to survive. To this end he manufactured tools which increased the power of his hands, these in fact were his primary means of production. The word *manufacture* has its etymological roots in the Latin expressions *manus* and *factum*, meaning *hand made* or *something done by hand*. With his hands and with tools man created objects and further instruments of production to satisfy his needs.[35] Technological forms derived their meaning from the use to which they were put. Man, however, produced not only utilitarian objects for everyday use but also works symbolizing his ideas. Symbolic creations, such as the erection of stone columns as memorials and circular temples and graves for the perpetuation of life and death, required the investment of technique for spiritual purposes. Early civilizations devoted a significant part of their technical means to non-utilitarian production, such as the making of musical instruments and the application of ornament to objects. The useful was not distinguished from the beautiful, nor art from technology. Technique and art were directed towards the practical application of skills to define

[35] Panayotis A. Michelis, "Art and Technology," *Aisthetikós, Essays in Art, Architecture, and Aesthetics,* Wayne State University Press (Detroit), pp. 43-58.

products of functional purpose as well as of symbolic value. Both art and technique represented, as asserted by Lewis Mumford in his book *Art and Technics*, formative aspects of the human organism. Art was standing for the inner and subjective side of man with its symbolic structure constituting a language form by which man became able to "externalize and project" the conditions of his inner state. Technique, on the other hand, developed mainly out of necessity to "meet and master" the external conditions of life.[36] Various historical periods, according to Mumford, understood technique and art as being in a state of effective unity. In Antiquity, for example, the word technique was applied to art, including both fine art and utilitarian practice. Art production engaged in the making of useful artifacts as well as revealed symbolic contents. Hence, art was considered a form of expression, a manifestation of significant values.

A primary form of symbolic representation, if not the most important one, was to be found in beauty. The concept of beauty addressed the Ideal and Universal. In its physical manifestation beauty transcended the finite and real conditions of the world into the infinite and ideal. Beauty has been commonly defined within Western philosophy of aesthetics as having two differing forms of expression, a subjective and an objective form. Inasmuch as beauty was thought to be the result of artistic achievements and an expression of inner personal values, it was considered subjective. But as the maker did not express his individual feelings and ideas and instead followed

[36] Lewis Mumford, op. cit., pp. 31, 32.

a model and applied criteria established independently of him, beauty was considered objective.

The subjective approach to the concept of beauty applied to the making of artifacts and, therefore, to art as a form of production, led to a great diversification of products and solutions. Technical means of production taken beyond the mere satisfaction of utilitarian needs were engaged in a search for beauty involving primarily aesthetic rather than technical considerations. Jacques Ellul in *The Technological Society* gives the following example of this:

We are amazed when we inspect, say, a museum of arms or tools, and note the extreme diversity of form of a single instrument in the same place and time. The great sword used by Swiss soldiers in the sixteenth century had at least nine different forms (hooked, racked, double-handed, hexagonal blades, blades shaped like a fleur-de-lis, grooved, etc.). This diversity was evidently due to various modes of fabrication peculiar to the smiths; it cannot be explained as a manifestation of a technical inquiry.[37]

Modifications of established prototypes, such as the multiple formal solutions of swords and lances, or the variations of decorative pattern in vernacular architecture, or the infinite variety of stone tracery in the windows of Gothic cathedrals, did not by any means result exclusively from technical considerations but from the will to express subjective values. Technique was to a major degree dependent on the aesthetic

[37] Jacques Ellul, op. cit., pp. 72, 73.

preoccupations of the maker, for it was impossible to conceive of an object that was not to be beautiful. This notion was also applied to the manufacturing of instruments involved in making; tools had to be beautiful in order to be useful. However, the contemporary idea that the beautiful is that which is well adapted to use, a frequently accepted concept derived from the modern emphasis on efficiency, was in the past of little consideration. On the contrary, beauty permitted the "introduction of uselessness into an eminently useful and efficient apparatus."[38]

An alternative and exceptional view was offered by Cicero in *De Oratore*. He believed that an essential interdependence between utility and beauty must exist:

...carry your mind to the forms and figure of human beings or even of the other living creatures: you will discover that the body has no part added to its structure that is superfluous, and that its whole shape has the perfection of a work of art and not of accident. Take trees: in these the trunk, the branches and lastly the leaves are all without exception designed so as to keep and to preserve their own nature, yet nowhere is there any part that is not beautiful. Let us leave nature and contemplate the arts: in a ship, what is so indispensable as the sides, the hold, the bow, the stern, the yards, the sails and the masts? yet they all have such a graceful appearance that they appear to have been invented not only for the purpose of safety but also for the sake of giving pleasure. In temples and colonnades the pillars are to support

[38] Ibid., p. 73.

the structure, yet they are as dignified in appearance as they are useful. Yonder pediment of the Capitol and those of the other temples are the product not of beauty but of actual necessity; for it was in calculating how to make the rain-water fall off the two sides of the roof that the dignified design of the gables resulted as a by-product of the needs of the structure-with the consequence that even if one were erecting a citadel in heaven, where no rain could fall, it would be thought certain to be entirely lacking in dignity without a pediment.[39]

"Beauty consists in a certain consonance of diverging elements," wrote Thomas Aquinas. This divergence within the concept of beauty allowed the craftsman to express his personal ideas in the processes of production. However, the concept of "diverging elements" presupposed a given norm from which the maker could 'diverge'. Norms and prototypical solutions resulted from two primary sources: one derived from technical considerations and use, the other addressing the concept of beauty in its objective form. The former being inherently connected with practical matters referred to the concept of utility, the latter in transcending the material world into the realm of the symbolic was expressed in beauty.

The first determining factor in the formation of standard types was that the various solutions which resulted from technical production were subject to trial and error. The more successful solutions, in terms of their usefulness as well as the degree

[39] Marcus Tullius Cicero, *De Oratore*, Book III, 179, 180, translated by H. Rackham, The Loeb Classical Library, Harvard University Press (Cambridge, Massachusetts), p. 143.

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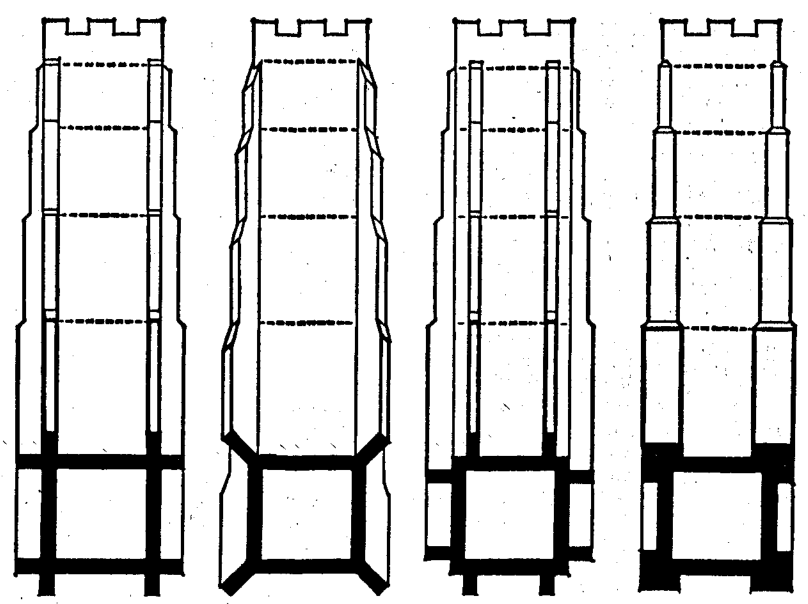

Gothic buttress types: Angle Buttress, Diagonal Buttress, Setback Buttress, and Clasping Buttress. From: N. Pevsner *Dictionary of Architecture*, 1966.

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of efficiency of the production method, were progressively stabilized and understood as accepted standards. Technical development most commonly resulted from the attempt to further perfect existing solutions or by the establishment of new types as derived from the norms of existing types. The discovery of the wheel, one of the most common examples used by historians to describe the early development of technology, was a prototypical solution derived from technical necessity. The wheel was the answer to the problem of transferring forces into rotary motion. Whether used as a means to facilitate transportation, as a gear mechanism for hoisting objects, or as a devise for raising water, the concept of the wheel remained consistant.[40] Within the evolution of technical development the wheel did not deviate from its basic configuration for it constituted a type form and principle of technical use. Similar was the development of type solutions in architecture. Construction methods providing specific solutions to given problems when successfully applied often determined the standards for building procedures and their resulting forms. The Gothic buttress system, for example, was a typical method of Medieval construction, derived from technical necessity. Buttresses were developed from pier structures and provided additional strength to walls, usually counteracting the lateral thrust of other building parts. Such architectural solutions were often further distinguished by their specific characteristics, such as was made by the differentiation between *angle, diagonal, setback,* and *clasping buttresses*. These forms were integrated into a standard vocabulary of

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[40] Lewis Mumford, *Technics and Civilization,* Harcourt Brace Jovanovich (New York), 1934, p. 80.

building construction and constituted the norm from which the craftsman and builder could 'diverge' to address the realm of subjective expression as manifested in beauty.

The second major determining source of normative influence for the making of artifacts was the reference to beauty as determined by formal rules. Since this understanding of beauty addressed generally accepted norms of what was considered beautiful, it was called objective. Beauty in its objective form manifested itself in proportion and symmetry, in the harmony of the parts in relation to the whole, and in measure.[41] For visible beauty and for works of architecture or sculpture, *symmetria* was used as the principal term; for audible beauty and for musical works, *harmonia* was the applied expression. The order of symmetry was most commonly described by reference to the proportional systems of the human figure, and the order of harmony was usually explained by the proportional ratio inherent within music. The terms symmetry and harmony were by no means lightly applied. The Greeks and Romans used them because they were convinced that beauty - particularly of the visible and audible kind - consisted in the arrangement and proportion of parts, in form.

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41 This concept of beauty originated among Pythagoreans, probably in the fifth century B.C., and is maybe best expressed in the following statements: *"order and proportion are beautiful and useful"* (Stobaeus IV, 1, 40), and *" No art comes about without proportion. All art therefore arises through number. So there is a certain proportion in sculpture and also in painting. Generally speaking, every art is a system of perceptions, and a system implies number; one can therefore justly say: things look beautiful by virtue of number"* (Sextus Empiricus VII, 106). See W. Tatarkiewicz, "Form in the History of Aesthetics", *Dictionary of the History of Ideas, Studies of Selected Pivotal Ideas,* ed. by Philip P. Wiener, Charles Scribner's Sons (New York), 1973, vol. II, pp.216-225.

The correspondence of musical and geometrical relations originated from Pythagorean philosophy, probably in the fifth century B.C., which asserted that musical tones could be measured in space and, therefore, identified by numbers. Strings produced harmonious sounds when their length was in proportion to the relatively simple ratio of one to two, two to three, and so forth.[42] The Pythagorean proposition that harmony depended on numerical relationships was maintained and further developed by Plato.[43] The discovered harmony within music and its corresponding measurements were considered to metaphorically depict the mysterious order which pervaded the universe. On this belief was built much of the symbolism of numerical relationships which had an "immeasurable impact on human thought."[44] Numbers expressed the harmony of the world and revealed the secret order of things. The Pythagorean-Platonic theory of numerical sequences was of significance for succeeding historical periods; its strongest influence on the concept of architectural beauty, however, was to fully develop within the Renaissance. During the quattrocento and cinquecento the harmonic ratios of the Greek musical scale in its coalescence with measured spatial distances was applied to

[42] *"Pythagoras had discovered that musical consonances were determined by the ratios of the numbers 1, 2, 3, and 4. If two strings were made to vibrate under the same conditions, one being half the length of the other, the pitch of the shorter string would be one octave above that of the longer one. If the lengths of the strings were in the relation of two to three, the difference in pitch would be a fifth, and if the relation was three to four, the difference in pitch would be a fourth. Thus the consonances on which the Greek musical system was based - octave, fifth, and fourth - were expressed by the progression 1:2:3:4. This progression contained not only the simple consonances, but also the two composite consonances which the Greeks recognized, namely octave plus fifth (1:2:3) and two octaves (1:2:4)."* See R. Wittkower, op. cit., pp. 103, 104.

[43] The harmonic system within Platonic theory was derived from the square and cube of the double and triple proportion, leading to the geometrical progressions 1, 2, 4, 8 and 1, 3, 9, 27.

[44] Rudolf Wittkower, op., cit., p. 104.

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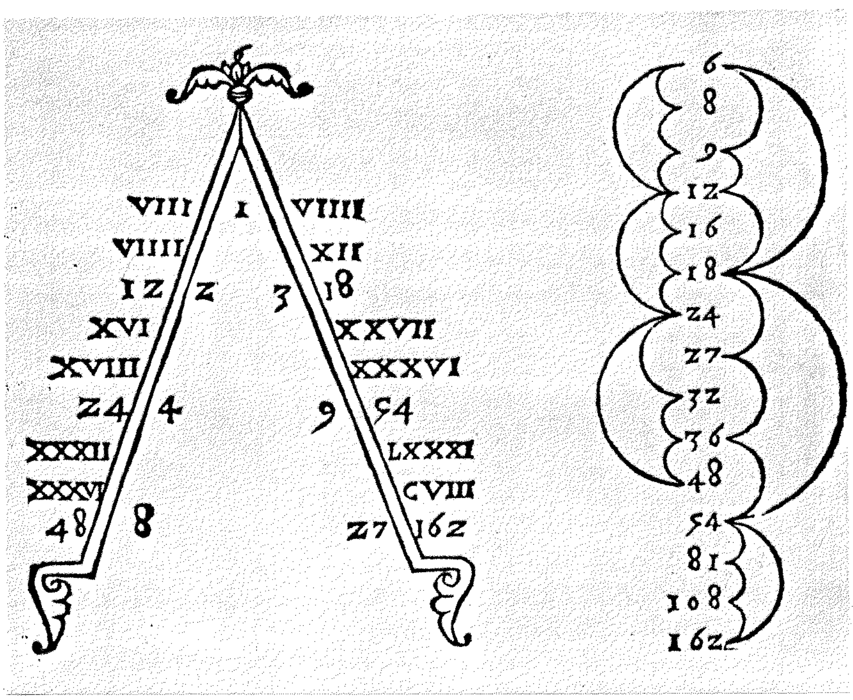

Diagram from Francesco Giorgi's
De Harmonia Mundi, 1525.

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architectural proportion, in theory as well as in practice. Alberti's *De re aedificatoria* discussed the correspondence of musical intervals with the beauty of proportional systems in architecture. With reference to Pythagorean philosophy Alberti stated that "the same Numbers by means of which the Agreement of Sounds affects our Ears with Delight, are the very same which please our Eyes and our Mind."[45] This doctrine remained fundamental for the Renaissance understanding of beauty as based on proportion. The Franciscan monk Francesco Giorgi was the first to derive the proportional systems of architectural form directly from the interlocking ratios of Pythagorean-Platonic numerical progressions. These had been analyzed by Franscesco Giorgi in a treatise on the harmony of the universe entitled *De Harmonia Mundi* (1525). In his famous Memorandum, a recommendation for the design of the Venetian church S. Francesco della Vigna dated 1535, Francesco Giorgi suggested that all the proportions of the building should be in accordance with harmonic numbers. Musical harmony was transferred by means of mathematical relationships into architectural space. This Memorandum was, as Wittkower later recognized, a key document of sixteenth-century architectural theory. Francesco Giorgi wrote:

In order to build the fabric of the church with those fitting and very harmonious proportions ... I should proceed in the following manner. I should like the width of the nave to be nine paces, which is the square of three, the first and divine

[45] Leon Battista Alberti, *Ten Books on Architecture*, translated into Italian by Cosimo Bartoli and into English by James Leoni, edited by Joseph Rykwert, Alec Tirandi (London), 1955, Book IX, chap.5., p. 197.

number. The length of the nave, which will be twenty seven will have a triple proportion ..."

The text continuous in placing this process of design in analogy with divine creation which in itself was described by reference to artificial production:"We, being desirous of building the church, have thought it necessary, and most appropriate, to follow that order of which God, the greatest architect, is the master and author... ." It was thought that the making of architecture according to harmonious rules achieved beauty by following the order of divine will. Beauty in its objective form followed a system of order derived from the harmonious proportions of music. These were transferred into mathematical terms which again were translated into spatial ratios. Following those lines, the physical and material reality of architectural production was transcended in addressing the metaphysical conditions of divine making.

A second model to which architecture referred in order to achieve beauty and hence approach the divine was based on the proportional relationships of the human body. Francesco Giorgi's Memorandum quoted above furthermore united the numerical relations of musical harmony with those derived from the proportional system of the human figure. After having described the interconnection of music and architecture Francesco Giorgi added:

To this perfect and complete body we shall now give the head, which is the cappella grande. *As for the length, it should be of the same proportion, or rather symmetry which one finds in* *each of the three squares of the nave ...that its width be six paces, like a head, joined to the body proportionately and well balanced.*[46]

Architecture seen in analogy to the human figure was a concept formulated by Vitruvius and later reaffirmed by Alberti. A portico of a temple, for example, was considered perfect if its height, width, and the arrangement of columns were determined according to the accepted norms. These were established in agreement with the proportional relations inherent within the human body which constituted the model of reference to nature. The human figure was described by Vitruvius in relation to the most perfect geometrical figures, the circle and the square:

...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 centered 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.[47]

The symmetrical perfection of the human figure, as determined by pure geometrical shapes, should, according to Vitruvius, be reflected in the proportions of sacred buildings. The directness of the image which superimposed the human figure with the circle and the square had an almost mythical impact on

[46] Francesco Giorgi's Memorandum on the design of San Francesco della Vigna is quoted from: Peter Murray, *Renaissance Architecture,* Electa Editrice (Milan), 1971, pp.309, 311.

[47] Vitruvius, op. cit., p. 73.

architects and scholars of the Renaissance period. Leonardo da Vinci's celebrated drawing of a man inscribed in a circle and a square was one of many derived from an interpretation of Vitruvius's text and revealed the deep and fundamental connection between man, geometrical order, and architecture as a manifestation of absolute truth.

Beauty in its objective form, whether derived from musical harmony or from the symmetry of the human figure, provided an order for architectural production. But most importantly the norms which the maker followed allowed man to address beauty, universal, and ultimate truth through his processes of making. Technical necessities as manifested in prototypical solutions and construction standards were brought into unison with the norms of proportion and measure. This unity of technique and beauty was a fundamental force in determining formal canons within the understanding of architecture as a discipline. Technique addressed form in its most fundamental sense by merging the means of art production with the quest for beauty.

The definition of beauty in its reference to order paralleled the concept of form for which the criteria of disposition, arrangement, and order were primary constituents. The equivalence between beauty and form was inherent within the dualism of form and matter. Matter was that undetermined and indefinite mass which awaited to be shaped. When form was imposed upon matter the things of the world were brought into a state of existence. The process of creation in this sense was to give order and proportion to matter. Beauty in relation to the concept of Being was expressed in terms of light, of bringing something into the light or of making things visibly appear. Matter on the other hand was amorphous, ugly and dark. The equivalences of beauty with light, respectively of matter with darkness, were equally important. Within this dialectic established between darkness and light beauty was considered a creative force in the making of things. Therefore, art which was considered as the act of bringing things into physical existence addressed form and beauty as equivalent terms, both being of fundamental significance for the making of artifacts.

Architecture in its function as shelter was inherently utilitarian, and in being a form of art production it was also to be inherently beautiful. Architecture had the potential to unite the two, utility and beauty, within its aegis. Vitruvius's proposition on architecture is recalled which united solidity with utility and beauty as expressed in the consolidation of the three terms *firmitas*, *utilitas*, and *venustas* to one expression. Architecture, according to Vitruvius, was to be physically determined from the organization of construction brought to synthesis with the necessity of use and the order of beauty.[48] Although Vitruvian theory emphasized the unity of the above three terms, he considered the aim of beauty a primary determining factor in architectural production. In Vitruvius's formulation of the fundamental principles of architecture (*De Architectura*, Book

48 *"All these must be built with due reference to durability, convenience, and beauty. Durability will be assured when foundations are carried down to the solid ground and materials wisely and liberally selected; convenience, when the arrangement of the apartments is faultless and presents no hindrance to use, and when each class of building is assigned to its suitable and appropriate exposure; and beauty, when the appearance of the work is pleasing and in good taste, and when its members are in due proportion according to correct principles of symmetry."* Vitruvius, ibid., Book I, Chapter IV, p. 17.

I, Chapter II) a significant position was assigned to the manifestations of beauty. Of the six qualities of architecture that Vitruvius recognized as many as four (*ordinatio, dispositio, eurythmia,* and *symmetria*) consisted in the correct arrangement or disposition of parts. The aim of beauty was of fundamental consideration for the making of architecture. It became the foundation of the discipline from which the architectural object was to be determined. This priority of the beautiful, as emphasized by Vitruvius's work, originated from Greek philosophy for which the apex of civilization was not to be found in material considerations but in contemplation, the goal of highest intellectual activity. The concept of beauty in addressing perfection and harmony contributed to the Greek ideal and was extended by Vitruvius into the field of architecture. The dominance of form and beauty was further carried by succeeding historical periods and became the *a priori* concern of the discourse of architecture, which has since been treated almost exclusively as a formal problem.

Process and Product

The superiority of the non-utilitarian to the utilitarian can be reached by yet another route. In its origin the concept of art was primarily identified with the act of making and not with the products of art *per se*. In particular, art was understood to be production and engaged the ability, skill or craft of the maker in the processes of creation. Although art was very much considered to be process-oriented, a major cultural value was assigned to the products of art production. Artifacts resulted from the processes of making. Simultaneously, however, process was derived from product in that the objects which were to be created disclosed a strong presence within making and were considered as to their use, form and essence constituent causes of artificial creation. Aristotle asserted in the doctrine of the four causes that the purpose and essential form of things were included as preconditions of art in the maker's vision of the final object. Technique in this sense was directed toward a determined end which found manifestation in the expression of values, ideas, and necessities in object form. Since artifacts served to improve man's existence on earth, they were considered to be closer to the realization of the human condition. Process, although involved in the attainment of human ends, was a step further removed and placed in a "servant" position. In other words, the goal of technique, its works or products, which the activity of making posited as its object, was considered instrumental for the realization of civilization.[49]

The priority given to product over process further disclosed a clear hierarchical structure within objects of different purpose. Art production included from such a point of view not only techniques as means but also the products it created. Some of these, such as buildings to provide shelter, were of direct necessity; others were in themselves means to other products, such as tools. As technical instruments these were directly involved in building and manufacturing procedures and were lowest in rank. Their value was determined from a comparison with objects of use which directly contributed to the betterment of man. Objects of direct necessity were considered above the instruments used in the processes of making. This

[49] Webster F. Hood, op. cit., p. 349.

polarity was established by Aristotle in the distinction between "instruments of production" and "instruments of action."[50] Technique was considered an instrument in the strict sense of the word whereas an "instrument of action" was an item of immediate use. A hammer, for example, was an "instrument of production," and a chair, which was made by employing a hammer, a saw, and a lathe, was an "instrument of action." Techniques were means engaged in procedures, whereas finished objects had reached an ultimate end in being items of direct necessity. Hence, "instruments of action" were considered more important than "instruments of production," and the product was placed over the process, for the end of art technique was something that could be used for human existence making its perfection possible by allowing man to go beyond mere production, beyond art.[51] Technique gave man the possibility to gradually achieve the full realization of his existence, but it did not formally constitute that possibility in itself. On the contrary, technique was understood as an agent, or a neutral tool, for man to achieve his aim for perfection. Therefore, the object which resulted from production in being closer to ultimate ends was considered prior to the means engaged in its processes of creation.

A further differentiation was made between the things that man required for satisfying his primary needs and those which provided man with pleasure. Such objects were regarded as being of higher value by contributing to human leisure as opposed to

[50] "As production and action are different in kind, and both require instruments, the instruments which they employ must likewise differ in kind. But life is action and not production."

[51] Webster F. Hood, op. cit., p. 348.

being limited to the instrumentality of man's survival. The supremacy of "objects of pleasure" over "objects of use" was a further manifestation of the dichotomy between the utilitarian and the non-utilitarian. This hierarchical relationship within objects was regarded by Aristotle as a system of values from which he assessed the reknown of the maker: "It is also probable that, as more arts were discovered - some dealing with the necessities of life, others with its recreations - those who discovered the recreational arts were thought of as wiser than the others because their sciences were not developed to be useful."[52] Music, dance, and acting when performed for the sake of pleasure were regarded as arts of the recreational kind. This form of art production consisted in the action of the artist and embraced art without the creation of physical products.[53] Technique was the skill of the performer when executing his art. Additionally, pleasure could also reside in objects. Rather than being transmitted by the action of the artist, joy and play could come from objects made for entertaining purpose. Such objects as the mechanical toys of the first century A.D. by Hero of Alexandria were often of remarkable ingenuity and contributed to technical progress. Hero's puppet theater was a complex mechanism of gear-wheels, which comprised all the technical know-how within the branch

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52 Aristotle, *Metaphysics,* op. cit., p. 42.

53 The classification of the arts based on the form of art expression, ranging from intellectual to purely physical manifestations of art, was made by the Roman rhetorician Quintilian in the first century A.D. Quintilian, inspired by Aristotle, divided the arts into three groups. In the first he included those arts which addressed the study of things; he called them "theoretical" and gave astronomy as an example. The second group embraced the arts which comprised solely the action of the artist; Quintilian called them"practical" and gave dance as an example. The third group was determined by the arts producing objects which continued to exist when the action of the artist had ended; he called them "poetic," with painting serving as an example. See W. Tartarkiewicz, op. cit., p. 458.

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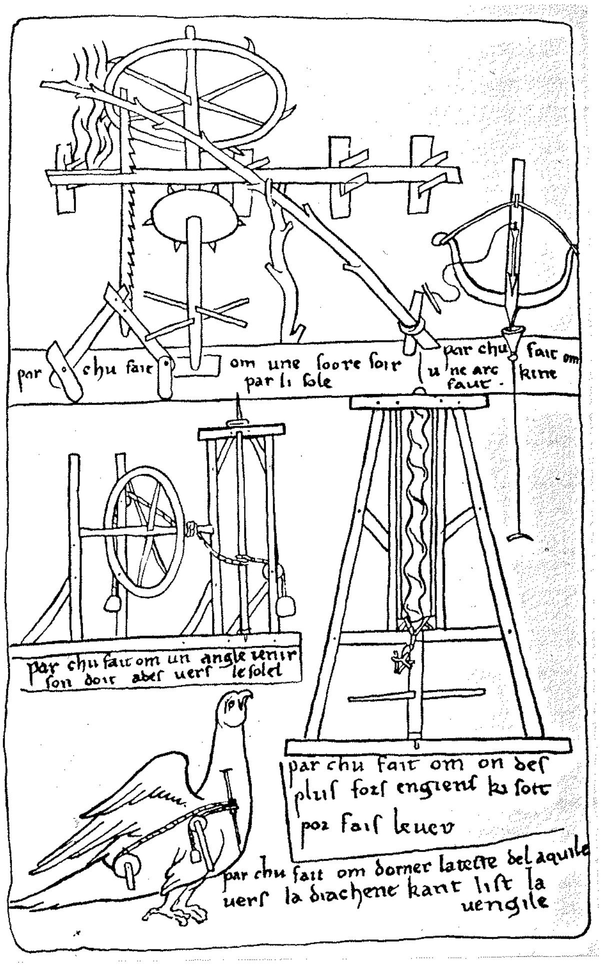

"Machines" from the sketchbook of
Villard de Honnecourt, 1225-1250.

110b

of mechanics of that period. Weights were attached to strings and were carried over pulleys in order to transfer forces onto wheels which as a result made small figures move and turn on a tablet. Such objects enjoyed great popularity partly because their development contributed to varied artistic skills and largely due to the astonishment created by the spectacle they presented. In this type of objects technical means were placed in the service of pleasure. Technique which generally was regarded as being of utilitarian purpose was committed as well to the non-utilitarian.

Technical devices for purposes of pleasure are to be found throughout the history of architecture and were of significance for technical development. They allowed a free play of the imagination brought to synthesis with the exploration of technique in addition to the pleasure they offered. It was not thought unbecoming for a serious artist to engage in the production of what we should regard as little more than toys. Villard de Honnecourt, in the mid-thirteenth century, included in his work the design of bizarre and amusing objects. One of the sheets from his Sketchbook shows mechanisms which made "a saw saw by itself," a cross-bow that could not miss its target, an angel pointing with his finger always to the sun, a device for raising weights, and an eagle that turned its head during the reading of the Gospel. A similar attitude toward the work of the artist is to be found at the court of the Counts of Artois in the fourteenth century. In their castle at Hesdin a gallery of machines had been built for the diversion of guests and the amusement of the household. The appointment of a "master of the amusement machines and of the painters" is an indication of the importance given to objects of play and pleasure within art. Most of the machines caused various forms of discomfort to anyone who had the misfortune to be invited. There were devices for projecting water, traps in the floor, and speaking figures which without warning caught the onlookers by surprise.[54] These rather peculiar uses of mechanical means should not blind us to the fact that artists and craftsmen had already achieved significant success with clockwork automatons. The oldest surviving example is a cock from an astrological clock in the cathedral of Strassbourg, dating from 1353, which crowed three times and flapped its wings on the hour. Many discoveries of these early machine constructions were of influence for succeeding periods. The elaborate fountains with mysteriously moving figures in the gardens of Renaissance and Baroque rulers were further developments of technical means at the service of pleasure.

Technique in all of these examples was of double significance. On the one hand it was understood as the ability of the maker to create mechanical objects, technique comprising the skills of the maker. The term on the other hand was used to identify those mechanical means which as technical devices made the object perform its function. This twofold aspect of technique was not limited to amusement machines and clockwork automatons, but was applied to forms of technological undertaking in general. The notion of technique as craft was competed by the understanding of technique derived from the association of the expression "machine" to technical matters. This was yet another

[54] Andrew Martindale, "The Changing Status of the Craftsman,"*The Flowering of the Middle Ages,* edited by Joan Evans, Thames and Hudson (London), 1966, pp. 308, 309.

indication for the shift that was to occur regarding technology with the introduction of modern science.

Objects made for the sake of providing man with pleasure and astonishment were often of symbolic value. Yet those objects which addressed only pleasure without a symbolic component were considered of lesser significance than those which were primarily made for symbolic purpose. Objects addressing religious and mythical contents were held in highest esteem. The concept of the supremacy of the object over technical means was furthermore intensified by the implicit hierarchy within the products of art: tools were considered of lesser value than objects of use, objects of use were of lesser importance than pleasurable objects, which in turn were placed lower in rank to symbolic objects. The subordinate role of technique to symbol and meaning is clearly expressed in a drawing of a mechanical device for opening the portal of a temple, a system developed in the first century A.D. by Hero of Alexandria.[55] Hero described in his work an apparatus which utilized the pressure of compressed or heated air to open temple doors when a sacrificial fire was lighted. The technical means to achieve the sensation of a portal which appeared to open by itself was a hidden machinery subordinated to the symbolic function of architecture. Machine technique, in this example, was at the service of man supporting the mythical aims of religious rituals.

[55] F. Klemm, *A History of Western Technology,* MIT Press (Cambridge),1964, pp. 35-39. See also H. J. Cowan, *The Master Builder,* Wiley & Sons (NewYork), 1977, pp. 16-19.

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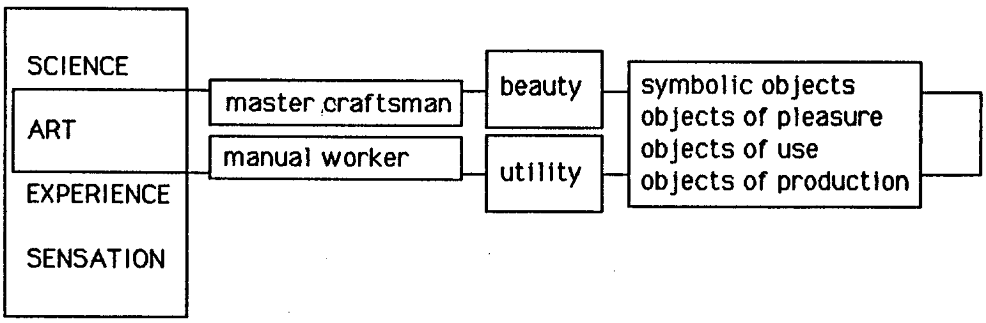

Diagram illustrating the pre-modern hierarchical
structure of art as a form of acquiring knowledge.

Analogous to the hierarchical relation between mechanical apparatus and architectural object was the subordinate position of manual techniques of production regarding symbolic objects. The skills of the craftsman and his techniques of making also provided man also with symbolic objects. In general, the act of making in itself could contribute to the expression of man's inner state, as an externalization and projection of feelings and desires. Making in this sense addressed the subjective manifestation of personal values. However, making was also directed toward the expression of social and cultural contents which to a major extent was objectified. The act of making addressed values which most commonly resided in the formalization of ideas, rules, and norms regarding the form of the artifact. In other words, the symbol was carried by the object and engaged the process only in so far as it contributed to the symbolic function of the product. From this vantage point one can understand the significant meaning assigned to the role of objects in Western civilization. Herein is to be found an early indication of the cultural emphasis given to products and goods which gradually gained importance with the development of modern society. This tendency might have reached its culmination within contemporary culture which is primarily guided by object-minded interests.

Art-Technology

Prior to the fifteenth century there was no evidence for any of the *mystique* which has since developed around the artist and his *œuvre* . Art was not regarded as stylistic nor was it romanticized as belonging to the *schönen Künste* or being exclusively of the fine arts. On the contrary, art was a basic human activity. Art comprised the processes that brought things into being, into a state of existence, and was primarily production. In that, the understanding of art was equivalent to the activity of the maker, to making. Furthermore, art was a form of acquiring knowledge pertaining to the sciences. In its entity art formed a body of theories and skills for the artist or artisan to engage in his profession and to execute his craft. The expression *technology*, derived from its Greek antecedent *technikon*, meaning that which belongs to *techné*, addressed the two meanings of art, as skill and as knowledge. *Techné* was first considered the term to identify the activities of the craftsman, and secondly it stood for the arts of the mind.[56] *Techné* united both, thinking and making within its aegis. The theory of art as *techné* or intelligible making was developed within the context of Greek philosophy by thinkers who maintained both that the process of constructing a work of art was demonstrable and that criticism of the product of the process was adequate. This understanding of art pertains to the definition of technology as the theory of practice. Art and technology were considered inseparable entities in the period prior to the Modern era.

Theories addressing making, in providing a conception of technology, determined a very specific notion of the role of technique within art production. Technique was simply a neutral instrument which attained its value from its results; technique was regarded as a means toward a determined end with its justification derived from the aim to perfect the human

[56] See Martin Heidegger, "The Question Concerning Technology," *Basic Writings*, edited by David Farrell Krell, Harper & Row (New York), 1976, p. 294.

condition. The concept of technique as an instrument originated in Antiquity to disclose a superiority of the products of creation over the means engaged in the processes of making. Within products beauty was given priority over utility. This system of clear hierarchical positions inherent within art production determined a clear understanding of a technological model. The hierarchical structure extended to the systems of human knowledge giving science a position of highest authority, its realm being that of theory, followed by art addressing the realm of making or practice. Experience and sensations, while important for the formation of knowledge, were considered of lesser value and placed lowest in rank. This hierarchical structure fundamentally determined the position of art-technology within man's system of thought and action up to the beginning of the modern era.

With the introduction of the new sciences the unity of art-technology was to be replaced by the emphasis given to the new entity of science-technology. The meaning of both terms, art and technology, changed fundamentally in being assigned to different aspects of production. The change in understanding was gradually manifested in the varying historical attempts to classify the arts. In antiquity the classification of the arts was a division of all human abilities; during the Middle Ages it was a division between purely intellectual (*artes liberales*) and mechanical arts; in the Renaissance attempts were made to further divide the arts into various categories ranging from "fine arts" to "applied arts;" and since the eighteenth century the classification has been primarily a division among the fine arts themselves. In other words, the field of art within the Modern era had been limited to exclusively fine arts. The separation of the artist and the artisan followed as a logical conclusion, and the term technique within art was limited to the skills of the artist. A parallel change of emphasis pertained to the understanding of technology. Rather than addressing the systems of thought regarding creative making, technology was defined as a body of technical knowledge including specialized procedures and methods. Technique as skill remained within technology but was of relatively minor concern. Technique was primarily equated with the instrumentality of technological operations necessary for fulfilling specific tasks. Technology at its best developed as a science, proposing the formulation of theories which established a framework of thought for man's technological undertaking.

The unity of science and technology did not disregard the structures of making and production as they had been formalized by pre-modern propositions. On the contrary, essential components of the early art-technology framework remained intact for modern society. Within the above described hierarchical structure of art-technology, various aspects of the science-technology framework were developed: the emphasis on utility, on objects, and on the instrumentality of technology. The priority given to utilitarian matters as well as the emphasis placed on objects continued to be effective in an exaggerated form. The most important of all the concepts which further determined the stake of technical undertaking was the notion of technology's instrumentality. Technique was further understood as an instrument and neutral tool to be invested in the human effort to conquer the natural world. In that the Aristotelian or traditional concept of technique as means toward a determined end remained the guiding principle within technology.

The concept of technique allowing man to overcome his natural condition was best expressed in the importance given to the Promethean myth. It disclosed the ideals of humanity of which Prometheus's symbols were the expression. The significance of the Promethean theme characterized first the art-technology complex in its essence and became later the base for the science-technology framework. The myth begins with the assumption that "man is a tool-using animal," and that the gift of fire, stolen by Prometheus from the gods, was the original source of man's development.[57] In Antiquity Prometheus was regarded as the rebel who opposed the unjust and tyrannous rule of the gods and who for love of man gave him fire and taught him all the arts. From Prometheus men learned to build houses; from him they received the science of mathematics, the alphabet, the art of taming horses, and navigating the oceans. In Plato's writings Prometheus took part in the creation of man by teaching him to honor the gods and to draw food from the earth; he thus gave man a share of the divine attributes. In medieval culture Prometheus was no longer considered the rebel but the "Reformer" who invented all the arts and the instruments necessary for man to conduct his life. In that Prometheus was the symbol of divine creative power. During the Renaissance Prometheus became the expression of man's individual position on earth and the symbol of the capacity for

[57] Lewis Mumford, *Arts and Technica*, op. cit., p. 34.

creativity which man alone among all living beings possessed. The human condition was directed not by divine will but by the free choice of man, for his nature was the realization of his condition. However, this emancipation was not complete since the model of man's making still resided in the imitation of divine making. The self-realization of man was considered infinite, its limits being those of the universe.[58] It was with the introduction of modern science that the Promethean myth developed at its fullest. For Francis Bacon and René Descartes the problem was not to lead the human mind to the level of the divine nor to contrive the human world from the infinite reality of the universe. Their exclusive aim was instead to liberate man from all the restrictions of the human imagination as were given by mythical thought and religious dogma. The condition of man was determined neither by divine will nor by the imitation of divine creation but by the actuality of human thought as the certainty of man's self-consciousness. This belief as expressed in Descartes's statement *cogito, ergo sum* (I think, therefore I am) was the compressed manifestation of man's emancipatory will. In that the fire stolen by Prometheus became the symbol of the modern science-technology complex through which man could control his situation on earth. Man's power was considered in no way infinite; it was on the contrary limited to the causal connections that regulated natural reality. Hence man's task did not consist in the celebration of his identity with the universe, but in understanding nature in scientific terms in order to extend the potentialities inherent

[58] The history of the Promethean myth is taken from Paolo Rossi, "The New Science and the Symbol of Prometheus," in *Philosophy, Technology and the Arts in the Early Modern Era*, Harper & Row (New York), 1970, pp. 174-186.

within the natural environment. Man was not "added to nature" but was part of it, and technology was man's tool to transform nature and prolong its possibilities. Technology became the base for a new myth, replacing the determinism of God with the determinism of science.

In opposition to the Promethean myth was the belief supported by the propagators of the art-technology framework that Orpheus and not Prometheus was to be regarded as man's first teacher and benefactor; man became human, not by making fire his servant but because he found it possible by means of his symbols to express beauty, to enrich his life with memories of the past and formative impulses toward the future, and to expand and intensify those moments of life that had value and significance.[59] This position asserts that the arts represented a uniquely human need, based on the capacity for symbolic expression. Unlike animals, man was able to abstract and represent aspects of his environment in the form of symbols. The priority given to the function of meaning and its manifestation in object form was recognized and strongly supported by Lewis Mumford:

Man was perhaps an image maker and a language maker, a dreamer and an artist, even before he was a toolmaker. At all events, through most of history, it was the symbol, not the tool, that pointed to his superior function. Doubtless the two gifts necessarily developed side by side, since the arts required tools for their expression.[60]

[59] Lewis Mumford, op. cit., p. 35.
[60] Ibid., p. 35.

It follows that Orpheus was placed on as high a pedestal as Prometheus. However, within the synthesis of art and technique priority was given to the meaning of things and not to the means of their creation. Orpheus, the player of the lyre, who attempted to rescue Eurydice from the depths of Hades, often been referred to as Pluto's technological underworld, represented a part of man's nature that Prometheus, for all his love of man, never could have brought to its full development.

The diverging positions of the Orphean and Promethean myth, rather than being united were gradually placed even further apart with the development of the Modern era. This rupture was the expression of the diametrically opposed interests of art and science, a dichotomy which seemed irreversible. The discipline of architecture, with the potential to unite the two, occupied a schizophrenic position within the Modern era. On the one hand architecture was an art, its function being the manifestation of meaningful contents in symbolic form. Architecture addressed beauty, imagination and the irrational. Architecture on the other hand was building, requiring techniques for its processes of making. It pertained to the scientific, efficient, and rational. Art and technique had become separated, the symbolic and technical function of architecture, although dependent on one another, avoided the discourse, their division was total.

3. Chapter

THE DICHOTOMY BETWEEN ART AND SCIENCE

THE DICHOTOMY BETWEEN ART AND SCIENCE

"Our fine arts were developed, their types and uses were established, in times very different from the present, by men whose power of action upon things was insignificant in comparison with ours. But the amazing growth of our techniques, the adaptability and precision they have attained, the idea and habits they are creating, make it a certainty that profound changes are impending in the ancient craft of the Beautiful. In all the arts there is a physical component which can no longer be considered or treated as it used to be, which cannot remain unaffected by our modern knowledge and power. For the last twenty years neither matter nor space nor time has been what it was from time immemorial. We must expect great innovations to transform the entire technique of the arts, thereby affecting artistic invention itself and perhaps even bringing about an amazing change in our very notion of art."

Paul Valéry, "La Conquète de l'ubiquité."[1]

The Mechanical Arts

The growth and blossoming of cities and their free civic institutions since the Middle Ages was linked with the development of an urban industry based on the organized trades of artisans and craftsmen. The processes of making were in the hands of skilled workmen who controlled the specific methods

[1] Paul Valéry, "The Conquest of Ubiquity," in *Aesthetics,* translated by Ralph Manheim, Pantheon Books (New York), 1964, p. 225. Walter Benjamin quotes the text by P.Valéry in "The Work of Art in the Age of Mechanical Reproduction," in *Illuminations,* Harcourt, Brace & World, Inc. (New York), 1968.

and techniques of their art in the production of artifacts. The term *mechanical arts* was applied to those activities which pertained to the use of tools and machinery in any type of manual work contributing to the material needs of life. To such a category of labor belonged typically the construction of shelter, the manufacturing of tools and machines, and the production of food, such as agriculture, hunting, and fishing. The expression *mechanical arts* addressed the crafts and trades of manual labor and was seen in opposition to the concept of the *liberal arts* which embraced the sciences of the mind. In belonging to different realms of human activity, a dichotomy existed between the mechanical and liberal arts in which the nature of the mechanical arts was primarily practical rather than theoretical, therefore inherently connected to the real and physical qualities of the material world.

The proximity of the practical arts to the conditions of reality gave to the work of the craftsmen, at base, an instrumental role in the functioning of society. Specialization of manual work into different groups of independent professions constituted the structure of productive forces in the city communities. A register of the city of Nüremberg established in 1363, in which the various groups of artisans were enumerated, is proof of the detailed division of labour at the end of the fourteenth century. Nüremberg, unlike other medieval towns, had no actual guild organization; in spite of that the city had no less than fifty groups of manual workers comprising 1217 Master-craftsmen.[2] Connected with the flourishing of organized

[2] Friedrich Klemm, *A History of Western Technology,* MIT Press (Cambridge, Massachusetts), 1964, pp. 95-97.

handicraft was the constant exploration of techniques resulting from the processes of production. Although strict limitations imposed by the Guilds often hindered technical progress, inventions and new possibilities for the making of artifacts constantly developed within practice from experiments with materials and methods.

The mechanical arts in their entity constituted a body of knowledge, which as such had not yet been recognized; however, its guiding force determined the possible evolution of technique and its influence on physical reality. The interdependence between technical matters and the visible world, and its reciprocal form of relationship, was the base for every form of production. The structure of making pertained to the direct connection between the act of production and its physical manifestation. The Englishman Roger Bacon (c.1214-1294) was one of the first to recognize the potential of this condition for the formation of knowledge. He proposed a form of relationship between craftsmanship and knowledge as based on the perceived reality of the results and processes of production. The importance given to observation and experiment within the mechanical arts was strongly advocated by Bacon. He considered that knowledge transmitted by tradition or gained by reason had to be proven by experiment:

For there are two modes of acquiring knowledge, namely, by reasoning and experience. Reasoning draws a conclusion and makes us grant the conclusion, but does not make the conclusion certain, nor does it remove doubt so that the mind may rest on the intuition of truth, unless the mind discovers it by the

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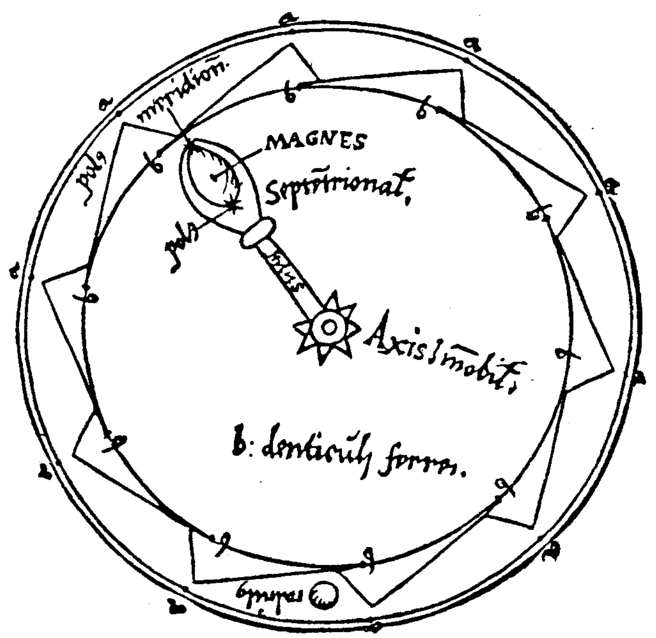

Magnetic perpetual motion device, 1269.
From: Pierre de Maricourt, *De Magnete*.

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path of experience; ... He therefore who wishes to rejoice without doubt in regard to the truths underlying phenomena must know how to devote himself to experiment. For authors write many statements, and people believe them through reasoning which they formulate without experience.[3]

Roger Bacon envisaged the use of experience as based on experiment to find practical applications of knowledge. In following such a course of action, according to Bacon, new discoveries could be made which could not be anticipated by rational speculation. Bacon's experimental empericism was based on the possibilities inherent within the practical arts, for he believed that new techniques could be developed from experiment and observation. This approach constituted a contribution to technology, confirming the importance of manual labor and craftsmanship for the new science. Bacon's interest in the various branches of the mechanical arts is well expressed in the figure of the *magister Petrus*, the *dominus experimentorum*, often mentioned in Bacon's written work. He was, as Bacon puts it, interested in metal founding, the working of gold and silver, mining, arms and military engineering, and the surveying of earthworks. In short, the *Magister Petrus* was a figure interested in all of the various fields of technology which had developed during his time. Many think him to be a fictive creation of Roger Bacon's mind, most probaly identified with Pierre de Maricourt, whose writings on magnetism (1269) provided remarkable contributions concerning general

[3] Roger Bacon, *Opus Maius,* translated by Robert Belle Burke, University of Pennsylvania, 1928.

experimental studies as well as the possible utilization of the magnet.

Pierre de Maricourt described a series of experiments which led him to a clear understanding of several properties of magnetism, an understanding to which little was added until the work of William Gilbert was published in 1600. Significant here is the fact that Pierre de Maricourt attempted to come to terms with the prejudice of the learned society against manual work. In his treatise on the magnet he emphasized that the investigator of magnetic phenomena had not only to be versed in theoretical speculations, but that he also had to be "industrious in manual work" (*industriosum in opere manuum*). According to Pierre de Maricourt, errors which by mere reason and mathematics could not be avoided could be corrected by the experiments of the "manual industry."[4] The conviction that the mechanical arts could contribute to knowledge, as stated by Pierre de Maricourt and Roger Bacon, led them both to speculate on inventions and possibilities of technical development resulting from the impulse of their creative imagination. Pierre de Maricourt sought to produce, as Villard de Honnecourt had done, a perpetual motion machine as based on his discovery of magnetic forces. Bacon foresaw a development of technological progress which significantly predated the technical advances of the time:

I will now mention some of the wonderful works of art and nature which there is nothing of magic and which magic could

[4] See Edgard Zilsel, "The Origins of Gilbert's Scientific Method" in *Roots of Scientific Thought*, edit. by Philip P. Wiener and Aaron Noland, Basic Books (New York), 1957, p. 247.

not perform. Instruments may be made by which the largest ships, with only one man guiding them, will be carried with greater velocity than if they were full of sailors. Chariots may be constructed that will move with incredible rapidity without the help of animals. Instruments of flying may be formed in which man , sitting at his ease and meditating in any subject, may beat the air with his artificial wings after the manner of birds .... as also machines which will enable men to walk at the bottom of seas or rivers without ships.[5]

Bacon's and Pierre de Maricourt's visions of technological possibilities are of interest insofar as they reveal the intention to further exploit the technical potential of their discoveries. Their propositions for the conception of technical knowledge based on experiment and experience merged with the creative power of their imagination. Production, carried by craftsmanship within the mechanical arts, was considered the base from which to attain knowledge through experiment and observation as guided by the generating force of human creativity.

The union of such factors as craftsmanship, empirical knowledge, and creative thinking led to the development of new technical possibilities as occured for example within the art of printing in the fifteenth century. The invention of

5 Roger Bacon, *Epistola de secretis operibus artis et naturae*, see Lewis Mumford, *Technics and Civilization*, Harcourt Brace Jovanovich (New York), 1934, p. 58.

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Johannes Gutenberg's alphabetic characters, formally determined by the invention of movable type printing, c.1440-45.

printing[6] from movable type credited to Johannes Gutenberg (1397-1468) was a technique developed from different branches of the mechanical arts. This invention was an achievement both in the realm of technology and of craftsmanship. Gutenberg's technical discovery was the development of an apparatus for type casting capable of producing any desirable quantity of standardized types. For shaping the type a copper matrix was used in which the letters were struck by means of a steel letter-punch cut in relief. Important is that Gutenberg combined techniques derived from several branches of the mechanical arts, and that he had to be familiar with the various metallurgical methods of production in order to realize his ideas. He was able to go beyond the technological limitations of the single groups of craftsmen in combining the practical knowledge of various trades into one new technical method. Most significant to the discovery was the conceptual structure of the method proposing standardization of replaceable parts as the technical equivalent to the division of written text into repetitive and recurring units. The use of the terms *movable type* and *typesetting* in their reference to the structure of written language, conceived of prototypical repeatable elements, could not be more appropriate to identify the relation between technique and conceptual structure. To divide existing entities into smaller units that again could be

[6] Printing from movable type had been developed in China prior to Gutenberg's invention, presumably in the tenth century A.D. during the early period of the Sung Dynasty. There is no clear evidence as to how the European development in printing may have been influenced by Chinese achievements. Most certain is that the introduction of paper came from China, and that Chinese block printing might have had some influence on European printing. However, no reliable proof has yet been found that the concept of printing from movable type in Europe was directly derived from the methods developed in China. See Thomas Francis Carter, *The Invention of Printing in China and its Spread Westward,* Columbia University Press (New York), 1925.

combined to form new entities of unitary character was a concept which was to become important for the structure of scientific thought. By breaking the once unified process of writing into a series of fractional operations Gutenberg's technique disclosed the characteristics of machine production, which for succeeding centuries would dominate the processes of production.[7] The development of a new method of printing, furthermore, constituted in its applied form a manifestation of technical knowledge brought to synthesis with the possibilities of artistic expression. Gutenberg's use of the possibilities of the new technique determined the form and appearance of the printed product. The specific form of the letters were adapted to the technological requirements of metal-work, for the letters which previously had been written by hand were now cut in metal, thereby necessitating new shapes. Technical development lead to new possibilities of formal expression for the printed book, an art in its own right.[8]

The concentration of skilled labor, typical for the European cities of the period, constituted a major generating force for the development of technique. But most importantly, it evolved as the possible link between various fields of human activity. On the one hand technique was closely connected to the creative aspect of the maker's work, thereby allowing symbolic expression. Technique on the other hand engaged in the

[7] The invention of printing from movable types has been discussed in relation to the historical development of mass production and machine art by Lewis Mumford in *Art and Technics* , Columbia University Press (New York), 1952, pp. 65-70.

[8] For further information on Gutenberg's invention see: Aloys Ruppel, *Johannes Gutenberg, sein Leben und sein Werk*, Verlag Gebr. Mann (Berlin), 1939, and H. Meisner & J. Luther, *Die Erfindung der Buchdruckerkunst*, Verlag von Velhagen & Klasting (Bielefeld), 1900.

formation of conceptual structures, thus contributing to knowledge. This hypothesis supports a twofold proposition. First, technique could be seen as the mediating factor between the mechanical arts and artistic expression, and second, technique could be regarded as the connecting element between the mechanical arts and scientific knowledge. Both aspects of technique, the former in reference to art and the latter in relation to science, were inherent within the mechanical arts. It was the structure of craftsmanship specifically which constituted the grounds for technique to establish a bridge between art and science. This was the condition which was to emerge in the early Renaissance, at the beginning of the modern era. But whether a synthesis of art and science could ever be achieved became one of the predominant questions for those disciplines, such as printing, ceramics, glassmaking, or architecture, which lay between the realms of art and science.

The Art of Building

To the group of artisans involved with architecture and the art of building belonged generally the trades of carpenters, ironers, glaziers, cabinet-makers, sheet metal worker, stone-masons, painters, and tool-makers. Their technical know-how, transmited from generation to generation, constituted in its totality a body of knowledge for the art of building. The various trades, in charge of the techniques of their craft, contributed to a larger entity which went beyond the specifics of the work at hand. The formation of a discipline of architecture as based on the skills of craftsmen engaged in the various trades was a necessity requiring a general framework which had yet to be defined. Within all fields of production the division of labor required the breaking up of barriers in order to address the formation of a unifying discipline. The different guilds and trades had to open their closed systems of rules and communications regarding methods and techniques which were limited to their specific fields of activity. Also, manual labor had to be exposed to the structure of the theoretical sciences in order to provide technical knowledge with a framework of conceptual ideas.

The art of building during the Renaissance was one of the first fields of production to unify the different practical arts involved in construction to form a total system, which became the discipline of architecture. The Vitruvian understanding of the role of the architect, versed in the practical arts as well as in theoretical discourse, became the guiding concept for this development. The figure of the architect exemplified the Renaissance ideal of man in the center of the Universe, in the role of creator. He represented the '*uomo universale.*' The architect was placed in a unique position, his task being to have a broad and general knowledge of all the aspects of the arts, in theory as well as in practice. This change of ideas with respect to the art of building was linked to the social development of the architect from the role of the master artisan to that of the artist genius, accepted into a culture that was higher on the social scale and linked to the courts of princes. The architect belonged to the cultured and learned circles of society.

Giorgio Vasari's (1511-1574) undertaking to write the biographies of well known Italian architects is an indication of the significant importance given to the new position of the architect during the Renaissance. Vasari's *Le vite dei più eccellenti scultori, pittori, e architetti,* first published in Florence in 1550, reveals the various fields of interest pertaining to the activities of the architect of the time. Architects were not only involved with the art of building but also occupied themselves with sculpture and painting, the construction of mechanical instruments, as well the study of the humanities. Filippo Brunelleschi (1377-1446), for example, was trained as a goldsmith as were the sculptors and painters Donatello and Lorenzo Ghiberti. Brunelleschi was also skilled in the art of building, in sculpture, in perspective and proportion, in hydraulics, and construction of scientific apparatus. In the biography of Brunelleschi, Vasari described the architect's interest in mechanics: "He became well acquainted with some highly educated people and started to speculate about problems of motion and time, and of weights and wheels, and how the latter can be made to revolve and by what means they are kept in motion; and he made with his own hands some very splendid and very beautiful clocks."[9] Brunelleschi's introduction to mechanics provided him with a sense for technical experimentation as based on empiricaly derived knowledge. Such experiments were done in workshops and ateliers in which material properties and production techniques were investigated. Some of these studios, like Lorenzo Ghiberti's during the preparation of the doors to the Baptistry in Florence, were transformed into industrial laboratories in

[9] Giorgio Vasari, *Le Vite de' Più Eccellenti Architetti, Pittori, et Scultori...,* (Florence, 1550); 2nd enlarged edition, (Florence 1568); English translation by George Bull, Penguin Books Ltd. (Harmondsworth, Middlesex), 1965, p. 135.

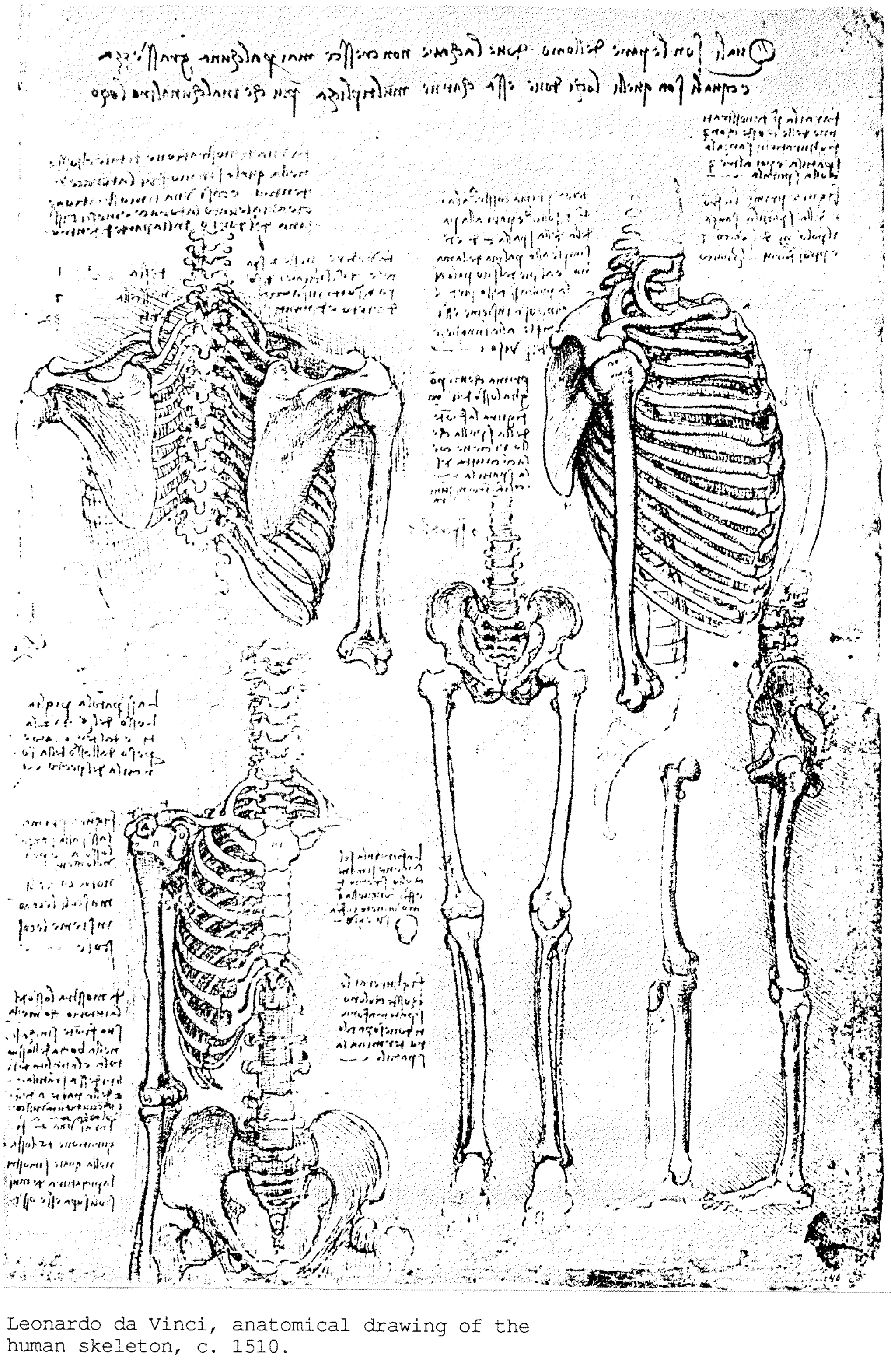
which production and experiment were unified in the processes of making. It was in these laboratories, which were a combination of workshop and studio, rather than in schools that architects, sculptors, and painters apprenticed. The tendency within the Renaissance to discuss and to influence the visible material reality of the world by means of the arts was manifested clearly in the Florentine workshop tradition. "Here, alongside the arts of stone-cutting and pouring bronze, as well as painting and sculpture, apprentices were taught the rudiments of anatomy, optics, calculus, perspective, and geometry, as well as the projected construction of vaults and digging of canals."[10] This type of empirical approach to the processes of making, a contributon to the contact between scientific and technico-artisan knowledge, was in fact the base upon which artists, engineers, and architects, such as Leonardo da Vinci or Filippo Brunelleschi, could develop their work. In this regard the artist of the Renaissance could be compared with Roger Bacon's *Magister Petrus*, for whom practical experience contributed to the formation of knowledge. In the workshops for perhaps the first time a fusion between technical and scientific activities, and between manual labor and theory might have been realized; however, the formalization of general theories had yet to be made. Of primary interest was rather the direct application of technical knowledge to practice. This is well described in another early biography on Brunelleschi, presumably written by Antonio di Tuccio Manetti, in the 1480's:

[10] Paolo Rossi, *Philosophy, Technology, and the Arts in the Early Modern Era*, (1962), Harper & Row (New York), 1970, p. 23.

... by virtue of having in the past been interested and having made clocks and alarm bells with various and sundry types of springs geared by many diverse contrivances, he was familiar with all or a great number of those contrivances, which helped him a great deal in conceiving different machines for carrying, and pulling, according to what the exigencies were. ... He considered the methods of centering vaults and other systems of support, how they could be dispensed with and what method had to be used, and when - because of the size of the vault or of other reasons - armatures could not be used. ... By his genius, through tests and experiments, with time and with great effort and careful thought, he became a complete master of these matters in secret, while pretending to be doing something else. He demonstrated that mastery later in our city and elsewhere, as this account will in part make known.[11]

The search for possible applications of technically derived knowledge exhibited strongly practical traits. Experiments, new methods of construction, and the development of tools and techniques were based on practical considerations which constituted the primary base for the processes of making. This approach to the making of artifacts, derived from the Renaissance impulse to directly influence the visible world, was manifested most forcefully in the work of Leonardo da Vinci. His extraordinarily developed power of illustration in the realm of the fine arts as well as within technical propositions offered a new method of approach to the concept of

11 Antonio di Tuccio Manetti, *The Life of Brunelleschi*, (*Vita di Brunelleschi*), edited by Horward Saalman, English translation of the Italian text by Catherine Enggass, The Pennsylvania State University Press (University Park, Pennsylvania), 1970, pp.50-53.



Leonardo da Vinci, anatomical drawing of the human skeleton, c. 1510.

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making. Leonardo's maxim "to render everything visible" led initially to the direct registration of existing phenomena as perceived by the eye and subsequently to the discovery of new propositions made visible in sketch and drawing form. In his anatomical drawings, as in the design of machines and structures, Leonardo contributed a precise method for the representation and description of reality. In this regard, since observation was followed by experiment, empiricism became experimentalism, making way for active and operative investigation. Thanks to his involvement with the Florentine workshop tradition Leonardo was acquainted with the properties of materials and the different methods of their utilization. From practical knowledge he was able to project new ideas for the construction of technical apparatus and machines. He notably recognized individual actuating mechanisms and their elements, which he was able to examine separately, as essential parts of the machine. The descriptive method of observation used in his anatomical drawings in which the different parts of the body were shown as separate functional entities allowed him to structure his technical constructions systematicaly according to the purpose of their performance. The analogy of man's anatomy to machine parts had already been made by Alberti in *Della pittura* (1435-36), in which the human body was considered as a system of weights and levers, of balances and counter-balances.[12] Leonardo's repertory of screws, springs,

12 Alberti, *On Painting*, translated by John R. Spencer, Yale University (New Haven), 1956), pp. 79-80: "*I have noted that the movements of the head are almost always such that certain parts of the body have to sustain it as with levers, so great is its weight. Better, a member which corresponds to the weight of the head is streched out in an opposing part like an arm of balance. We see that when a weight is held in an extended arm with the feet together like the needle of a balance, all the other parts of the body will displace to counterbalance the weight.*"

wheels, and other mechanical devices when assembled constituted the parts of machines which in their entity were to function as mechanical organisms. Many of Leonardo's technical drawings bear the character of practical workshop sketches from which the individual parts of the machines could have been manufactured; however, most of them were probaly never realized. To such technical devises belonged for example his automatic file-cutting machine and a lathe with treadle and crank drive which demonstrate Leonardo's interest in the use of mechanics for the making of tools. Most important for the development of technology was Leonardo da Vinci's structured approach which divided the functioning processes of machines into series of operative steps and divided the machine itself into identifiable parts assembled within a system of unitary character. Such a concept applied to the machine was conceived in affinity with the understanding of anatomical systems. The reference to the human body was further made explicit in an analogy between medicine and architecture mentioned in an letter written by Leonardo regarding the work on the Milan Cathedral:

You know that when medicines are rightly used they restore health to the invalid, and that he who knows them well makes the right use of them if he also understands what man is, and what life is, and the constitution of the body, and what health is. ... The case of the invalid cathedral is similar. It also requires a doctor architect who understands the edifice well, and knows the rules of good building from their origin, and knows into how many parts they are divided, what are the causes that keep together an edifice and make it last, what is the *nature of weight and of energy in force, and in what manner they should be combined and related to one another and what effect they will produce when combined.*[13]

The systematic approach to architecture exihibited in this extract proposed the concept of a unifying body of knowledge with rules and principles for the art of building. Leonardo mentions the division of structures into parts, their systems of relation, and the methods of their assembly, which together constitute the form of building. On this basis it is possible to discuss Leonardo's awareness of the nexus that had to be established between theoretical structure and practical activity. However, it seems that Leonardo, who was always curious about particular problems, actually demonstrated no interest in developing a systematic corpus of knowledge. His investigations appear fragmented, as is manifested in the scattered observations and brief notes of his writings which seemed to follow an obscure symbology. The form of Leonardo's nontransmittible and dispersed collection of facts and ideas could not by any means lead to a systematic methodology characteristic of modern science and technology. "He was alien to the concern, which indeed is a fundamental dimension of what is called technique and science, to transmit, explain, and prove his own discoveries to others."[14] The written work of Alberti, predating Leonardo da Vinci, was published in form of theoretical treatises. Similar emphasis on theory was given by

[13] Leonardo da Vinci, *Codex Atlanticus*, (fol. 270 r-c). See Carlo Pedretti, *Leonardo de Vinci Architecte*, Electa (Milano), 1978, translated into French by Marie-Anne Caizzi, Electa France (Paris), pp. 34-35. English text from F. Klemm *A History of Western Technology*, op. cit., p. 127.

[14] P. Rossi, op. cit., p. 27.

Dürer's publications on the compass and square (1525), on fortifications (1527), and on the proportions of the human body (1528), which were published after Leonardo's death.[15] Those works of Alberti and Dürer were written as systematic treatises which allowed the dissemination of ideas and information, which Leonardo's incoherent writings could not achieve. Nevertheless, Leonardo believed that practice could profit from theory: "Those who become enamored of practice without science are like pilots who board a ship without helm or compass, and who never are certain as to where they are going." As is explicitly put forward in that statement Leonardo strongly advocated a unity of thought and action, although he himself never attemted to formalize a theoretical framework for the activities of making. The work of Leonardo, based on his practical knowledge of the mechanical arts, addressed through his structured approach to specific problems a new understanding of making, which unfortunately he was unable to translate into theory.

Technical and practical knowledge pertained primarily to the field of the mechanical arts. But the architect of the Renaissance was also versed in the sciences of the humanities. As known from Manetti, Brunelleschi's education engaged in the study of various fields belonging to the group of the liberal arts: "Following the general tradition of men of standing in Florence, Filippo learned to read and write at an early age and to use the abacus." Manetti furthermore mentions that Brunelleschi had also to learn Latin, since his father was a notary expecting his son to enter the same profession. He also had learned mathematics and geometry from Paolo Toscanelli, a

[15] Ibid., p. 27.

respected mathematician, doctor of medicine, and learned man of Padua who was, according to Manetti, "on familiar terms with him for more than forty years."[16] The relation between Brunelleschi and Toscanelli is also mentioned by Vasari, who tells us that "although Filippo had had no theoretical training he was able to discourse so skillfully from practical experience that very often he bested Paolo in argument."[17] Toscanelli, well known for his mathematical studies, interested in optics and astrology and in the problems of navigation, was involved in a continuous dialogue with humanists and men of letters, with technicians and artisans. The collaborative relation between Brunelleschi and Toscanelli reflected the new possible interconnection of the arts and sciences within the Florentine culture of the fifteenth century. This culture addressed both the academic circles as well as artists, artisans, and technicians. "This world was a meeting ground for scholars and men of political commitment, for practitioners of science and mechanical arts, for lovers of the classics, and for those who were more interested in the modern world."[18]

Mathematical principles and geometrical relations constituted an important component of Renaissance architecture. Brunelleschi's inquiries in perspective and proportion, for example, were an indication of his interest in mathematical

[16] *"Master Paolo del Pozzo Toscanelli, mathematician and physician, who was, he said, on familiar terms with him for more than forty years, judged his power and experience [in architecture] as monor compared to his many other excellent skills, because, as Master Paolo said, it is really not possible for every artist to be apt or capable of such lofty matters."* Ibid., p. 54.

[17] Vasari, op.cit., p. 136.

[18] Paolo Rossi, op. cit., p. 25.

operations combined with the formation of rational structures for the procedures of making:

... he propounded and realized what painters today call perspective, since it forms part of that science which, in effect, consists of setting down properly and rationally the reductions and enlargements of near and distant objects as perceived by the eye of man: buildings, plains, mountains, places of every sort and location, with figures and objects in correct proportion to the distance in which they are shown. He originated the rule that is essential to whatever has been accomplished since his time in that area.[19]

Renaissance perspective provided a method by which to achieve proportionality between objects in space and their representation on the picture plane. In that the technical rules of perspective addressed the question of ratios between equal objects at various distances from the eye. The art of perspective as based on the understanding of geometrical and mathematical relations provided a rational structure for the perception of the world. Conversely the making of the world could be directed by rationality. In other words perspective was not only the science of proportionality between object and image, but also the science of proportion between the image of architecture as intended by the architect and the perceived image of the observer.

Brunelleschi's use of simple mathematical relationships and his understanding of the laws of linear perspective were

[19] Manetti, op. cit., p. 42.

constituent determinants for the spatial definition of the basilica of San Lorenzo in Florence. The plan is based on a square modular unit which by simple repetition creates the cross of nave, choir, and transepts. The nave itself is composed of four squares, whose adjacent aisles are structured by smaller squares each of which is one quarter the area of the primary module. The original plan of San Lorenzo, developed in 1419, was modified in the 1440's by the addition of twelve chapels and two niches, obtained by opening the side walls and creating small rectangular spaces half the area of an aisle bay. From this the simple proportional ratios 1:2 and 1:4 can be derived, which determined the plan geometry of San Lorenzo. The modular organization of the plan provided the structure for space to be conceived according to perspectival laws. The visitor who enters the church moves through the nave between two arcades which in definite progression visually diminish towards the distance. Essential is that this was consciously done to make the perception of a harmonic diminishing series in space a vividly felt experience. The effect is reinforced by the geometry of floor and ceiling. With the nave's floor pattern, laid out in squares corresponding to the size of the bays, space appears to be structured by a grided field which diminishes in perspective towards the vanishing point. Similarly created is the geometry of the coffers in the ceiling which are integrated within the module system of the building. The grid of the floor together with the gridded plane of the ceiling provide spatial coordinates and a orderly guide for architecture and its spatial experience.[20]

Brunelleschi's use of the laws of linear perspective was a major step towards the rationalization of space. The making of architecture according to metrical laws allowed a new approach to the arts to be based on the application of theoretical principles into practice. Renaissance architecture was conceived, as mentioned by Rudolf Wittkower, as an image of a pre-ordained, mathematical harmony of the universe. From here architects were led to understand that if infinite space was ordered according to immutable metric laws then all objects perceived in finite space had to be subject to unchanging optical laws, thus explaining the link between mathematical relations inherent within proportion and the newly discovered laws of perspective.[21]

It was the humanist Leone Battista Alberti who formalized the idea of a scientific conception of art in which mathematics, included in the theory of proportion and perspective, was considered the common ground of the artist and scientist. Alberti wrote in *Della pittura* :

It would please me if the painter were as learned as possible in all the liberal arts, but first of all I desire that he know

20 Rudolf Wittkower, "Brunelleschi and 'Proportion in Perspective'," in *Idea and Image*, Thames and Hudson (London), 1978, pp. 125-135. The essay was first published in the *Journal of the Warburg and Courtauld Institutes*, XVI, 1953.

21 Rudolf Wittkower mentions the connection between proportion and perspective
in the introduction of the 1971 edition of *Architectural Principles in the Age of Humanism*, W.W. Norton (New York), 1971.

geometry. ... Our instruction in which all the perfect absolute art of painting is explained will be easily understood by the geometrician, but one who is ignorant in geometry will not understand these or any rules of painting. Therefore, I assert that it is necessary for the painter to learn geometry.[22]

Alberti's proposition is of significance in so far as it puts forward a position in favour of an exposure of the arts to the theoretical sciences. Alberti's assertion specifically subjects painting to the rational as well as universal laws of geometric order. With those Alberti hoped to provide a theoretical framework which manifested in the technique of perspective would provide a scientific structure to art. And when applied to the art of building geometrical order and mathematical clarity would become constituent components of architectural conception. Although the concept of art advocated by Aberti was primarily based on practical training acquired under a master and apprentice system, it provided a theoretical structure which went beyond the material immediacy of manual work. The ascendancy of mind over hand gradually became explicit. Alberti's artist and architect was characterized by his intellect, yet his art was one which had to exist in matter.

The reference to a mathematical structure for the architecture of the Renaissance was double, addressing the two fundamentally opposed understandings of science. Mathematical order provided the art of building with a rational framework for conceptual operations, a constituent element of the new science. Secondly,

[22] Leone Battista Alberti, *Della Pittura* (1435-36), *On Painting*, edited by W.Stark, translated with introduction by John R. Spencer, Yale University Press (New Haven), 1956, Book III, p. 90.

geometry and mathematics asserted a mythical dimension to the art of building, referring to the order of the universe, a proposition derived from the discourse and theory of philosophy, i.e. the old sciences. This twofold aspect of the role of mathematics in architecture implied no contradiction; on the contrary this became the base for the development of a theoretical structure constituting the discipline of architecture. The art of building was exposed to theory. Practice constituted the field within which the construction of scientific knowledge could be formed. But practice also was to be exposed to the theoretical discourse of philosophical thought. The processes of making were therefore placed within a dialectical condition marked by the opposed propositions of the old and the new science.

The Ancients and the Moderns

The idea of knowledge a construction, based on the thesis that man can only truly know what he makes or constructs, was of primary significance for the discussion on the mechanical arts which assumed a singular intensity of interest in the years between 1400 and 1700. A new understanding of the concept of work and labor, a new definition of the function of technical knowledge, and a new view of the importance of artificial processes through which nature could be transformed, first made its way into the work of the craftsmen of the fifteenth century and subsequently became formalized in treatises during the following centuries. An appraisal of the arts emerged that was quite different from the one which had traditionally prevailed.

Prior to the Renaissance practical making, or art, was not concerned with general theories; intellectual activity belonged to the realm of science. The goal of science was not application but contemplation as was explicitly manifested in the almost total separation of science and technique. To apply scientific thought technically was a concept foreign to the ideas of pre-Renaissance philosophies, for which scientific thought corresponded to a conception of life, to wisdom. The traditional rejection of technique within the realm of science was a deliberate, positive activity involving self-mastery, recognition of destiny, and the manifestation of a given form of existence, which represented an apex of civilization and intelligence. This view changed drastically as a result of vital and pressing needs existing in Europe towards the end of the Medieval period. Science and art could not independently further develop without addressing one another. It was then argued that the methods employed by artisans in their processes of creation were also to be useful for acquiring knowledge of natural reality. The processes of art production for which practical operations were tantamount to servile labor assumed a guiding role in the formation of scientific theories. The technicians and craftsmen who worked in their shops, ateliers, and arsenals considered their operations, which were conducted on the premise that the means and methods of making contributed to knowledge, a form of intellectual cognition. Knowledge presented itself as a series of individual contributions provided by the efforts of various professions and organized in the form of a systematic discourse. The new orientation implied a rejection of the traditional concept of science as a pure contemplation of truth disinterested in practical labor.

Theory, rather than being limited to the exclusive discourse of science, gradually began to include art production as a generating force for the formation of thought. And conversely the possibility emerged for practical matters to be directed in accordance with theoretical propositions of scientific models. This new understanding, however, was not immediately accepted. Exponents of the new relationship between science and art were strongly opposed by the propagators of the traditional model of science in which science was considered as pure theory and art as pure practice. The disagreement between both fractions remained active for several centuries in the debate between the Ancients and the Moderns.

Bernard Palissy (1510-1589), the French potter, glassmaker, and garden architect who had achieved recognition in developing techniques for the manufacturing of white enamel, addressed in his treatises *Recepte Véritable* (1553) and *Discours Admirables* (1580) the question of knowledge as derived from practice.[23] Palissy naïvely asked whether it was possible to be knowledgeable about natural effects without having read books written in Latin.[24] He considered practical knowledge more

23 Bernard Palissy, *Oeuvres publiées d'après les Textes Originaux avec une Notice Historique et une Table Analytique* , edited by Anatole France (Paris, 1880), reprinted by Slatkine Reprints (Genève), 1969. This edition contains, among others, reprints of *Recepte Véritable par laquelle tous les Hommes de la France pourront apprendre a multiplier et augmenter leurs Thrésors. Item, ceux qui n'ont jamais eu cognoissance des Lettres pourront apprendre une Philosophie nécessaire a tous les Habitans de la Terre* (La Rochelle, 1553), pp. 11-152; and *Discours Admirables de la Nature des Eaux et Fontaines tant Naturelles qu' Artificielles* (Paris, 1580), pp. 163-457.

24 *"J'ay mis ce propos en avant pour clorre la bouche à ceux qui disent, comment est il possible qu'un homme puisse sçavoir quelque chose et parler des effects naturels, sans avoir veu les livres Latins des philosophes?"* from "Advertissement aux Lecteurs," in *Discours Admirables,* ibid., p. 166.

important than any exclusively theoretical speculation.[25] Palissy became popular in Paris between 1575 and 1584 through a series of public lectures in which he included physical experiments and the demonstration of natural objects from his own collection. In his *Discours Admirable*, which constituted an attack against the exclusive philosophy of the professors at the Sorbonne, Palissy redefined philosophy as the art of observing nature as based on knowledge derived from practical experience:

Through practice I prove that the theories of many philosophers, even the most ancient and famous ones, are erroneous in many points. Anyone can ascertain this for himself in two hours merely by taking the trouble to visit my workshop. Marvelous things can be seen here (demonstrated and proved in my writings and arranged in an orderly manner with texts at the bottom so that the visitor may be his own instructor). I assure you, dear reader, that you will learn more about natural history from the facts contained in this

[25] Two interesting and to a certain degree contradicting aspects of B. Palissy's work have been addressed by historians and theoreticians in the field of technology. The first is in reference to the mythical and magical dimension that Palissy assigned to technique and technical operations. A synthesis between technical and symbolic intentions constituted one of the guiding forces of his philosophy. See Alberto Pérez-Gomez in *Architecture and the Crisis of Modern Science*, MIT Press (Cambridge, Ma.), 1983, pp. 168-171. The second constituent component of Palissy's writings engages in a firm rejection of speculative philosophy, which he considered to be purely rhetorical. Pallissy instead regarded philosophy as a form of knowledge derived from observation and experience. See Paolo Rossi, *Philosophy, Technology and the Arts in the Early Modern Era*, op. cit., pp. 1-4.

book than you would learn in fifty years devoted to the study of the theories of the ancient philosophers.[26]

This extract from the introduction to the *Discours Admirable* demonstrates the clear emphasis given to practice and the rejection of the theoretical propositions of scholarly tradition. Paolo Rossi in his book *Philosophy, Technology and the Arts in the Early Modern Era* assigns to this same passage two major ideas which were to become central to Francis Bacon's philosophy. The first addressed the necessity to replace the "cult of books" by the emphasis given to a "cult of things". And the second asserted that knowledge could be formed from the fruitful "commerce of the mind with things."[27]

The polemic against *a priori* constructions of philosophy was a critique of the traditional concept of scientific discourse. Science, in its original understanding, came into play after the pragmatic necessities of human life were satisfied. The Ancients believed that only when man's existential needs had been met science could turn its attention to wisdom and to the contemplation of truth. This concept of science was rejected at the beginning of the modern era. Instead science became the

[26] "*... par pratique je prouve en plusieurs endroits la théorique de plusieurs philosophes fausse, mesmes des plus renommez et plus anciens, comme chascun pourra voir et entendre en moins de deux heures, moyennant qu'il vueille prendre la peine de venir voir mon cabinet, auquel l'on verra des choses merveilleuses qui sont mises pour tesmoignage et preuve de mes escrits, attachez par ordre et par estages, avec certains escriteaux au dessouz, afin qu'un chacun se puisse instruire soy mesme: te pouvant asseurer (lecteur) qu'en bien peu d'heures, voire dans la première journée, tu apprendras plus de philosophie naturelle sur les faits des choses contenues en ce livre, que tu ne sçaurois apprendre en cinquante ans, en lisant les théoriques et opinions des philosophes anciens.*" From "Advertissement aux Lecteurs" in *Discours Admirables,* Ibid., p. 166. The translation is taken from Paolo Rossi, op cit., p. 2.

[27] Paolo Rossi, ibid., p. 2.

field of knowledge derived from the methods of technology based on the appraisal of the mechanical arts and the recognition given to technical operations. Procedures utilized by artisans and craftsmen to create man-made objects, and thus to modify nature, provided the structure for empirical research towards the formation of knowledge. Conversely art production benefited for its processes of making from this new structure of knowledge.

Bernard Palissy portrayed in his direct and to a certain extent simplistic approach a view of knowledge which reflected a kind of 'scientific primitivism'. Theory was to be replaced by empericism as exhibited on an artisan level and books were to be rejected in the name of nature. But it was precisely this form of primitivism which provided the strength of his argument against the exponents of the official culture which despised manual labor and the mechanical arts.[28] Palissy was an artisan rather than a learned man, and it was this apparant innocense supported by an air of mythical belief that allowed his ideas to be highly popular. Similar ideas had earlier been expressed from within the academic culture. The Spanish philosopher and humanist Juan Luis Vives (1493-1540) published various writings in which we find the formulation of precisely those same concepts that Palissy latter developed. Vives was a scholar and tutor at the English court; he had made himself a name with his writings in the cultured and refined public of the humanist circles. In his treatises *Adversus*

[28] Ibid., p. 3.

pseudodialectico [29] (Against the Pseudodialecticians), 1519, and *De disciplinis* [30], published in 1531, Vives addressed the intellectual elite of Europe in his demand to expose their philosophical inquiries to those arts which were practiced in workshops and factories. Vives thought it absolutely necessary for scholars to pay attention to the technical aspects of the various mechanical arts. Major achievements of technical kind had been made in fields such as agriculture, building construction, navigation, and weaving. Those arts, according to Vives, had now to be addressed by theoretical studies of the academic world. In particular scholars should direct their interest to the techniques of the practical arts, "wherefore and how they were invented, pursued, developed, preserved," and how they could be applied to the use and profit of theoretical investigations.[31] Vives had clearly recognized that the traditional disdain of the educated society for vulgar and practical knowledge constituted the major obstacle for the realization of his ideas. Nevertheless he insisted that learned men should "not be ashamed to enter into shops and factories,

29 *Adversus pseudodialecticos* is a youthful work, a spirited attack on the logicians at the University of Paris, using as weapon his own thorough knowledge of dialectic acquired from them. See *Juan Luis Vives Against the Pseudodialecticians,* edited by Rita Guerlac, D. Reidel Publishing Company (Dortrecht, Holland), 1979, pp.47-109; and *Juan Luis Vives in Pseudodialecticos, a Critical Edition,* edited by Charles Fantazzi, E.J. Brill (Leiden, The Netherlands), 1979.

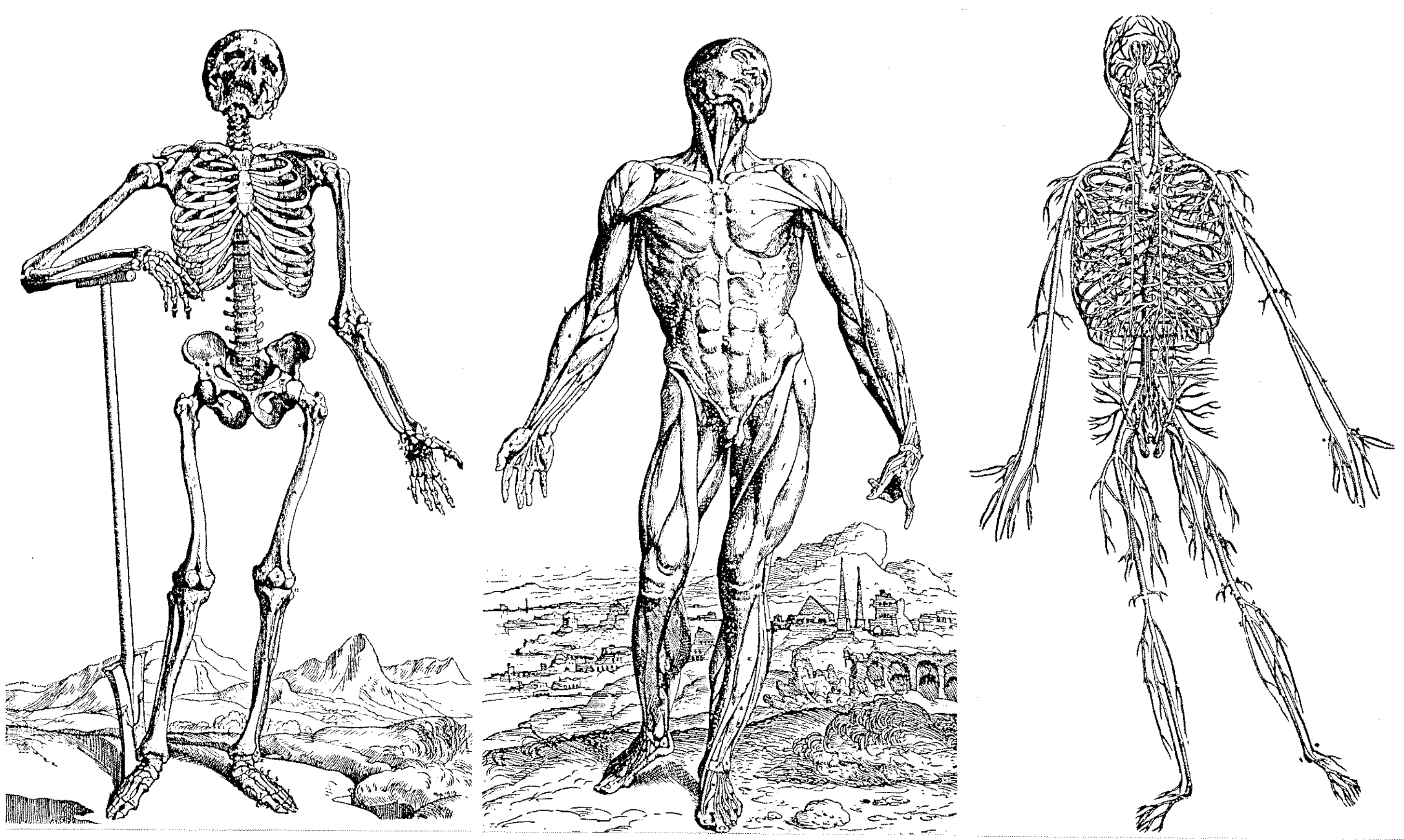
30 *De disciplinis* is a mature product of Vives's work. The treatise is divided in two parts. The first part, purely critical in tone, deals with the low state of education as he saw it in his time, and it is no coincidence that its title, *On the Causes of the Corruption of the Arts (De causis corruptarum artium)* addressed the little attention given to the practical arts in theory and philosophy. See "The Causes of the Corruption of Arts," in *Juan Luis Vives Against the Pseudodialecticians,* edited by Rita Guerlac, D. Reidel Publishing Company (Dortrecht, Holland), 1979, pp. 111-153. The second, positive part of Vives's treatise, *On Education (De tradendis disciplinis),* offers various propositions of how to direct learning and education. See *Vives: On Education. A Translation of the "De Tradendis Disciplinis" by Juan Luis Vives,* edited by Foster Watson (1913).

31 *Vives: On Education,* ibid., p. 208.

and to ask questions from craftsmen, and to get to know about the details of their work."[32] He strongly believed that the historical increase of human knowledge was derived from the work of those who had written their observations on the methods and techniques employed in the individual arts and thereby allowed future generations to further develop the techniques of their trades. But most importantly Vives fought for the formation of a theoretical base in support of practical operations. A mutual reciprocity of influence between practical and theoretical knowledge would herein provide a new conceptual structure for the processes of making and lead to a new order for the manifestations of thought.

The Flemish anatomist Andreas Vesalius (1514-64), who had undertaken medical studies in Paris and received the degree of Doctor in Medicine from the University in Padua at a very young age, strongly advocated, in complete agreement with Vives, a unity of theory and practice. He was opposed to the doctrine of the theoretical sciences which "despised the work of the hand". His critique was directed toward the professor of medicine, who, as Vesalius describes, is "perched on a high pulpit like a crow and with an air of great disdain repeats to the point of monotony accounts concerning facts that he has not directly observed, but has learned by rote from the books of others." The division of the medical arts between those who performed the dissections of the human body and those who engaged in discourse reinforced, according to Vesalius, the separation between manual work and the elaboration of theories. He therefore argued in favour of a scientific method which would

[32] Ibid., p. 210.

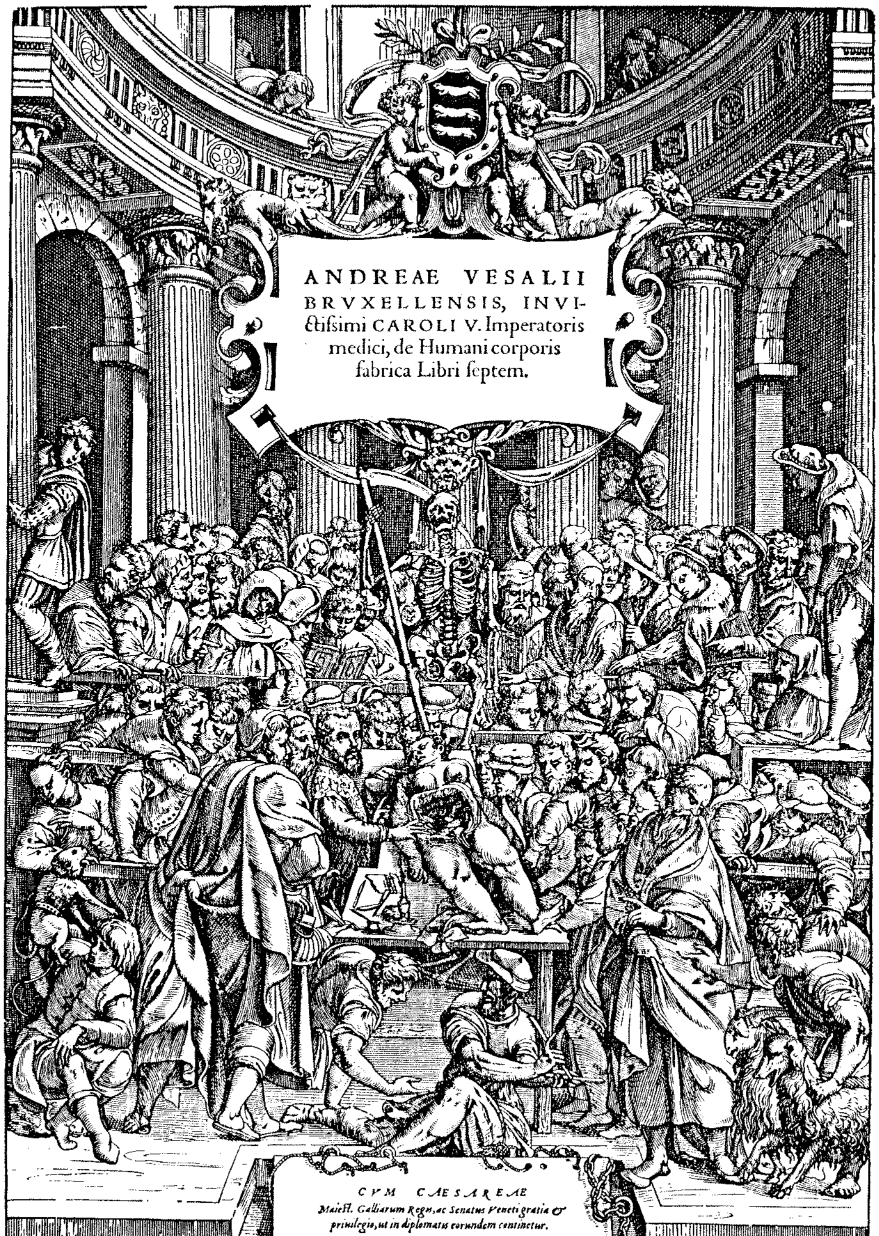


Andreas Vesalius, anatomical drawing of skeleton, muscles, and arterial system. From *De humani corporis fabrica*, 1543.

allow the practitioner to guide his work according to the structure of thought and the theoretician to base his intellectual assumptions on practical experience.

Vesalius's treatise *De humani corporis fabrica* (1543), a significant contribution to the new science, was based on the conviction that the condition of a particular field of knowledge required vast preparatory work of precise observation and description of factual material. Such an approach had to be rationally structured following systematic procedures of analysis. In order to achieve a high degree of accuracy the techniques of observation as well as the methods of recording required improvement. The dissection of the human body was the primary source for the gathering of factual information; it constituted an important component of Vesalius's teaching activity at the university. The fact that a professor descended from his academic chair to dissect and demonstrate personally was something entirely novel. The frontispiece of the *Fabrica* show a public demonstration of a dissection performed by Vesalius, represented in the center of the page, in an open air anatomical theater. Such open theaters, which were built as temporary wooden structures, are an indication of the new emphatic belief that the observations and results of scientific research must be widely communicated.

Of similar didactic intention were the various publications on anatomy by Vesalius. Those presented through precise illustrative techniques the results of scientific observation in the clearest and most comprehensible graphic images. The illustrations, probably made in the workshop of Titian, 153 a



Andreas Vesalius, title page of
De Humani Corporis Fabrica, 1543.

153 b

disclosed the inherent systematic structure within Vesalius's approach. The human body was presented as a series of different functional systems, such as skeleton, muscles, nerves, veins and arteries. Those where further subdivided into their constituent components; the different bones and muscles, for example, were shown as independed parts, detached from the functional system to which they belonged. The illustrations, furthermore, identified the various parts of the human body with numbers and letters, thus exhibiting the analytical intention of Vesalius's method. In other words, Vesalius's contribution to modern science was in the field of communicable and descriptive techniques which contributed through observation and the systematic organization of data to the formation of modern knowledge.

In the works of Palissy, Vives, and Vesalius clear indications are found of what in the coming era of the new sciences would develop as a strong and wide spread movement. Their contribution to different fields constituted the attempt to adopt new methods of judging and seeking truth as the base of human knowledge. This new approach to knowledge, which was to be called *modern* by philosophers such as Bacon and Descartes stood in total opposition to the *ancient* sciences, for which truth exclusively belonged to the activity of the mind, to discourse, and contemplation. It was exactly this position which was questioned by the moderns in their proposition to open knowledge and its underlying truths to the field of the practical arts. The procedures of artisans, engineers, and technicians were considered to contribute to knowledge; and most importantly, such procedures were recognized as having the dignity of cultural facts. Whether a unity of thought and action could be achieved allowing a fruitful interdependence of philosophy and production, of practice and discourse, remained the primary question for disciplines, such as architecture, which belonged to the arts as well as to the sciences.

The *Rudimenta* - Practice in Architecture

Antonio di Piero Averlino, known as Filarete (c.1400-1470), opened his *Treatise on Architecture*, written between 1461-64, by narrating the following story:

Once I was in a place where a noble man and many others were eating. In the course of a conversation about many different things they entered on architecture. One of them said, "It certainly seems to me that you have a high opinion of architecture, yet it doesn't seem as great a thing as many make it out to be. They say you have to know so many kinds of geometry, drawing, and many other things. It seems to me I heard someone speak the other day of a certain Vitruvius and of another who seems to have been named Archimedes. [He said,] "They have written about building, measure, and many other bits of information that one ought to know. I don't search out all these measurements and other things when I have something built. I don't go looking for as many principles of geometry as they advise, and still it comes out all right." Then one of the others who seemed to speak more seriously said, "Don't talk that way. I think that anyone who wants to construct a building needs to know measure very well and also drawing in order to lay out a large house, a church, or any other sort of building. I do not believe he could do it all correctly if he does not *have drawing, measuring, and other things. I also believe that anyone who commissions a building should know these things. Nevertheless, do not say that, since it is not my craft, I only know enough to argue about it. I would pay a great deal to find someone who would teach me what it takes and what measure should be used to make a building [well] proportioned, the source of these measurements, and why one reasons and builds in this manner. I would also like to know what their origins are."*[33]

Filarete's story placed at the very beginning of his treatise on the theory and practice of architecture was primarily of didactic intention. This is given particular emphasis if one considers that the primary aim of the treatise was instruction and education. The positions outlined in the dialog pertained to two opposed fractions within the field of architecture. The first position, expressing a resistance to theory and characteristic of a sensibility that was still exclusively artisan, sought to engage in the production of building by application of practical knowledge, i.e. knowledge derived from experience. The other standpoint advocated a more modern position engaging the practical arts with the theoretical sciences of the liberal arts. Filarete's bias is evident. He favored the intellectual discourse of the humanities which he hoped would guide the procedures of manual work. Although addressing the realms of building practice and theoretical discourse, the treatise did not attempt to establish the

33 Antonio Averlino Filarete, *Trattato di Architettura di Antonio Filareto* (1461-64), *Treatise on Architecture*, translated with an introduction and notes by John R. Spencer, Yale University Press (New Haven), 1965, pp. 4-5.

connection between the two. Both were treated as separate entities. The treatise rests on the literary device of the construction of an ideal city, Sforzinda, and its port, Plusiapolis. A fiction of this sort provided Filarete with the opportunity to describe in considerable detail his concept and vision of an ideal architecture. To address the art of building in its ideal form meant to refer, both to the necessity of construction techniques as well as to the formal implications of theoretical intentions.

The partially imaginary trips to explore the territory around Sforzinda, or to seek out materials for construction, and the description of building structures for the ideal city provided the grounds for Filarete to discuss materials and techniques required for the practice of architecture. The making of a building for him relied upon three essential skills - knowledge of materials, techniques, and planning which were subsumed under the category of *rudimenta*. The importance of the concept of *rudimenta* in all the arts was manifested by the emphasis it received in literature, painting, sculpture, and architecture for the knowledge of material, method, and design was considered a prerequisite of art production.

Filarete devoted a section of the treatise (Book III) to a critical listing of construction materials. In addition to the description of common building materials, such as lime, sand, brick, stone, and wood, emphasis was given to new techniques of iron production. As Filarete had received the commission for the bronze doors of St. Peters (1433), on which he worked for a period of twelve years, he developed interest in the methods of metal processing. Filarete mentions a journey to the ironworks[34] describing the techniques and machines required for the manufacturing processes of iron, including a description of great water-powered bellows and pig iron furnaces to produce molten iron. Yet, with the exception of a few innovations the general trust of Filarete's construction repertoire seems rather to be based on the conventions of traditional building practice. The recommended methods of assembly, the description of the construction process of a building from the foundations to the roof, followed the precepts of the commonly accepted construction procedures of the time, which had evolved from medieval tradition. In this regard most of the proposed construction principles were derived from the experiences of the manual worker and were transmited to the reader by means of rules of thumb. According to Filarete the thickness of the foundation, for example, had to be wider than the wall it had to support, and that generally one "should leave more foundation outside than inside."[35] Typically such prescriptive recommendations constituted the approach to building technology, by reference to individual rules, unconnected to the structure of a theoretical system. In the actual construction of the walls that were to rise above the foundations, Filarete supplied the reader with a significant amount of information, including some more inventive solutions. One such example proposed a refinement for the mason's scaffolding, for he considered its traditional use to be inefficient. The new proposal suggested a lighter and movable type of wooden staging:

34 Ibid., Book XVI, Folio 127r, p. 220.

35 Ibid., Book IV, Folio 29r, p. 50.

... I made a special arrangement of the scaffolding so two masters could work together and have ladders to serve them, ... they thought it would go faster to build the scaffolds one after the other as they went along, ... When the scaffolding was ready and the masters had finished the part of the wall that remained, they leaped up on the scaffolding while the [other] masters soon built the remaining scaffolding, ...[36]

This improvement suggested that the scaffold structures could follow the masons along the lenght of the wall, thus saving a great quantity of wood. For the construction of the walls themselves Filarete proposed a method which had its origin in Roman building techniques. The method was based on the principle of the cavity and consisted of laying the stone or brick courses such as necessary to create a hollow wall. As the construction of the wall progressed, the intervening spaces were filled with rubble and mortar. A further developement of this type of wall construction was introduced by Filarete in his narration of the architect's house.[37] The arrangement of headers and stretchers, while questionable from the point of stability, provided interlocked chases (left and right of the drawing) to contain downspouts and ventilation pipes for the sewage system. The apparently weaker central section of the wall was to be reinforced with rubble fill. This proposition, probably derived from common practice, was in agreement with Filarete's basic concept of architecture, for he believed in the Vitruvian "Fundamental Principles of Architecture" which

[36] Ibid., Book IV, Folio 28v, p. 50.
[37] Ibid., Book XVIII, Folio 150v, p. 258.

included the unity of economy, solidity, and suitability. The introduction of chases within the building fabric allowed the walls to be lighter, thereby lowering the load on the foundations and reducing the amount of rubble fill required without weakening the structure. Whether the brick bond described in the treatise was actually Filarete's invention or a further development of an existing method, it is in so far of significance as it reveals a conceptual approach to the art of building characteristic of Filarete's methods of architectural planning and design.[38]

The design of the plan in Filarete's treatise was primarily determined by the arbitrary choice of a primary geometric form within which all parts of the building were organized. Based on simple arithmetic relations the interior of the original geometric shape was subdivided to form a matrix, called by Filarete "the linear drawing." With such a diagramatic drawing providing order and plan organization, major and minor spaces as well as the approximate location of supports could be determined. This plan essentially represented the intellectual concept of the building before technical and material considerations would be made. The following step in the design process required that the "linear drawing" be adjusted to provide the location of walls and buttresses without altering the proportions of the interior spaces. Geometric shape and proportional system were of such high priority that Filarete often became involved in complex plan manipulations to preserve their integrety. The plan for the first temple of Plusiapolis,

[38] The specific references concerning Filarete's concept of techniques and materials of construction are borrowed from the introduction to the treatise by John R. Spencer, ibid., pp. xxiii-xxv.

designed by the architect "Onitoan Nolivera,"[39] is an example of how Filarete's cavity walls allowed him to preserve the predetermined geometry and proportion of the interior spaces when walls were to be introduced within the diagram of the plan.[40] The "linear drawing" was solely a technique introduced in the design process whose purpose was to maintain the pure and ideal configuration of space, yet whose justification and reason surpassed the concept of *rudimenta*. Building materials, techniques of construction, and planning methods, the *rudimenta* of architecture, were for Filarete only what the name implied, the basic vocabulary which was to be learned before the *art* of building could be approached. In this regard, although believed to be of valuable necessity, information concerning the *rudimenta* was not given highest priority in the treatise, it was periodicaly mentioned but did not constitute the core of the Filarete's text. Knowledge of the *rudimenta* is then assumed throughout the treatise and was given particular reference in the chapter on the education of the architect:

"There are many, many things relevant to the architect. The architect [should] know how to build various things and decorate them with various ornaments. That is [he should] understand many skills and be able to demonstrate them with the work of his hand, with rules of measure, proportion, quality, and suitability. [He should be able] to draw [them and make them] in relief as they will be built. ... I say that if he does not know how to do them with his own hand, he will never

[39] In the treatise, the architect is named "Onitoan Nolivera," by nationality "notirenflo," which is inverted spelling for Antonio Averlino from Florence (florentino).

[40] Ibid., Book XIV, Folio 107v & 108 r, pp. 188, 189.

know how to show them or to explain them so they will turn out well. He must be clever and imaginative in making different things and in showing them by his own hand. In addition to these two things, that is, knowing how to do it with his own hand and being inventive, it is also necessary for him to know how to draw. Although he may be inventive and know how to do things with his own hands, still, if he does not know how to draw, he will not be able to make correct or worthy things, for in the art of decoration those things only are worthy which come by way of drawing."[41]

The reference to manual work and the required knowledge of construction techniques as well as the importance given to drawing skills in the planning process, while emphasized for the education of the architect, were all considered merely the first steps towards an approach to architecture. The *rudimenta* for the art of building were placed within a broader and more important framework provided by the meaning of architectural concepts which reached beyond method and technique. Thus, the role of drawing within the planning stage established the bridge between conceptual structure and practical execution. The drawing allowed visual representation of an idea to become manifested prior to its physical and material realization. While Leonardo da Vinci's and Vesalius's anatomical drawings constituted the registration of factual observations, the role of architectural drawing in the design process was instead that of hypothetical and theoretical investigation. The drawing was the means by which the project was conceived. Brunelleschi's use of linear perspective in defining space and

41 Ibid., Book XV, Folio 113r-115r, pp.197-202.

Leonardo's sketches of technical inventions were early indications of how the representational quality of drawing could influence the processes of making and therefore also determine the final product. But what was completely new for the field of architecture was the autonomous position of drawing and design within the making of architecture. This understanding of the architectural design as a distinct phase of production placed the architect in a position that was neither exclusively practical nor exclusively theoretical. The architect's task was rather to establish the connection between discourse and practice.

Since drawing belonged to the *rudimenta* it was as a technique considered subservient to intellectual construction. The Aristotelian hierarchical structure which gave priority to thought over action remained effective within the field of architecture. Filarete's treatise rested on the dichotomy between *Ars* and *Scientia,* providing an understanding of architecture which strongly depended on theoretical concepts in its practical processes of material realization. The key to Filarete's understanding of *Scientia* is to be found in the words spoken by Lodovico Gonzaga after his visit to Sforzinda:

"My lord, I seem to see again the noble buildings that were once in Rome and those that we read were in Egypt. It seems to me that I have been reborn [back in ancient times] on seeing those noble buildings. They seem very beautiful to me." [42]

[42] Ibid., Book XIII, Folio 100r, pp. 174, 175.

The concept of rebirth constituted the basic theoretical framework for the architecture that Filarete advocated. The operative words in the quoted passage, *rinascere a vedere,* which variously rendered presented problems of interpretation, nevertheless indicated the sense of rebirth and of visibility important to the arts. The projected architecture of the treatise was in this regard not the result of any bizarre fantasy of Filarete, but instead a serious attempt to recreate in Renaissance terms the art of the past.[43] In order to propagate the visible manifestation of this new old art, the *arte antica,* Filarete's choice of an Utopian construction allowed him, in didactic manner, to provide a theoretical base for the *rudimenta* of architecture. The importance given to the drawing in the design process received hereby additional emphasis, for its power of formal representation could transcend discourse within practice.

The *Arte Antica* - Discourse in Architecture

Scientia in the Renaissance received its primary justification from its reference to Antiquity. It provided the conceptual framework for the art of building in its development from the mechanical to the liberal arts. The humanist's interest in Antiquity was a major force in the formation of the concept of a discipline of architecture. The discipline which was to unite the practical knowledge of the mechanical arts with the theoretical knowledge of the liberal arts was strongly marked by the understanding and image of classical antiquity as perceived by the cultured circles of the Renaissance period. Again, Brunelleschi's work constituted the historical turning

43 Ibid., "Introduction," p. xxxvi.

point, revealing in his architecture an affinity to the monuments of Classical Antiquity. Manetti recalls Brunelleschi's visit to Rome were he studied the extant buildings of ancient Roman architecture:

So he went to Rome where at that time one could see beautiful works in public places. Some of those works are still there, although not many; some have been removed, carried off, and shipped out by various popes and cardinals from Rome and other nations. In studying the sculpture as one with a good eye, intelligent and alert in all things, would do, he observed the method and symmetry of the ancients' way of building. He seemed to recognize very clearly a certain arrangement of members and structure just as if God had enlightened him about great matters. Since this appeared very different from the method in use at that time, it impressed him greatly. And he decided that while he looked at the sculpture of the ancients to give no less time to that order and method which is in the abutments and thrusts of buildings... He decided to rediscover the fine and highly skilled method of building and the harmonious *proportions of the ancients and how they might, without defects, be employed with convenience and economy.*[44]

This reference to the masters of Antiquity in Manetti's *Vita di Brunelleschi* is relevant for the understanding of the period. Classical Antiquity was considered the apex of human civilization, the knowledge of its history and culture therefore required in humanist circles. Antiquity became the model for the arts in two respects, summarized in the above quote, "...he observed the method and symmetry of the ancients' way of building." Renaissance architects were interested in the building "methods" used by the ancients as well as in the formal "symmetry" of their architecture. Both references to ancient form and technique provided the field of architecture with a base of universal rules and principles. Those were understood to contribute to a form of objective knowledge, thereby constituting the core of the new discipline of architecture.

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44 Manetti, op. cit., p. 50. See also Vasari, op. cit., pp. 139-141: "*Filippo and Donatello... spend several years at Rome, where they would study, the one architecture, and other sculpture. ... They saw everything there was to see, both in Rome and in the countryside around, and they recorded the measurements of every good piece of work they came across... concentrating utterly on the architecture of the past, by which I mean the good ancient orders and not the barbarous German style which was then fashionable. ... while he* [Brunelleschi] *was in Rome he continually investigated all the problems that had been involved in vaulting the Pantheon. He noted and made drawings of all the ancient vaults and was always studying their construction. ... There was no kind of building of which he did not make drawings: round, square, and octagonal temples, basilicas, aqueducts, baths, arches, colosseums, amphitheatres, and all the brick temples, from which he noted the methods used in binding and clamping with ties and encircling the vaults. He recorded all the methods used for binding stones together and for balancing and dovetailing them; and he investigated the reason for there being a hole hollowed out in the centre and underside of all large stones, discovering that it was for the iron used to haul them up... He subsequently brought this into use again and employed it himself.* "

Giorgio Vasari's *Le Vite*, in addition to its value as a biographic source of the lives of architects, painters, and sculptors, is a document revealing the historical awareness of the changing conditions within the arts in general during the Renaissance period. In the preface of his work Vasari derived the origin of art in the divine gift of God and traced its manifestations in the perfection of the arts in ancient Greek and Roman culture. According to Vasari, toward the end of the Roman Empire decline set in, followed by the total destruction of the barbarian invasions: "when human affairs begin to decline, they grow steadily worse until the time comes when they can no longer deteriorate any further." Vasari saw in the Renaissance the restoration of lost cultural values.[45] He considered the primary task of his period, for which he applied the metaphor of rebirth in the expression *Renascita,* to engage in the resurrection of the culture of classical antiquity. The urge was to create something new and not merely to follow tradition. Classical antiquity, which was regarded as the foundation of all civilization, was to be the model for this new beginning. In other words, the contribution of the Renaissance lay not in the strict imitation of ancient theories and buildings but in the re-establishment of rules and principles as a universal discipline.

[45] A few years prior to the publishing of Vasari's *Le Vite* appeared Giangiorgio Trissino's *L'Italia liberata dai Goti*, a great heroic epic of the sixteenth century discribing the expulsion of the Goths from Italy and the survival of classical traditions. This work not only combined history with mythology, but also threw much light on astronomy, medicine, alchemy, mathematics, as well as on military and civic architecture. Trissino was an all-round humanist with an encyclop dic knowledge, it was him who introduced Palladio to architecture. See R. Wittkower, *Architectural Principles in the Age of Humanism*, op. cit., pp. 57-65.

The great forward movement of the Renaissance derived its vigour from looking backwards. The search for truth was a search for the early, the pure, and the ancient; the past was always better than the present. The classical humanist recovered the literature and the monuments of classical antiquity with a sense of return to the pure state of a civilization better and higher than his own. The sketchbook known as the *Codex Escurialensis,* made by a member of Ghirlandaio's studio about 1491, and the drawings of the Dutch painter Maerten van Heemskerk representing Roman ruins as he saw them in the 1530's, are evidence of the progressing interest in ancient architecture. Such records of the monuments of ancient Rome seemed, however, to be relatively inaccurate, guided by a romantic or nostalgic view of the past. Measured drawings in the modern sense were a long way in the future; nevertheless, as a quotation from Manetti's *Life* reveals, Brunelleschi's and Donatello's interest in the precise recording of Roman buildings was an indication of technical accuracy required for historical reference[46]:

... together they made rough drawings of almost all the buildings in Rome and in many places beyond the walls, with measurements of the widths and heights as far as they were able to ascertain [the latter] by estimation, and also the lengths, etc. In many places they had excavations made in order to see the junctures of the membering of the buildings and their type ... When possible they estimated the heights [measuring] from base to base for the height and similarly [they estimated the

[46] Peter Murray, *Architecture of the Renaissance,* Electa Editrice (Milano), 1971, p. 18.

heights of] the entablatures and roofs from the foundations. They drew the elevations on strips of parchment graphs with numbers and symbols which Filippo alone understood.[47]

An increased degree of precision would later emerge in the sixteenth century with Palladio's realism in recalling the monuments of ancient Rome. As is historically documented, Palladio's archaeological inquires into the past were tinged with imaginative awareness of what might have been. His *restorations* constituting hypothetical reconstructions of ancient monuments were projections of his understanding of architecture merged with the discovered formal vocabulary of historical precedents. Palladio's contribution herein was primarily within the realm of a formal rather than a technical discourse. The precise measurement of existing forms led to the refinement of profile and proportion, which were considered the essence of the *arte antica.* Architecture as a liberal arts and academic discipline manifested itself as a formal discourse only insofar interested in technical matters as material realization necessitated.

A further component of the orientation towards Antiquity was the enthusiastic study of the classical languages and the discovery of new sources of ancient writings. Humanist effort in this period was also directed towards the technical literature of antiquity and sought to apply it in practice, but always, again, with the intention of using classical knowledge as a point of departure for new technical achievements. The first printed edition of Euclid appeared in Venice in 1482,

[47] Manetti, op. cit., p. 52.

followed in the sixteenth century by the publication of Latin editions of Pappus, Hero, and Archimedes, to mention a few. Of primary significance for the field of architecture was Vitruvius's treatise *De architectura*, written about the year 20 B.C. The book was not entirely forgotten in the Middle Ages but was effectively re-discovered at St. Gall in 1414. The first printed text appeared in Rome in 1486, followed by a series of additional editions[48] in the sixteenth century. Various attempts had been made to illustrate the text by providing visual interpretations of Vitruvius's propositions, i.e. to make visible what had been asserted in written language. Fra Giocondo's edition of 1511, for example, followed the technical recommendations of the Vitruvian chapter "On Foundations and Substructures" in providing a drawing with plan and elevation of a retaining wall.[49] Another illustration by Fra Giocondo represented the Archimedean screw, a device for raising water

48 The first printed edition of Vitruvius's Ten Books on Architecture was published in Rome in 1486, edited by Sulpizio da Veroli. The next editions were those of Fra Giocondo (Florence, 1511) and Philander (Rome, 1544). The illustrated translations by Cesariano (Como, 1521) and Daniele Barbaro (Venice, 1567; with illustrations by Palladio) were notable for the period.

49 Vitruvius, *De Architectura*, Book VI, ChapterVIII, "On Foundations and Substructures": "*6. ... First, let the walls be given a thickness proportionate to the amount of filling; secondly, build counterforts or buttresses at the same time as the wall, on the outer side, at distances from each other equivalent to what is to be the height of the substructure and with the thickness of the substructure. At the bottom let them run out to a distance corresponding to the thickness that has been determined for the substructure, and then gradually diminish in extent so that at the surface their projection is equal to the thickness of the wall of the building. 7. Furthermore, inside, to meet the mass of earth, there should be saw-shaped constructions attached to the wall, the teeth extending from the wall for a distance equivalent to what is to be the height of the substructure, and the teeth being constructed with the same thickness as the wall. Then at the outermost angles take the distance inwards, from the inside of the angle, equal to the height of the substructure, and mark it off on each side; from these marks build up a diagonal structure and from the middle of it a second, joined on the angle of the wall. With this arrangement, the teeth and diagonal structures will not allow the filling to thrust with all its force against the wall, but will check and distribute the pressure.*"

for which Vitruvius had described the method of construction. Various translations of Vitruvius's treatise not only addressed the educated society but were expressly directed to the artisan and craftsman. For example, Jean Martin, the French translator of *De Architectura* (1547), dedicated the edition to "the workers and other people who do not understand the Latin language". And Walter Rivius, the German translator (1578), addressed his edition "to the artisans, artificers, stonecutters, architects, and weavers." These references to the workmen are insofar of significance as that they exposed the conflicting cultures of humanists and artisans to one another. An awareness emerged regarding the unity that could be established between theoretical knowledge and practical activity, a unity in favour of which Vitruvius had argued in his chapter on the education of the architect.

The necessity of a dialogue between practice and discourse is also mentioned by Daniele Barbaro (1513-1570) in his 1556 commentary on Vitruvius. In being widely translated and published, Vitruvius's text became the source for a broad range of commentaries addressing particular issues of that treatise. The commentaries, including that by Barbaro, represented an attempt to cover with an encyclop dic field of vision the various points put forward in the Vitruvian text. Barbaro's extensive publications drew from a considerable body of knowledge, refering to a number of sixteenth century technical treatises, such as Dürer's writings on proportion and the use of the compass, or Pedro de Medino's work on navigation. Barbaro was also a mathematician, historian, and philosopher who had published and edited different Latin translations of

Aristotle. Both his interest in technical matters as well as his profound knowledge of philosophy reflected in the commentary on Vitruvius the assertion of a synthesis of theory and practice. In this respect Barbaro wrote:

Why... have practical men not acquired credit? For the reason that architecture is born of discourse. Why the men of letters? For the reason that architecture is born of construction. To be an architect, which is an artificial generation, one must seek discourse and construction together.[50]

Interdependence of thought and action was derived from Plato's and Aristotle's philosophical propositions on science and art. Science was concerned with *certain truth* (il vero necessario), that is the truth in the objects themselves, found by unassailable proof. The arts were concerned with *uncertain truth* (il vero contingente), that is truth depending on man's will as manifested in human creation. The link between the two was to be found in those arts such as architecture which in their processes of creation made use of the sciences, as for example geometry and mathematics, thereby pertaining to the truths of the *certain* and the *uncertain*.[51] After having addressed the relation between art and science, Barbaro continued with a definition particular to the arts. In following Aristotle's philosophy he explained that "experience created art." Thus experience relied on the senses while the

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50 *I dieci libri dell'Architettura di Vitruvio tradotti e commentati da Monsignor Barbaro*, printed by Francesco Marcolini (Venice, 1556); P. Rossi, op. cit., p. 18.

51 Rudolf Wittkower, "The Architect as *Uomo Universale*," *Architectural Principles in the Age of Humanism*, op. cit., p. 67.

arts were derived from universal principles discovered by experience.[52] Art was therefore near to Wisdom which belonged to the sciences concerned with the knowledge of *certain truth.* In applying those ideas to the Vitruvian text on the education of the architect Barbaro commented that: "The artist works first in the intellect and conceives in the mind and symbolizes then the exterior matter after the interior image, particularly in architecture."[53] From this a clear understanding of architecture was derived; the art of building was directed in its processes of making by the intellectual capacity of man manifested in built form. Architecture was not considered an isolated discipline but instead understood as one of the innumerable manifestations of the human mind which followed the same laws. Barbaro's commentary on Vitruvius "Fundamental Principles of Architecture" stated the universality of such principles pertaining to all sciences. He declared that such principles were to be found in other fields as well:

...these terms are general and common and as such have their definition in the general and common science which is the first and is called metaphysics. But when an artist wants to apply one of those elements to his own profession, then he restricts that universality to the particular and special needs of his own art.[54]

The interconnection between philosophy and making, the manifestation of thought into action, and the relation of

52 Aristotle, *Metaphysics* , Book I, op. cit., p. 40.
53 R. Wittkower, op. cit., pp. 67-68.
54 Ibid., p. 68.

theory and practice as propagated by authors such as Barbaro, who based their thinking on the authority of the ancients, constituted the primary and most significant consideration of Renaissance treatises addressing the discipline of architecture. But the concept of a discipline which proposed a unifying theoretical system of knowledge for the art of building carried a bias in favour of intellectual reasoning. Barbaro referred specifically to mathematics as a means by which to establish the scientific authority of the arts. Mathematical sciences pertained to universal truth and as their origins could be traced back to ancient culture there could be no doubt of their importance. A hierarchical structure was furthermore introduced. Those arts requiring number and geometry were considered superior. Conversely, those activities which did not refer to mathematical law were, according to Barbaro, "sordid" and "base." In asserting such a hierarchy within man's system of thought and action Barbaro concluded by reintroducing the distinction between science and technique, thus separating once more reasoning and discourse from practice and manual work:

The arts that serve, with dignity and greatness, the convenience and use of mortals - such as the art to travel by sea called navigation, the military art, the art of building, medicine, agriculture, hunting, painting, sculpture, and similar activities - can be considered in two ways. First, by how they are discussed and how, by way of reasonings, they find the causes and rules of operation; second, by way of working hard on some external matter with manual dexterity. This is why some arts have more science and others less. But the following *criterion enables us to know the more worthy arts: all those which require the arts of numbering, geometry, and mathematics - all such arts have a quality of greatness about them. The rest, without the aforementioned arts (as Plato says), is sordid and baser than something born of mere imagination, a fallacious conjunction and experience forsaken by the truth.*[55]

The superiority of mathematics, explicitly referred to by Barbaro in the priority given to the "force of proportion," to the "divine force of numbers," and to the "consonance of the weight of number and of measure" which, as he asserted, presided the world, revealed the intention to elevate the arts to the level of the theoretical sciences. The defense of the mechanical arts emerged as an attempt to demonstrate that in reality they were *liberal*, being linked more to the arguments of mathematics than to the work of the hand.[56] This condition within the understanding of the arts was of paradoxical nature. On the one hand the actual union between discourse and practice asserted the necessity for a fruitful exchange between intellectual speculation and manual production, allowing thought to guide action and, conversly, allowing action to inform thought. The attempt to demonstrate the scientific nature of the arts on the other hand betrayed this synthesis, restating the schism between theory and practice. The conception of a discipline for the field of architecture was inherently marked by this seemingly self-contradictory yet real condition.

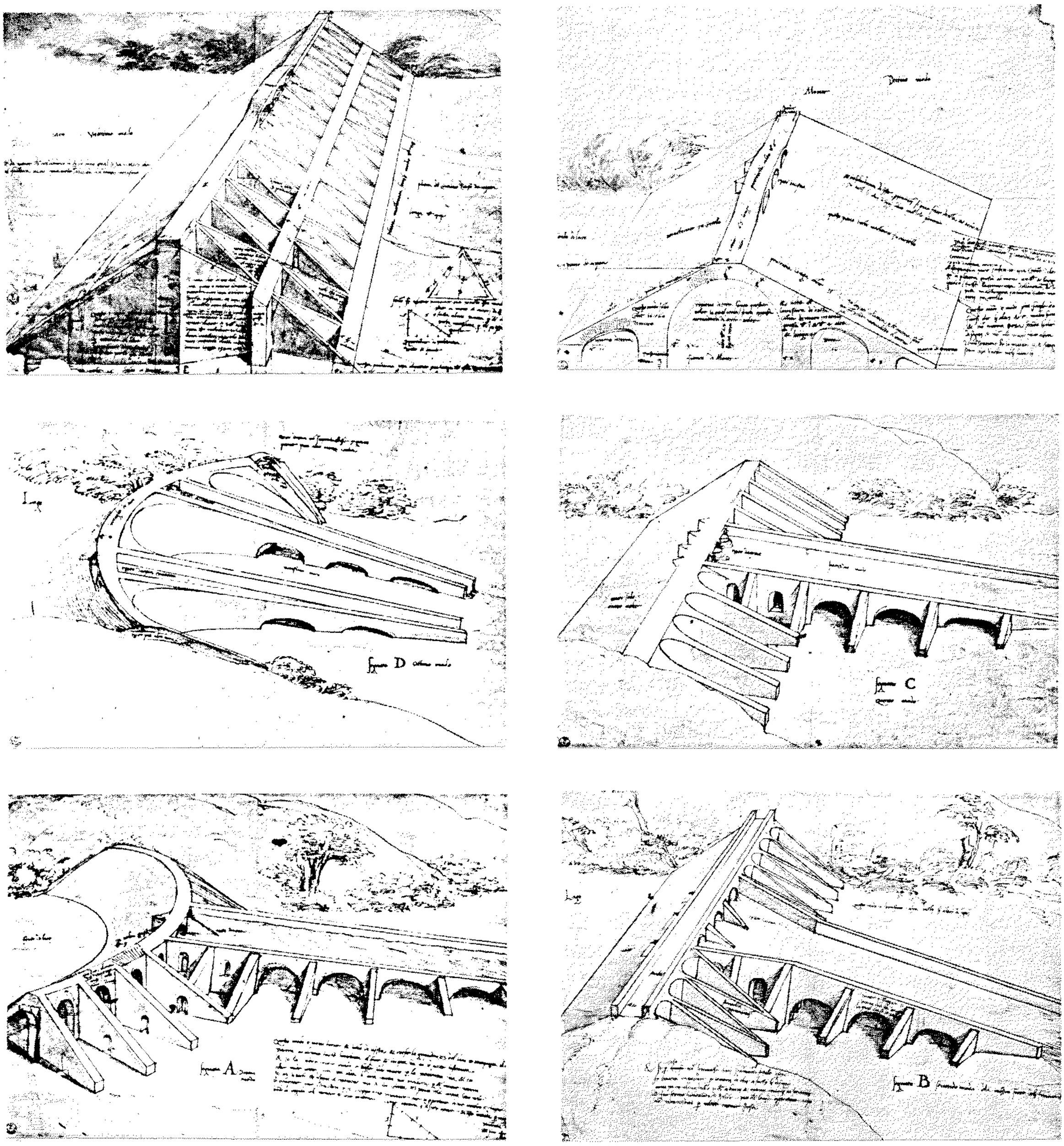
[55] *I dieci libri dell'Architettura di Vitruvio tradotti e commentati da Monsignor Barbaro*, printed by Francesco Marcolini (Venice, 1556), p.7; P. Rossi, op. cit., pp. 60, 61.

[56] P. Rossi, ibid., p. 61.

The Discipline of Architecture

Theory and discourse were conjoined with the concept of practice and action in the work of the architect during the Renaissance. The task of the architect pertained not to action *per se* but instead to the idea of making as an intellectual construction. The architect was not "a carpenter or a joiner," nor was he considered a builder in the strict sense of the term; the "manual operator," as was described by Alberti, was "no more than an instrument" in the processes of architectural realization. However, he was to know all the practical aspects of his art in addition to the knowledge of the theoretical sciences. This conceptual union of the mechanical with the libral arts in the person of the architect was well described by Alberti in the preface to his treatise on architecture:

But before I proceed further, it will not be improper to explain what he is that I allow to be an Architect: For it is not a Carpenter or a Joiner that I thus rank with the greatest Masters in other Sciences; the manual Operator being no more than an Instrument to the Architect. Him I call an Architect, who, by sure and wonderful Art and Method, is able both with Thought and Invention, to devise, and with Execution, to compleat all those Works, which, by means of the Movement of great Weights, and the Conjunction and Amassment of Bodies, can with the greatest Beauty, be adapted to the Uses of Mankind: And to be able to do this, he must have a thorough Insight into



Baldassarre Peruzzi, six reconstruction proposals for the Bruna River Dam, c. 1530 (Gabinetto Disegni e Stampe degli Uffizi, Firenze).

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the noblest and most curious Sciences. Such must be the Architect. But no return.[57]

"Art and method" brought together with "thought and invention" portrayed a glorified image of the architect-engineer who "by means of the movement of great weights" and "the conjunction and amassment of bodies" could satisfy human needs as well as realizing beauty. Thus the due reference to durability, convenience, and beauty emerged from a conceptual union of theory and practice. The eulogy of the figure of the architect-engineer firmly asserted in the preface to Alberti's *De Re Aedificatoria* was followed by the praise of how he could conceive of techniques able to displace enormous masses of water and rock, drill holes into mountains and to fill up valleys, drain and reclaim swamps and divert waters, regulate the cources of rivers, build ships and bridges, instruments of warfare, fortresses, and open new roads and new trade routes to all parts of the world.[58] These references pertaining to the field of engineering were common practice in architecture as was exemplified by Francesco di Giorgio Martini's (1439-1501) *Tratti di architettura ingegneria e arte militare* and Baldassarre Peruzzi's (1481-1536) investigations of dam structures.[59] The architect did not engage in such activities through physical labor but instead through his intellectual capacity to recreate, in *abstractum,* the concepts inherent

57 Leone Battista Alberti, *Ten Books on Architecture*, translated into Italian by Cosimo Bartoli and into English by James Leoni, edited by Joseph Rykwert, Alec Tiranti Ltd. (London), 1955, p. ix.

58 Ibid., pp. ix, x.

59 See Nicholas Adams, "Architecture for Fish: The Sienese Dam on the Bruna River -Structures and Design, 1468-1530," in *Technology and Culture*, The University of Chicago Press (Chicago), Oct. 1984, Vol. 25, Number 4, pp.768-797.

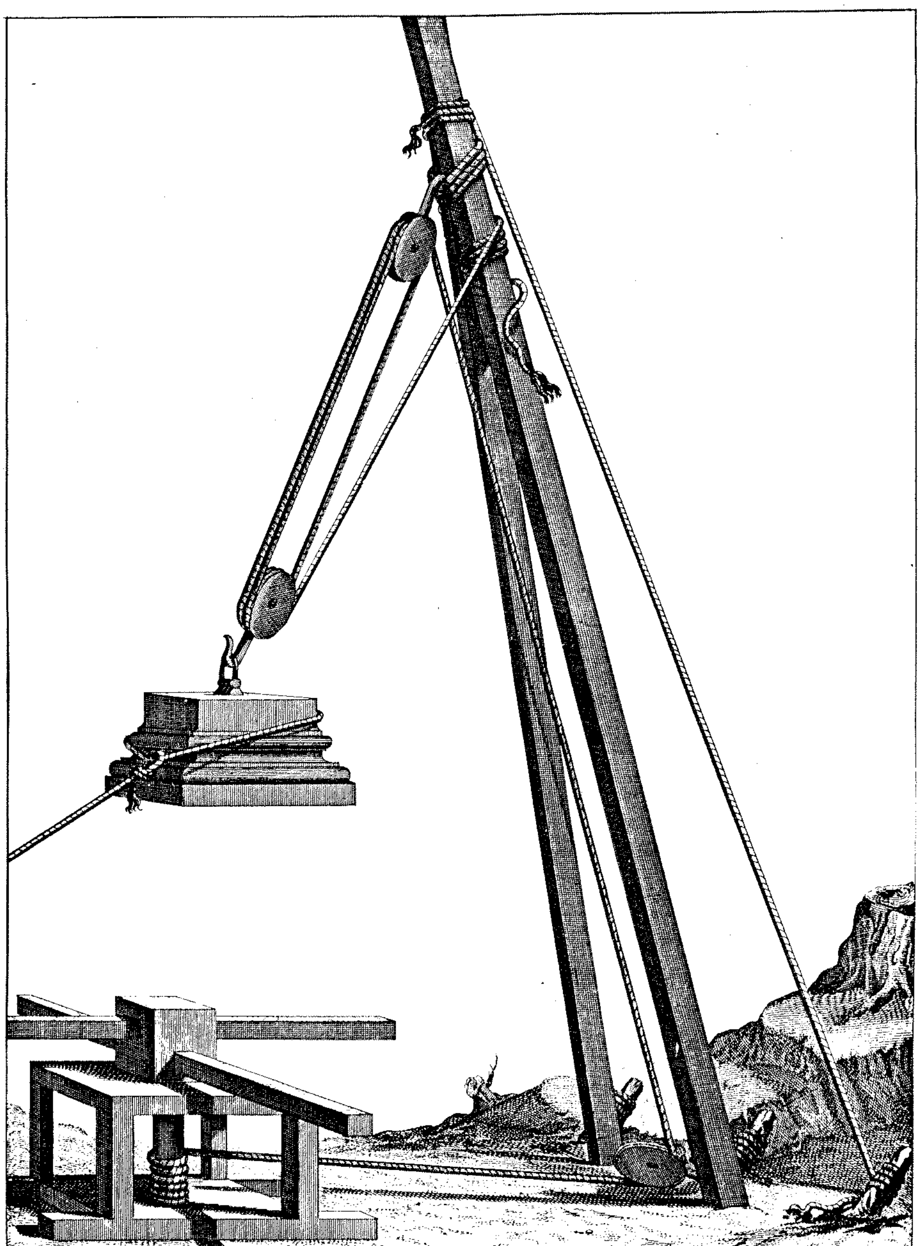

Illustration of a crane from the edition of
De Re Aedificatoria by James Leoni, 1726.

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within manual work. Thus in order to achieve a great number of tasks a conceptual approach to architecture was required. Rather than proposing specific precepts and predetermined solutions to given problems, as was custom in medieval treatises, Alberti asserted the necessity of a system of general concepts by which possible propositions could be addressed to forthcoming questions. This was what Alberti's treatise intended to achieve by deriving his propositions from general principles approaching the field of architecture as a systematic discipline. The tasks of the architect-engineer pertained, therefore, to the knowledge of natural laws such as those Galileo, a century later, would find indispensable for the understanding of the functioning of the world. In a chapter entitled *Of Wheels, Pins, Leavers, Pullies, their Parts, Sizes and Figures,* (Book VI, Ch.VII), Alberti for example explained the concept of balance and the phenomena of bending moments by describing the physical properties of a suspended arrow in different conditions[60], as was to be later illustrated in the Leoni edition of the treatise. After having established an understanding of such basic principles, Alberti applied them to further derive the mechanics of wheels and levers in demonstrating the distribution of forces on ropes and pullies which carried the weight of a stone statue. From his observations he concluded that the more pullies there were, the more the weight could be divided, thus allowing a greater weight to be moved by a smaller force. Following those principles Alberti proceeded in the following chapter to describe their direct application in a description for the construction of cranes. Solutions to specific problems were

60 *De Re Aedificatoria* , op. cit., Book VI, Ch. VII, p. 122.

derived from the understanding of universal laws as manifested in the definition of general principles.

Alberti's approach to the art of construction while described in scientific terms exhibited primarily rational traits. Unlike Vitruvius, Alberti divided the architect's work into two main sections: designing and building. The former was conceived by thought and imagination, the latter by matter and work. Design was to be the composition of "lines and angles, conceived in the mind," defining what was to be built with great precision. Building construction was considered the totality of procedures and materials accounted for in the making of architecture. Alberti included in this category the work of the experienced artificer, or *artifex*, who knew how to form building materials according to the architect's design. Respectively the maker was to design according to the possibilities inherent within the craftsman's work. Thus in order to conceptually address the question of building practice within the design Alberti provided a systematic framework for the understanding of that practice. This ordering structure was further supported by the precise reference to universal principles as derived from natural law.

As Vitruvius had already noted and as later reiterated by Alberti, the discipline of architecture in engaging in quite varied tasks, could be divided accordingly into different classes which together would form a coherent and comprehensive system. Such a unifying structure, according to Alberti, could equally pertain to city planning, to the fabric of a building, or to the construction of a fireplace, for principles could be applied through deductive reasoning to all departments of architecture. The attempt to systematize the field of knowledge of architecture implied an understanding of it as an autonomous discipline, with its own rules and principles. To systematize meant to arrange according to a system that was an ordered and comprehensive assemblage of facts, principles, and theories for the purpose of an understanding of a unitary compound of several parts. Vitruvius's definition of the "Fundamental Principles of Architecture" as well as his distinction of the different "Departments of Architecture" was clearly to be seen as one of the first propositions for a systematic approach to architecture. While with Alberti the phenomenon of systematization of the field lead to the aspect of an architecture as a discipline, systematization was also introduced with an understanding of the building as an assemblage or combination of parts forming a complex whole.

Alberti conceived of a building as an entity made out of parts or elements which according to specific rules were *con-structed* (put together) to achieve a certain purpose, thereby defining form. The art of building was understood to be divided into six primary entities pertaining to specific aspects of the building site and fabric: "...the whole Art of Building consists in six Things, which are these: The Region, the Seat or Platform, the Compartion, the Walling, the Covering and the Apertures."[61] Those constituted the primary systems according to which a building was designed; they were described as follows:

[61] Ibid., Book I, Ch.II, p. 2.

(1) Design considerations pertaining to the aspect of *region* addressed environmental conditions of the site in terms of climate and topography. Alberti sought an understanding of environmental and contextual parameters as determing factors of the design.

(2) The *seat* or *platform* was considered to be a specific and determined location within the *region.* The purpose of the platform was to provide a sound base for the building, addressing the conditions of soil and drainage. To delimit the foundations a method of measurement was recommended, this being a demarking with "radical lines" the specific location of the building platform. This system of coordinates provided a matrix which physically represented the rational base for architecture.

(3) The *compartition* was the system of subdivision accounted for in a building according to spatial, functional, and structural criteria, providing the understanding of an edifice as a compound of identifiable units. "The Compartition is that which sub-divides the whole Platform of the House into smaller Platforms, so that the whole Edifice thus formed and constituted of these its Members, seems to be full of lesser Edifices."[62] A house was for example divided into various spatial components, such as courtyard, hall, parlour, portico, and the like. Such parts, placed in relation to one another, contributed to the building as a whole.

[62] Ibid., Book I, Ch.II, p. 2.

(4) The walls were considered the primary elements determining the vertical system of spatial division and structural support. Alberti's discussion on walls included a definition of the column as conceptually being a portion of the wall; "a Row of Columns being indeed nothing else but a Wall open and discontinued in several Places."[63] The wall, as continuous surface or as column, thus constituted for Alberti one of the primary elements of architecture.

(5) The category of *covering* comprised the horizontal system of spatial division and structural support, including such building components as roof, floors, and ceilings. The purpose of covering included the protection of a building and its inhabitants from the natural elements, providing a physical barrier to rain, humidity, wind, and sun. Alberti deduced the specific arrangement of coverings according to general principles as derived from natural laws, thus explaining the slope of the roof, the overlap of building materials to avoid water penetration, and so forth.

(6) The system of apertures included openings for light and air, entrances, and vertical elements such as stairs, chimneys, wells, and drain pipes which require openings through floors and roof.

For Alberti the concept of entity and part played a significant role in conceiving of architecture. He divided the building in various systems as Leonardo da Vinci and Vesalius would later conceive in their anatomical drawings and dissections of the

[63] Ibid., Book I, Ch. X, p. 14.

human body. Alberti's systematization, his division of the building in elements, which according to a system of relation or structure would be arranged to form an entity of unitary character, pertained at base to an atomistic conception of the world. The adjacency to atomism was specifically expressed in Alberti's discription of the *compartition*, providing a definition which could generally be applied to the entire system of his model:

The whole Force of the Invention and all our Skill and Knowledge in the Art of Building, is required in the Compartion: Because the distinct Parts of the entire Building, and, to use such a Word, the Entireness of each of those Parts, and the Union and Agreement of all Lines and Angles in the Work, duly ordered for Convenience, Pleasure and Beauty, are disposed and measured out by the compartition alone: for the City, according to the Opinion of Philosophers, be no more than a great House, and on the other Hand, a House be a little City; why may it not be said, that the Members of that House are so many little Houses; such as the Court-yard, the Hall, the Parlour, the Portico, and the like? [64]

The conceptual divisibility of material things asserting an autonomy of parts which could be further subdivided, and always maintaining a structure or system of relationship between part and whole, was based on a highly abstract concept of logic characterizing the ultimate matters of concrete reality. Alberti's reference in *Della Pittura* to mathematical structure for the art of painting, seen in the light of his propositions

[64] Ibid., Book I, Ch. IX, p. 13.

pertaining to the systematization of architecture, paralleled the structure proposed by general and abstract relations among building components for the art of building. Such abstract structures were taken to indicate the underlying and ultimate concrete aspects of reality. Systematization furthermore constituted a mode of procedure for the design which based on rational analysis furthered a conceptual approach to the processes of architectural creation. Making and problem solving proceeded by the methodic decomposition of any complex problem into its logically ultimate components. Architecture had become scientific.

Alberti's rational model indicated a gradual shift of emphasis from a philosophic to a scientific atomic theory. In a general sense atomism may be defined as the theory that nature is composed of relatively simple and unchangeable minute particles which are too small to be directly observable. The observable changes in nature can be explained by their reduction to changes in the configuration of the particles. The observable multiplicity of the existing forms in nature are likewise based upon differences of forms and configuration of such basic elements. While the atomic theory traditionally supported in philosophical terms the idea of order in nature, including the aspect of certain universal permanence or a given order, the new atomic theory within science changed the order of nature insofar as this became the order of a mechanism. The laws and principles of nature were not only the signs of the rationality of nature, but also the means for the manipulation of nature. The significance of scientific inquiry lay in the conviction that nature formed a unity, which could be analyzed quantitatively as well as qualitatively. The concept of the division of entities into parts, which constituted the actual building blocks of reality, received a new significance. The relation between the forms of particles or elements and the form of a compound of elements could be determined in its structure allowing science to conceive of artificial processes through which nature could be transformed. The scientific atomic model, conceived as an explanatory framework for natural phenomena, was essentially transfered to those disciplines which engaged in the physical making of the human environment. Alberti in proposing a conceptual framework to the art of building applied the atomic model to the discipline of architecture, thereby providing a systematic mode of explanation for the process of design.

The Representational and Ontological Concepts of Form

The conceptual order of Alberti's approach to the making of architecture disclosed also a rational structure to his aesthetic understanding of building. According to Alberti the aesthetic appearance of a building consisted of two elements: Beauty and Ornament. He defined beauty "to be a Harmony of all the Parts, in whatsoever Subject it appears, fitted together with such Proportion and Connection, that nothing could be added, diminished or altered, but for the Worse."[65] The reference to the notion that beauty was manifested in proportion and symmetry, in the harmony of parts in relation to the whole, pertained to an objective rather than subjective understanding of beauty. Harmony, as Alberti subsequently explained, did not result from personal fancy, but from

65 Ibid., Book VI, Ch. II, p. 113.

objective reasoning.[66] He wrote: "The judgement which you make that a thing is beautiful does not proceed from personal opinion, but from a secret argument and discourse implanted in the mind itself." This aesthetic concept primarily existed in human reason; a concept with which his works on painting and sculpture had already been inspired, its justification was derived from the order of nature.

The analogy to nature was explicitly established in the parallel between architecture and the human body. Alberti periodically states in the treatise that a building is like a body, a human body in particular, so that in the formation of architecture we ought to imitate nature. In order to discover the roots of architectural beauty, Alberti analyzes those of natural beauty. He concludes: "That the Beauty of all Edifices arises principally from three Things, namely, the Number, the Figure and Collocation of the several Members."[67] The analogy to nature in general and to the human body in particular further supported the understanding of a building as a system, implying a systematic approach to the design process in its aim of achieving beauty. For Alberti, as the human body was made of members such as arms, legs, torso etc., in analogy the building was composed of walls, columns, beams, architraves, and pediments. Similarly the structure of relation between architectonic parts followed the laws and principles discovered in nature. A system, however, was considered more than the mathematical sum of its parts. An architectural system,

66 See R. Wittkower, "Alberti's Approach to Antiquity in Architecture," *Architectural Principles in the Age of Humanism*, op. cit., p. 33.

67 *De Re Aedificatoria*, op. cit., Book IX, Ch. V, p. 194.

paralleling the human body, represented in itself a unity on a higher level. The character of the whole dominated the interrelationship of the parts, allowing architecture to go beyond its own instrumentality, reaching into the realm of what Alberti called *Beauty.*

The building as well as the human body were considered to be composed of two factors, lineaments and matter, which were conceptually quite separate from one another. The former was in reference to the idea of building, whereas the latter addressed the physical phenomenon of building. The *lineaments* of a building were the "lines and angles" of the design as conceived by the mind. The *matter* pertained to construction. If the lineaments were considered one thing and the material quite another, there had to be a third factor which united them. According to Joseph Rykwert, editor of the 1955 reprint of the Leoni edition, this third element was *ornament* : "As two numbers (Timaeus of Locri had explained) cannot be related without some third marking the relationship so that we can comprehend it, the lineaments, which are of the mind, had to be welded to brute matter by some third thing which makes the first comprehensible, or perceptible, in terms of the other: and that is ornament."[68] Thus ornament established the connection between the concept of beauty within the "idea-building" and beauty as realized in the "phenomenon-building."[69]

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68 Joseph Rykwert, "Inheritance or Tradition", in *Architectural Design,* Vol. 49, No. 5-6, 1979, pp. 2, 3.

69 The expressions "idea-building" and "phenomenon-building" are use by Joseph Rykwert to identify the former with the understanding of building as an idea in the design and the latter with the phenomenal and physical reality of building construction.

Alberti devoted four of the ten books to the question of ornament, thereby empasizing its significance within his theory of architecture. The contemporary meaning of the word *ornament*, defined as applied decoration to beautify the appearance of an object or a building, coincides only partially with Alberti's understanding of the term. The meaning of ornament in the Albertian sense was double, disclosing two different conceptual structures for the discipline of architecture, a representational and an ontological structure. Both, as the word *structure* implies, pertained to the systematization of the field.

Ornament, according to Alberti, is "somewhat added and fastened on, rather than proper and innate."[70] This definition of the term refers primarily to a representational understanding of ornament as applied form. The composition of the façade of S. Andrea in Mantua, for example, based on a formal fusion of two architectural motives, a temple front and a triumphal arch which were incompatible systems in antiquity, reveals the use of ornament as derived from an architectural vocabulary of forms applied onto a building. Formal elements such as column, architrave, and pediment constituted the primary parts which were united according to specific rules to form entities, a temple front or a triumphal arch for example. Alberti approached such compositions in analytical terms determining the autonomous identity of architectural elements and their systems of relationship in order to form new entities of unitary character. Ornament hence constitutes the vehicle to

[70] *De Re Aedificatoria*, op. cit., Book VI, Ch. II, p. 112.

visibly describe the union between the "idea-building" and the "phenomenon-building" by means of formal imagery. This understanding of ornament pertained to a representational structure of the art of building, its formal component parts, rules, and principles being constituting factors of the discipline of architecture.

The reference to an ontological concept of form is diametrically opposed to the representational approach to architecture. Ornament was quite essential to the making or the experience of any building since, according to Alberti, without ornament no building may be used, inhabited or even seen. The essentiality of building, the idea-building, was an intellectual construction which ornament was to transcend. But ornament was considered not only to represent the idea-building in image form but to physically constitute its condition of existence; in other words, ornament embodied the essence of building. In this regard ornamentation was not conceived as something merely added on but as the fulfillment of innate beauty. In the second chapter of his sixth book, Alberti implied, as Rykwert put it, "that ornament is the corporeal or carnal manifestation of the building," constituting the idea-building into a physical phenomenon.[71] The proper arrangement of the structure, the choice of materials, and the work of the artificer were, therefore, discussed by Alberti under the heading of *ornament*. Beauty thus pertained not only to the intellect but also to the skill of the craftsman as well as to the natural qualities of material characteristics. Alberti sought to disclose within beauty the structure inherent within

[71] Joseph Rykwert, op. cit., p. 3.

making; he wrote that "Beauty and Ornament in every Thing arise from Contrivance, or the Hand of the Artificer, or from Nature." The beauty of a building depended primarily on the intellect, or the *ingenium*, which determined the placement, distribution, and disposition of parts. Secondly a building was admired as the work of the craftsman who by massing, connecting, disjointing, and polishing unformed matter gave grace and dignity to architecture. Lastly beauty pertained to the materials of which a building was made, for material qualities, weight, density, and durability were given by the law of nature.[72] Ornament was regarded as the embodiment of those conditions of existence pertaining to the making of architecture made manifest in form.

The twofold conceptual structure of form in its representational and ontological mode of existence was best expressed in Alberti's understanding of the column for the discipline of architecture. He emphasized repeatedly in his treatise that "the principlal Ornament in all Architecture certainly lies in the Column," for it was considered the supreme element, both in terms of work and beauty.[73] By placing the column in the category of ornament Alberti disclosed its value as either a decorative or as a constructive element.

In order to support the concept of decoration the column had to lose its function as the unique architectonic and structural element which it had fulfilled in Greek architecture, to become

[72] Ibid., p. 4; see *De Re Aedificatoria*, op. cit., Book VI, Ch. IV, p. 115.

[73] *De Re Aedificatoria*, op. cit., Book VI, Ch. XII, p. 130.

part of the language of applied ornament.[74] The emphasis placed on the architectonic quality of the wall, which was understood to be the primary constituent element of Renaissance architecture, led Alberti to resolve the incompatibility between the three-dimensional and plastic quality of the column and the flat character of the wall by substituting pilasters for columns. This idea was first realized in the façade of the Palazzo Rucellai, begun about 1446, for which Alberti, in reference to the Colosseum in Rome, created a system of pilasters and entablatures to enhance the grandeur of the building. The use of the pilaster, as mentioned by Wittkower, constituted the logical transformation of the column for the decoration of the wall: "It may be defined as a flattened column which has lost its three-dimentional and tactile value."[75] Thus the column as decoration, independent of structure, pertained to a "designed" architecture in which the representation of an iconographic vocabulary was the principal goal.

Simultaneously, the representational form of the column was implicitly contradicted by Alberti in his definition of the column as a tectonic and structural element of the wall: "And having occasion to define a Column, it would not be at all improper to say, that it is a certain strong continued Part of the Wall, carried up perpendicular from the Foundation to the Top, for supporting the Covering."[76] Additionally Alberti

[74] Hubert Damisch, "The Column and the Wall," in *Architectural Design*, Vol. 49, No. 5-6, 1979, p. 18.

[75] R. Wittkower, *Architectural Principles in the Age of Humanism*, op. cit., p. 36.

[76] *De Re Aedificatoria*, Book I, Ch. X, p. 14. See also R. Wittkower and H. Damisch.

conceived of the column as a residue of a pierced wall, a conception diametrically opposed to that of Greek architecture: "... a Row of Columns being indeed nothing else but a Wall open and discontinued in several Places."[77] This definition was primarily of conceptual nature. From a technical point of view the construction of a wall gave even greater emphasis to the column as a structural member. Since a wall was not uniformaly monolithic but, according to Alberti, consisted of a "Variety of Parts," the column was understood as the primary element of a load bearing skeleton contained within the wall. And again the analogy to the human body was reinstated by comparing the column to bones and ribs. Thus the column, in being the constituting element of the wall-skeletton, was conceptually not limited to vertical support but was also considered to be the generating element in the formation of arches, beams, window jambs, sills, and lintels: "And indeed I take an Arch to be nothing more than a Beam bent, and the Beam or Transom to be only a Column laid crossways."[78] Thus the wall in its totality was made of the following components: the skeleton for structural support, the external revetment or *cortex* for weather protection, the inner filling, and the internal shell. With this composite nature of the wall Alberti intended to define a mode of construction in which the skeleton could not be isolated, allowing as well the relationship between column and wall to be visually expressed by the column as ornament. The articulation of the façade of the Palazzo Rucellai reveals Alberti's intention to visually demark the structural concept of the construction, thereby depicting the existential

[77] Ibid., p. 14.
[78] Ibid., Book III, Ch. VI., p. 47.

condition of tectonic qualities as expressed in form. The ontological structure of form thus pertained to the attemt to make visible the inherent structure of things and the way in which they were made. As Jean Martin, the French translator of the treatise, put it: Alberti's analysis of the elements of the art of building "gives each thing the proper reasons concerning the matter;" the purpose of ornament was to bring these reasons into appearance.

The representational and ontological concept of form, were constituent factors of the discipline of architecture. Although sharing a position of importance within Albertian theory, both concepts were to gradually develop during the succeeding centuries into two inherently opposed traditions within the field of architecture. The representational concept essentially supported the understanding of the making of architecture as an art, primarily engaging in a discourse on form, for the discipline had been elevated to a liberal art. The image of the designer was the one of the architect-artist, his work being determined by the manifestation of architectural form. The ontological concept on the other hand led to the conception of the making of architecture as a science in the modern sense, principally engaged in the revelation of method and technique in their conditions of existence, for the discipline of architectrure pertained to the new science as it had developed from the mechanical arts. The designer, understood as an architect-engineer, addressed the tectonic quality of construction revealed in its condition of being.

The dichotomy between art and science developed into a polarity within architecture, resuming in the separation between form and technique in their roles as constituent factors in the processes of making. Since form requires technique for its realization, and as technique leads to formal appearance, the division between form and technique could not be total, thus allowing the possibility for mutual interdependence.

4. Chapter

ARCHITECTURE AS ART

The Representational Structure of Form and Technique

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The Representational Structure of Form and Technique

"... 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 - whether in the service of pleasure or of knowledge - was posited as a form of repetition: the theater of life or the mirror of nature, that was the claim made by all language, its manner of declaring its existence and of formulating its right of speech."

Michel Foucault, "The Prose of the World," *The Order of Things*.[1]

The Natural and Artificial Sign

Comparison as based on formal appearance implies the disclosure of likeness or resemblance between one thing and another, revealing a visible system for the understanding of the world. Resemblance has constituted one of the primary determining factors for the formation of knowledge within the history of Western culture until the end of the sixteenth century. In

1 Michel Foucault, *Les Mots et les Choses* (1966); *The Order of Things, An Archaeology of the Human Sciences*, Vintage Books Edition (New York), 1973, p.17.

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Albrecht Dürer, Northern Sky, 1515.

order to understand the functioning of the world it was necessary for man to compare the objects of his immediate experience and create groupings and classifications of things having common or similar characteristics. It was understood that knowledge required the detection of the visible signs which nature had placed on the surfaces of things, permitting man to depict resemblances and therefore comprehend the relationships inherent within the order of nature. In other words, this approach to knowledge discerned a system of resemblances which revealed a network of analogies and similitudes, providing access to an understanding of nature's given order. Such a form of acquiring an understanding of the world predominantly directed man's epistemological context, i.e. the origin, nature, methods and limits of human knowledge.

The position of the stars in the sky, for example, was seen in reference to formal characteristics as marked by pictorial identification. This is well expressed in Albrecht Dürer's drawings of the northern and southern skies in which the various configurations of stars depict different images; a bear, lion, or hydra, for example, provide an iconographic structure for constituting a visual order of the sky. Such drawings superimposed the instrumentally determined facts of reality with signs of symbolic representation by means of overlaying the map of the sky, showing the specific location of the stars, with the figurative images of their constellations.[2] The order of nature was thus expressed by means of visual

[2] *Albrecht Dürer 1471 bis 1528 / Das gesamte graphische Werk,* with introduction by Wolfgang Hütt, Rogner & Bernhard (München), 1970, pp. 1781-1785.

resemblances, for affinities of appearance were considered inherent within all of the natural world.

Prior to the emergence of the new science, knowledge was based on a combination of observation, experience, scholastic theories, magic, and religious beliefs, appearing from a contemporary point of view to be extremely heterogeneous. Knowledge nevertheless formed a coherent picture. Every observation based on sensory impressions fitted a whole whereby each thing had its place as one element within a complex network which had been established by divine or mythical power. Through the identification of resemblances connection between things were established. The formal resemblance of a plant to the shape of the human eye, for example, indicated as late as the sixteenth century that the plant could be used for treating eye diseases.[3] A seed in the form of a tooth was a safeguard against snake bites, and yellow juices were considered as a cure for bilious troubles.[4] Such interdependencies were indicated on the surface of things, revealing potential structures of relationship through visible signs. All things of the world were signed, their signatures understood as visible demarkation allowing recognition of analogies and the internal order of things. Philippus A. Paracelsus, a Swiss physician and alchemist of the early sixteenth century, derived the understanding of the world as a system of signs from divine intention.

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3 François Jacob, *The Logic of Life, a History of Heredity,* Pantheon Books (New York), 1974, p.21.

4 Claude Lévi-Strauss, "The Science of the Concrete," *The Savage Mind* , translated from *La Pensée Sauvage* (Paris, 1962), University of Chicago Press (Chicago), 1966, p. 16.

It is not God's will that what he creates for man's benefit and what he has given us should remain hidden ... even though he has hidden certain things, he has allowed nothing to remain without exterior and visible signs in the form of special marks - just as a man who has buried a hoard of treasure marks the spot that he may find it again.[5]

The above can be summarized by the view that classification as based on resemblance identified order from aesthetic perception. Formal expression allowed the reading of relationships between things of similar appearance. Such visual identities were further equated with common qualities understood to be inherent within objects sharing signs of resemblance. Visual relationships contributed thereby to the formation of meaning. The conception of knowledge of the physical world was thus primarily directed by the visible structure of objects as perceived by man.

Similarly, the processes of art production were considered to be based on the concept of resemblance for the making of objects and artifacts. As knowledge of the natural world revealed systems of visual interdependencies, the production of artifacts was based on the recognition of formal resemblances. Thus the act of making, paralleling natural creation, could visibly indicate meaningful relationships by means of signs.

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5 Philippus Aureolus Paracelsus, "Die 9 Bücher der Natura Rerum," in *Works,* ed. Suhdorff, vol.IX, p. 393. See Michel Foucault, *The Order of Things,* op. cit., p. 26.

"Artificial signs" were derived from "natural signs."[6] Art involved the formation of resemblances and the representation of visual adjacencies following the example of nature.

The model of reference for art was nature which was regarded as the source of perfection. Art therefore imitated nature. In varying form and degrees, the concept of *mimesis*, understood as the imitation of appearance, was applied to the definition of art from Antiquity to the Renaissance.[7] Defined by Socrates and further developed within Platonic and Aristotelian thought, mimesis was accorded a primary function within the arts. Plato's conception of art as imitating reality is primarily described as a passive and faithful act of copying the material world. The relation between art and imitation is brought forth in the dialogue of*The Republic* in which three levels of creation are differentiated. The first level addresses the essential *Idea* of an artifact as conceived by God; a piece of furniture, a bed for example, was a concept given to man by divine hand: "God ... wished really to be maker of actual bedhood, not of a particular bed, not to be a mere bed-maker; consequentially he created one bed unique in the nature of things."[8] The second level of creation was defined by the work of the carpenter. The "craftsman who made the bed," while

6 The expressions "natural sign" and "artificial sign" indicate whether a sign was given by nature or established by man. See Michel Foucault, *The Order of Things,* op. cit., p. 61.

7 See Erich Auerbach, *Mimesis, the Representation of Reality in Western Literature*, first published in Berne, Switzerland, 1946, translated from the German by Willard R. Trask, Princeton University Press (Princeton, New Jersey), 1953. See also Rensselear W. Lee, "*Ut pictura poesis* : The Humanistic Theory of Painting," in *The Art Bulletin,* December 1940, Vol. XXII, no. 4, pp. 197-269.

8 Plato, *The Republic,* Book X; from *Great Dialogues of Plato,* translation by W. H. D. Rouse, New American Library (New York), 1956, p. 396.

addressing the essence of the artifact that was to be produced, was giving form to the *Idea;* making was therefore the imitation of the nature of things. The painter who in his work represented a bed was considered to act at a level even further removed from divine intention, for he was imitating the product of the carpenter. Thus, the artist was called "the imitator of the thing of which the others were craftsmen, ...the imitator in the third generation from nature."[9] In addressing the difference between the Idea, the manufacturing process and the representation of an artifact, Plato defined *mimesis* within such arts as painting or poetry as the imitation of appearances. Art in this regard did not constitute truth in itself but instead was considered as attempting the representation of truth.

Aristotle, accordingly, supported the importance of the concept of *mimesis* for the arts, for he regarded imitation as being a natural characteristic of mankind. He, however, added to Platonic theory the idea that imitation had an artistic value of its own. These points were formulated in his *Poetics*:

Imitating is natural to human beings from childhood onwards: man differes from other animals in being extremely imitative; his first steps in learning are made through imitation, and all people get pleasure from imitations. An indication of this is what happens with works of art: there are things that give us great pain when seen in the flesh, yet we enjoy looking at

[9] Ibid., p. 397.

pictures of them that are exact likenesses - things such as the most repellent animals and corpses.[10]

For Aristotle the quality of art lay not in the precise and correct representation of true facts but in the way the work of art was executed. He expressed this priority in the remark that: "It is less of an error not to know that the female deer has no horns than to paint a picture that is poor representation."[11] Imitation meant to Aristotle not faithful copying but instead the interpretation of reality. Artistic imitation, whether painting or poetry, could present things in another light: "Since tragedy is an imitation of men who are better than ordinary, we ought to imitate the good portrait painters: although they reproduce the figure of a particular person, they nonetheless make it, as they paint it, more beautiful that it really is."[12] Imitative art, in this respect, could emphasize certain characteristics, thereby revealing the general, typical and essential of the object that was represented. The creation of a work of art was not a product of pure imagination; art unfolded the essence of things as given by nature, which was regarded as the source of perfection.

The idea that art imitates nature was upheld and debated through succeeding centuries of Western civilization. This concept of *mimesis* was supported by Cicero in the first century B.C. and readopted by Thomas Aquinas during the Middle Ages in the expression *ars imitatur naturam.* Imitation as the

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10 Aristotle, *Poetics ;* from *The Philosophy of Aristotle*, edited by Renford Bambrough, New American Library (New York), 1963, p. 414.

11 Ibid., p. 429.

12 Ibid., p. 425.

copying of reality seemed, however, for a number of thinkers as early as the Roman period oversimplified and was instead replaced by writings and debates on imagination, invention, and inspiration. During the Middle Ages it was held by Saint Augustine that if art was imitation, then it should concentrate on the invisible world which was considered to be more perfect. Since the products of art belonged to the visible material world, art could address the invisible by means of symbols rather than by imitating reality. The definition of art as the imitation of nature, however, prevailed and can be accorded the primary theory of the arts through the early Renaissance. Lorenzo Ghiberti spoke of having tried to imitate nature (*imitare la natura*) "as well as it was possible for him,"[13] and Alberti in *Della Pittura* maintained that there is no better way to beauty than by imitating nature: "He who dares take everything from nature will make his hand so skilled that whatever he does will always appear to be drawn from nature."[14] If art was to imitate nature, then respectively natural phenomena could resemble the products of art. Alberti addressed this reciprocal view in his treatise on painting by describing nature in the role of the artist:

Nature herself seems to delight in painting, for in the cut faces of marble she often paints centaurs and faces of bearded and curly headed kings. It is said, moreover, that in a gem from Pyrrhus all nine Muses, each with her symbol, are to be found clearly painted by nature.[15]

[13] L. Ghiberti, *Commentaries*, 1436, ed. Morisani, II, 22.

[14] L. B. Alberti, *Della Pittura*, 1435-36. *On Painting*, translated by John R. Spencer, Yale University Press (New Haven), 1956, Book III, p. 93.

[15] Ibid., Book II, p. 67.

The reference to nature was of significance for the field of architecture. Beauty in architecture as founded on harmony, measure, and proportion was to be derived from the order of nature. Vitruvius had made this connection in his description of the orders and in his commentary on the proportions of temples. The ideal model to which Vitruvius referred was the human figure for this symbolized natural creation in its ultimate perfection: "Therefore, since nature has designed the human body so that its members are duly proportioned to the frame as a whole, it appears that the ancients had good reason for their rule, that in perfect buildings the different members must be in exact symmetrical relations to the whole general scheme."[16] This idea, accepted as an axiomatic rule, was specifically applied to the Doric, Ionic and Corinthian orders as models of proportional beauty. The column constituted the primary load bearing element of Greek architecture, and as addressed by Vitruvius, was determined in its size and measurement from the proportion of the human body. In addition to being analogous to the proportional systems inherent within the human body, the column was seen as a pictorial and metaphorical representation of the figure of man or woman. The image of man was represented by the Doric order: "Thus the Doric column, as used in buildings, began to exhibit the proportions, strength, and the beauty of the body of a man."[17] The Ionic order was determined to be in resemblance to the "terms characteristic of the slenderness of women," and the

[16] Vitruvius, *The Ten Books on Architecture*, translated by Morris H. Morgan, Dover Publications (New York), 1960, Book III, Ch. I, p. 73.
[17] Ibid., Book IV, Ch. I, p. 103.

Corinthian order was conceived as "an imitation of the slenderness of a maiden; for the outlines and limbs of maidens, being more slender on account of their tender years, admit of prettier effects in the way of adornment."[18] The column which technically was purely a load bearing element received additional significance by being a representation of the human body. The making of form surpassed the realm of construction by attaining representation, for form in architecture resulted from the concept of *mimesis* as being the imitation of nature. The man-made "artificial sign" thus mirrored those signs which man had discovered in nature.

The meaning of form within Vitruvian theory was twofold. Form in its primary meaning was equivalent to the disposition and order of parts; the form of a portico, for example, was constituted by the arrangement of columns, placed according to measured relationships. Beauty in architecture thus pertained to proportion as discovered in nature. The definition of form when applied to that directly given to the senses suggested another meaning of the term; rather than referring to order and number, form instead belonged to the appearance of things. The reference to nature was thus established through visual resemblances. The Doric order, for example, represented the characteristic signs of the body of the man in its idealized formal appearance. While the former definition of form referred to the concept of order as based on component parts and their structures of relation, the latter understanding of the term addressed the question of appearance as marked by the meaning of represented images. Both concepts of form were part of the

[18] Ibid., Book IV, Ch. I, p. 104.

Vitruvian understanding of architecture, allowing the reference to nature to occur at the level of structure and order as well as at the level of meaning and appearance.

Meaning and content were not limited to the representation of imagery but adhered also to the concept of form as a system of order. The meaning inherent within proportion, disposition, and arrangement of parts lay in beauty as the signifying content of pictorial representation. Form referred to both the visual structure and appearance of nature, thereby signifying beauty.

The distinction between form and content was clearly made by Vitruvius in his chapter on the education of the architect: "In all matters, but particularly in architecture, there are these two points: - the thing signified, and that which gives it its significance."[19] That which was signified was architecture in its physical and formal manifestation; that which gave significance was the theoretical content of architecture. In order to address the question of meaning within form the architect had to have knowledge of the theoretical sciences. Particular emphasis was given by Vitruvius to the knowledge of history: "A wide knowledge of history is requisite because, among the ornamental parts of an architect's design for a work, there are many the underlying idea of whose employment he should be able to explain to inquirers." Form in this context is not derived from the reference to nature but instead from the representation of historical knowledge. History provided the explanation of form. The example given by Vitruvius

[19] Ibid., Book I, Ch. I, p. 5.

described the historical reason for the use of sculptured female figures in architecture, the Caryatides:

> *... suppose him* [the architect] *to set up the marble statues of women in long robes, called Caryatides, to take the place of columns, ... he will give the following explanation to his questioners. Caryae, a state in Peloponnesus, sided with the Persian enemies against Greece; later the Greeks, having gloriously won their freedom by victory in the war, made common cause and declared war against the people of Caryae. They took the town, killed the men, abandoned the State to desolation, and carried off their wives into slavery, without permitting them, however, to lay aside the long robes and other marks of their rank as married women, so that they might be obliged not only to march in the triumph but to appear forever after as a type of slavery, burdened with the weight of their shame and so making atonement for their State. Hence, the architect of the time designed for public buildings statues of these women, placed so as to carry a load, in order that the sin and punishment of the people of Caryae might be known and handed down even to posterity.*[20]

The column, as in the case of the Caryatides, was a bearer of meaning symbolizing the moral of an historical episode, in this case being the load bearing function of the column allegorically depicting the burden carried by the women of Caryae. Form and sign in architecture thus pertained not exclusively to the representation of nature but were also derived from the reference to culture and civilization.

[20] Ibid., Book I, Ch. I, pp. 6, 7.

The personalization of the orders suggested by Vitruvius was not exclusively based on the depiction of the human body. In addition to the anthropomorphic meaning of the Doric, Ionic, and Corinthian columns the reference to nature was essentially a reference to historical architectural form. Vitruvius described the origins of the orders from Greek architecture. The discipline of architecture, according to Vitruvius, was to address those forms that had been historically established. This concept relates equally to the architecture of the Renaissance which, in accepting Vitruvius's authority, saw the Roman and Greek culture as the historical models of authority. The column in its representation of the human body was an inherited artifact of cultural value. Sebastiano Serlio (1475-1554), for example, recommended that the Doric order be used for churches dedicated to male saints and "men of armes,"[21] the Ionic for matronly saints and "peaceable people,"[22] and the Corinthian for "Saints that were Virgins,"[23] particularly the Virgin Mary. And while Vincenzo Scamozzi (1552-1616) upheld Serlio's propositions calling the Corinthian order *virginal*, later, Sir Henry Wotton (1568-1639), distorted the meaning of the Corinthian order by calling it "lascivious" and "decked like a wanton courtezan."[24] Essentially, however, the symbolic content of the orders was primarily determined by their

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21 Sebastiano Serlio, *The Five Books of Architecture*, 1437-47, "The maner of the Dorica, and the Ornaments thereof," Dover Publications (New York), 1982, Book IV, Fol. 16.

22 Ibid., "Of the order of Ionica, and the Ornaments thereof," Book IV, Fol. 34.

23 Ibid., "Of the order of Corinthia worke, and the Ornaments thereof," Book IV, Fol. 45.

24 John Summerson, *The Classical Language of Architecture*, MIT Press (Cambridge, Massachusetts), 1963, p. 12.

significance as culturally accepted forms which were transmitted through history. As in the case of the orders, form was conceptually established and historically evolved as "artificial signs" to which architecture referred.

To summarize, the meaning of architectural form was given by its historical importance. *Mimesis* within the field of architecture, whether referential to natural or cultural conditions, gradually developed as the imitation of historically determined form. Since form was the bearer of meaning it was form that was represented. In other words, the making of architecture involved the representation of "artificial signs;" that which was signified received its meaning from form as a cultural artifact.

Construction as Metaphor

The concept of form representing form evolved as one of the guiding principles of architecture which periodically reoccurred throughout history. If form assumed such an authority within the discipline of architecture, it must be asked how form relates to technique and considerations of construction. The process of establishing standardized solution types within building construction led to prototypical forms which gradually became accepted as linguistic formulae. Such forms were independent of those technical considerations necessitated by the processes of architectural production; form assumed an autonomous position. Technique was only of significance insofar as it had given form its original manifestation while being replaced by other methods of production. The techniques changed but the forms remained the same. However, the original techniques often left their marks on the surface of the form that evolved, thereby allowing formal expression to be depicted as the sign of the initial construction.

The form of the Doric column, as mentioned by Vitruvius, was most probably derived from timber construction.[25] The Doric order executed in stone was, in effect, a carved representation of a wooden structure. Thus not being a literal replication but a sculptural equivalent, the approach indicated an understanding of construction as referential sign. The change of materials from timber to the more permanent stone must have gradually occurred. Architecture had descended, through the Greeks, from the first primitive epoch of human history and was therefore considered to be possessed of a sort of natural rightness - almost a work of nature. The established hypothesis was that architecture had originated when primitive man built himself a hut in which the basic elements of architecture as well as its principles and rules of organization were set forth. Vitruvius supported this view in asserting that the Doric order developed from a timber prototype and that the original temples had had tree trunks for columns. An allusion to this assumption was made by Bramante in his design for the cloister of S. Ambrogio (1497-98), where some of the stone columns were covered with carved representations of stumps of

[25] Ibid., Book IV, Ch.II, p. 107."... *starting from carpenter's work, artists in building temples of stone and marble imitated those arrangements in their sculptures, believing that they must follow those inventions.*" Although suggested by Vitruvius, the literal translation of the forms of timber construction into stone has not been proven and is still under discussion.

sawn-off branches[26], and the same theme appeared later again during the sixteenth century in a drawing by Philibert de L'Orme[27]. So, according to Vitruvius, the earliest temples of the ancient world were built of wood; over time some of them were rebuilt in stone. Although the building techniques fundamentally changed, the forms were not altered as their sanctimonious meaning was culturally embedded. Hence, the carpentry details were copied in marble. The construction of new temples further copied the copies until the Doric order in its formal manifestation became an accepted formula.[28] Architectural morphology and syntax were hereby established and allowed certain transfers of form independent of original construction techniques.

The formal details of the Doric order, which historically evolved as the accepted norm, can hypothetically be explained in terms of the methods of assembly of timber construction. The entablature, divided in architrave, frieze, and cornice, can be read as a representation of the roof structure. The architrave corresponds to the primary structural member or main beam, while frieze and cornice signify the successive horizontal layers of cross beams and roof decking. The *mutules*, as described by Vitruvius, were "devised from the projections of the principal rafters," the *triglyphs* were derived from the boards fastened to the end of the cross beams "so that the cutting off of the ends of the beams, being concealed, would

[26] The columns could also be seen as a reference to the Sforza family, since the tree trunk was part of Ludovico Sforza's coat of arms.

[27] See *Architecture de Philibert de L'Orme, Edition intégrale de 1648*, Pierre Mardaga éditeur (Bruxelles), 1981, Livre VII, Chapitre X, p. 214.

[28] John Summerson, op. cit., p. 12.

not offend the eye," and the term *metope* was used to identify "the space between the beams."[29] The *taenia* was probably a binding member which appears to be secured to the triglyphs by the *guttae* representing wooden pegs. Such details, which were developed from a system of timber construction and copied in stone, crystallized into a precise formal language of architecture.

The different parts of the entablature were arranged according to specific formal rules which had originated from technical considerations. The making of architecture, therefore, had to be in agreement with the rules of formal expression; to break them, as Vitruvius asserted, meant to work on the basis of false principles. To explain his point Vitruvius described the correct formal arrangement of *mutules* and *dentils* for the Ionic order as derived from the placement of principal and common rafters in timber construction:

The system of triglyphs and mutules was invented for the Doric order, and similarly the scheme of dentils belonged to the Ionic, in which there are proper grounds for its use in buildings. Just as mutules represent the projection of the principal rafters, so dentils in the Ionic are an imitation of the projections of the common rafters. And so in Greek works nobody ever put dentiles under mutules, as it is impossible that common rafters should be underneath principal rafters. Therefore, if that which in the original must be placed above the principal rafters, is put in the copy below them, the result will be a work constructed on false principles. ...

[29] Vitruvius, op. cit., Book IV, Ch.II, pp. 107, 108.

Hence the ancients held that what could not happen in the original would have no valid reason for existence in the copy.[30]

The representation of historically derived form was of significance for the architecture of the Roman period for which ancient Greek architecture was the cultural model and historical precedent. But Roman architecture was from the point of view of structure and construction inherently different. Greek architecture belonged strictly to the system of *trabeation*, a construction primarily based on posts and lintels while Roman buildings other than temples were designed on the basis of arches and vaults. A possible connection between the two systems could, therefore, not occur at the level of structure. Since arched and vaulted buildings required massive piers to carry the loads it was structurally inappropriate to support arches by means of columns. Additionally, columns and their entablatures had historically become identified as a formal unity so that a separation of the post and its lintel seemed conceptually impossible. The combination of the arcuated and trabeated systems while structurally inadequate could only be achieved by means of formal representation. In the façade of Colosseum in Rome, build in the first century A.D., both systems were combined by treating the trabeated system simply as a means of expression. The row of arches in this example were framed within a continuous colonnade, which had no primary structural purpose. Despite its original function as load bearing construction, the Greek system of posts and beams was applied onto the wall, implying structure without being *de*

[30] Ibid., Book IV, Ch.II, pp. 108, 109.

facto an element of the structural system. The vertically aligned colonnades of the façade were representations of a system of construction that had lost its functional justification yet been elevated to a purely formal gesture.

This transfer from the *real* to the *implied* explains a relationship between technique and architectural form that was metaphorical in nature. Metaphor was the mode of expression in a transfer of meaning from one form with a particular meaning to the same form with another meaning. The column and the beam had been divorced from technical considerations and become elements of formal significance, yet form signified technique without being of technical necessity. The concept of construction as metaphor had already been established as a mode of formal expression in the transfer from timber to stone for the development of the orders. When applied to the superimposition of the trabeated to the arcuated system, the metaphorical use of construction received additional significance as column and beam had been disengaged from structural considerations. With this twofold reference to the concept of metaphor the orders became to be primarily valued in their manifestation as pure form. They were understood to be part of the formal language of architecture and were considered the elements of a vocabulary to which specific grammatical expressions pertained.

Metaphor, a concept belonging to the system of language, was applied to architectural forms. The Roman rhetorician Marcus Fabius Quintilianus in his treatise *Institutio Oratoria*, written in the first century A.D. and published in 1863/64, mentioned the term *metaphor* as an aspect of the rhetoric, in referring to the old Greek expression *metaphora,* meaning transfer. In his eight book the word was more precisely defined as a transfer of meaning from one thing with a particular meaning or without meaning at all to the same thing with another meaning - or new meaning. The metaphorical use of construction was essentially rhetorical in nature allowing within an architectural discourse of form the transfer of meaning to occur, from technique as a method of construction to technique as referential sign.

The relation between *implied* and *real* structure was furthermore supported by technical considerations. The construction of walls during the Roman period allowed the differentiation between structural and non-structural parts. Although monolithic in their formal expression, walls were generally composite constructions, conceived as an arrangement of successive vertical layers. In a critical remark Vitruvius compared in his chapter "Methods of Building Walls" the quality of monolithic Greek masonry to the composite construction of Roman walls:

... our workmen, in their hurry to finish, devote themselves only to the facings of the walls, setting them upright but filling the space between with a lot of broken stones and mortar thrown in anyhow. This makes three different sections in the same structure; two consisting of facing and one of filling between them. The Greeks, however, do not build so; but laying their stones level and building every other stone lengthwise into the thickness, they do not fill the space between, but

construct the thickness of their walls in one solid and unbroken mass from the facings to the interior.[31]

Despite Vitruvius's expressed bias in favor of the Greek method, the Roman construction prevailed. Walls were commonly faced with courses of either brick or stone. The various types of masonry construction were identified according to this facing, which was the visible and most distinctive feature of the finished product. However, the essential part of the structure was constituted by the core behind the facing. The center section of the wall forming the core was made of a material composed of an aggregate of stone and gravel laid in mortar. This Roman concrete, or *opus caementicium,* was used in its early development as a mass of mortared rubblework to fill the spaces within the framework of traditional masonry walls. It developed progressively from the second century B.C. to the first half of the second century A.D. to a structural material in its own right. What Roman builders discovered, by accident in the first place and subsequently by empirical experience, was that by substituting for ordinary sand the sand-like *pozzolana* [32] they could produce a lime mortar of quite unprecedented strength. With the load-bearing quality of the *opus caementicium* used for the core of walls, the facing successively lost its primary structural function. It was used

[31] Ibid., Book II, Ch. VIII, p. 51.

[32] To Vitruvius, who in technical matters often refects the accumulated experience of generations of builders, *pozzolana* was just another type of sand. What Vitruvius could not know was that it was not really a sand at all. Sand consists essentially of particles of rock, whereas *pozzolana* , for all its sandlike appearance, is a volcanic deposit. Its chemical composition, and in particular its high silica content, gives it a number of properties valuable to the builder. It can be used to create a compact substance which is not only capable of bearing great weight, but which also possesses a surprisingly high degree of tensile stength.

as a formwork to shape and to contain the core, thereby allowing the builder to maintain a certain precision within the process of construction.[33]

Andrea Palladio described in the first of the *Quattro Libri dell' Architettura* (Venice, 1570) several typical construction methods of Roman walls showing their composite nature as well as the use of *opus caementicium*. Plate I, II, and VI illustrate different applications of concrete as it was used in Roman building practice. The first plate shows a combination of brick and concrete forming the structural framework of the wall. The brick (A, B, and D) is used to stabilize the corners; it is furthermore laid in courses through the thickness of the wall acting as a structural tie as well as a means by which to secure the horizontal alignment of the wall. The facing in stone (C) forming a diagonal pattern was called *opus reticulatum*, literally meaning "network masonry;" it was used as the formwork for the concrete (E) which acted as a load-bearing material. Interesting is that as the wall is illustrated by Palladio in its three dimensionality, the facing is shown as a two dimensional layer. It was this facing which determined the visual character of the wall from which also its terminology was derived. In the wall detail shown in Plate II the diagonal facing is replaced by brick (E), this type of wall construction was primarily used for major public structures; Palladio mentions that "after this manner are the walls of the

[33] See Heinz-Otto Lamprecht, *Opus Caementitium Bautechnik der Römer*, Beton Verlag (Düsseldorf), 1984; John B. Ward-Perkins, "Rome: The New Concrete Architecture,"*Roman Architecture*, Harry N. Abrams (New York), 1977, pp. 97-194; D.S. Robertson, "Roman Construction. Arches, Vaults, and Domes," *Greek and Roman Architecture*, Cambridge University Press (Cambridge), 1929, second edition 1943, pp. 231-266.

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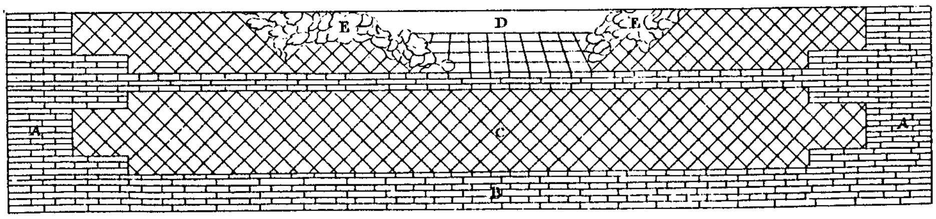
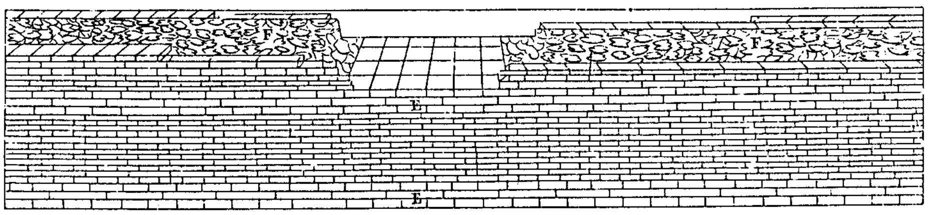
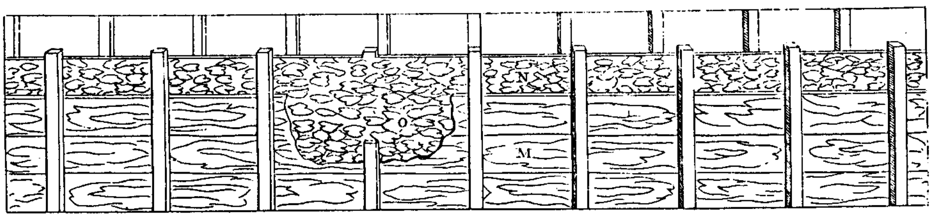
Plate I



II



VI



A, *the angles made of brick.*
B, *courſes of bricks that bind the whole wall.*
C, *the net-work.*
D, *courſes of bricks through the thickneſs of the wall.*
E, *the inner part of the wall, made of cement.*
E, *the courſes of bricks that bind the whole wall.*
F, *the middle part of the wall, made of cement, between the ſeveral courſes and the outward bricks.*
M, *planks laid edgeway.*
N, *inward part of the wall.*
O, *face of the wall, the planks being taken away.*

Roman wall constructions by Andrea Palladio,
The Four Books of Architecture, 1570.

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217 b

Rotunda, the baths of Dioclesian, and all the antient buildings that are at Rome."[34] The wall in Plate VI shows a construction method which neither requires a brick framework nor any kind of facing, a technique belonging to the standards of contemporary building practice. The wooden planks (M) used as formwork were removed after the concrete (N) had dried. In this case the wall's formal appearance was given by the exposed concrete (O). Such a technique was usually used for foundations and substructures. When applied to visibly exposed surfaces this type of construction most commonly included the facing of walls with other materials.

With the technical possibilities of Roman concrete the facing evolved as a veneer of secondary technical necessity. When no additional coating of plaster or marble was applied, as for example in the façades of the tomb of Annia Regilla along the Via Appia, the external brickwork determined the primary visual characteristic of the wall. Core and facing were functionally separated allowing the latter to be the expression of form independent of structural requirements. The ornamental use of brickwork was thereby made possible in its reference to traditional form.

Roman architecture, however, did not always visibly expose the brick or stone facing of concrete structures. Buildings of significance, whether of public or private function, were often faced with an additional layer of plaster or marble. For example, Domitian's residence, known as the Domus Augustana (92

[34] Andrea Palladio, *I Quattro Libri dell'Architettura* (Venice 1570); *The Four Books of Architecture*, with introduction by Adolf K. Placzek, Dover Publications (New York), 1965, Book I, Ch. IX, p. 8.

A.D.), was throughout a brick-faced concrete structure. Virtually nothing of what one sees today was visible in antiquity. The walls were faced with marble veneer and decorative marble orders in the main rooms and plaster in the service rooms.[35] Such a use of veneer in architecture allowed a further dissociation between structure and decoration, thereby supporting the autonomy of representational form.

The brick-facing of such structures, while not exposed, assumed a mediating position between the structural core and the applied layer of veneer. The market of Trajan (112-113 A.D.), for example, was in terms of its structure a brick-faced concrete construction. It was covered in those parts of the building which were considered of public significance with a veneer of stucco and marble. Formal elements such as pilasters, triangular and segmentally curved pediments, as well as half-pediments were applied onto the surface of the curved façade which today faces the Forum of Trajan. The brickwork, originally not directly exposed, constituted the substructure for the decoration and was articulated in relief according to the shape of the applied forms.

The decoration of the hemicycle of Trajan's Markets, while derived from a classical vocabulary of forms, counteracted the massive, load-bearing quality of the wall. Taken separately, the use of pilasters, of alternately curvilinear and rectilinear entablatures, and of decorative aediculae gave life and movement to the wall surface thereby visually attaining the effect of the dematerialization of the wall. Such formal

[35] Ward-Perkins, op. cit., p. 107.

elements created a balance to the heaviness of Roman masonry without concealing its underlying structure. The system of arches contributed as much to the façade composition as did the layer of applied decoration. Architectural expression resulted from the juxtaposition of formal systems, one of which was derived form structural considerations, the other purely representational in nature.

The synthesis of both the functional and decorative aspects of form constituted one of the qualities of the Roman Pantheon (c.118-128 A.D.) which Renaissance architects would later consider the classical model of reference.[36] The formal scheme of the Pantheon's interior discloses a composition in which decorative and structural elements are conjoined. The hemispherical dome, made of concrete, appears to rest on a continuous wall which seems to be carried by an entablature supported by Corinthian columns and pilasters. The load-bearing structure, however, is a brick-faced concrete construction combined with an elaborate system of relieving arches. The primary circular wall, as shown by the plan, consists of eight piers, separated by niches so deep that the walls behind them have little load-bearing function. Each niche is spanned by a barrel-vault of brick directing the loads of the dome into the piers. Those vaults are concealed within the wall and only revealed at the entrance and its opposite niche. Here, the decorative entablature, visually supported by columns and pilasters, appears to carry the vaults of entrance and altar.[37]

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[36] See William L. MacDonald, *The Pantheon, Design, Meaning, and Progeny*, HarvardUniversity Press (Cambridge, Massachusetts), 1976.

[37] D.S. Robertson, op. cit., pp. 246-251.

As shown in a sectional drawing by Sebastiano Serlio, this combination of arch and column constituted a formal entity. Form herein resulted from a combination of functional and decorative elements in which real and implied structure were united. Although, the superimposition of arch and column technically constituted a contradiction of terms, their unity evolved into an autonomous formula later adopted during the Renaissance as an element of formal authority.

As columns, architraves, and pediments had lost their functional purpose, they had become autonomous forms, part of a vocabulary of architecture which could be applied as a veneer onto the surface of buildings. While those forms were independent of technical considerations they metaphorically depicted their structural origin. Form thereby pertained to a strict system of rules for it had evolved into a grammatical structure within the language. The composition and arrangement of formal elements, however, often resulted from the free interpretation of the established grammar, allowing a playful manipulation of form. The decorative elements of the curved façade of Trajan's Markets, for example, were only partially true to their structural origin as established by the Greeks. The use of repetitive aediculae with segmentally curved pediments or half-pediments developed from an understanding of architecture as a decorative art in which the manipulation of form was fully subjective. Such deformations of the classical language was only possible as form had been divorced from technique and become exclusively decorative.

The concept of architectural form as applied ornament paralleled the understanding of form as resulted from technical innovation. Roman concrete made new methods of wall and roof construction possible. In place of a tradition in which the horizontals of ceiling and architrave were clearly displayed as resting upon the verticals of walls and columns, an entirely novel understanding of form evolved replacing the traditional structural verities by the logic of new constructional methods. The traditional Greek system, however, was not totally rejected but instead remained a constituent part of the formal language of architecture. Roman construction was primarily an architecture of walls and surfaces, whereas the vocabulary of referential forms to which it aspired pertained to a system of linear construction elements such as columns and architraves. With the superimposition of the two systems a new formal unity evolved which the Renaissance would later accept as a linguistic formula.

The Linguistic Model

Due in large part to the development of theory, the architecture of the Renaissance had become elevated from a mechanical to a liberal art. While building practice was inherently connected to technical considerations, the discipline of architecture predominantly became engaged in a formal discourse. Form was of primary consideration. Renaissance architecture had become an art in the modern sense that architecture was considered primarily an aesthetic discipline as opposed to a discipline conditioned by its means of production. The architect was considered an artist and designer. His work pertained to the creation of drawings by which buildings were represented. In designing the composition of plan and façade, the architect's aim was to attain perfection in the arrangement of formal elements. Priority was given to appearance and expression of built form rather than to the development of technical innovation, for aesthetics were hierarchically above procedures and methods of production. Construction, of which the architect was knowledgeable, was however not neglected. The art of building was a necessity of importance belonging to the activity of the craftsman. In that technique was respected. Yet the processes of production were placed at the service of formal expression, for it was considered that form pertained to the revelation of perfection and truth.

The concept of form had its origin in the Aristotelian understanding of creativity in terms of giving form to matter. *Matter* was regarded as whatever substance could be formed whereas *form* was originally seen as the manifestation of a concept or idea.[38] The term *form* thereby defined not only the visible shapes of objects but also included the understanding of form as pure idea. Such concepts in architecture did not remain purely abstract but were visually revealed by the signifying function of physical form. In other words, the conceptualization of form was made as a recognizable and meaningful representation. Architecture in this sense was essentially iconographic in nature for it visually disclosed the concepts and ideas inherent within form.[39]

38 See Aristotle, *Metaphysics*, Book VII.

39 See Dalibor Vesely, "Architecture and the conflict of Representation," *AA files*, Architectural Association (London), 1985, Number 8, pp. 21-22.

Throughout the fifteenth and sixteenth centuries the assumption was made that antiquity represented unity and perfection. By the seventeenth century classical architecture assumed the role of an "unquestioned and unquestionable model of excellence."[40] One of the crucial elements in the development of formal representation within Renaissance architecture was a tendency toward idealization. It was through idealization that visible representation moved closer to the conceptual ideas inherent within architectural forms. Those were to be found within the architectural vocabulary of the past which had originated from classical antiquity. The belief prevailed that antiquity had evolved from the "rude"[41] beginnings of early civilization; this culture had been perfected by the Greeks until it "reached its apogee in the art of imperial Rome."[42] Renaissance architects studied the buildings of antiquity from which the rules of architectural form were deduced. They attained an understanding of what John Summerson calls the Classical Language of Architecture.[43] Monuments of the Roman period such as the triumphal arches, the Pantheon, and the Colosseum were taken as evidence of the progressive development of architecture toward the idea of perfection. Those structures were carefully recorded in drawing and text as documented and published by Sebastiano Serlio (1475-1554) and a generation later by Giacomo Barozzi da Vignola (1507-1573) and Andrea Palladio (1508-1580). The representation of the forms of

40 Joseph Rykwert, "Classic and Neoclassic," *The First Moderns* , MIT Press (Cambridge, Massachusetts), 1980, p. 2.

41 Ibid., p. 3.

42 Ibid.

43 John Summerson, *The Classical Language of Architecture*, MIT Press (Cambridge, Massachusetts), 1963.

antiquity evolved as the guiding theme of architecture. This antique style, however, was to a considerable extent a product of Renaissance conceptualization. The repertoire of forms constituting the vocabulary of architecture was not exclusively a product of factual reality but was as much determined by the idealized image of history. During the Renaissance and succeeding centuries, this reference to history, whether based on extant remains or the interpretation of the past, developed as one of the primary sources of formal justification.

The fifteenth and sixteenth centuries were as much marked by the emergence of modern science as by the revival of Greek and Roman architecture. The rational systematization inherent within scientific thought had its influence on architectural theory. A conceptual framework gradually became established structuring the reference to historical form. Compositional and formal elements were considered constituent parts of a system of rules and principles encompassing the discipline of architecture which was regarded as a language. The forms of architecture were given as predetermined entities, part of a vocabulary which had historically evolved. Similarly, the rules and principles, according to which forms were arranged, determined the structure of formal compositions and were as much standardized as the forms themselves. The language of architecture disclosed a strict grammar which the architect followed in the process of design.

The analogy between architecture and language was until the middle of the sixteenth century less determined by an interest in rhetoric than by the significance of linguistic construction. This analytical approach as applied to the arts was clearly expressed by Alberti in his treatise *On Painting* in which he proposed that the structure of language could be considered a model of didactical significance for painting:

I should like youths who first come to painting to do as those are taught to write. We teach the latter by first separating all the forms of the letters which the ancients called elements. Then we teach the syllables, next we teach how to put together all the words. Our pupils ought to follow this rule in painting. [44]

Similarly, the structure of language was implied within the Renaissance understanding of the discipline of architecture. The differentiation between elements and the rules according to which those elements were put together, in contemporary linguistics the concepts of *morphology* and *syntax*, equally pertained to the Renaissance concept of architecture. This understanding of the construction of language as applied to architecture was of such significance that it remained the model of reference for the justification of formal composition up to the twentieth century. While the degree to which the analogy between language and architecture holds true may be questioned, and to what extent the notion of phonemes, morphemes and sentences can be transferred between linguistics and architecture, the importance lies in the possibility of an analytical approach to the system of architecture by understanding the system of language as a model of reference.

[44] L.B. Alberti, *Della pittura*, op. cit., p. 92.

Historically, the language of architecture evolved through a process of solving technical problems which required technical solutions. These solutions were standardized within the evolution of architectural history and became part of the grammar of the language, consisting of a vocabulary of prototypical parts such as column, wall, and beam. Also within the language were the rules and principles of assembly such as stacking, layering and framing, which acted to con-struct the basic elements into a whole. Building construction was considered the process, art, or manner of the arrangement and connection of parts or groups of parts into a whole. This definition is equivalent to the term *construction* in linguistics, meaning the arrangement and connection of words or group of words in a sentence. The arrangement of parts in the field of architectural construction led to standardized solution types which historically became established as prototypical forms and as linguistic formulae of canonical proposition. Although derived from technical considerations, architectural elements such as plinth, column, pilaster, entablature, and pediment were divorced from their technical function, and came to be understood as pure form. Yet, form was determined by the representation of its original condition which lay within the realm of building construction.

The vocabulary of standardized forms and the principles determining formal relationships in the Renaissance constituted the *a priori* components and rules of architectural composition. To such a system belonged the orders representing a formal unity of foremost importance. Vitruvius had described three of the orders: Ionic, Doric, and Corinthian, as well as briefly mentioning the Tuscan order. He, however, did not attempt to present them as a set of canonical formulae embodying all architectural virtue nor as what has later been considered their 'proper' sequence. Such systematization was to occur within the theoretical treatises of the Renaissance. It was not Alberti but Sebastiano Serlio who contributed to the strict categorization of architectural form. Alberti, although having added a fifth order, the Composite, generally remained in agreement with the proportion and appearance of the orders as presented by Vitruvian theory. Sebastiano Serlio, almost a century later, was the first to present the five orders as the primary components of the formal system of architecture. His five books of architecture, published between 1537-1547, to which a sixth book was added in 1551, were a contribution to the systematization of architectural form, for they represented the first fully illustrated architectural grammar of the Renaissance. Serlio opens the discussion on the orders in his fourth book with an illustration showing the five orders placed in linear sequence, each an independent entity yet together forming the complete set of the orders. The different orders in Serlio's woodcut were each elevated on a pedestal, their authority thereby further emphasized. This gesture of dramatic intention was supported by the accompanying text in which Serlio introduced the orders as characters are presented in a play:

In the beginning of this Booke, I observed the Comedians order, who (when they intend to play any Comedy) first send out a Prologue, who in few wordes giveth the audience to understand what they intend to entreat of, in their Comedie. So I, meaning

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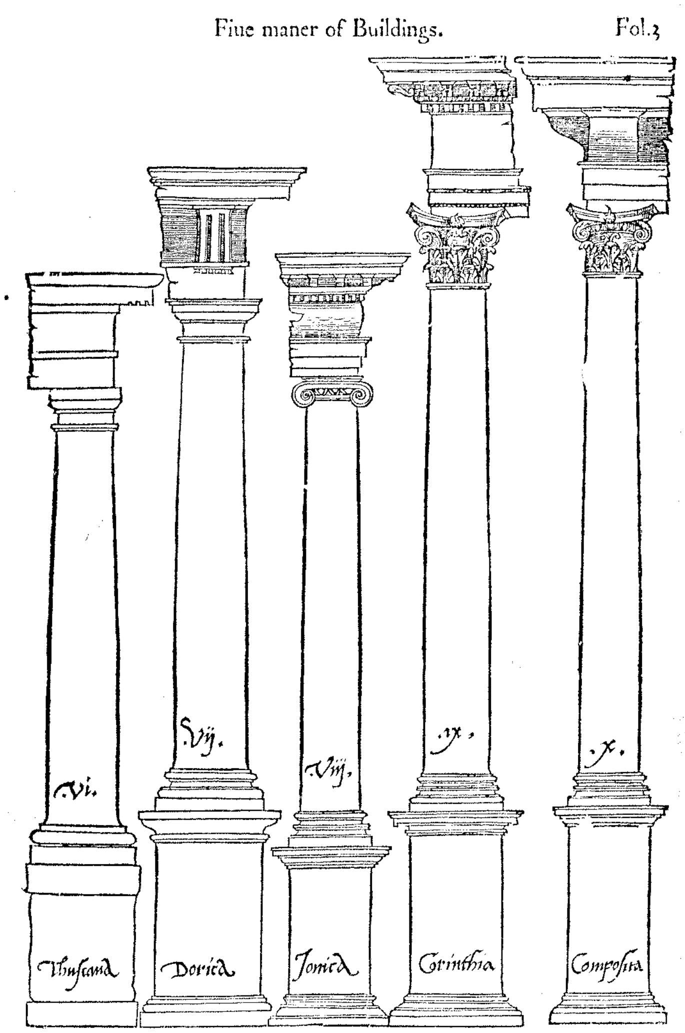

Sebastiano Serlio, woodcut of 1540 from *The Five Books of Architecture* showing the five orders as a complete and authoritative series.

in this Booke to entreat of due manner of Buildings, viz. Thuscan, Dorica, Ionica, Corinthia and Composita, have thought and, that in the beginning thereof, men should see the Figures of all the several kinds whereof I purpose to entreat of. And although that in the Columnes and their ornaments, all the measures and proportions are not set downe, but onely the principall, by generall rules; yet will I not fayle, as occasion shall serve, to let them downe in particularities: but this is done, as I sayde, to [have shown] *in generall rules for an Introduction onely, the better to be understood of every workeman, and in the beginning will observe Vitruvius order and termes marked on the sides with A, B, C, that every workeman may name them according to his country speech.*[45]

After having presented the orders as the principal characters in his treatise on architecture, Serlio revealed the didactic purpose of his book by addressing the workman of different countries, who "may name them [the orders] according to his country speech." The dissemination of the rules and principles of the discipline of architecture was to Serlio and authors such as Vignola and Palladio an intention of primary significance in their work. The language of architecture was considered universal, not limited to place and time. Primacy was given to the orders for they were regarded as the very touchstone of architecture embodying the wisdom of the ancients and truth in the building art. The authority of the orders was thus emphasized by being presented as a unity illustrated in one plate. This didactical gesture became the accepted standard for architectural treatises of succeeding centuries, for the

[45] Sebastiano Serlio, op. cit., Book IV, Fol. 3.

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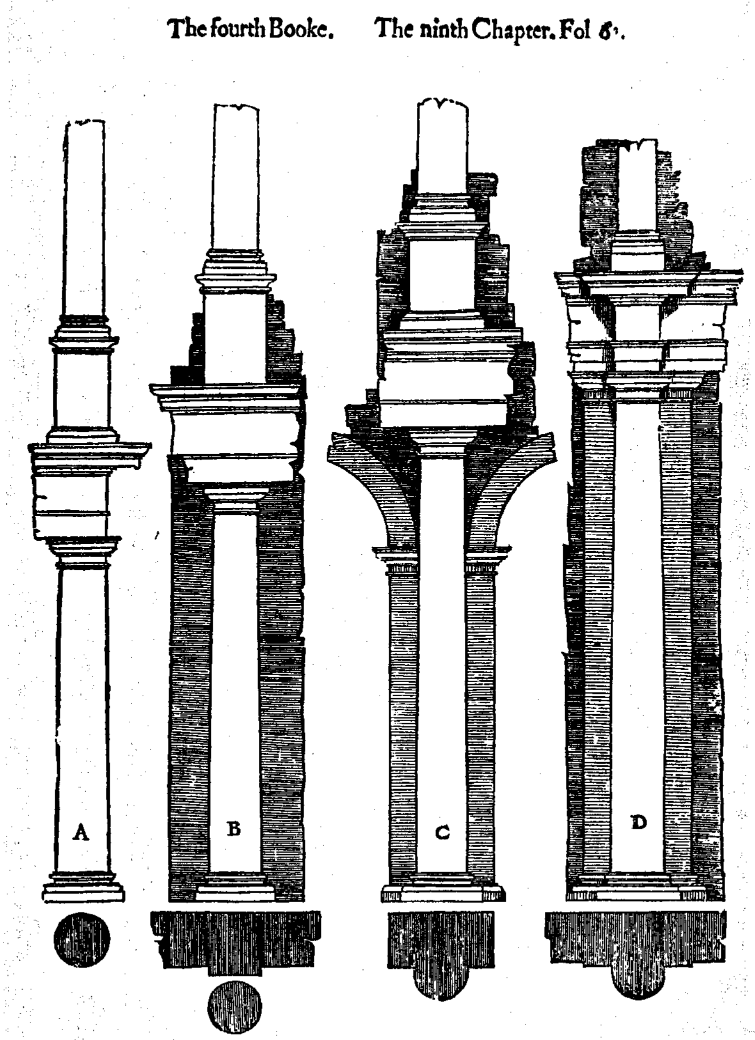

Sebastiano Serlio, "Of foure maner of Simmetries," plate from the *Five Books of Architecture*, Book IV, 1540.

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proper understanding and application of the orders became the foundation of architecture as an art.

Most seventeenth and eighteenth century textbooks of architecture open with a plate of the five orders arranged side by side: "Bloem in Switzerland, De Vries in Flanders, Dietterlin in Germany, Fréart and Perrault in France and, in England, Shute, Gibbs and Sir William Chambers."[46] Such treatises were the textbooks of architecture determining the theoretical framework of the field. While architecture in the Renaissance was understood to be essentially academic, architectural treatises provided the vocabulary of formal elements and the rules of composition which the architect was to apply in the design of buildings. Technical advice was periodically given, addressing questions of material and method, but the principal subject matter generally focused on formal considerations, for architecture as an art was involved primarily with the composition of form.

Each order constituted a strict composition of column and entablature, forming a grammatical expression within the language of architecture. Correspondingly an entire vocabulary of architectural forms were precisely identified as the arrangement of parts placed according to specific rules. Such formal entities constituted the component parts of a catalogue of architectural forms which were further arranged to form entire compositions. Serlio, for example, proposed four different positions of the column in relation to the wall, which he systematically described and illustrated under the

[46] Summerson, op. cit., p. 10.

heading "Of Foure Maner of Simmetries" in the fourth book of his treatise. Serlio regarded such rules as *a priori* formal constructions of architectural composition to be followed in the design of buildings:

The Workeman is to have a great judgement, because of the diversities of composition in Ornaments of buildings, for that there are some places in Architecture, of which there may, almost, certain rules be given, for they are no accidents that happen contrary to our opinions, for every day we see some Columnes, that with their different positions, [show] *different measures in themselves, according to the places where they stand. These alterations are so made in buildings in 4 ways, ...*[47]

The first of the four propositions is the load-bearing, free standing column. Next is the detached column standing in close proximity to the wall, the column remaining freestanding while the entablature may be connected to the wall. The third column is partially encased within the wall. And last in the sequence, the pilaster is shown with superimposed half-column. Each of the columns was drawn to be of a different height. As the load-bearing function of the column decreased from the first to the fourth type, conversely their height increased. Serlio's aesthetic judgement was in this directed by technical experience; the proportion resulting from the diameter of the column to its height was placed in relation to the weight that the column theoretically was to support. But when the column was of little structural importance, as in the fourth column

[47] Sebastiano Serlio, op. cit., Book IV, Fol. 63.

type, the argument was primarily aesthetic rather than technical. Similar in logic was the justification of the pilaster which Serlio described as supporting the entablature in the fourth drawing. Pilasters, formally determined by the representation of columns or reinforcing piers, were elements of architectural compositions and had generally no or very little structural purpose.

The form of such architectural elements as well as the rules of composition according to which they were arranged were derived from the idealized image of methods and materials of construction not necessarily coinciding with the reality of building practice. Thus, the iconographic vocabulary of architecture was based on the depiction of the forms as well as the logic of ancient building construction from which the laws of composition were derived. The combination of the arcuated and trabeated systems as observed in the façade of the Roman Colosseum, for example, evolved during the Renaissance to a distinctive motif of stylistic expression. Vignola and Palladio presented by means of precise engravings various combinations of the arch with the orders as formal unities. These were grammatical constructions in which the interdependence of the different elements allowed that no dimension could be altered without affecting the entire composition. The orders and the arch, while originally having evolved through the exigencies of construction, had become formal entities. Parallel development occurred with other stylistic elements, such as the triumphal arch motif which Alberti borrowed for the façade and interiors of S. Andrea in Mantua. Also, the *Venitian Window*, a triple opening in which the central arch was supported by the entablature of adjacent columns, constituted a compositional entity, that being the formal arrangement derived from the interior elevation of the Roman Pantheon used by Brunelleschi in the façade of the Pazzi Chapel. From this evolved the *Motif Palladio*,[48] a name given by the French to the combination of arch and columns framed by a superior order, as proposed by Serlio in his treatise[49] and later applied by Palladio to his façade of the Basilica in Vicenza.[50]

Architectural form did not result from the subjective will of the designer but was instead determined by an aesthetic canon which had been culturally established. The discipline of architecture was thus based on an understanding of form that was inherently objective. The language of architecture was strictly determined by formal and compositional rules which were to be applied by the architect in the design of buildings.

Form and Composition as the Foundation of Theory

The linguistic structure of the discipline evolved during the High Renaissance as the primary framework of architectural theory. Formal elements and compositional principles were integrated within a theoretical system which was considered the foundation of design. Building practice was hereby subordinated

48 Emil Kaufmann describes the façade of the Pazzi Chapel as "the true precursor of the pattern which later became famous as the Palladian motif." Emil Kaufmann, "The Renaissance-Baroque System," in *Architecture in the Age of Reason*, Harvard University Press (Cambridge Massachusetts), 1955; Dover Publications (New York), 1968, p. 80.

49 Sebastiano Serlio, op. cit., Book IV, Fol. 29.

50 The formal arrangement of the Palladian or Serlian motif consists of an opening where an arch stands over columns whose entablatures are the lintels of narrower side openings. In Palladio's Basilica this triple opening is framed in the bays formed by a superior order and it is to this formal entity that the term Palladian motif is confined. See Summerson's description of the *Venetian Window* as compared to the Palladian motif; op. cit., p. 52.

to theory allowing the dominance of form over technical considerations. Such interest in academic discourse received an unprecedented level of development with Andrea Palladio's contributions to the field.

The architectural treatises of the Late Renaissance such as Vignola's *Regola delli Cinque Ordini d'Architettura* and Palladio's *Quattro Libri* assume an unprecedented clarity in the description of formal elements surpassing Serlio's relatively rough drawings in accuracy and quality. The only published drawings of Roman ruins where those of Serlio which must have seemed to Palladio, as he visited Rome, to be of inadequate precision. Refinement of profile and proportion, considered the essence of the antique, was one of the primary characteristics of Palladio's approach to the forms of architecture. Formal elements were drawn with great care following exact measurements and geometric rule. This realism and scientific precision in recording the architectural forms of the past was clearly described in the preface to his treatise: "... I set myself to search into the reliques of all the antient edifices, ... I began very minutely with the utmost diligence to measure every one of their parts; of which I grew at last so sollicitous an examiner, ... that I might entirely, from them, comprehend what the whole had been, and reduce it into design."[51] To "reduce" the forms of the ancients "into design" meant for Palladio not the direct representation of facts but instead the search for prototypical and essential form. Perfection did not lie in archaeological accuracy but in the precision of the drawing or design representing the form in

[51] Andrea Palladio, op. cit., "The Author's Preface to the Reader."

its ideal and reduced state, which was then considered universal: "I therefore hope, that the manner of building may with universal utility be reduced, and soon brought to that pitch of perfection, which in all the arts is greatly desired, ..."[52] The conviction that a universally applicable vocabulary of architectural forms was both desirable and possible was fundamental to Palladio's approach to architecture. Beauty, according to Palladian theory, was therefore not only rooted in historical correctness but included most importantly the concept of idealized form, which was as such to be manifested in design.

For Palladio and his contemporaries the foundation of the fine arts was the design (*disegno*), which represented the abstract idea of the object that was to be created. Designing was an activity pertaining to the intellect, for the drawing made by the architect reflected the perfect form or design existing in his mind. This theoretical assumption is founded on Plato's concept of Ideas characterized by a fundamental dualism between intelligible and sensible objects. Forms or ideas, according to Platonic thought, were transcendent universals, constituting true reality as opposed to the base existence of particular material objects. Palladio's primary interest in prototypical forms and rules of composition adhered to the philosophical propositions of Platonism. A close reading of the *Quattro Libri*, furthermore, reveals Palladio's familiarity with Aristotelian philosophy. His logical and deductive method of approach as well as the belief in the primacy of thought over action exhibit Aristotelian characteristics. Most importantly,

[52] Ibid.

Palladio's approach to historical forms, which he represented in idealized types, clearly reflected an adherence to Aristotle's doctrine of imitation, declared in the *Poetics* to be the supreme principle in the arts. *Mimesis* within art was not the direct representation of factual reality but instead the process of unfolding the general, typical, and essential characteristics within represented form. Both the Aristotelian theory of imitative art and the Platonic argument of the knowledge of ideal forms found great support within the northern Italian *intelligenzia*.[53]

The reference to a philosophical body of knowledge was only possible during the High Renaissance in that architecture was considered a theoretical discipline addressing "the universal and necessary rules of art."[54] The architect was regarded as a scholar, his search for perfect form in architecture was no longer derived from technical considerations, as originally implied by art production, but instead increasingly from academic discourse.

Palladio's career as an architect and author of historical and theoretical writings can be seen as symptomatic of the changing concept of art during the Renaissance. As a young man he had

53 Platonic and Aristotelian philosophies were integral to Daniele Barbaro's understanding of architecture which was familiar to Palladio through Barbaro's Vitruvian commentaries. As stated by Rudolf Wittkower, Palladio's work represented for Barbaro the physical manifestation of his philosophical position. See Rudolf Wittkower, *Architectural Principles in the Age of Humanism* (1949), W.W. Norton (New York) 1971, pp. 66-69.

54 "*And although variety and things new may please every one, yet they ought not to be done contrary to the precepts of art, and contrary to that which reason dictates; whence one sees, that although the ancients did vary, yet they never departed from some universal and necessary rules of art, as shall be seen in my book of antiquities.* " Andrea Palladio, op. cit., Book I, chap. XX, "Of Abuses."

learned the craft of building, initially as a stonecutter's apprentice in Padua and later in Vicenza as an assistant in the workshop of a local plasterer, stonemason, and carver.[55] At that time he joined the guild of Bricklayers and Stonemasons, an act illustrating his relationship to the organization of trades which constituted the system of productive forces within society as had originated from the medieval period. Palladio's exposure to the rudiments of building and his formation as an artisan and craftsman marked his early professional life which received an unexpected turn when at the age of 30 he was introduced by Count Giangiorgio Trissino to the ideas of the humanist circles. Trissino belonged to the *intelligenzia* of Vicenza; he was distinguished for his humanistic studies advocating, as Wittkower described it, "a formal, esoteric and dogmatic classicism, free from any popular tendencies."[56] Trissino's Villa at Cricoli was built to realize his dream of creating a learned academy, the 'Accademia Trissiniana' as it was later called. Young men of aristocratic families frequented Trissino's Academy, and though Palladio was not of noble birth he was introduced to the life at Cricoli. Trissino gave him the classical name *Palladio* whose association with the wisdom of Palas Athene indicated his elevated status.[57] Such reference to antiquity guided the program of the academy which adhered to the Renaissance ideal of education as based on classical scholarship. Palladio's exposure to humanist circles, where he became acquainted with the writings of Vitruvius and the monuments of antiquity, had a formative influence on his

[55] Lionello Puppi, *Andrea Palladio*, Electa Editrice (Milan), 1973, pp. 5-8.

[56] Rudolf Wittkower, op. cit., p. 58.

[57] James S. Ackerman, *Palladio*, Penguin Books (New York), 1966, p. 20.

approach to architecture. His understanding of the art of building was from then on determined by an interest in classical studies and theory from which he derived the vocabulary and principles of architecture. Palladio became a humanist himself; his career was marked by the change of status from a craftsman involved with practical matters to a scholar engaged in intellectual discourse.

The twofold aspect of Palladio's professional life was founded on entirely different educational systems from which he had received his formation. His early education was based on the traditional apprentice and master system where learning occurred within the working conditions of the workshop or atelier, i.e. places of production in which questions of practical concern were constantly raised. The other type of education for Palladio was the academy in which students trained in philosophy, in the art of holding an argument, and in rhetoric were exposed to a theoretical body of knowledge. In the succeeding centuries academies would not be limited to educational pursuits but would evolve as professional organizations of significant power.[58] Trissino's academy to which Palladio had been exposed thus represented not an isolated occurrence. The creation of such academies resulted form the cultural awareness to structure and institute the

58 See Nikolaus Pevsner, *Academies of Art, Past and Present*, Cambridge University Press (London), 1940.

intellectual forces within society.[59] Eventually, Palladio himself became a promoter of an academic institution in 1555 when the *Accademia Olimpica* was founded in Vicenza. The academy there was constituted by a group of twenty-one local intellectuals in which Palladio was the only architect included.[60] Palladio's career thus represented the changing role of the architect from a master craftsman to an intellectual involved in academic discourse.

Academies specifically addressing art and architecture began in the sixteenth century. The first, the *Accademia del Disegno*, was founded in Florence in 1563 by Giorgio Vasari.[61] Palladio became a member of the Academy of Design in 1566. Its program was to institutionalize the professional and academic tasks of the architects, painters, and sculptors of the time. Artists had been previously organized into guilds which controlled the rules and working conditions of the individual trades. With the emergence of academies of architecture in the sixteenth and seventeenth century, such as the French *Académie d' Architecture* founded in 1671, the role of the architect changed. The process of building construction was no longer

59 The term *academy* originated from the name of a mythical hero called *Academus* who owned a garden near Athens. That the word was later associated with teaching is due to Plato who held his school in Academus's garden. *Academy* later came to be applied to the followers of Plato's philosophy and was eventually used to identify groups of intellectuals engaged in scholarly activity. The revival of Platonism during the fifteenth century lead to the creation of Lorenzo de' Medici's Platonic Academy in the 1470s. Starting as an informal philosophical discussion group, it became an official institution, an academy in the modern sense, and the model for literary, scientific, and artistic societies which were to spread all over Europe. Joseph Rykwert, op. cit., pp.14, 15.

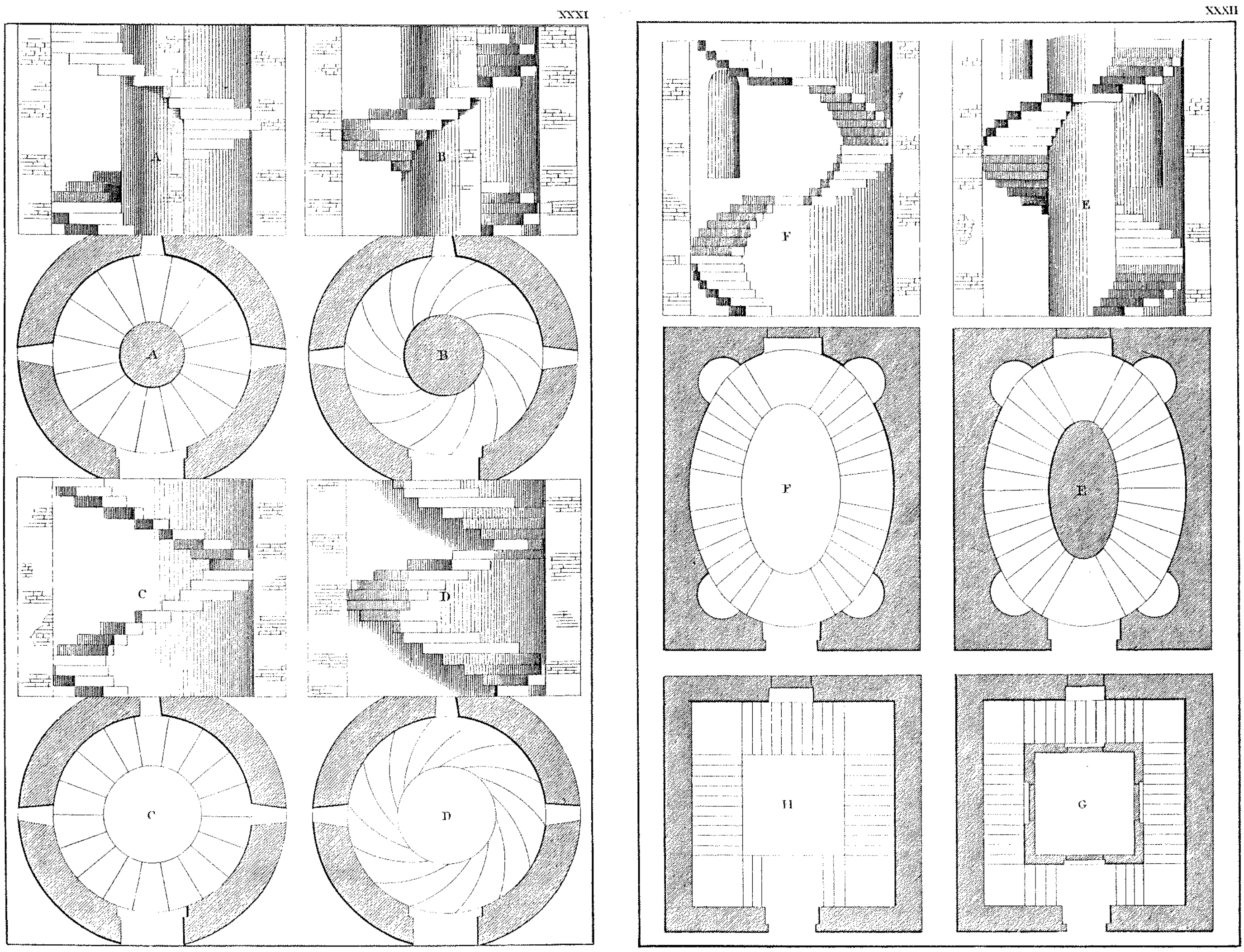
60 James S. Ackerman, op. cit., p. 31.

61 Giorgio Vasari, *The Lives of the Most Excellent Painters, Sculptors, and Architects*, translated by George Bull, Penguin Books (New York), 1965, pp. 440, 441.

part of the architect's duty as he now belonged to a professional elite involved with the formulation of a body of theory. Academic discourse provided the structure for form and composition which constituted the primary subject matter of architecture.

Technique and the Rhetoric of Form

The development of Palladio's career is indicative of the changing understanding of art in so far as he represented the change of influence between the traditional guilds and the new academies. A thread of continuity between both phases of his professional life can be established. Any attempt, however, to trace a unity of thought between practice and theory in Palladio's work must be questioned as the periods within which he worked as an artisan and then as an architect posed separate problems and tasks, each clearly demarcated from the other. His writings proposed a theory of architectural form and not a theory of building production. While technical considerations were accounted for in the *Quattro Libri*, particularly in the First Book's description of building materials and techniques, no theoretical framework was attempted by which to structure the field of architectural construction. Palladio's writings remained within the tradition of technical treatises addressing building practice as a body of precepts and common rules, thus propagating a traditional understanding of architectural technology. The approach to construction was not guided by the formulation of theoretical principles as emerged within other



Andrea Palladio, "Of stairs, and the various kinds of them; and of the number and size of steps," *The Four Books of Architecture*.

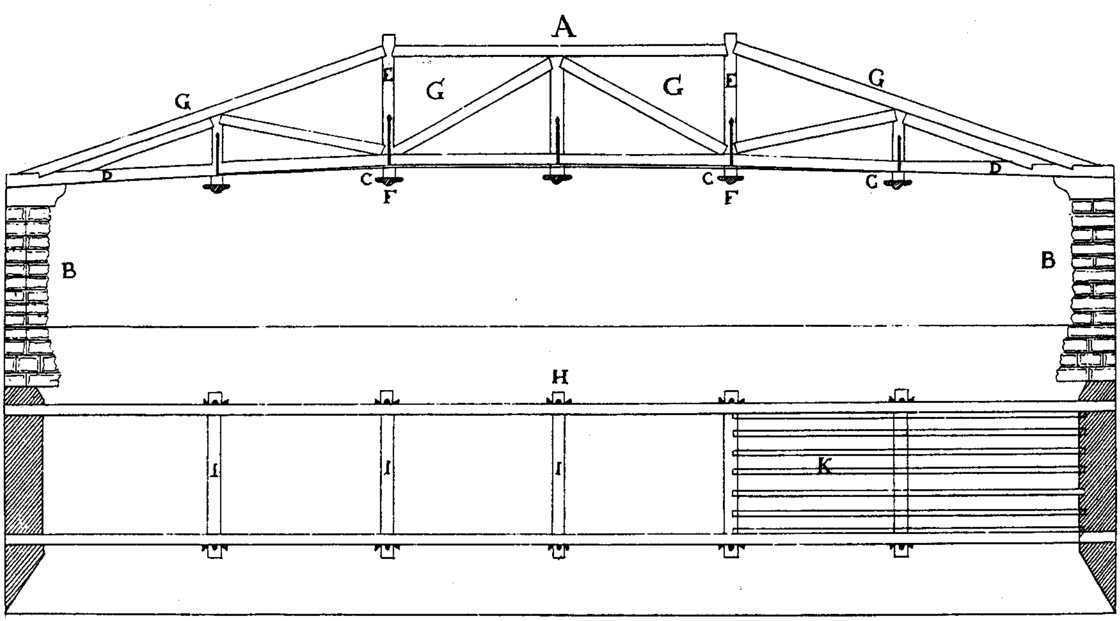
fields, as, for example, Guidobaldo del Monte[62] and Galileo[63] proposed for the field of mechanics. On the contrary, Palladio's theoretical principles addressed primarily formal and compositional matters, thus maintaining the understanding of technique as a practical means for achieving specific and predetermined forms.

Palladio's contribution lay in his academic approach to architectural form. Logical and deductive reasoning were applied to formal and compositional considerations enabling the formulation of prototypical form and principles of composition. As these were deduced from historical analysis and "reduced" into design, architecture resulted from the search for the essential and universal. The *Four Books* reveal Palladio's methodology in the presentation of form as pure type, often presented within typological sequences. Chapters on the orders, following the example previously set by Serlio, were clearly structured; each column type was represented in four plates, the first showing the free standing column, the second the column superimposed with the arch, followed by two detail drawings of the column base on a pedestal and the capital with entablature. Also didactically organized were forms of stair design, shown with circular, oval, and square plans, alphabetically ordered and drawn as a catalogue of standardized solution types.[64] Similarly, Palladio's own designs of private

62 Guidobaldo del Monte, a contemporary of Palladio, published a work on mechanics in 1577 in which he approached the theory of simple forces by means of general principles applied successfully to hoisting apparatus. See Guidobaldo del Monte, *Mechanicorum*, (Pesaro, 1577); Daniel Mögling *Mechanische Kunstkammer*, (Frankfurt, 1679).

63 Galileo Galilei, *Le mecaniche*, written 1593; *Galilei, le opere*, Vol. 12, (Florence, 1891), p. 147 ff.

64 Andrea Palladio, op. cit., Book I, chap. XXVII, pp. 34-35.



Andrea Palladio, Bridge of Cismone, from
The Four Books of Architecture.

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houses were presented to the reader as a typological sequence from which Wittkower was able deduce the systematization of the ground-plan typical of Palladian villas.[65] Palladio's methodological approach to architecture exhibited scientific traits; his theoretical contribution, however, did not pertain to the exposition of natural law as applied to the principles of construction but instead to the revelation of universal rule of architectural form and composition.

An analysis of Palladio's built work reveals a similar relationship between form and technique. Both, theory and building practice were considered to be of importance; architectural form, however, was rarely determined by the possibilities of materials and methods of production. The exigencies of construction were subservient to the forms and rules of architectural composition, the former being in the service of the latter. Yet the idea of revealing the tectonic quality of materials and methods was a concept not unfamiliar to Palladio. The several designs for bridges in the *Quattro Libri* and the executed project for a covered wooden bridge over the Brent (1569) disclose a different attitude toward construction than is to be found in his approach to architecture. The projects for wooden bridges show a rigorous functionalism in the understanding of structure in which the different members were clearly expressed as being derived from technical considerations. The texts accompanying the plates in his treatise, furthermore, indicate an analytic awareness of structural properties. Without quantitative verification of static performance, as those had yet not been developed,

[65] Rudolf Wittkower, op. cit., pp.70-73.

Palladio was able to address the principles of configuration and load distribution inherent to his designs.[66] With exception of those few bridges in which formal expression followed functional necessity, the aspect of construction in architecture was not considered the primary determinant of form. Technique remained secondary whereas priority was given to the expression of the classical vocabulary of architectural form.

The understanding of architecture as a formal language was most visibly apparent in the composition of façades, for the two-dimensional quality of a wall surface allowed the direct application of formal elements. These elements were most commonly derived from the repertoire of architectural forms and their respective rules of composition, irrespective of technical or functional considerations. The classical temple front, a formal element associated with "grandeur and magnificence,"[67] was invariably integrated into the façade designs of private villas, thus disclosing Palladio's interest in the free adaptation of prototypical form.[68] As such reference to sacred architecture allowed him to ennoble domestic buildings, this transfer of form from one type of building to another reveals a clear conception of architectural

66 Palladio for example described how the loads carried by the bridge could contribute to the structural stability of the entire structure: *all the parts are supported the one by the other; and their nature is such, that the greater the weight upon the bridge, so much more they bind together, and increase the strength of the work.* Andrea Palladio, op. cit., Book III, chap. VII, pp. 65.

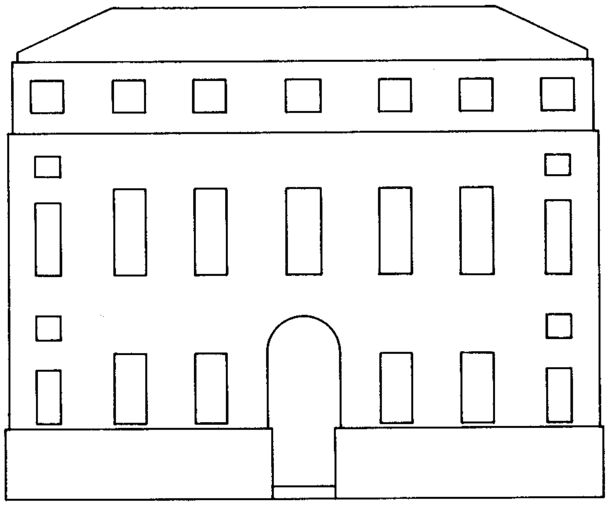
67 Andrea Palladio, op. cit., Book II, chap. XVI, p. 53.

68 See Rudolf Wittkower's discussion on Palladio's use of the temple front as an element of formal composition in the design of private houses; op. cit., pp. 74-76.

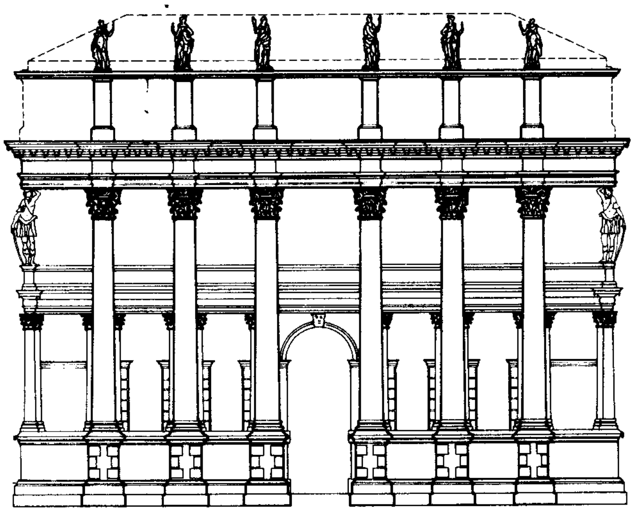
composition in which "ready-made units"[69] could freely be applied. The temple front, according to Palladio, had evolved in antiquity from the private house. The assumption can then be made that the form of the pediment was believed to have been derived from typical roof construction. The use of the classical portico for private buildings seemed therefore to be legitimate as it had originated from ancient building practice. For Palladio the temple front constituted a prototypical form in its pure state and could be universally applied. He was one of the first architects, as asserted by Wittkower, "to graft the temple front on to the wall of the house."[70] With such formal transpositions, the concept of the *motif* in architecture acquired an unprecedented vitality. Façade composition evolved as the academic exercise *par excellence* allowing the designer an artistic liberty in the arrangement of stylistic elements, anticipating the compositional freedom of the Late Renaissance and Baroque period. As a matter of fact, such artistic liberties were taken by Palladio toward the end of his career.

The façade of the Palazzo Valmarana in Vicenza (1565-66), exemplifies the free arrangement of form and reinterpretation of compositional rules characteristic of Palladio's late work. Most importantly this work reveals the relation between technique and form inherent within Palladio's architecture. The design of the building's front is an elaborate composition of a highly developed vocabulary of formal elements. The superimposition of giant orders, smaller Corinthian pilasters,

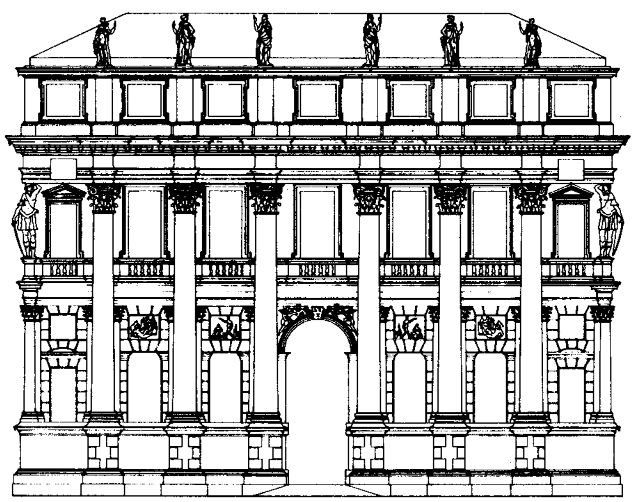
69 Ibid., p. 75.
70 Ibid.



REAL STRUCTURE



APPLIED STRUCTURE



Andrea Palladio, façade of the
Palazzo Valmarana, Vicenza, 1565-66.
Real and *implied* structure.

caryatides, and rustication constitute an independent decorative system that is applied onto the surface of the load bearing wall of the street façade. These formal elements are traditionally derivative of the means of construction, signifying structure without having *de facto* any technical function. Real and implied constructional elements contribute to a formal unity. The rustication, while depicting the courses of stone blocks, emphasize the wall-quality of the façade; the giant orders, which appear to support a continuous entablature, imply a structural framework thereby contributing to the visual lightness of the wall.[71]

Both rustication and pilasters, to name two examples, had been stylized and systematized within the language of architecture and were as such applied in the composition of façades. As the word *rustication* implies, it was initially conceived as a way of laying rough stones in which each particular stone retained some of the individuality it had when hewn from the quarry. This roughness was recognized as a element of formal and artistic expression indicating a rustic quality. Serlio had proposed in a plate of his Fourth Book different possible formal articulations of rusticated walls, thus emphasizing the highly stylized quality of *rustication* as a formal element. Similarly the process of formalization pertained to the development of the giant order. It derived from the structural column as transformed into a flattened pilaster and later

71 James Ackerman, op. cit., pp. 109-112; see also Lionello Puppi, op. cit., pp. 369-371.

modified by such as Alberti[72] and Michelangelo[73] into an element of double story height without any load bearing purpose. Most formal elements in architecture whether pilaster, rusticated wall, pediment, or keystone were derivative of construction. Similarly, rules of composition were determined by the arrangement of parts placed in accordance with original building assemblies, forming the base for aesthetic formulation. Palladio's treatise, for example, gave elaborate directions for the disposition of the orders in a façade, so "that the most solid may be placed undermost, as being the most proper to sustain the weight, and to give the whole edifice a more firm foundation."[74] As production methods were replaced by newer processes of construction, the unchanged forms represented signs of previous techniques. Theory in architecture primarily addressed form as the representation of practice at a conceptual level while simultaneously disregarding the physical and material aspect of building production. Such a seemingly paradoxical condition constituting the representational structure of architecture was founded on the Platonic and Aristotelian doctrines of imitative art in search of the essential idea inherent within objects. As formal elements conceptually addressed the realm of building construction, the manifestation of idealized form was indicative of an understanding of theory as the transcending of practice. Ideal architectural form remained connotative of

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72 The use of giant pilasters in Alberti's façade of S. Andrea at Mantua was derived from the arrangement of columns typical of Roman triumphal arches.

73 Michelangelo was the first to combine giant Corinthian pilasters with a smaller Ionic order in the façades of the twin palaces on the Capitoline Hill.

74 Andrea Palladio, op. cit., Book I, chap. XII, p. 11.

technique from which it had originated while built form typically disregarded the properties of material and the current methods of construction.

A twofold and contradictory understanding of technique resulted within the architectural system of the Renaissance and Baroque eras. On the one hand technique adhered to the essential idea of idealized form as its conception had originally been determined by the exigencies of ancient construction. The concept of making as an art of production, or *ars fabricandi*, of the craftsmen, on the other hand, defined technique as a purely instrumental means for the construction of building. The former definition evolved within the understanding of architecture as an imitative art for which technique constituted a referential sign, while the latter concept of technique was considered a rudiment of architecture in so far of importance as necessitated for the realization of form.

The dichotomy between theory and practice is most visibly apparent in Palladio's built work in which the supremacy of design over construction is clearly expressed. Although the wall of the Palazzo Valmarana seems to be almost eliminated as a result of the superimposition of architectural motifs, technically the wall is of load bearing function. The absence of *truthful* construction is further emphasized by a metaphorical use of materials. Plaster and brick out of which the wall above the pedestals is made was formed in imitation of stone.[75] Structural walls of this kind were composite constructions, a technique originating from Roman building practice. Walls were faced with brick while their core was filled with rubble and mortar. If compared to Roman concrete, however, the type of cement commonly used during the Renaissance was technically inferior. The structural properties of the wall were largely due to the load bearing quality of the brick layers which in turn were additionally reinforced by stone piers and lintels around openings and at corners. The brick and stone were not revealed as a visual demarkation of the construction; on the contrary, walls were covered with stucco allowing an independent treatment of this exterior layer for compositional purposes. The formal components of façades were thus treated as part of an autonomous system disregarding the tectonic quality of the construction.[76] At the most extreme, compositional intentions contradicted the structure, as was clearly exemplified by Palladio in the façade of the

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75 See William J. Anderson's critique of Palladio's and Michelangelo's disregard of material properties in the construction of their buildings. William J. Anderson, *The Architecture of the Renaissance in Italy*, first edition 1896, Batsford (London), 1909, pp. 148-153.

76 Professor Howard Burns, Harvard University, directed my attention to a document on the *Duomo* of Brescia, dated March 1567, in which Palladio's understanding of building construction is clearly stated. "*Quanto sia circa la materia di fare li detti pilastri et cornici, la mia opinione saria che le M.V. nella chiesa di dentro facessero i pilastri della nave grande et delle navi picciole di pietra viva, quanto si può arrivare con le mani, et il resto di pietra cotta, eccetto che la parte di sopra della cornice, perchè vorrei che anche quella fosse di pietra viva, et così le consiglio a fare, perciochè tutto quello che sarà di pietra cotta si copriria poi di stucco che accompagnerà et unirà benissimo uno con l'altro, ... Quanto poi a fare i pilastri, volti et altre parti di pietra cotta nè anco questa è cosa nuova, anzi usitatissima dagli antichi, et più durabile che la pietra viva, onde si vede le fabbriche antiche di pietra cotta si veggono più intere che quelle di pietra viva, ... Medesimamente in Mantova S. Pietro, S. Barbara, S. Benedetto sono tutte di pietra cotta, et adesso in Venetia si fabrica pur della medesima pietra cotta la chiesa di S. Giorgio Maggiore, la quale fabbrica io governo, et spero conseguirne qualche onore, perciochè le fabriche si stimano più per la forma che per la materia.*" See Giangiorgio Zorzi, *Le chiese e i ponti di Andrea Palladio*, Neri Pozza Editore, 1967, p. 89.

Pallazzo Valmarana. The articulation of the end bays, where the giant order is replaced by a small Corinthian pilaster supporting a caryatide figure, creates a disquieting effect in weakening the corners at a point where greatest strength was required, as criticized by Tommaso Temanza in the 18th century.[77]

Formal manipulations which exhibited a deliberate break with established classical conventions occurred within the work of the Mannerist architect Giulio Romano (c.1492-1546) and later evolved as elements of artistic expression in Palladio's and Michelangelo's architecture. Giulio Romano's Palazzo del Té in Mantua (1526-35) reveals in the articulation of the courtyard façade a rhetorical use of architectural form, an attitude representing a critique to the strict rules of purist composition. His vocabulary not only disregarded the tectonic structure of the brick walls from which the Palazzo is primarily constructed but also challenged form and composition in their reference to technique as representational sign. While traditional architectural form and compositional rules adhered to the construction methods from which they had originally been formed, Giulio Romano broke with such tradition thereby contradicting the principles of architectural grammar as they had culturally evolved. The window frames of the courtyard façade in the Palazzo Té are crowned with unique triangular pediments, set on top of rusticated keystones; at regular intervals the Doric triglyphs of the entablature appear to have slipped thus dislocating the central stone of the architrave;

[77] See Wittkowers reference to Tommaso Temanza's critique which he expressed in *Vita di Andrea Palladio*, Venice, 1762; Wittkower, op. cit., p. 85.

the niches of the smaller bays have keystones which are grotesquely overscaled, while the keystone of the center arch seems absurdly small; and the various forms of rusticated patterns are irregularly applied, periodically exposing the flatness of the wall surface. Giulio Romano's approach disclosed an inherently different understanding of architectural composition in which formal elements were allowed to be fully transformed. He thereby questioned the concept of imitative art which he sought to substitute with the freedom of artistic invention. Formal manipulations resulted from the subjective will of the designer rather than adhering to the accepted canon of architecture considered to be objective.

Antiquity remained the primary model of reference during the late sixteenth century. The representation of form, however, was not contrived from strict imitation but began to allow imagination and invention to contribute to design. The term *imitatio* was gradually being replaced, not by *creatio* - originally belonging to theology, but by *inventio*.[78] A similar redefinition of artistic creativity occurred also in other fields as for example in the art of poetry. The French poet Pierre de Ronsard (1524-85) offered a compromise to the dichotomy between tradition and innovation in combining *imiter et inventer*, proposing that in poetry one ought to imitate and invent. A more extreme position was held by G.P. Capriano who asserted in *Della vera poetica* (1555) that poetry was an invention out of nothing.[79] Gian Lorenzo Bernini almost a

78 See W. Tatarkiewicz's discussion on imitation and invention in "Mimesis," *Dictionary of the History of Ideas*, edited by Philip P. Wiener, Charles Scribner's Sons (New York), 1973, Vol. III, pp. 228, 229.

79 Ibid.

century later adopted this same concept for the art of painting when he said that "painting shows that which does not exist."[80] Since painting, according to Bernini, revealed "that which does not exist", the artist's work pertained to the realm of the imagination and invention rather than to imitation. One of the few architectural documents of the Cinquecento which specifically stated that *invenzione* belonged to the province of the artist had been written by Bartolomeo Ammanati (1511-1592). In an open letter which he addressed in 1582 to the Accademici del Disegno, the Academy founded by Vasari in 1563, he declared that solely the artist could assume responsibility for his inventions.[81] Creativity and invention were described as particularities of the artist's work of which he was to be responsible. To include the possibilities of artistic invention within design meant for the artist-architect a new liberating freedom which without doubt became manifest in the work of Michelangelo and later reached an unprecedented development within the Baroque era.

The subjective approach to architecture as an art form was most strongly manifested in the transformation of architectural motifs applied as ornament and decoration onto the surface of buildings. Similarly technical matters were addressed in reference to the possibilities of artistic expression. Vasary published in 1550 his famous *Lives of the Artists* in which he prefixed an introduction pertaining to what he considered the

80 F. Baldinucci, *Vita di Bernini*, 1st ed. 1682; 1948 ed., p. 146.

81 Peter Murray, *Architecture of the Renaissance* , Electa Editrice (Milan), 1971, p. 244. Ammanati wrote: "*We know that most of the people who give commissions do not provide any inventions, but leave things to our judgement, ... and when we do meet with a patron who asks for things which are shameful or obscene, we ought not to obey him.*"

primary arts of design, i.e. architecture, sculpture and painting.[82] Repeatedly in the text of the *Lives* Vasari referred to the introduction as the *parte teorica* or *capitoli delle teoriche*.[83] In fact the introduction is only to a small extent theoretical as only a few remarks are made on the general character of the arts and their aesthetic principles. The chapters of the introduction instead focus on technical aspects of art and contain practical directions about materials and processes. Vasari's descriptions of architectural techniques, however, do not attempt to address the methods of construction required for the erection of structures but are restricted to those means which adhere to the beautification of buildings:

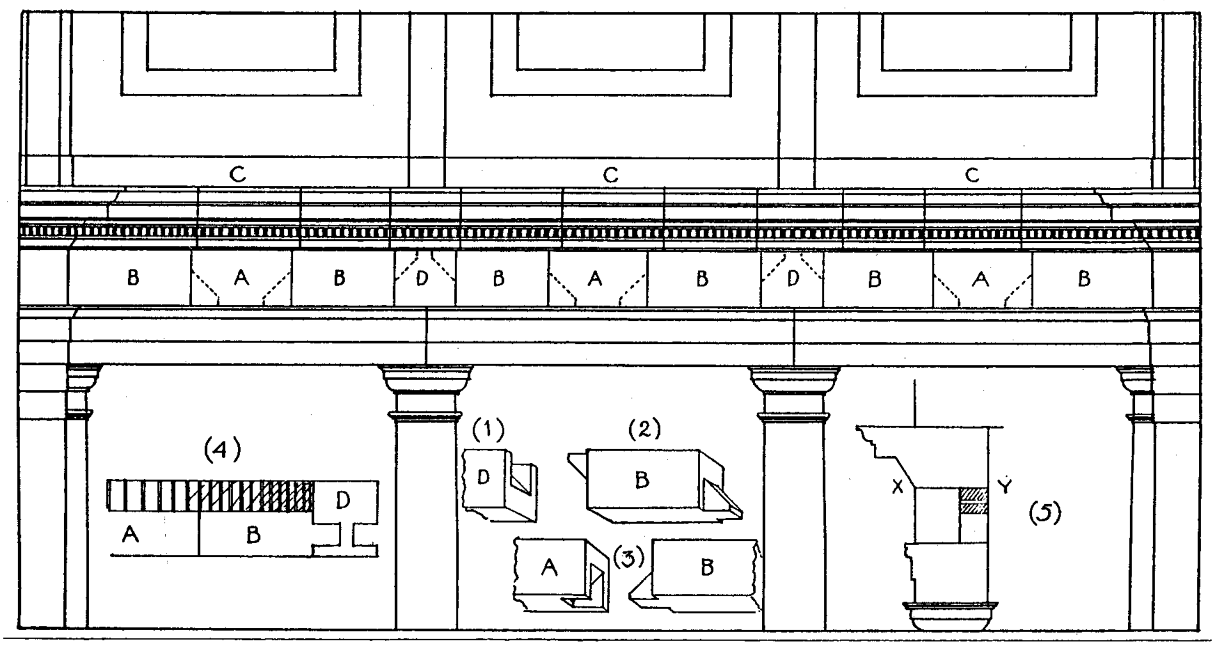
... leaving on one side ... the mode of preparing the foundations, as well as everything else that is used in building; disregarding also questions of water and localities and sites, ..., I shall only discuss, for the use of our artificers and for whoever likes to know, the essential qualities of buildings, and in what proportions they should be put together and of what parts composed in order to obtain that graceful beauty that is desired .[84]

Although Vasari was an architect involved with major projects such as the transformation of the Palazzo Vecchio in

[82] The introduction to the *Lives* was first translated into English and published in 1907. See *Vasari on Technique being the Introduction to the three Arts of Design, Architecture, Sculpture and Painting, prefixed to the Lives of the most Excellent Painters, Sculptors and Architects*, translated by Louisa S. Maclehose, edited by G. Baldwin Brown (London), 1907; Dover Publications (New York), 1960.

[83] Ibid., "Introductory Essay," p. 1.

[84] Ibid., "Of Architecture," pp. 26, 27.



Construction of the portico of the Uffizi
according to Giorgio Vasari's description, 1560-1580.
From *Vasari on Technique*, 1907.

Florence (1555) and the construction of the Uffizi (1560-80), his understanding of "the essential qualities of buildings" was primarily directed by an interest in profile and ornament. The techniques presented to the reader in the introduction to the *Lives* pertain to methods, skills, and resources required for the manufacturing of decorative parts. The discussion on materials consists of the presentation of valuable stones, such as porphyry, serpentine, granite, marble, and slate which "the artificers use for ornament or for sculpture."[85] In the chapter on "The Work of the Mason" stone carving techniques were to be applied "when the stone does not remain plain dressed, but is chiselled into mouldings, friezes, foliage, eggs, spindles, dentels and other sorts of carving, ..."[86] Vasari's approach to architectural techniques is dominated by an interest in ornament which was not exclusively to be made of stone but could also be formed in plaster. To Vasari these materials were chiefly of importance in producing something of the effect of painting, and while he dealt with materials and their manipulation from a technical point of view, the complete result was to be largely envisioned as a picture.[87] With moulded stucco work applied on brick a variety of details could be built in representation of stone creating effects of artistic quality. The interest in architectural scenography can be explained from the fact that Vasari's activities were not limited to architecture; he spent a greater part of his career as a painter and as a kind of artistic impresario arranging temporary decorations for state ceremonies. These festive

85 Ibid., p. 63.

86 Ibid.

87 Ibid., "Introductory Essay" by G. Baldwin Brown, p. 20.

decorations, a important component of the social and political life of the sixteenth century, offered artists opportunities for experimenting in lath and plaster not possible in permanent materials.[88]

The chapters of the introduction to the *Lives* on the proportions of the orders engaged to a significant extent in the discussion on "profiles of the mouldings" which were to be made in stone or plaster.[89] In this context Vasiri consciously formulated the distinction between structure and surface decoration. He described an interesting construction technique of avoiding loads transferred onto architraves. The non-structural and decorative function of architraves could be made feasible by means of a hidden substructure which acts as the primary system of support. This was achieved, as Vasari had proposed for the portico of the Uffizi, through the introduction of hidden flat arches of brick spanning from column to column.[90] The system of arches was of load bearing function allowing the exposed entablature to be purely decorative. Similarly the frieze was divided into interlocking blocks forming a self supporting flat arch; such a device avoided the transfer of loads onto the architrave.

Do not let the stones of the said frieze rest on the architrave, but let a finger's breadth be between them; in this way, making an arch, the frieze comes to support itself and does not burden the architrave. Afterwards make on the inside,

88 Peter Murray, op. cit., p. 245.

89 *Vasari on Technique*, op. cit., p. 65 and pp. 68, 70.

90 Ibid., "A constructive device to avoid charging architraves," pp. 70-74.

for filling up the said frieze, a flat arch of bricks as high as the frieze, that stretches from die to die above the columns. Then make a piece of cornice as wide as the die above the columns, which has the joints in front like those of the frieze, and within let the said cornice be keyed like the blocks of the frieze, ... so as to lock them in the form of an arch. In this fashion everyone can see that the frieze sustains itself, as does the cornice, which rests almost entirely on the arch of bricks.[91]

Neither the brick arches nor the system of interlocking stones were revealed on the façade of the Uffizi; instead the horizontal and continuous line of the entablature visually implied its function as a component of the structural system. In order to achieve this intention a relatively complex construction was required to allow the pure forms of architrave, frieze and cornice, to be expressed. While Vasari justified the use of such substructure from a technical point of view his method provided a clear and conscious disengagement of structure and façade decoration, thus allowing the free manipulation of architectural form which was the true task of the artist.

For Vasari the work of Michelangelo constituted the epitome of perfection. He was, according to Vasari, send by divine will to reveal to mankind the absolute truth inherent within the arts:

... the benign ruler of heaven ... decided to send into the world an artist who would be skilled in each and every craft,

91 Ibid.

whose work alone would teach us how to attain perfection in design (by correct drawing and by the use of contour and light and shadows, so as to obtain relief in painting) and how to use right judgement in sculpture and, in architecture, create buildings which would be comfortable and secure, healthy, pleasant to look at, well-proportioned and richly ornamented. Moreover, he determined to give this artist the knowledge of true moral philosophy and the gift of poetic expression, so that everyone might admire and follow him as their perfect exemplar in life, work, and behavior and in every endeavor, and he would be acclaimed as divine. ... And therefore he chose to have Michelangelo born a Florentine, so that one of her own citizens might bring to absolute perfection the achievements for which Florence was already justly renowned.[92]

Vasari's eulogy of Michelangelo portrayed the image of the ideal artist of the Late Renaissance, inherently representing an understanding of architecture as art. Aesthetic expression and invention as based on the subjective will of the artist then constituted the prime principles of formal manifestation. The fact that Michelangelo identified himself not as an architect but rather as a sculptor was indicative of the importance given to the concept of the artist-architect during the Cinquecento. Freedom of formal articulation in which painting, sculpture, and architecture were to merge into an indivisible whole inherently questioned the predetermined rules of the established language of architecture. Vasary addressed this break with the tradition of the discipline in the

92 Vasari, *Vite* , op. cit., pp. 325, 326.

description of Michelangelo's design intentions for the Medici mortuary chapel:

He wanted to execute the work in imitation of the old sacristy made by Filippo Brunelleschi but with different decorative features; and so he did the ornamentation in a compositee order, in a style more varied and more original than any other master, ancient or modern, has ever been able to achieve. For the beautiful cornices, capitals, bases, doors, tabernacles, and tombs were extremely novel, and in them he departed a great deal from the kind of architecture regulated by proportion, order, and rule which other artists did according to common usage and following Vitruvius and the works of antiquity but from which Michelangelo wanted to break away.
The licence he allowed himself has served as a great encouragement to others to follow his example; and subsequently we have seen the creation of new kinds of fantastic ornamentation containing more of the grotesque than of rule or reason. Thus all artists are under a great and permanent obligation to Michelangelo, seeing that he broke the bonds and chains that had previously confined them to the creation of traditional forms.[93]

Michelangelo's work in Florence marked a decisive break with Vitruvian classicism established only a few decades earlier in Italy. The design of the interior façades of the Medici Chapel disclose a free variation on the vocabulary of architecture allowing the invention of new forms for cornices, capitals, and bases. The pilasters are not of any known Order and the niche-

[93] Ibid., p. 366.

like recesses, or aedicule, above the doors manifest an intense personal freedom in the composition of the parts. The broken segmental pediment seems to have lost the greater part of its lower border while the central panel was made to penetrate into the pedimental zone. This unorthodox arrangement of the parts appears to have dislocated the bottom of the niche where a great block of marble was introduced. While Michelangelo's work is strongly marked by the arbitrariness of his approach to design, Vasary indicated that the same liberty taken by lesser artists could result in "grotesque" creations. In other words the work of the artist was regarded as a careful balance between subjective expression and objective rule.

Architecture as an art form placed technique at its complete disposal. Craft and technical skill were the means by which to attain perfection of form within the work as demonstrated by the excellent craftsmanship of Michelangelo's buildings. The forms, however, did not reveal constructional logic either through the exposition of tectonic qualities or as representational signs of original building techniques but instead adhered to the scenographic intentions of the artist's creative work. This attitude toward the production of architecture was most strongly critiqued at the end of the 19th century by the British historian William J. Anderson:

The qualities in Michelangelo's work which appear to have led architecture into the dark and devious ways of the barocco decadence, were: chiefly, its insincerity, in which may be included not only an absence of truthful construction or logical articulation, but the tendency to employ architectural *features as mere scenery, and to introduce false or unnecessary windows, niches, panels, consoles and balustrades, arising out of an unwholesome dread of unbroken wall surface; second, a quality which from its nature had less disastrous consequences, that of exaggerated scale, well exemplified by the vulgar Corinthian pilaster treatment of the Palazzo dei Conservatori ..., as well as in the gigantic pilaster and attic of the exterior of St. Peter's. ... but his enormous reputation as a painter and sculptor, at a time when men were less disposed to restrict genius to a narrow field, led to his architecture becoming the mode, and under the conviction that so great a personality could do nothing wrong, every solecism, vice, vulgarity, was painfully copied by those who came under influence of his work.*[94]

Despite the fact that this critique resulted from the biased vantage point of its position in history, the expressed reservations were an indication of the extreme dichotomy between form and technique which was to evolve during the succeeding centuries as one of the dominant concerns of architectural production. During the seventeenth century the question of artistic freedom in architecture was confronted with the logic of scientific thought which required a rational approach to the making of form. With the Age of Reason a new understanding of the means and methods of architectural production evolved which would allow the direct manifestation of technique within built form.

94 William J. Anderson, *The Architecture of the Renaissance in Italy*, first edition 1896, B.T. Batsford (London), 1909, p. 148.

Positive and Arbitrary Beauty

With the increasing importance of scientific thinking during the seventeenth century the question of beauty in architecture was newly debated. The subjective approach to architectural form evidenced during the Late Renaissance was confronted with the structure of rational thought which was to guide architectural theory for succeeding centuries. Theoretical discourse would not any more be dissociated from practical considerations but instead directly address the physical and concrete reality of the world. A redefinition of the relation between form and technique within the field of architecture resulted.

Italy, the birthplace of the Renaissance, ceased in the seventeenth century to be the main place of production and of inspiration for the arts. The new center of artistic development was Paris where the arts were organized and encouraged as part of the state system. Jean Baptiste Colbert (1619-83), Louis XIV's Minister of Building and Finance, was the most powerful patron in France. He enrolled the arts in the service of the French crown by creating academies which were financially supported by the state government. The *Petite Académie,* a small subcommittee of the French Academy[95] was formed to guide the minister in all matters concerning the state patronage of the arts, and in 1671 the Academy of Architecture was founded whose purpose was to provide a body of theory addressing the question of beauty in architecture. The state did not limit its support to the field

[95] In the 1620's a group of French patricians organized regular meetings whichwere incorporated as the French Academy by Louis XIII under Richelieu's patronage in 1635.

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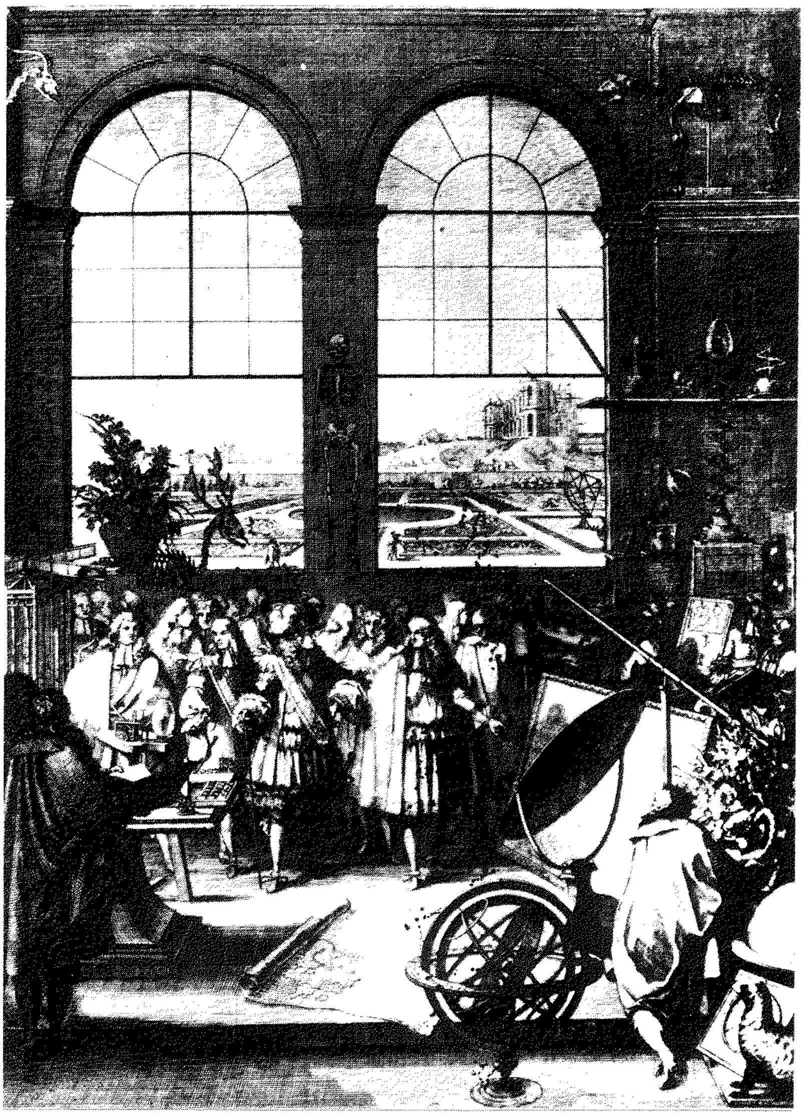

Sebastien Leclerc, frontispiece of Claude Perrault's *Histoire des Animaux* showing the king at the Academy of Science, 1671.

of artistic production, but also encouraged the development of scientific research through the creation of the French Royal Academy of Science in 1666. The progress and proliferation of the arts and sciences were constituting factors of the state's program. Both art and science hereby attained an unprecedented level of development which lend to new understanding of their fields.

Within this context the representational structure of architectural form received new significance. The relation between the subjective taste of the artist's work and the rules of an objective grammar of architecture was newly defined from the premises provided by modern science. The theoretical work of Claude Perrault (1613-88) offered one of the major contributions for the understanding of architecture as an art form conceptually based on the structure of scientific thought.[96] Perrault possessed a wide knowledge in the fields of art and science; his contributions ranged from scientific and scholarly work to the design of buildings. The eastern façade of the Louvre is probably the best known of his built works of architecture.[97] He had originally been trained as a physician and was appointed as a comparative anatomist to the *Académie*

[96] The significance of Perrault's work in relation to the origins of modern architecture has been pointed out by Eduard F. Sekler in *Wren and his Place in European Architecture*, The Macmillan Company (New York), 1956, pp. 37-57. See also Joseph Rykwert, "Positive and Arbitrary,"*The First Moderns*, MIT Press (Cambridge, MA), 1980, chapter 2; and Alberto Pérez-Gómez, "Claude Perrault and the Instrumentalization of Proportion," *Architecture and the Crisis of Modern Science*, MIT Press (Cambridge, MA), 1983, chapter 1.

[97] Although Perrault's authorship has repeatedly been questioned, there is no doubt that he was appointed in 1667 by Colbert as a member of a committee in charge of redesigning the eastern façade of the Louvre.

des Sciences on its foundation in 1666.[98] The significance of this institution was made evident in the frontispiece of Perrault's *Histoire des Animaux,* an engraving by Sébastien Leclerc documenting the state's interest in the sciences. The engraving portrays a fictionalized vision showing Louis XIV and Colbert visiting the Academy of Science. In the background is Perrault's observatory under construction.

A great part of Perrault's life was devoted to scientific research. As documented by another engraving by Leclerc, Perrault conducted animal dissections which constituted the base for his writings on comparative anatomy. He was not, however, only the author of a collection of scientific essays but wrote also on architecture. Perrault was the editor and commentator of a new translation of Vitruvius's *Ten Books* . This was another enterprise sponsored by Colbert which contributed to Perrault's reputation in architectural circles.[99] Of greatest significance for the theory of architecture was the small treatise that he published in 1683 which Perrault considered as a form of appendix to his edition of Vitruvius's *Ten Books*. This work, entitled *Ordonnance des Cinque Espèces de Colonnes,* constituted a fundamental departure from traditional architectural theory.[100] The rational

98 A summary of Perrault's scientific career is given by J. Lévy-Valensi, *La Médecine et les Médecins Français au XVIIe Siècle,* (Paris, 1933), pp. 521 ff.

99 Claude Perrault, *Les Dix Livres d'Architecture de Vitruve, Corrigez et Traduits Nouvellement en François, avec Notes et des Figures,* (Paris 1673; second edition, 1684). The second edition was re-published by Pierre Mardaga Editeur (Paris), 1979.

100 Claude Perrault, *Ordonnance des Cinque Espèces de Colonnes,selon la Méthode des Anciens,* (Paris, 1683); *A Treatise of the Five Orders in Architecture,* translated by John James, (London, 1722). For an account of Perrault's work and a discussion of his *Ordonnance,* see Wolfgang Herrmann, *The Theory of Claude Perrault,* (London), 1973.

structure of scientific thought was here for the first time explicitly applied to the discussion on aesthetics and the understanding of form. In all, Perrault's contributions to architecture and science can therefore not be considered independently for they were guided by a coherence of intentions which lay behind the entirety of his work.

Perrault's revolutionary ideas on architecture are most precisely summarized in the detailed preface to the *Ordonnance*. The starting point is the criticism of the "classical" doctrine. He questioned the most sacred premises of traditional architectural theory abandoning the idea that the forms and rules of architecture were something *a priori* given. The text was directed against those contemporaries who insisted that the close imitation of the ancients was the only proper way for an architect to proceed in the design of buildings. He wrote that it is "hardly to be imagined what a superstitious reverence architects have for those works we call *Antique*, in which, they admire every thing, but principally the mystery of their proportions, which they are pleased to contemplate with profound respect, without daring so much as to undertake an inquiry into the reasons" of why and how architectural forms were determined.[101] A similar critique, directed to François Blondel, had been formulated by Perrault in a footnote of his edition of Vitruvius's *Ten Books*. Blondel, founding member and professor of the Academy of Architecture, had attacked the use of double columns in the façade of the Louvre as being an inappropriate deviation from the classical rules of architecture. Perrault refuted Blondel's criticism by calling

[101] Claude Perrault, *Ordonnance*, op.cit., p. xiv.

his main objection to be "founded on a prejudice and the false supposition that it is not possible to abandon the habits of ancient architects."[102] The conclusion is further made by Perrault that if the formal rules of architecture are guarded such that no new inventions can be tolerated, then no development of the arts could ever be possible. If there were a rule that dictated the imitation of antiquity, he continued, architecture would have never progressed and "we would not need to search for new means to acquire the knowledge which we are lacking and that every day enriches agriculture, navigation, medicine, and all the arts."[103]

The concept of architecture as an evolving discipline was influenced by the idea of scientific progress. Modern science was not regarded as a hermetic field but instead as being in constant historical development allowing the continuous growth of human knowledge. The arguments which Perrault considered essential within scientific thought were equally valid when applied to the arts. Architecture was not to be seen as a closed system of predetermined formal rules or techniques but rather was to be understood as constantly changing, allowing the formal language of architecture to evolve as well as new building methods to be discovered. Similarly, Perrault conceived of his architectural theory as a momentary stage in a continuous line of development, a contribution to the formation

102 Claude Perrault, *Les Dix Livres*, footnote 16, op. cit., p. 79."*La principale objection sur laquelle on appuye le plus, est fondée sur un prejugé & sur la fausse supposition qu'il n'est pas permis de se départir des usages des Anciens; que tout ce qui n'imite pas leur manieres doit passer pour bizzare & pour capricieux, & que si cette Loy n'est inviolablement gardée, on ouvre la porte á une licence qui met le déreglement dans tous les Arts.*"

103 Ibid.; see also Alberto Pérez-Gómez, op. cit., p. 27.

of rationally determined knowledge. This modern concept of knowledge stood in total opposition to the traditional view of the world. While the old system based its premises on an universal order founded on the belief in transcendental causes, modern thought proceeded from a perfectly intelligible world, determined exclusively by the clarity of rational thought. This separation between faith and reason constituted the essential issue in the Dispute of the Ancients and the Moderns, the *Querelle des Anciens et Modernes*.

Claude Perrault's brother Charles Perrault, who was Colbert's assistant at the *Petite Académie* and author of reputation, addressed the conflict of ideology between modern knowledge and the classical tradition in the four volumes of his *Parallèle des Ancients et Modernes*.[104] The book was a commentary on the dispute which divided French intellectuals on the issue of ancient authority. It was a debate which not only constituted a disagreement about taste but which also was concerned with the direction of artistic policy supported by the state. Beyond artistic and political considerations, the dispute primarily addressed the role of history for contemporary knowledge and the relation of the past to modern thought; profound convictions about the nature of progress were here at odds. The achievements of the ancients were not by any means questioned, for their importance in the formation of classical culture was an accepted fact; what was critiqued was rather the mythical belief in ancient authority dictating a given order of the world based on the understanding of truth as something

104 Charles Perrault, *Parallèle des Ancients et des Modernes*, Paris, 1688-1697.

previously given. The Perrault brothers sided with the moderns in the dispute. The new logic asserted that reason was to be substituted for faith as the primary determinant of knowledge. Thought was no longer conceived as a closed process determined by ultimate und universal truths.

In his scientific writings Claude Perrault questioned the *a priori* value of a conceptual system which traditional philosophy postulated. Instead Perrault suggested the construction of hypothetical systems which could provide explanations for the understanding of the world. Rather than limiting knowledge to one single and exclusive model, Perrault accepted the relativity of various positions; he thus viewed critically the importance traditionally given to true causes. Ultimately, according to Perrault, "truth is but the totality of visible *phenomena* that can lead us to the knowledge of that which Nature wanted to hide. ... It is an enigma to which we can give multiple explanations, without ever expecting to find one that is exclusively true."[105] In other words, theoretical systems were no longer connected with the transcendental structure of a cosmological scheme but with the structural laws of reality as perceived by man.

One of the primary questions at hand was how to apply the propositions of modern scientific thought to architecture, to the formal vocabulary of the discipline, and ultimately to beauty. The rational discussion addressing fundamental problems of architecture led Claude and Charles Perrault to

105 Claude and Nicolas Perrault, *Oeuvres Diverses de Physique et de Méchanique* (Leyden, 1721); see also Alberto Pérez-Gómez, op. cit., p. 26.

differentiate in theoretical terms between "positive" and "arbitrary" phenomena within the field. The rules guiding "positive", or "convincing," beauty were inevitable and given by the structural laws inherent within architecture. They were considered to be produced "naturally" as they were and through themselves.[106] On the other hand, "arbitrary" beauty depended on taste and custom. The juxtaposition of both terms, "positive" and "arbitrary," allowed Claude Perrault a clear exposition of his argument. In the *Ordonnance* he disclosed the principle criteria for recognizing his difference between "positive" and "arbitrary" beauty. Architects, according to Perrault, must have some reason for finding certain proportions agreeable:

..., although we often like Proportions that are conformable to the Rules of Architecture, without knowing why we [like] them, it may, however, be truly said, that we ought to have some Reason for this Love, and the Difficulty is only to know whether this Reason be always something that is positive, as is that of the Consonance of Musick, or whether it is not most commonly founded upon Custom only; and whether that which renders the Proportions of a Building agreeable, be not the same thing with that which makes a [fashionable dress] please on account of its proportion, ...[107]

To clarify the distinction between "positive" and "arbitrary" reasons Claude Perrault referred in the *Ordonnance* to the rules of musical harmony in comparison with those of

106 Claude Perrault, *Ordonnace*, op. cit., pp. iv- vii.
107 Ibid., p. v.

architectural beauty. The systems of proportion in architecture, he writes, are not "certain and invariable, as those are which make the Delicacy and Agreement of Sounds in Music, which depend not upon us, but are such as Nature has fixed and established, with so precise an exactness, that they cannot be altered, without immediate Offence to the ... Ear."[108] Perrault abandoned the classical concept which propagated an analogy between visual and musical harmony; he thus questioned for the first time in history the understanding of proportional systems as being *a priori* given. Proportional rules in architecture could not be justified as being determined by universal law but were instead a product of the imagination and, therefore, considered "arbitrary." At the other extreme, "positive" beauty in architecture did not depend on proportion but was formed, as it was believed that musical harmony was generated, by natural principles. The laws inherent in the fields of mechanics and statics, for example, were founded on "positive reason" and therefore paralleled the absolute beauty of musical harmony. Similarly, "positive" beauty in architecture was to be founded on direct and obvious principles as observed in other disciplines such as in the construction of "Fortifications and Machines, where a Line of Defence, for Example, cannot be longer than the reach of the Artillery, nor one Arm of a pair of Scales shorter than the other, without rendering these things absolutely useless and defective."[109]

108 Ibid., p. iii; see also Joseph Rykwert, *The First Moderns*, p. 33.
109 Ibid., p. xii.

The proportional system of the classical orders as advocated by Alberti, Serlio, Vignola, Palladio, and Scamozzi, for example, showed great dimensional discrepancies; therefore, according to Perrault, the rules pertaining to the orders could not have been deduced from "positive" reasons. Instead he asserted that their origin must have been arbitrary, that "they have no other Foundation than Chance, and the [caprice] of the Workmen, who sought for no Reason to guide them in the Determination of those things, the Preciseness of which, was of no Importance."[110] Roland Fréart de Chambray had already pointed in his *Parallelè de l'Architecture Antique et de la Moderne* (1650) to the difference in the correspondence of measurements when comparing the orders of various authors. Unlike his predecessors he did not provide the rules of each order but instead compared and criticized the principles of proportion used in ancient and contemporary buildings. His intention was to provide the architect with a method for identifying the most appropriate order and to choose the most correct proportions. Fréart, in other words, while not proposing an ultimate model to follow understood the different historical solutions of the orders in relative terms. However, he critiqued in his treatise *Parallèle de l'Architecture Antique et de la Moderne*, first published in 1650, those who "pretended to modify the classical orders through fantastic interpretations." Although upholding the traditional canon derived from ancient doctrine, Fréart can be regarded as a precursor of Perrault's scepticism on the subject matter concerning the authority of the orders. Perrault took Fréart's propositions a step further explaining the origin

110 Ibid., pp. xv, xvi.

and continuity of traditional form, for which he could not find "positive" reasons, as being essentially determined by custom.

The systems of architectural proportions, Perrault believed, were not "true" but only "probable." This argument was refuted by François Blondel in his *Cours d' Architecture*, the first textbook for the students of the Royal Academy of Architecture, where he rejected the notion of relative values for the determination of beauty.[111] Blondel was not opposed to the role of "taste" within architectural beauty, but he did not accept the idea that beauty might ultimately result from custom. He strongly believed in the absolute rather than the relative nature of architectural beauty. The basis for the rules inherent within the orders were determined by nature which provided everlasting principles analogous to those rules which pertained to music. Blondel's theory was in accordance with the traditionally advocated correspondence between musical harmony and architecture. A chapter of the fifth book of his *Cours d'Architecture* even attempted to justify scientifically the principles of architectural proportion. In this chapter, entitled "Proofs That Proportions Are the *Cause* of Architectural Beauty and That This Beauty Is Founded in Nature, Like That Produced by Musical Accords," the connection between scientifically determined principles of natural phenomena and the beauty of architectural proportions was made.[112] Blondel believed that proportional systems of architectural beauty were

111 The*Academie Royale de l' Architecture* was founded in 1671 and remained the guiding school of architecture in France until 1793 when it was closed after the revolution.

112 François Blondel, *Cours d' Architecture, Enseigné dans l'Académie Royale de l'Architecture*, 2nd ed. (Paris, 1698), Book V. For the same argument and the translation of the title see Pérez-Gómez, op. cit., pp. 45, 46.

as constant as the principles of natural laws, as for example the proportional relationship between a force and the dimension of a lever. Analogeous to scientific principles, proportions of beautiful buildings were determined by induction and experience. As such laws were considered given, Blondel maintained the metaphysical justification of architecture, remaining in agreement with the traditional theory of proportion providing stable and invariable principles for the discipline. In asserting the universal and "positive" nature of aesthetic rules in architecture, Blondel's theory contrasted with Perrault's rational logic. In the *Ordonnance* Perrault had asserted that proportional systems were essentially "arbitrary" and not based on "positive" reasons.

According to Perrault, "positive" beauty was determined by clearly perceivable criteria "founded on solid convincing Reasons". These were visible components of the art of building generated by three fundamental categories: (a) the quality and richness of building materials, (b) the delicacy and exactness of the workmanship, and (c) the general disposition or symmetry of building parts to one another.[113] Although not explicitly mentioned in the *Ordonnance,* Perrault's criteria inherent within "positive" beauty were all essentially based on considerations of building construction. The first point addressed the matter of which architecture is made, the second referred to the process of production and the propriety of

113 Ibid., p. vi."... *j'appelle des beautez fondées sur des raisons convaicantes, celles par lesquelles les ouvrages doivent plaire à tout le monde, parce qu'il est aisé d'en connoistre le merite & la valeur, telles que sont la richesse de la matiere, la grandeur & la magnificence de l'Edifice, la justesse & la propreté de l'execution, & la symmetrie ...*"

execution, and the third was manifested by the corresponding arrangement of building components within the entire structure. Such categories provided architecture with the expression of "positive" beauty as disclosed in visible form and were thus essential to the representational structure of architecture. In other words, the representation of constructional logic and tectonic quality implied in Perrault's text was considered a constituent aspect of formal definition.

The theory advocated by Perrault was not without contradictions. While a rational approach to architecture was proposed, at the same time his theory remained faithful to classical antiquity. Perrault's interest in the traditional vocabulary of architectural forms was specifically revealed in his elaboration on the orders which constituted the very subject matter of his *Ordonnance des Cinq Espéces de Colonnes, selon la Méthode des Anciens*. While the superiority of "modern" architecture was a fundamental premise of Perrault's philosophy, the attempt was made to reconcile traditional form with the rational structure of modern thought. The traditional symbolic implications of the orders and their proportional system was therefore abandoned. Rather than justifying the orders as being derived from "positive" reason, Perrault emphasized the value of their arbitrariness. Beauty as based on "positive" reason was complemented by those considerations which addressed good taste as custom commonly set forth. Perrault did not reject "arbitrary" beauty; on the contrary, he firmly believed that it had its place within architecture. "Arbitrary" beauty, from which for example the proportion of the orders were historically derived, could not be ignored for it was considered to depend on the acceptance of culturally and socially determined rules. To make his argument clear Perrault compared the existence of "arbitrary" beauty with man's inclination which allows him to "like fashionable things, and the ways of speaking which fashion has fixed at court."[114] The vocabulary of forms in architecture were derived as much from "arbitrary" reasons as they were believed to follow the rules of "positive" beauty. Perrault went a step further, declaring that the architect must have knowledge of the more subtle rules governing "arbitrary" beauty which were considered necessary for achieving good design:

It is certain, then, that there are some Beauties in Architecture, which are positive, and some that are only arbitrary, thou they seem positive through prejudice, from which it is very difficult to guard our selves. It is also true, that a good judgment is founded on the Knowledge of both these Beauties; but it is certain, that the Knowledge of arbitrary Beauties, is most proper to form what we call a right taste, and it is that only which distinguishes true Architects from those that are not so; because common sense alone is sufficient for knowing the greatest part of positive Beauties; ...[115]

While the rules of architectural proportion were regarded as being derived from custom, they were nevertheless considered fundamental for what was considered to be successful

114 Ibid., pp. vi & vii; for the translation of the quote see Rykwert, op. cit., p. 36.
115 Ibid., p. x.

architecture. In this proposition lies the most revealing contradiction of Perrault's theoretical constructions, and it was on this issue that Claude and Charles Perrault's ideas essentially parted.[116]

Claude Perrault did not question the authority of the classical orders *per se* ; on the contrary, he proposed a rational system of proportion which he considered to be perfect and therefore conclusive. In order to define the ideal dimensions of the orders he applied a method commonly used in modern science. By determining the arithmetic mean, or *juste milieu*, between the various dimensions proposed by different ancient and modern authors, Perrault sought to find the rational justification for the perfection of his order. Furthermore, he determined a modular unit, the *petit module*, which would allow a regulating relationship between pedestal, shaft, capital, and entablature to be established. His new module, one-third of the diameter of a column instead of the traditional semidiameter, was determined by the lowest common denominator of the orders so as to suggest the most simple fractional system which could easily be memorized and applied. Perrault's scientific method, although regarded as a means for ultimate perfection, disclosed an understanding of beauty as based on relative rather than absolute values. He herein justified his proposition by the

[116] Walter Kambartel, *Symmetrie und Schönheit; über mögliche Voraussetzungen des neueren Kunstbewusstseins in der Architekturtheorie Claude Perraults*, (Wilhelm FinkVerlag, München, 1972), pp. 103-107. "*Während Charles Perrault die positiven Schönheiten über die arbiträren stellt, um in der fortschreitenden Vervollkommnung der positiven Schönheiten den Beweis für die Überlegenheit der Moderne über die Antike zu erblicken, stellt Claude Perrault gerade umgekehrt die arbiträren Schönheiten über die positiven, um in der Fortschrittsindifferenz der arbiträren Schönheiten die Bedingung für die künstlerische Gleichrangigkeit von Antike und Moderne zu sehen.*"

need to provide a "probabilistic abstract framework" as a guide for architects and workmen to rationally approach the arbitrary forms of architecture.[117] Therefore precise rules were necessary in order to allow the forms of "arbitrary beauty" to be determined. In the preface to the edition of Vitruvius's *Ten Books*, Perrault addressed the need to provide a rational framework for those forms which historically, through custom and 'good taste,' had evolved into the vocabulary of the discipline:

Beauty has no other foundation than the imagination [la fantaisie]; which works in such a way, that things are pleasing if they accord with the idea each one of us has of their perfection. Rules are therefore essential to form and to correct this ideal, and it is certain that if nature refuses rules ... to all that depends on chance, on the will and on habit, then human institutions must supply them, and for that a certain authority is necessary which will do duty for positive reasons.[118]

Perrault proposed a system of rules which seemed to justify the liberty he took in determining proportion and ornament of the orders. Since this new system was intended for application, simplifying the task of architects and craftsmen when building the orders, his theory constituted the foundation of technical instructions. In other words, Perrault's theoretical proposition was understood as an *ars fabricandi* for the maker.

117 This expression is borrowed from Joseph Rykwert, *The First Moderns*, op. cit., p. 42.

118 Perrault, *Les Dix Livres*, op. cit., preface.

This was a concept which would become the guiding principle within the relation between theory and practice through the succeeding centuries. Abbé Cordemoy, for example, was strongly influenced by Perrault's understanding of theory as an abstract framework intended for practical application. This is revealed in Cordemoy's *Nouveau Traité* in which Perrault's proportional system based on the *petit module*, was directly reproduced in an engraving of the orders.[119] The title of Cordemoy's treatise in its unabriviated form *Nouveau Traité de Toute l'Architecture ou l'Art de Bastir Utile aux Entrepreneurs et aux Ouvriers*, refers in fact to *architecture* as the *art of building* of which contractors and workmen had to have knowledge. Theory and practice were placed here in direct relationship.

The interdependence of theory and practice inherent within Perrault's doctrine led to an interest in the representation of "positive and "arbitrary" beauty as manifested in build form. Since, according to Claude Perrault, the formal expression of "positive" beauty was not necessarily dependent on particular artistic skills but was primarily determined by common sense, the presence of "positive" beauty in a building was not so much due to the architect's design as to such parameters as the quality of the materials, the excellence of execution, and the proper disposition of structure.[120] The work of the architect which was manifested in the design addressed primarily the realm of "arbitrary" beauty. The creation of architectural form was therefore a matter of taste and a product of the

119 Abbé Cordemoy, *Nouveau Traité de Toute l'Architecture ou l'Art de Bastir Utile aux Entrepreneurs et aux Ouvriers*, 1st ed., Paris 1706; 2nd ed. Paris, 1714.

120 Joseph Rykwert, op. cit., p. 116.

imagination. This freedom within design, however, was to be regulated according to rules guiding the architect's imagination. Such a proposition allowed Perrault, for example, to justify the double columns used in the eastern façade of the Louvre, an element of composition strongly criticized by Blondel who saw in it a deviation from the classical rules of architecture. French taste, according to Perrault, indeed differed from that of the ancients; a preference for lightness and free-standing structures inherited from Gothic architecture marked the aesthetic values which had been established through custom. The pairing of columns in the Louvre façade as well as their disengagement from the wall reflected this French taste.

Perrault believed that the role of the architect was to elevate the building above the "merely commonsensical positive beauties," as Joseph Rykwert puts it, "by endowing it with its clothing or arbitrary beauty."[121] This relation between structure and decoration was considered in the façade of the Louvre where formal intentions and constructional implications were interconnected. The columns which followed Perrault's Corinthian order were load bearing in the sense that they carried a major entablature as well as their own weight. The structural simplicity was revealed in what has been called *parlare piano* in architecture. The row of columns formed a simple and unified façade without any formal exaggeration. The central temple front motif was counteracted by the "anticlimax of the row of columns."[122] Compared to the Baroque architecture

121 Ibid., p. 93.

122 Emil Kaufmann, *Architecture in the Age of Reason*, (Harvard University Press, 1955), Dover Publications (New York) 1968), p. 127.

of the time the façade appears straightforward and modest in its formal expression, thus anticipating the Neoclassical preference for simple forms. Architecture became representational of "positive" reasons without necessarily rejecting the vocabulary of traditional forms.

The construction of the Louvre façade was not as simple as the formal composition might suggest. The main architrave supported by the columns was composed of two ranges of flat arches, or *voussoirs*, placed above one another. This required elaborate stone-cutting and that the masonry be carefully tied. The use of cramp iron as a building technique for holding stone together was not new; what was unconventional in the Louvre façade was the complex system of metal ties and clamps which contributed to a reinforced masonry construction.[123] This substructure of wrought iron was carefully hidden so as not to impair the architectural composition. Additionally, from an enclosed gallery above the soffits of the colonnade the ironwork could regularly be inspected for rusting. Such technical considerations lay clearly within the realm of "positive" reasons as defined by Perrault. Technique and execution in this sense were considered to be of necessity without contributing to the expression of form. At the other extreme, it was "arbitrary" beauty which provided aesthetically pleasing forms. In the Louvre façade, "arbitrary" beauty was not only manifested in the double columns and the theme of the temple front for the articulation of the center but also in the decorative stone details which represented trophies of arms and various forms of ornamental foliage. Those forms were the

123 Joseph Rykwert, op. cit., pp. 88, 89.

expression of "arbitrary" beauty which, according to Perrault, constituted one of the primary tasks of the architect. Consequentially, the architect's work did not reside within the realm of reason but instead in that of taste and fancy.

While Claude Perrault's work essentially disclosed a preference for "arbitrary" reasons within art and architecture, his brother gave priority to the revelation of "positive" reasons. Charles Perrault did not attempt to reconcile the philosophy of the ancients with modern thought. He believed instead in the higher state of modern consciousness, for within historical evolution he considered modern times to be more experientially advanced. The constant progressive development of knowledge within history could not other than result in the superiority of modern civilization. René Descartes's word game "c'est nous qui sommes les Anciens" was repeated by Charles Perrault to justify that his generation, in being more experienced than those of the past, could correspondingly be called "ancient" in that the Age of Reason had reached an unprecedented level of maturity.[124] The moderns were considered superior due to their advancement in technical knowledge from which "positive" beauty was determined. Herein, according to Charles Perrault, lay the task of the architect, i.e. to make buildings which were solid and well built in their construction, functionally convenient,

124 Charles Perrault, *Parallèle des Anciens et des Modernes en ce qui regardeles Arts et les Sciences*, op. cit., p. 49. Descartes's quote from Walter Kambartel, op. cit., p.106: "*Nous n'avons aucune raison pour tenir si grand compte aux Anciens de leur antiquité. C'est nous qui sommes les Anciens, car le monde est plus vieux aujourd'hui que de leur temps et nous avons une grande experience.*"

and therefore magnificent.[125] The forms of "arbitrary" beauty, on the other hand, could not be of primary significance as they belonged to the realm of mere taste. Such arbitrary forms could easily be varied and be applied as long as they were culturally accepted. The formal manifestation of "arbitrary" beauty, he wrote, "could be totally different ... without being less pleasant, if our eyes were equally accustomed to it."[126] Architecture, in other words, was essentially determined by "positive" reasons which addressed such parameters as the quality of materials, the processes of execution, and the constructional logic according to which building elements were arranged. The architectural design was thus defined as the correct placement of components according to material, function, and technique, allowing beautiful structures to result. It is implied from his writings that Charles Perrault declared beauty to be derived from syntactic relations among the elements of a given formal system.[127] Although this proposition was not directly stated but only implied, his theory nevertheless pointed to a concept which in succeeding centuries would gradually become dominant. Charles Perrault opened the way for understanding architecture not any more as the representation of form but instead as the revelation of "positive" reason. A step toward an ontological approach to the relation between form and technique was made.

[125] Charles Perrault, ibid., p. 159 f."*Mais le véritable merite d'un Architecte est de sçavoir faire ... des bâtimens qui soient tout ensemble, solides, commodes & magnifiques.* " This set of requirements, it should be noted, correspond with Vitruvius's *firmitas, utilitas,* and *venustas*, written centuries earlier and considered one of the canons of architectural theory.

[126] Ibid., p. 132.

[127] Alberto Pérez-Gómez, op. cit., p. 35.

Form and Technique

The understanding of architecture as a discipline with precisely defined rules and principles for the making of form emerged during the Renaissance as the predominant concept of the art of building. While this development was further expanded in the seventeenth century during the Age of Reason the concept of the discipline of architecture received new significance. The representational structure of form gradually became divorced from its metaphysical and symbolic values which were replaced by the direct manifestation of rational thought. Scientific knowledge was dissociated from mythical belief. Architecture came to address the concrete rather than the symbolic, for its principles became identified with those of science. This was a proposition which presumed a fundamental analogy in the methods and sources of those fields of knowledge concerned with the search of truth inherent within natural law.

The change of emphasis from a predominantly irrational or symbolic realm to that of reason, consequentially led to a newly defined relation between theory and practice in architecture. A different meaning of technology resulted. The binominal term *technology*, which refers to the connection between *techné* and *logos*, recognizes by definition a paradigm of both theory and practice, i.e. the relation between the construing and the constructing of architecture. Rather than perceiving theory as the transcendental justification of *praxis* , as traditional science originally propagated, theory instead became understood as an *ars fabricandi* of the maker, craftsman, and architect. Theory thus evolved as the foundation of technical instructions intended to be easily and directly applicable. One of the most important concepts of traditional theory was the acceptance of an invisible *mathesis*, assuring the role of architecture as a true art of imitation. The representational structure of architecture was herein justified. The increasing interest in rational thought evident in architectural intentions during the Age of Reason fundamentally questioned the understanding of architecture as a representational art. The principles of architecture were instead identified with those of modern science. A relation between theory and practice evolved in which the former was understood as a description of the principles and technical means of the latter. From this resulted a direct connection between rational theory and the reality of practice.

The interdependence of theory and practice advocated by modern science found its physical manifestation in architecture within the relation between technique and form. Prior to seventeenth century, technical considerations were placed in the service of formal expression. During the Renaissance, the form, equated with the conceptual idea of the whole work, was considered the nobler part of the design. Form therefore triumphed over matter. Technique as a neutral device of production was placed at the disposal of a design idea in order to achieve a specific formal expression. The work of Michelangelo and the writings of Vasari, which gave priority to subjective artistic expression, disclosed an interest in the dominance of form over technique. However, this hierarchical structure did not completely deny the importance of the methods and materials of production. Technique was integrated within formal considerations at an iconographic level whereby form alluded to technique through the representation of an idealized image of construction. Bramante, Serlio, as well as Palladio, for example, based their vocabulary of architectural forms on the representation of technique through imagery. While built form typically disregarded the properties of material and the methods of construction, ideal architectural form remained connotative of technique from which it had originated. Such a manifestation of idealized form was indicative of an understanding of theory as a transcendental justification of practice.

With the emergence of modern science and its predominant emphasis on rationality, a new interest resulted in the direct manifestation of technique within formal expression. The theoretical work of Charles and Claude Perrault, especially their understanding of "positive" beauty, allowed a justification of form as being directly determined from technical considerations. Form thereby was considered the product of methods and materials employed in the processes of production. Constructional logic, while pertaining to the pragmatics of architecture, contributed to a tectonic understanding of form. In these terms the essential meaning of architectural form was founded on operative constructional techniques exhibiting reason and economy of means. Generally, such an approach identified the most basic configuration of the architectural artifact in its prototypical form.

This seemingly positivist approach did not, however, reject the role of content and meaning in architecture. The task of theory was to disclose the rationality inherent within natural order. From the late seventeenth century, the revelation of the laws observed in nature became the guiding principle of artistic production. Architecture was able to maintain its symbolic value by reference to the means and methods of technical processes which were considered to be directly deduced from natural laws. The increasing interest in technique and the renewed priority given to practice, which would develop during the succeeding centuries, constituted a search for truth in architecture. Its meaning was manifested by the revelation of the conditions of being inherent within the processes and products of architecture. The possibility for an ontologically based understanding of technology was given.

5. Chapter

ARCHITECTURE AS SCIENCE

The Ontological Structure of Form and Technique

ARCHITECTURE AS SCIENCE

The Ontological Structure of Technique and Form

"*There was a time when it was not technology alone that bore the name* techné. ...
Once there was a time when the bringing-forth of the true into the beautiful was called techné. *The* poésis *of the fine arts was also called* techné.
At the outset of the destining of the West, in Greece, the arts soared to the supreme height of the revealing granted them. They illuminated the presence of the gods and the dialogue of divine and human destinings. And art was simply called techné. *Why did art bear the modest name* techné? *Because it was a revealing that brought forth and made present, and therefore belonged within* poésis. *It was finally that revealing which holds complete sway in all the fine arts, in poetry, and in everything poetical that obtained* poésis *as its proper name. The poetical thoroughly pervades every art, every revealing of coming to presence into the beautiful. ...*
Throughout everything technological, the essence of technology may come to presence in the coming-to-pass of truth."
Martin Heidegger, "The Question Concerning Technology"[1]

The Concept of Scientific Progress

Within the history of modern knowledge the progress of science has generally been equated with the progress of civilization. This concept is based on the view that science is a human

[1] Martin Heidegger, "Die Technik und die Kehre" (1953); "The Question Concerning Technology," in *Basic Writings* , edited with introduction by David Farrell Krell, Harper & Row (New York), 1977, pp. 315-317.

construction which develops in stages and to which "each one can make his contribution to the limits of his powers and capacities."[2] This concept suggests the definition of scientific processes as a collaborative undertaking in which the formation of knowledge is seen as "the product of a coöperation for non-personal ends."[3] Modern science is thus conceived as a program for the development of society and the benefit of man-kind.

The understanding of modern science as being in constant historical development allowing the continuous growth of human knowledge had been fundamental to such as Claude and Charles Perrault in the seventeenth century. Architecture, from their point of view, was not regarded as a closed discipline but rather as constantly progressing, similar to the advancement of science. Claude Perrault, for example, conceived of his theory of architecture as representing a phase within historical development, in a process of ever increasing rationalization; his brother Charles had asserted in the *Querelle des Anciens et Modernes* that progress depended on the slow accumulation of knowledge during the course of time and that the development of civilization was based on perpetual and indefinite growth.[4] The architecture of their period was considered a momentary stage in a continuous line of development and their theoretical

2 Paolo Rossi, "The Idea of Scientific Progress," in *Philosophy, Technology and the Arts in the early Modern Era*, translated from *I Filosofi e le Macchine,* 1962, by Salvator Attanasio, Harper and Row (New York), 1970, pp.63-99.

3 Edgar Zilsel, "The Genesis of the Concept of Scientific Progress," 1945; published in *Roots of Scientific Thought*, edited by Philip P. Wiener and Aaron Noland, Basic Books Inc. (N.Y.), 1957, pp. 251-275.

4 Paolo Rossi, *Philosophy, Technology and the Arts in the early Modern Era*, op.cit., p. 90.

propositions contributions to the formation of rationally determined knowledge. This revolutionary view, which advocated the concept of architectural progress, influenced succeeding generations. The idea of progress evolved in the eighteenth and nineteenth centuries as a guiding concept within the field of architecture and significantly marked the relation between form and technique.

The concept of progress and the understanding of scientific knowledge were based, as Edgar Zilsel[5] suggested in his article, "The Genesis of the Concept of Scientific Progress" published in 1945, on the following premises. First, the notion of progress implied the understanding of science as being formed by a continuous process in which "step by step through contributions of generations of explorers" a body of knowledge was successively created. Second, the concept of scientific progress necessitated the view that such a "process is never completed," allowing revisions to be made and new developments to be integrated. Third, the idea of progress was based on the conviction that a single scientific tradition must exist and that the "contribution to this development, either for its own sake or for the public benefit, constitutes the very aim of the true scientist."[6] These premises which fundamentally marked the approach to modern science had not been developed within the traditional contexts of classical antiquity and medieval

5 The work of Edgar Zilsel, whose research on the sociological foundations of science emphasizes the view that modern science owes its origin to the work and writings of craftsmen in the Renaissance, constitutes a significant contribution to the history of the beginnings of modern culture. The results of his studies were published in a series of articles from 1918-1945.

6 Edgar Zilsel, "The Genesis of the Concept of Scientific Progress," op.cit., p. 252. See also Paolo Rossi, *Philosophy, Technology and the Arts*, op.cit., p. 64.

scholasticism but were particular to modern thought. The concept of progress originated in Europe at a time when an unprecedented series of discoveries significantly modified human existence. Inventions such as the compass and the printing press offered new possibilities for the expansion of civilization. Furthermore, such technical innovations became the subject matter of a significant number of treatises published during the sixteenth and seventeenth centuries encouraging the proliferation of inventions and new ideas. To the technical literature of the period belong, for example, such works as Vannuccio Biringuccio's book *Pirotechnia* (1540) on metallurgy, Georg Agricola's *De re metallica* (1556) on mining technology, Agostino Ramelli's *Le diverse et artificiose machine* (1588) on mechanics, and William Gilbert's *De magnete* (1600) on the compass. Zilsel emphasized the role of the artisans and craftsmen in the formation of science. He asserted that "the modern idea of progress through cooperation stems, like many other elements of modern scientific procedure, from the superior artisans of the fifteenth and sixteenth centuries."[7] The advancement of science was thus rooted in technological progress. Technical treatises, in which master craftsmen and engineers transmitted their knowledge or discoveries with the conscious aim of promoting understanding of their fields, advocated the gradual progress of technology.

The technical advances which inspired confidence in the continuing development of technology were paralleled by

[7] Edgar Zilsel, ibid., p. 252.

advances in scholarship and academic learning.[8] The concept of scientific progress as a constituent component of knowledge found its first expression within the philosophy of Francis Bacon (1561-1626) and was later further developed by philosophers including René Descartes[9] (1596-1650), Gottfried Wilhelm von Leibniz[10] (1646-1716), and Georg Wilhelm Friedrich Hegel (1770-1831); the latter who conceived of history as the progressive actualization of human reason.[11] Within this line of development, Francis Bacon was of significance in that he conceived of science in its modern sense. In Bacon's work the progress of knowledge was proclaimed as a controlling scientific and philosophical program. This concept was first addressed in *The Advancement of Learning* (1605) and then expanded in the *Novum Organum* (1620), *De Augmentis Scientiarum* (1623), and in the author's utopian vision *New Atlantis* (1627). The study of mechanical arts held a central place in Bacon's program for the development of science. In the *New*

8 See A. C. Keller "Zilsel, the Artisans, and the Idea of Progress in the Renaissance," in *Roots of Scientific Thought*, edited by Philip P. Wiener and Aaron Noland, Basic Books Inc. (N.Y.), 1957, pp. 281-286.

9 In the *Discourse on Method* Descartes expressed the hope that the future may see "the invention of an infinity of devices by which we might enjoy, without any effort, the fruits of the earth and all its commodities, ...". See *Descartes, Discourse on Method and the Meditations,* translated by F. E. Sutcliffe, Penguin Books (New York), 1968, Discourse 6, p. 78. Descartes also established a connection between philosophy and the mechanical arts; in the *Regulae* Descartes wrote: "There is here a resemblance between our method and the procedures of those mechanical arts which are independent of outside aids, and which themselves teach how to fabricate the tools they need." See "Rules for Guidance of our Native Powers,"*Descartes Philosophical Writings*, translated by Norman Kemp Smith, Random House (New York), 1958, Rule VIII, p. 35.

10 Leibnitz believed that the work of craftsmen and technicians offered a significant base for the formation of theories, for practice was considered a more particular and compounded theory. See Paolo Rossi, "Philosophy, Technics, and the History of the Arts in the Seventeenth Century," in *Philosophy, Technology, and the Arts in the Early Modern Era*, op. cit., pp. 128-134.

11 See G. W. F. Hegel, *Reason in History*, translated by Robert S. Hartman, Bobbs-Merrill Company (Indianapolis, Indiana), 1953, pp. 11, 12, and 20.

Atlantis Bacon described an ideal state ruled by a body of scientists and scholars. They were organized according to the various categories of labor and groups of trade. At their disposal were laboratories, workshops, factories, and agricultural stations allowing the research of technical innovations. Bacon placed the production processes of the mechanical arts as the model for scientific inquiry. His work called for a total reform of academic discourse, replacing the rhetoric-literary culture of traditional philosophy by a technico-scientific one.

By taking the mechanical arts as a model for cultural development, it was possible, according to Bacon, to give rise to a type of culture which could be compatible to progress. In such a culture, "the work of mechanics and empiricists will be conjoined with that of the philosophers," and in this way could surpass the mere instrumentality of technical matters.[12] This historical change, according to Bacon, depended on a series of material factors which necessarily involved a significant modification in the mode of thinking within philosophy. A new understanding of philosophy emerged as being based on the conjunction of empirical work and rational thought. Walter E. Houghton writes that Bacon based his conception on two premises: "in general, from the first principle of his thought, the inductive study of nature for the use and benefit of man; and in particular, from the groundwork for such a study in a

[12] See Paolo Rossi, op.cit., p. 86.

new natural history that would include and emphasize the mechanical arts."[13]

In the *Advancement of Learning* (1605) as well as in the *Preparative towards a Natural and Experimental History* (published in 1620 as an appendix to the *Novum organum*) the concept of a historical evolution of the trades was for the first time explicitly made. Bacon writes, "the history of Arts is of most use, because it exhibits things in motion, and leads more directly to practice."[14] The writing of such a history would allow the further development of civilization through the proliferation and discovery not only of ingenious practices in trades, but also of scientific principles and axioms. This idea constituted the major thrust of Bacon's program for his 'advancement of learning':

... the use of history mechanical is of all others the most radical and fundamental towards natural philosophy; such natural philosophy as shall not vanish in the fume of subtle, sublime, or delectable speculation, but such as shall be operative to the endowment and benefit of man's life. For it will not only minister and suggest for the present many ingenious practices in all trades, by a connexion and transferring of the observations of one art to the use of another, when the experiences of several mysteries shall fall under the consideration of one man's mind; but further it will give a more true and real illumination concerning causes and

13 Walter E. Houghton, Jr., "The History of Trades: its relation to seventeenth-century Thought," in *Roots of Scientific Thought*, edited by Philip P. Wiener and Aaron Noland, Basic Books Inc. (New York), 1957, pp. 354-381.

14 Ibid., p. 359.

axioms than is hitherto attained. ... so the passages and variations of nature cannot appear so fully in the liberty of nature as in the trials and vexations of art.[15]

Today, the terms *causes* and *axioms* are closely associated with hypothesis and laboratory experiment. In the seventeenth century, however, such laboratories did not exist. It is therefore not surprising that Bacon turned to factories and workshops, for they provided the necessary conditions in which technology and science could develop. The materials, instruments, and techniques employed by craftsmen within their work offered the possibility for a methodological approach to scientific research. This idea was mentioned by Bacon in an 1608 entry of his diary describing the issues to be considered when compiling a history of trades. First, the approach to a history of the mechanical arts had to address the quantity and quality of the materials used by craftsmen in the fabrication of artifacts; then, the instruments and machines employed in the artisan's work were to be analyzed, followed by a study of the procedures typical of production processes. Finally, after considering problems and qualities of such work, axioms and

[15] Francis Bacon, *The Advancement of Learning*, 1605; in *Francis Bacon, The Advancement of Learning* and *New Atlantis*, edited by Arthur Johnson, Clarendon Press (Oxford), 1974, p. 71.

directions could be deduced for the formation of general principles.[16]

The interdependence between art and science advocated by Bacon formed the foundation for the progressive advancement of modern knowledge. Such progress, leading to the improvement of the human condition, required that the knowledge of techniques be integrated into the field of philosophy, from which by tradition technology had been excluded. Historically, the techniques of production inherent within the mechanical arts had been perfected by artisans, builders of machines, engineers, and architects, all of whom were outside traditional science. Their methods, Bacon argued, must become the object of scientific study and intellectual reflection.

Bacon's proposition implied a substantial union between the two basic forms of human activity, manual and intellectual labor. This view evolved from the consideration that "knowledge also is a kind of *making* that involves *making*," and that "making by itself is a form of cognition" which generates knowledge.[17] Bacon here asserted the identity of truth and utility, the former being the subject of philosophy and science while the

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16 The following quote from Bacon's diary is taken from: Walter E. Houghton, Jr., "The History of Trades: its relation to seventeenth-century Thought," op.cit., p.358: "*To procure an History mechanique to be compiled with care and diligence, and to profess... the experiments and observations of all Mechanical Arts, the places or things to be inquired are; first the materials, their quantities and proportions; next the instruments and engines required; then the use of every instrument; then the work itself and all the process thereof with the times and seasons of doing every part thereof. Then the errors which may be committed, and again those things which conduce to make the work in more perfection. Then all observations, axioms, directions. Lastly all things collaterally (placed, incidentally or intervening)*."

17 Rodolfo Mondolfo, *Alle origini della filosofia della cultura*, (Bologna) 1956, p. 147.

latter pertained to the arts in general and to the mechanical arts specifically. In paragraph 124 of the first book of the *Novum Organum* the identity rather than the opposition between *truth* and *utility* was expressed in the assertion "*ipsissimae res sunt veritas et utilitas.*" In this respect truth is considered to be in conformity with reality, allowing the understanding that the objects of the material world, i.e. the things themselves, pertain to truth and usefulness at the same time. Bacon was searching for the essential condition of the physical world, not in terms of its appearance but instead by emphasizing its condition of being. Bacon's statement "*ipsissimae res sunt veritas et utilitas*" has been analyzed by Paolo Rossi[18] to correctly mean: *"things as they really are, considered not from the viewpoint of appearance but from that of existence, not in relation to man but in relation to the universe, offer conjointly truth and utility."*[19] From this philosophical position a new understanding resulted within the relation between form and technique. The unity of truth and utility, which presupposed the interdependence of theory and practice as an existential condition, offered an ontological rather than a representational approach to the connection between form and technique. Form signified the objective reality of things as they were in their essential condition, thus including technical matters. The definition of form as the truthful expression of technique received here for the first time its philosophical justification.

[18] Paolo Rossi is the author of a remarkable study on Francis Bacon, *Francis Bacon, from Magic to Science*, Routledge & Kegan Paul (London), 1968, translated from *Francesco Bacone: Dalla Magia alla Scienza*, 1957.

[19] Paolo Rossi, "Truth and Utility in Bacon," in *Philosophy, Technology and the Arts in the Early Modern Era*, op.cit., p. 160.

As technique in general gradually advanced through history, it became essential that man be aware and have knowledge of its development in order to understand the interdependence between intellectual discourse and technical production within the culture. Bacon proposed the concept of a history of ideas which would include the advancement of the mechanical arts. Theoretical propositions as well as practical methods of production were to be compiled, studied, and organized. To achieve such a systematic *corpus* of knowledge it was necessary, according to Bacon, to found institutions and research organizations allowing the collaboration among scientists. Bacon's account of Salomon's House in his utopian fable *New Atlantis* (1627) represents a description of the type of society which he hoped would be established in England. The House of Salomon, also called *College of the Six Days' Works*, was a kind of scientific institute. Its organizational structure was based on a division of scientific labor into (1) collectors of books from foreign countries, (2) scholars who compiled information from all the available literature, (3) men who studied the methods practiced in workshops and ateliers, (4) innovative scientists engaging in new experiments, (5) those who assembled the results, (6) men who had the task to investigate the practical application of discoveries, (7) scholars who were to identify new research projects based on previous experiences, (8) those who executed the research, and (9) those who were asked to deduce fundamental principles and axioms from all the work.[20] The results were then published to allow the

[20] Francis Bacon, *New Atlantis*, 1627; in *Francis Bacon, The Advancement of Learning* and *New Atlantis*, edited by Arthur Johnson, Clarendon Press (Oxford), 1974, pp. 245, 246.

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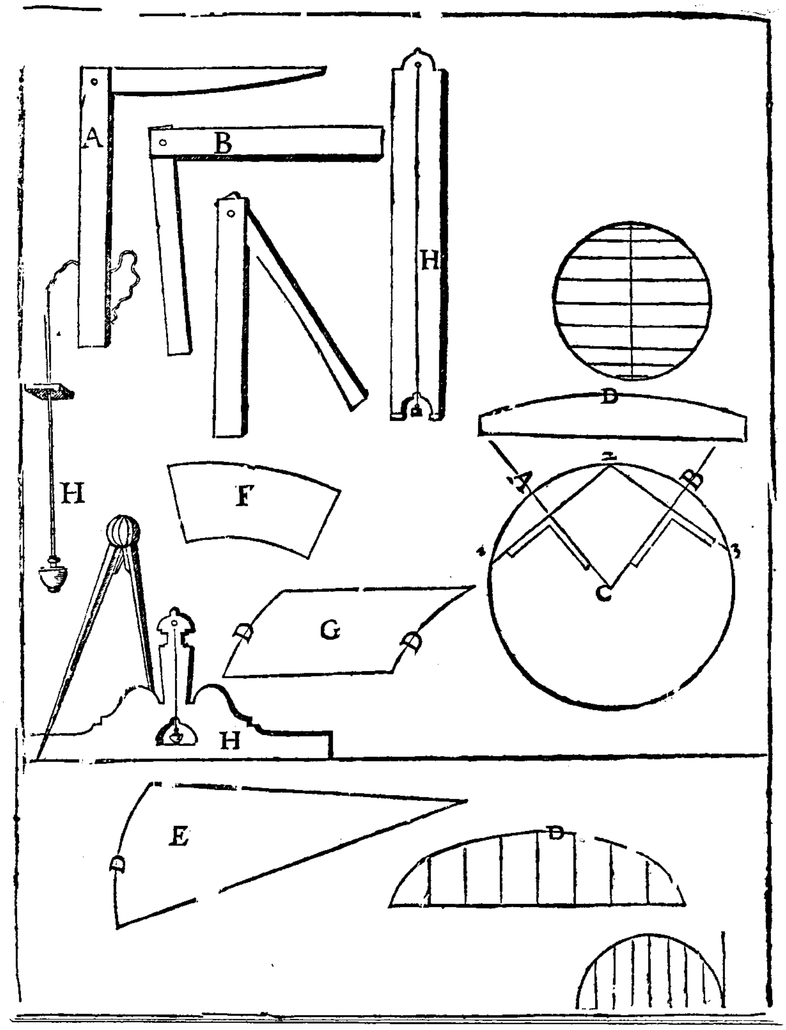

Philibert de l'Orme, instruments for determining the shape of stone and wooden arches, from *Le Premier Tome de l'Architecture*, Paris, 1567.

proliferation of discoveries into other countries. Salomon's House, which also acted as a college, offered the instruction of novices and apprentices whereby insuring the future succession of the institute.

The ideas expressed by Bacon in the early seventeenth century were realized a few decades later when the first modern scientific academies were founded, L'Accademia del Cimento in 1657, the British Royal Society in 1662, and the French Académie des Sciences in 1666. Their common aim was the development and the progress of scientific knowledge. The mechanical arts became the subject of intellectual discourse; manufacturing processes and technical means of production were studied and placed for the first time within the framework of theory. Bacon's project essentially led to the conception of *technology* as a body of knowledge which constituted an overall structure for the understanding of technical matters in theory and practice.

Construction Technology

The concept of scientific progress influenced the understanding of architecture as a constantly advancing discipline. As science addressed the mechanical arts, similarly within the field of architecture an increasing interest developed in practical considerations. New emphasis was given to the exigencies of construction. Toward the end of the seventeenth and the beginning of the eighteenth centuries, a series of treatises were published addressing methods and techniques employed by craftsmen for the production of buildings. Such a development led to the conception of the field of construction

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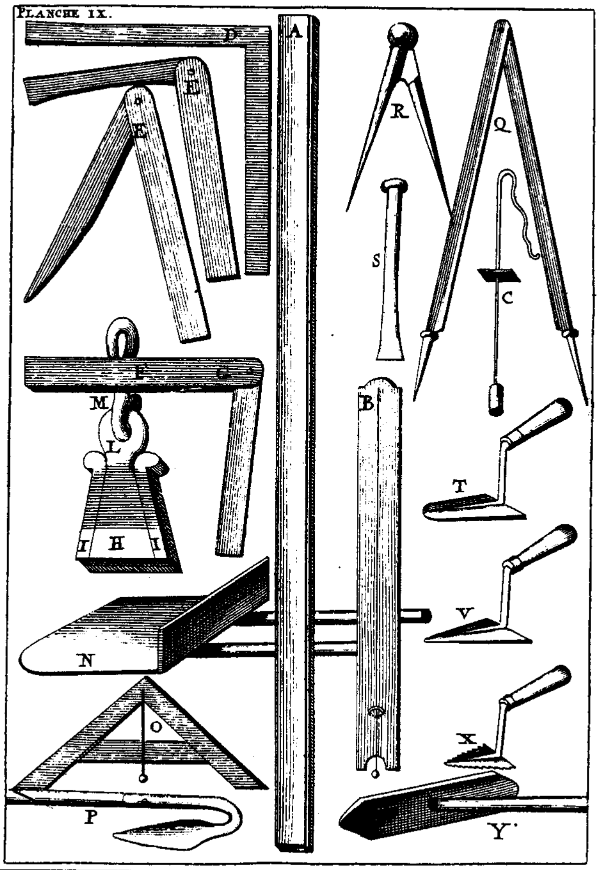

André Félibien, plate showing the different tools used by the masons in building construction, from *Des Principes de l'Architecture, de la Sculpture, de la Peinture*, Paris, 1699.

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technology, since practice was now viewed from a theoretical standpoint allowing the incorporation of building practice within a structured framework of knowledge.

The Frenchman André Félibien (1619-95), the Secretary of the *Académie des Sciences* and the *Historiographe des Bâtimens du Roi,* published in 1676 a book entitled *Des Principes de l'Architecture, de la Sculpture, de la Peinture* .[21] In the preface Félibien wrote that a great number of existing treatises on architecture had been published, but that only a few authors as Philibert de l'Orme, François Derrand, Girard Desargues, and Jousse de la Fleche had attempted to address the techniques of construction.[22] Philibert de l'Orme, for example, was trained in the closely organized circles of masons, and his written works *Nouvelles Inventions pour Bien Bastir et à Petits Fraiz* (1561)[23] and *Le Premier Tome de l' Architecture* (1567)[24] revealed his interest in building practice. Several chapters of Philibert de L'Orme's *Architecture* showed different methods of geometric projection and instruments for determining the shape of stone and wooden arches. In the *Nouvelles Inventions* construction details of wooden vaults were shown and the method of their assembly explained. Such attempts to describe the methods of construction, according to Félibien, did not yet

21 André Félibien, *Des Principes de l'Architecture, de la Sculpture, de la Peinture et des autres arts qui dépendent; avec un Dictionnaire des Termes propres à chacun de ces Arts,* Paris, 1699; Gregg Press Limited (Farnborough, England), 1966.

22 Ibid., preface.

23 De L' Orme, Philibert, *Nouvelles Inventions pour bien Bastir et à Petit Fraiz,* Paris, 1561. *Architecture de Philibert de L'Orme, edition integrale de 1648,* Pierre Mardaga éditeur (Paris), 1981.

24 De L' Orme, Philibert, *Le Premier Tome de l'Architecture,* Paris 1567, re-edited with the *Nouvelles Inventions* in 1568, 1576, 1626, 1648, 1894. *Architecture de Philibert de L'Orme, edition integrale de 1648,* Pierre Mardaga éditeur (Paris), 1981.

constitute a complete theoretical framework for construction technology. He considered his contribution as a first step toward the creation of a theory of construction. Félibien emphasized the academic value of his work, presenting it as the result of an enterprise that reflected the interest of the Academy of Architecture and distinguished architects.[25] Félibien believed that technique was a most important component of architecture, for which he used the term *la science de bastir*, the science of building. His treatise was intended to instruct those interested in architectural construction. The section on architecture provided explanation of techniques and tools used by the various trades. In order to compile the information Félibien mentioned that he had to establish direct contact with artisans, visit their workshops, and examine their means of production.[26] This was not an easy task, for traditional craftsmanship had been for a long time completely separated from the academic world. A dichotomy existed between practice and theory which began to be addressed.

After a brief discussion on the orders, Félibien's book on architecture primarily focused on the division of trades in construction, thereby structuring the treatise. To the categories of labor belonged masonry, carpentry, roofing, plumbing, paving, cabinetry, locksmithing, and windowmaking. Each chapter described the purpose of the work and presented in

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25 André Félibien, *Des Principes de l'Architecture*, op.cit., preface.

26 Félibien mentions that it was a difficult task to gather information from the artisans: ".. *j'ai esté obligé d'avoir encore recours aux Ouvriers: Il a fallu entrer dans leurs boutiques, visiter leurs ateliers, considerer leurs machines, & leurs outils, & les consulter sur leurs divers usages, & souvent s'éclaircir avec eux sur des noms differents qu'ils donnent à une mesme chose; & c'est ce qui a fait le plus de peine.*"

plates the different tools, instruments, or machines employed by the artisans in their craft. Often the place of production was mentioned and illustrated, allowing the reader to receive an understanding of the context in which the work was performed. Félibien provided definitions of the various terms used by the craftsmen to identify their tools and techniques, for he was concerned about the confusion of words and concepts prevailing within the field of construction.[27] He therefore appended to his treatise a dictionary, the *Dictionnaire des Termes Propres, a l'Architecture, a la Sculpture, a la Peinture*, which provided precise explanation of the terminology used within the arts and crafts. In addition to the specific definitions of building materials, tools, and methods, the meaning of certain general words was explained. Architecture, for example, was defined, in Vitruvian terms, as the science of the art of building "requiring a vast diversity of studies and knowledge by which to understand the work of all the arts pertaining to the field."[28] Félibien's definition of architecture, his work on the terminology of construction, as well as his great interest in technique, reflected the spirit of the time. His work constituted a step toward the realization of the project which Francis Bacon had called the advancement of modern knowledge.

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27 " *... nous voyons cependant que plusieurs Auteurs & Architectes mesme, aussi bien que les Ouvriers, ont donné differens noms à un mesme membre d'Architecture, pour s'accommoder à l'usage de chaque pays, & mesme les confondent souvent, appellant improprement une partie d'un nom qui ne luy convient pas, ...*"

28 "*Architecture, est l'art de bien bastir; selon Vitruve 1.I.c.I. c'est une science qui doit estre accompagnée d'une grande diversité d'études & de connoissances, par le moyen desquelles elle juge de tous les ouvrages des autres arts qui luy appartiennent.*" From Félibien's *Dictionnaire des Termes Propres a l'Architecture, a la sculpture, a la peinture, et aux autres arts qui en dépendent*, Paris, 1699.

In 1702, three years after the re-publication of Félibien's treatise, a small book entitled *Mémoires Critiques d'Architecture* [29] was released in Paris, written by the *Président du Bureau des Finances*, Michel de Frémin. His writing conveys an unusual objectivity, taking some ideas of Claude and Charles Perrault to their logical conclusion. Frémin proposed a definite break with the authority of the orders, emphasizing instead the value of architecture as an building art:

L'Architecture est un Art de bâtir selon l'objet, selon le sujet & selon le lieu; par cette définition, je designe que l'Architecture n'est rien moins que la simple connoissance des cinq Ordres. Je fais entendre que cette connoissance-cy est dans l'Architecture la moindre partie, & qu'un Architecte qui ne sçait parler que des mesures des cinq Ordres est un Architecte très-petit & très-mince. [30]

In the *Mémoires Critique* Frémin essentially addressed problems of construction. Architects, he asserted, should be direct in their approach to their art and informed regarding matters of building practice. He emphasized, however, that the architect was not a craftsman; his role being the rational coordination of all the aspects of architectural production. The architect was to regulate with his intellect the processes of design and construction, "controlling the unity and coherence of his

[29] Michel de Frémin, *Mémoires Critiques d'Architecture. Contenans l'Idée de la Vraye et de la Fausse Architecture; ...* , Paris, 1702; republished by Gregg Press Limited (Farnborough, England), 1967.

[30] Ibid., Sixième Lettre, p. 22.

inventions."[31] Frémin distinguished between "true and false architecture," a concept which he called "*L'idée de la vraye et de la fausse Architecture*." True architecture, according to Frémin, was based on rational principles as determined by the use of common sense for the choice of materials, the use of craftsmanship, and the correct arrangement of building components. The foundation of Frémin's theory refers to the concept of "positive" beauty which Claude Perrault and his brother Charles had advocated. At his most extreme, Frémin proposed the application of physics in architecture by which simplicity and regularity could be achieved.[32] Frémin discouraged the use of ornament; its excessive use was considered in disagreement with the natural principles of construction. Such an emphasis on decorative parts led to a "false" conception of architecture.[33] In this respect Frémin expressed his suspicion regarding seductive architectural drawings nicely rendered but lacking in architectural consistency.

Frémin's position, especially his concern for the utilitarian might indicate a proto-positivistic attitude.[34] However, the reference to natural principles, his interest in the production

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31 *"... il est neanmoins vray que sa pratique ne fait pas absolument l'Architecte, c'est l'invention, c'est la précision, c'est la justesse dans l'invention, c'est un jugement guidé par beaucoup de sagesse & confirmé sur beaucoup de docilité, qui peuvent décider du prix de l'Architecte, ..."* ; ibid., Troisième Lettre, p. 7.

32 *"... si les règles de l'Art vous manquent, vous n'avez qu'à vous servir de celle de la Physique; elles vous conduiront plus juste, & en vous les r'appellant je vous promets que si vous les consultez bien, vous ferez une distribution toute complette. Vous n'auriez pas crû qu'avec de simples principes de Physique l'on pût bâtir une maison & la rendre absolument regulière; ..."* ; ibid., p. 40.

33 Ibid., p. 58.

34 See Alberto Pérez-Gómez, *Architecture and the Crisis of Modern Science*, MIT Press (Cambridge), 1983, p. 51.

of building, as well as the priority given to the function of the architectural project, reveal Frémin's adherence to Bacon's natural philosophy. The connection between truth and utility constituted the dominant idea within Frémin's concept of a "true" architecture. He even asserted that those architects with a knowledge of philosophy, i.e. the theory of modern science, were to be considered excellent.[35]

The increasing rationalization evident in architectural intentions at the beginning of the eighteenth century indicated an assimilation of the concepts of natural philosophy within architecture. Architects gradually identified the principles of architecture with those of science, while presuming a fundamental analogy in those methods that led human knowledge to the attainment of truth. Such development was not limited to the field of architecture but pertained at the time to all the technical arts. Theories of construction were only a small part of a larger project, that being the conception of a body of technological knowledge.

The increasing interest in the mechanical arts in the eighteenth century found its culmination with the publication of the *Great Encyclopedia*, credited to Denis Diderot's (1713-84) and Jean Le Rond d'Alembert's (1717-83).[36] The *Encyclopédie*, which was to significantly influence the

[35] *"... car suivant cet axiome, vous allez penser qu'un vieux Repetiteur de Philosophie doit être un excellent Architecte; cela cependant est vray, ... ,"* Frémin, op. cit., p. 40.

[36] Denis Diderot and Jean Le Rond d'Alembert, *Encyclopédie, ou Dictionnaire Raisonné des Sciences, des Arts, et des Métiers par une Société de Gens de Lettres,* Paris, 1751-1780, reprint of the first edition, Friedrich Frommann Verlag (Stuttgart-Bad Cannstatt), 1966, 34 vols.

understanding of building practice, was subtitled *Dictionnaire Raisonné des Sciences, des Arts et des Métiers* . The text of the encyclopedia was published at intervals between 1751 and 1776, while the plates were issued between 1762 and 1777. The compilation of the *Encyclopédie* was a major enterprise disclosing the prevailing efforts within society to structure the knowledge of advancing technique. Francis Bacon's vision of a history of trades, which had preoccupied the Royal Society[37] in England for more than a century, was finally realized in France. The origin of the French *Encyclopédie* can nevertheless be traced back to British efforts. In 1745 the publisher André François Le Breton commissioned a translation of Ephraim Chambers's two-volume *Cyclopaedia, or Universal Dictionary of Art and Sciences*, which had been published in London in 1728. Initially, the work proceeded slowly but began to progress rapidly in 1747 when Denis Diderot was appointed as the new general editor. Diderot was a philosopher and man of letters who had already gained significant reputation as the editor of the *Dictionnaire universel de médicine* . For the scientific entries of the *Encyclopédie* Diderot collaborated with the mathematician and physicist Jean Le Rond d'Alembert. Together they were able to produce an encyclopedia unlike anything that had previously been published, fare surpassing the scope of the English precursor.

In 1750, a year prior to the publication of the first volume of the *Dictionnaire Raisonné*, a promotion campaign was undertaken

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[37] An account on the Royal Society's plan to compile a "History of Trades" is given by Walter E. Houghton, Jr. in his article "The History of Trades: its Relation to Seventeenth-Century Thought," in *Roots of Scientific Thought*, op. cit., pp. 354-381.

to gain general public interest. Since one of the major goals of the encyclopedia was the dissemination of scientific and technological knowledge, it was important to announce the forthcoming release of the work. A prospectus[38] was issued in which the *Encyclopédie* was described as "the work of a large group of men of letters, experts, and specialists, who have set themselves the task of assembling and condensing all, or virtually all, human knowledge in eight volumes of text and two volumes of illustrations."[39] While the encyclopedia finally encompassed seventeen volumes of text and eleven volumes of plates, the prospectus outlined the principle collective effort of the enterprise. The *Encyclopédie* was in fact to a large extent a compilation of previously assembled material, for Diderot was able to draw on a large number of specialized treatises. In the section on human anatomy, for example, plates were borrowed from Andreas Vesalius's treatise *De humani corporis fabrica* [40] which had been published more than a century earlier in 1543. To illustrate casting techniques, plates were made after a publication by Germain Boffrand, who was a member of the Royal Academy of Architecture.[41] The technique which he proposed in the *Description de ce qui a été Pratiqué pour Fondre en Bronze d'un seul Jet la Figure Equestre*

[38] See "Prospectus de l'Encyclopédie," in *Diderot uvres Complètes*, Hermann (Paris), 1976, vol. V, pp. 84-130.

[39] The quote from the prospectus is taken from the "Introduction" to *Diderot Encyclopedia, The Complete Illustrations 1762-1777*, edited by Jacques Payen and Roger Lewinter, Harry N. Abrams Inc. (New York), 1978, p. ix.

[40] See *The Anatomical Drawings of Andreas Vesalius*, edited by J.B. De C.M. Saunders and Charles D. O'Malley, Crown Publishers, Inc. (New York), 1982.

[41] See Germain Boffrand, *Description de ce qui a été Pratiqué pour Fondre en Bronze d'un seul Jet la Figure Equestre de Louis XIV* , Paris, 1743; republished by Gregg International Publishers (Farnborough, England), 1969.

de Louis XIV (1743) was included in the *Encyclopédie*, for it constituted an exemplary technical study on how to cast a bronze equestrian statue in one piece. Other material for the encyclopedia was provided by the Académie des Sciences which had been commissioned by Colbert in 1675 to assemble a *Description of the Arts and Crafts.*[42] Additionally, various scholars were asked to contribute their knowledge: Jean-Jacques Rousseau, for example, wrote the entries on music and political economy; Voltaire provided articles on literary criticism, history, and politics; and d'Alembert, in addition to his collaboration on the scientific sections, was the author of the *Discours préliminaire*, the introduction to the *Encyclopédie*.[43] Although one of the intentions of Diderot was to encourage new scientific discoveries, the encyclopedia did not offer technical innovations. The achievement lay in the attempt to document and systematize the knowledge of modern civilization. The *Encyclopédie* was a historical document, a major project which necessitated the collaboration of many, technicians, engineers, mathematicians, scientists, and philosophers, all of whom worked toward the same goal of the advancement of knowledge. A systematic approach seemed necessary by which to achieve a unified body of knowledge, as d'Alembert mentioned at the beginning of the "Preliminary Discourse:"

[42] Material for the project of the Académie des Sciences had been assembled since 1675 but had not yet been published. Permission was given to include some of the work in the *Encyclopédie*. Eventually, the Academy of Science began to release the *Description of the Arts and Trades*. In 1761 the first volume appeared, and by the time of the French Revolution seventy-six volumes had been published.

[43] See Jean Le Rond D'Alembert, *Preliminary Discourse to the Encyclopedia of Diderot*, Bobbs-Merrill Company (New York), 1963.

The work which we are undertaking and wish to complete has two goals: insofar as it is an encyclopedia, it must explain the order and interrelations of human knowledge; as a systematic dictionary of the sciences, arts, and crafts, it must contain not only the general principles which are the foundations of each science and every mechanical or liberal art but also the most essential details which constitute its body and substance. ... If anyone were to reflect on the connection between certain discoveries, it would easily be perceived that the sciences and the arts lend each other aid and consequently that there is a chain uniting them. While it is often difficult to reduce each science or art to a small number of rules or general principles, it is not easier to condense the infinitely varied branches of human knowledge into a unified system.[44]

The Cartesian ideal of the unity of knowledge was similarly applied to the field of architecture. Jacques-François Blondel (1705-74), author of the article "Architecture" in the first volume of the encyclopedia, conceived of architecture as a unified and universal science. The school Blondel had instituted in the early 1740's was to realize his program by offering a large number of different subjects; in addition to drawing, history, and theory, courses were given in mathematics, geometry, topography, mensuration, surveying, and stereotomy. And, his *Cours d' Architecture*, edited and published by Pierre Patte after Blondel's death, constituted an extensive body of architectural theory, an encyclopaedic work

[44] D'Alembert, "Preliminary Discourse," in *Denis Diderot's Encyclopedia* , edited and translated by Stephen J. Gendzier, Harper & Row (New York), 1967, p.1.

on architecture.[45] Blondel believed that the architect must not only have knowledge of all the theoretical sciences but that these, most importantly, were to be applied to practice.[46]

Although Blondel did not have extensive knowledge of architectural construction, he nevertheless argued that theory must address the real conditions of practice. The word *Architecte*, he wrote in the *Encyclopédie*, has its etymological root in the Greek terms *archi* and *tektón* , meaning *principal ouvrier*, or chief worker. Similarly, the definition of architecture as "the art of building," as given in the article "Architecture" of the encyclopedia, indicated the importance of practical matters: "Architecture est, en générale, l'art de bâtir."[47] While addressing the significance of building construction, Blondel's theory also advocated the consideration of function within the dicipline. In the *Encyclopédie* as well as in the first volume of the *Cours d'Architecture*, Blondel emphasized the important role of utility; he asserted that architecture had originally been conceived of necessity.[48]

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45 Jacques-François Blondel, *Cours d'Architecture ou Traité de la Décoration, Distribution et Construction des Bâtiments; contenant les Leçons données en 1750, & les Années suivantes, par J.F.Blondel, Architecte, dans son École des Arts*, ed. by Pierre Patte, Desaint (Paris),1771-77, 9 vols.

46 Ibid., "Dissertation sur l'utilité de joindre a l'étude de l'architecture celles des sciences et des arts qui lui sont relatifs," vol. 3, pp. xiii-lii.

47 See the articles "Architecte" and "Architecture" by Jacques-François Blondel in the*Encyclopédie*, first edition, (Paris) 1751, vol. I, pp. 616-618; third edition, Jean-Léonard Pellet (Genève), 1778, vol. III, pp. 249-255.

48 "*... nous dirons en général que son origine [architecture] est aussi ancienne que le monde; que la nécessité enseigna aux premiers hommes à se bâtir eux-mêmes des huttes, des tentes, & des cabanes; ...*"; from the article "Architecture" from the *Encyclopédie*. See also "De l'utilité de l'Architecture," in the *Cours d' Architecture*, vol. 1, pp. 118-143.

Consequentially, requirements of use had to be integrated within architecture.

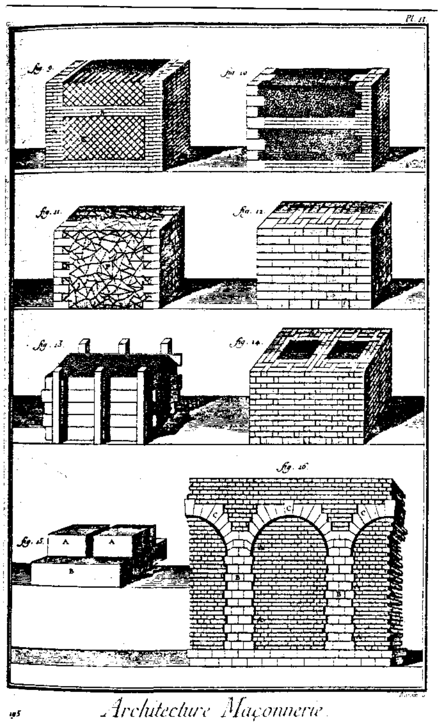
Both construction and function were to be reconciled with aesthetic considerations. Despite the fact that Blondel's position generally adhered to the traditional and classical principles of architectural form and proportion, his theory asserted the unity of construction, function, and beauty. This reconciliation of *firmitas, utilitas,* and *venustas* was described in Blondel's *Cours d'Architecture* as the *triple unité* by which aesthetic and practical matters were to be united: "L'unité consiste dans l'art de concilier dans son projet la solidité, la commodité, l'ordonnance, sans qu'aucune de ces trois parties se détruisent."[49] This synthesis within architecture was also implied in Blondel's entries within the *Encyclopédie* where he defined the task of the architect being "la construction, distribution & décoration." Similarly, the definition of architecture as "l'art de composer & de construire les bâtiments, pour la commodité & les différens usages de la vie," clearly emphasized the importance of durability and convenience for architectural composition.[50]

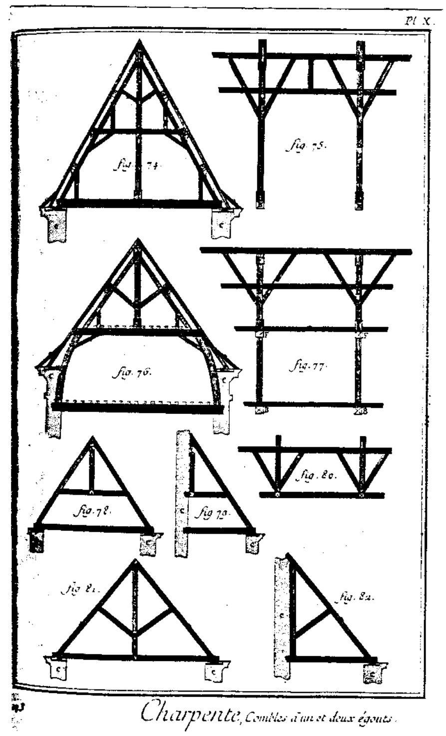
[49] Jacques-François Blondel, *Cours d' Architecture*, vol.1, p. 398. A similar proposition was made by Blondel in his *Architecture Françoise* in which three different types of proportion were distinguished. The first kind of proportional relation between architectonic parts was determined according to functional requirements; for example the dimension of a step was to be in agreement with the measurements of the human body. The second type was defined in reference to considerations of the building fabric, such as determining the dimensions of walls in accordance to their structural performance. The third understanding of proportion pertained to beauty and was traditionally applied to the classical orders. See *Architecture Françoise* (Paris), 1752, p. 318.

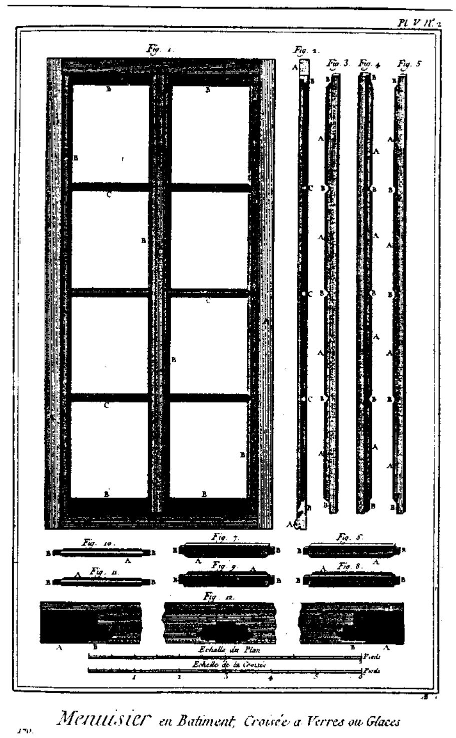
[50] *Encyclopédie*, op. cit., pp. 616, 617.

The general program of the *Encyclopédie* coincided in many respects with Blondel's theoretical assumptions. His systematic and rational approach to the field of architecture as well as his interest in the parameters of production and use were shared by the authors of the encyclopedia. The sections addressing various aspects of the field of architecture, although including a great number of illustrations on classical monuments, disclose the interest of the authors in techniques underlying building production. A significant part of the *Encyclopédie* is devoted to the traditional trades including such crafts as carpentry, joinery, masonry, locksmithing, metalworking, and cabinetry. Material properties as well as manufacturing processes were examined; various tools were illustrated and described as André Félibien had done in his treatise *Des Principes de l'Architecture*. The production, for example, of window glass, brick, ceramic, cast iron, metal sheeting, and lead piping, which all were of importance within the building trade, were addressed in detail.

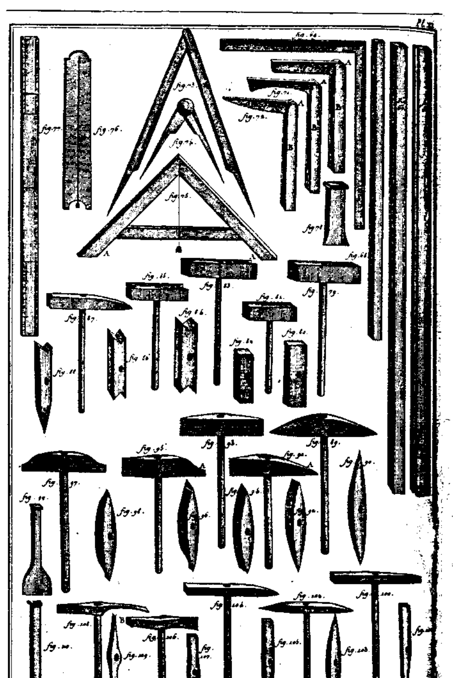
While offering descriptions of a large number and diversity manufacturing processes, the *Encyclopédie* provided a general overview of the productive forces within society. The article entitled "art" was actually an homage to the applied and mechanical arts. Diderot asserted that these should be given the same status as the liberal arts. He mentioned in the *Prospectus de l'Encyclopédie* that craftsmen were consulted and their workshop visited in order to compile the information on the traditional trades:

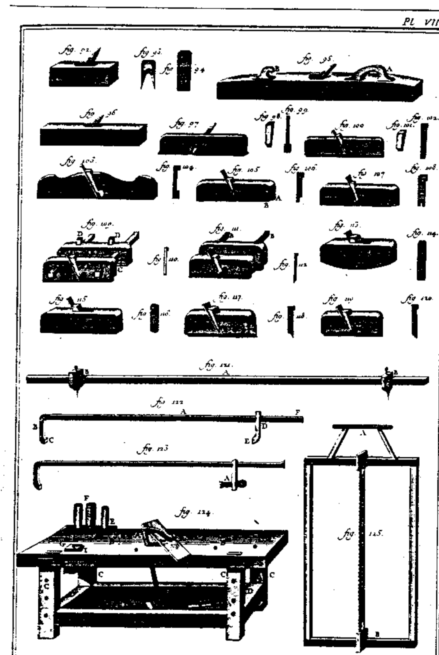






Plates from Diderot's *Encyclopédie* (1751-1776) showing wall, roof, and window details as belonging to the trades of the mason, carpenter, and window maker.





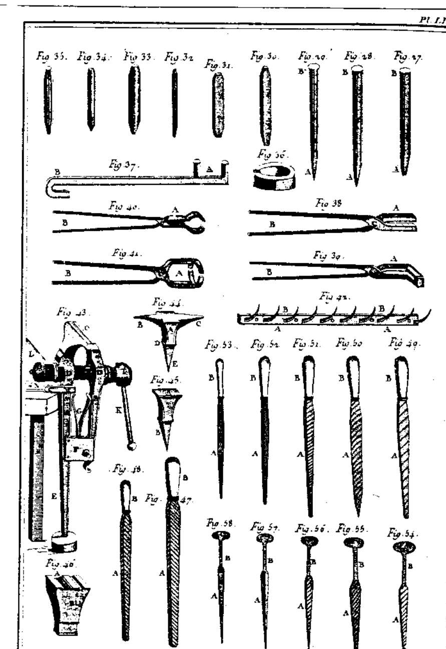


Illustration of different tools as used within masonry, carpentry, and locksmithing; from Diderot's *Encyclopédie* (1751-1776).

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We have turned to the most skilled workers of Paris and of all France, we have taken trouble of going into their shops, in order to question them directly, and to commit to writing what they dictated to us, to develop their thoughts, to draw out from them the terms proper to their profession, to lay out panels, to define them, to converse with those from whom we had obtained memoirs and (an almost indispensable precaution) to rectify in long and frequent conversation with some artisans that which other artisans had imperfectly, obscurely, and sometimes erroneously explained. ... With respect to them we had to exercise the function in which Socrates once gloried, the difficult and delicate function of effecting the parturition of souls: obstetrix animarum.[51]

Diderot truly felt himself to be the new Socrates; he wanted to bring to light the knowledge inherent within practice which theory for centuries had neglected. Although the *Encyclopédie* appears to be quite descriptive and realistic, advocating a pragmatic understanding of the world, the project was essentially guided by a symbolic intention. The philosophical implication of the encyclopedia lies in its claim to be "an index to the universe viewed in the light of its relationship

[51] "Prospectus de l'Encyclopédie", op. cit., pp. 99, 100: "*On s'est adressé aux plus habiles de Paris & du royaume. On s'est donné la peine d'aller dans leurs ateliers, de les interroger, d'écrire sous leur dictée, de développer leurs pensées, d'en tirer les termes propres à leurs professions, d'en dresser des tables, de les définir, de converser avec ceux dont on avait obtenu des mémoires, & (précaution presque indispensable) de rectifier dans de longs & fréquents entretiens avec les uns, ce que d'autres avaient imparfaitement, obscurément, & quelquefois infidèlement expliqué. ... Il nous a fallu exercer avec eux la fonction dont se glorifiait Socrate, la fonction pénible & délicate de faire accoucher les esprits,* obstetrix animorum."

with man."[52] In its attempt to present a history of trades, the *Encyclopédie* discloses an adherence to Francis Bacon's proposition to trace the development of the mechanical arts.[53] The search for truthful expression as advocated by Bacon was inherent within the ideological program of the encyclopedia. Diderot's project attempted to propose a coherent structure of human knowledge, which can be seen as revealing man's triumph over nature. As such knowledge, however, was considered to represent only a stage within a continuous development, the *Encyclopédie* remained open for future expansion. Seen in this light, Diderot's work seems to convey a belief in technique as based on a confident and optimistic understanding of technological progress. In breaking down machines and manufacturing processes into their component parts and sequences, the object of analysis became a symbol. Artifacts were seen in the form in which they actually existed. The description of their condition of being as perceived and systematized by man constituted the primary aim of the *Dictionnaire Raisonné*, establishing a universal order.

The structure proposed by Diderot for understanding the system of human knowledge was summarized in his "encyclopedic tree" which was first published in the *Prospectus* and later revised for the first edition. The "encyclopedic tree" followed Bacon's systematization in its division into the three main branches of knowledge, i.e. memory, reason, and imagination. The field of

[52] Roger Lewinter, "Diderot and the Encyclopedia," translated from French by Vivienne Menkes, introduction to *Diderot Encyclopedia; The Complete Illustrations 1762-1777*, Harry N. Abrams (New York), 1978, p. xxxi.

[53] The significance of Francis Bacon's work for the project of the *Encyclopédie* was repeatedly acknowledged by Diderot in the *Prospectus*.

architecture was represented with one entry in each of the three primary divisions. The practical art of building was placed with the traditional trades under the category of "Natural History", as the processes of craftsmanship were considered to deal with the transformation of nature. Military architecture belonged to the field of mathematics and therefore was placed under the heading of science and reason. Civil architecture was mentioned as a poetic art belonging to the realm of the imagination. Diderot explained that civil architecture, while in accordance with geometric and static principles, could also be understood as a mathematical science. Also, acknowledging the fact that architecture necessitates the traditional trades for its realization, Diderot wrote, that architecture could also very well be considered part of the practical arts.[54] In other words, within the system of human knowledge architecture was seen as a product of the imagination uniting both the theoretical sciences as well as the practical arts. The "encyclopedic tree" in representing a structured framework of knowledge was not devoid of symbolic intentions. This was explicitly expressed in the frontispiece of the first edition which allegorically depicted the system underlying Diderot's "encyclopedic tree":

Beneath a temple of Ionic architecture, sanctuary of Truth, we see Truth wrapped in a veil, radiant with a light which parts the clouds and disperses them.
On the right of Truth, Reason and Philosophy are engaged, the one in lifting the veil from Truth, the other in pulling it away.

54 "Prospectus de l'Encyclopédie", op. cit., p. 117.

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Frontispiece by C.- N. Cochin of the first edition of the *Encyclopédie*, 1751.

At her feet Theology, on her knees, receives her light from on high.

Following the line of figures, we see grouped on the same side Memory, and Ancient and Modern History; History is writing the annals, and Time serves as a support for her.

Grouped below are Geometry, Astronomy, and Physics.

The figures below this group show Optics, Botany, Chemistry, and Agriculture.

At the bottom are several Arts and Professions that proceed from the Sciences.

On the left of Truth we see Imagination, who is preparing to adorn and crown Truth.

Beneath Imagination, the Artist has placed the different genres of Poetry - Epic, Dramatic, Satiric, and Pastoral.

Next come the other Arts of Imitation - Music, Painting, Scupture, and Architecture.[55]

During the Enlightenment at the time when the *Encyclopédie* was compiled, the theories of Sir Isaac Newton (1642-1727) generally had been accepted in Europe. Newton argued in favor of a systematization of knowledge through the observation of nature. He furthermore attempted, as had Bacon and Galileo previously, to deduce general principles from the diversity of observed phenomena. Newton proposed a relation between theory and practice in which the former aspired to be a description of the technical means of the latter. Physical reality revealed the ultimate meaning of human existence, for truth was considered to be inherent within the material world. In other

55 Translated from the 1751 edition of the *Encyclopédie* , in Jean Le Rond D'Alembert, *Preliminary Discourse to the Encyclopedia of Diderot,* op. cit., p. vii.

words, an idea of metaphysical implication guided theory, its task being to disclose the rationality evident in natural order and thus to express its truthful condition. Diderot's enterprise which gave renewed priority to practice was founded on the same symbolic intention. The systematization of knowledge reinforced the understanding of theory as a metaphysical justification of practice.

The sections of the *Encyclopédie* pertaining to the various branches of science followed Newton's model, in that scientific principles were frequently formulated. The entries addressing the traditional arts, however, were primarily descriptive. The formulation of general principles inherent within manufacturing and construction had to await the nineteenth century and the full development of the Industrial Revolution. Within the field of architecture, however, constructional principles were initially introduced at a purely aesthetic level during the early eighteenth century and were only later defined in quantitative and axiomatic terms.

The Representation of Construction in France

The growing interest in reality which emerged during the period of the Enlightenment influenced the understanding of compositional form within the field of architecture. The priority given to utility and the importance assigned to practical matters was to become represented by architectural form. Several treatises on architecture published during the eighteenth century disclosed a preference for aesthetic principles which necessitated the truthful expression of construction. As this proposition was fundamentally theoretical in nature, the revelation of technique within form was primarily considered in ideal rather than explicitly real terms.

In 1706, a few years after the publication of Michel de Frémin's *Mémoires Critiques*, another treatise on architecture, the *Nouveau Traité de Toute l'Architecture*, was written by the Abbé Jean-Louis de Cordemoy.[56] While this book primarily offered an academic discussion, Cordemoy referred to the art of building addressing contractors and craftsmen; the treatise was subtitled on *l'art de bâtir utile aux entrepreneurs et aux ouvriers*. Cordemoy's knowledge of architectural practice, however, was not extensive. In this regard, his treatise disclosed an abstract integration of practical issues within theory. While avoiding specific descriptions of building materials and techniques, construction was addressed in *abstractum* as a significant aspect of architectural theory.[57] Following the example set by Félibien, at the end of his treatise Cordemoy included a dictionary, the *Dictionnaire de Tous les Termes d' Architecture*, in which he defined the terms used in his treatise. The word *architecture* , recalling Félibien's definition, was described as "the science or art of building." According to Cordemoy, the making of architecture

56 Abbé de Cordemoy, *Nouveau Traité de Toute l' Architecture ou l' Art de Bastir; Utile aux Entrepreneurs et aux Ouvriers*, Paris, 1706, 1714; republished by Gregg Press Limited (Farnborough, England), 1966.

57 "*On entend par les parties d'un Bâtiment, non seulement les pièces dont il est composé, comme une cour, un vestibule, une salle, &c. mais aussi celles qui entrent dans la construction de chacune de ces pièces: tels que font les Lambris, les Plafonds, les Chambranles, & sur tout les Colonnes entières, dont il est principalement question dans ce Traité.*" Ibid., p. 3.

required the knowledge of all the arts pertaining to the production of building.[58]

Cordemoy was probably inspired by Frémin in his search for truth and simplicity in architecture.[59] He insisted, as Frémin's writings had implied, that the purpose of a building should be expressed in its form. His conception of an honest and economical architecture was based on the revelation of construction and its elemental principles. Cordemoy thus argued in favor of simplified geometric forms, preferring plain masonry surfaces and discouraging, in accord with Frémin, the use of ornament.[60] While Cordemoy advocated the unity of all the parts within the arrangement of architectural components, he demanded that each element retained its autonomy. This quality, which asked for the independence of architectural elements, was called *dégagement*. He argued in favor of an architecture which was expressive of its constituent parts and therefore elemental in its conception. The use of the free standing column and the straight lintel were, for example, encouraged as such elements revealed the structural properties of load bearing members in their purest form. Pilasters were considered to be primarily ornamental and consequentially their

[58] *"Architecture est la science ou l'art de bien bâtir. Elle renferme, selon Vitruve, une diversité infinie de connoissances & d'études, sans lesquelles on ne peut juger comme il faut de tout ce qui appartient aux autres Arts qui en dépendent."* Ibid., p. 225.

[59] Robin D. Middleton, "The Abbé de Cordemoy and the Graeco-Gothic Ideal: A Prelude to Romantic Classicism", in *Journal of the Warburg and Courtauld Institute*, Vol. 25, 1962 and Vol. 26, 1963. See Vol. 25, p. 281.

[60] *"... ce qui fait voir en passant que le trop d'ornemens est un vice qu'il est bon d'éviter."* Abbé Cordemoy, op. cit., Ch. II, p. 93.

use generally discouraged.[61] In an 1962 essay entitled *The Abbé de Cordemoy and the Graeco-Gothic Ideal* , Robin Middleton reveals the seminal role played by de Cordemoy in the development of Neoclassical Rationalism in France:

He vigorously condemned the bas-relief effect of contemporary architecture and rejected scornfully the numerous motifs that were scattered over the surface of buildings, blurring their outlines with continuous and uneasy modelling. ... He went even further; he declared that pedestals, applied orders of columns and pilasters should be dispensed with, ... He desired, above all, a simplified rectangular architecture. He disliked acute angles and all curves. He approved only of rectangular door and window openings. He liked roof lines to be horizontal. Demanding the use of flat roofs or, as a more practical alternative, Mansart roofs, he sought to do away with the pediment altogether. [62]

The preference for *dégagement* and rectangularity, according to Middleton, led Cordemoy to ultimately "entertain the idea of an architecture surprisingly Greek in its principles." The structural clarity so vehemently upheld in the *Nouveau Traité* "led to an analysis not only of the buildings of ancient Greece

[61] "*Je sçay bien que la plûtpart des Architectes croyent qu'un Ouvrage sera d'autant plus beau, qu'il y aura plus d'ornemens; & c'est ce qui les portes à multiplier mal-à-propos ces demi-Pilastres, parce qu'il multiplient par là des demi-bases, des demi-chapiteaux, & des ressauts dans l'Entablement. Mais toutes ces choses font un fort mauvais effet. Il faut donc s'abstenir autant qu'on le peut, non seulement de ces fausses beautés qui résultent de cette pénétration de Pilastres, mais même de mètre ensemble deux demi-Pilastres qui forment un Angle rentrant, quoyqu'il s'en trouve dans quelques Ouvrages fort approuvez. Car ils suposent toûjours une pénétration mutuelle, contraire à cette exacte régularité qui plaît si fort dans l'Architecture.*" Ibid., p. 64.

[62] Robin D. Middleton, op. cit., p. 283.

but also of those of Gothic-France".[63] Most important was the fact that both Greek and Gothic architecture clearly expressed the function of their respective construction. Herein lay the essential characteristic of a formal style in which aesthetic principles were deduced from an ideal and abstract image of construction. Cordemoy addressed the practice of building at an intellectual level, without having specific knowledge of the techniques and processes of production. It was on this issue that he was sharply criticized by Amédée-François Frézier (1682-1773) who reproached Cordemoy for his lack of practical experience.[64]

Frézier was a military engineer, architect, and author of a renowned treatise on fireworks.[65] His theoretical and practical work relied on technical knowledge as guided by the new empirical science. Based on his experience as an engineer, he argued that arches and piers were more suitable for stone construction than the column and lintel system preferred by Cordemoy; he also believed that the pediment was a legitimate form since it expressed the slope of the roof. Generally, however, the disagreement with Cordemoy was rather of academic nature, for Frézier shared an essentially similar standpoint.[66] This became most evident in a treatise published by Frézier in 1737 entitled *La Théorie et la pratique de la coupe des pierres*

63 Ibid., pp. 283, 284.

64 The second edition of the *Nouveau Traité* (1714) included three responces to the critical letters of Amédée-François Frézier which had been published in the Jesuit review *Mémoires de Trévoux* .

65 Amédée-François Frézier, *Traité des feux d'artifices,* Paris, 1706.

66 Robin Middleton, op. cit., p. 287.

et des bois pour la construction des voûtes.[67] Frézier's interest in Gothic construction was guided by the conviction that scientific principles could be applied to architecture. He postulated that geometry, mechanics, and statics could directly inform the construction of structural members. Gothic architecture was described as "a precise, calculated affair, dependent on a carefully worked out system of vaulting;" the columns of Gothic cathedrals "upheld the ribs of the vaults, which in turn supported infilling panels or webs of brickwork or stone."[68] An unprecedented economy of means characterized Gothic structural systems whereby the distribution of loads was skillfully applied allowing piers and ribs to be of minimal dimension. The reference to Gothic construction, however, was not new within French architectural theory. Philibert de l'Orme had repeatedly described the Gothic vault and rib system as an independent structural framework. And, François Derand's treatise *L'Architecture des voûtes*, first published in 1643, addressed the structural elements of Gothic vaults as well as the methods underlying their assembly. New in Frézier's approach was the attempt to justify the specific choice of a construction system from scientific principles. The Gothic example offered Frézier certain observations which supported his view of architecture as a rational operation. The interest in Gothic architecture that formed such a remarkable part of the theories of Frémin, Cordemoy, and Frézier was a precursor

67 Amédée-François Frézier, *La Théorie et la pratique de la coupe des pierres et des bois pour la construction des voûtes, ou Traité de steréotomie à l'usage de l'architecture*, Strasbourg and Paris, 1737, to which the *Dissertation historique et critique sur les ordres d'architecture* was appended in 1738.

68 Robin Middleton, op. cit., p. 289.

of the ideas which Viollet-le-Duc would later develop during the nineteenth century.

Cordemoy's and Frézier's understanding of construction as a constituent factor of formal expression was further elaborated by the abbé and *hommes de lettres* Marc-Antoine Laugier (1713-1769). In the preface of his treatise *Essai sur l'Architecture*, published in 1753, Laugier expressed the need for clear principles in architecture.[69] He wrote: "There is no work as yet that firmly establishes the principles of architecture, explains its true spirit and proposes rules for guiding talent and defining taste."[70] Laugier believed that architecture should have as sound principles as did science. In stating that it was not sufficient to only know the technical aspects of production, Laugier clearly emphasized the necessity for a theoretical foundation of practice. Cordemoy was praised for his treatise contained "excellent principles and well-considered notions."[71] But with the exception of Cordemoy, Laugier maintained, most modern authors had avoided the "depths of theory." In architecture as in all other arts which are not

69 Abbé Marc-Antoine Laugier, *Essai sur l'Architecture*, Paris, 1753; for the translation in English see *An Essay on Architecture*, translated with introduction by Wolfgang and Anni Herrmann, Hennessey & Ingalls, Inc. (Los Angeles), 1977.

70 Ibid., Preface, p. 1.

71 Ibid., Preface, p. 2. In 1753 the *Essai sur l'Architecture* was sharply criticized for it was believed that Laugier had 'almost completely copied' Cordemoy's treatise. The critique was not justified: Laugier had acknowledged in the preface of his treatise that he had reiterated some of Cordemoy's ideas as well as having further developed them. See also Laugier's *Avertissement* which was added to the beginning of the second edition of 1755: "*The author of the* Examen *believes he humiliates me by incessantly repeating that all I do is to copy M. de Cordemoy who, he says, is the father of all my ideas. ... The reading of his treatise has much contributed to the development of my own ideas. But although I have profited by his learning, I believe myself to be more than a mere copyist of his views.*" Ibid., p. 149.

purely mechanical, "it is above all important to learn to think:"

An artist should be able to explain to himself everything he does, and for this he needs firm principles to determine his judgments and justify his choice so that he can tell whether a thing is good or bad, not simply by instinct but by reasoning and as a man experienced in the way of beauty.[72]

Convinced that architecture held absolute values, Laugier set himself the task of identifying the true causes of architectural beauty. In order to establish those "evident" principles that could become the foundation of practice, Laugier proceeded from empirical observations. First, he noticed how widely his reactions to architectural works varied. Then, through repeated experiments, he discovered that the same buildings always led to the same impressions. From this Laugier deduced that the concept of essential beauty in architecture must exist, independent of custom and convention.[73] The truth he was searching for pertained to an understanding of natural philosophy. As a Jesuit priest Laugier was well informed about the development of modern science. Newton's method based on the observation of facts and the discovery of natural laws was known in France. Scholars, such as Charles Louis Montesquieu, Denis Diderot, Jean d'Alembert, and Jean Jacques Rousseau had been exposed to Newton's ideas and had adopted his method to their fields of enquiry. The assumption can be made that

72 Ibid., Preface, p. 1.

73 For a thorough analysis of the theoretical implications of the *Essai sur l'Architecture* see, Wolfgang Herrmann, *Laugier and Eighteenth Century French Theory*, Chapter III: "The Theoretical Foundation", A. Zwemmer (London), 1962, pp. 35-52.

Laugier hoped to do for architecture what French scholars had done in their respective fields. He associated his work with the new achievements of natural history, science, and philosophy.[74]

The fixed and unchangeable laws of architecture could not be disclosed, according to Laugier, through the exclusive analysis of proportional systems. In his opinion, previous treatises on architecture had primarily been concerned with exacting measurements of the Orders or the study of antique monuments. Laugier believed those authors to be arbitrary in their approach, for they had been guided by prejudice, conventions, and above all the authority of the past. The same critique was also directed against Charles-Etienne Briseux who had published a treatise entitled *Traité du Beau Essentiel* in 1752, a year prior to the release of Laugier's *Essai sur l' Architecture*.[75] Briseux was of the conviction that his own work revealed the essential principles of beauty in architecture. Those principles, however, reaffirmed traditional harmonic proportion as the absolute rule of beauty. Laugier was critical of Briseux's writing in not accepting the cause of absolute beauty to be proportion alone.[76] Laugier implied that his attempts in

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74 Ibid., p. 36.

75 Charles- Estienne Briseux, *Traité du Beau Essentiel dans les Arts, appliqué particulièrement a l'Architecture*, Paris, 1752; reprint of the 1752 edition by Minkoff Reprints (Genève), 1974.

76 The second edition of the *Essai*, published in 1755, was considerably enlarged, mainly by additions in which Laugier replied to criticism by Etienne Briseux. Laugier also attacked Briseux's *Traité du Beau Essentiel*: "*M. Briseux has just printed a work in a magnificent way in which he wastes much time to prove the need for proportions, ... It would have been of greater value if M. Briseux had applied himself to giving us rules which are capable of satisfying enlightened reason and of leading us with certainty to true proportions. What he says about it is founded only on a practice for which he gives but false reasons.*" From the *Essai sur l' Architecture*, 2nd edition, op. cit., pp. 63, 64.

the *Essai sur l' Architecture* went further and that the cause of beauty for which he was searching "was of greater intrinsic value than that produced by proportion."[77]

Laugier was not *per se* rejecting the concept of beauty; he strongly believed that criteria must indeed exist for identifying what he called *beautés essentielles* in architecture. Such absolute beauty, Laugier wrote, is "independent of mental habit and human prejudice."[78] Beauty, instead, pertained for him to the faculty of reason, when he writes: "The domain of beauty expands as the result of reflexion".[79] In placing reason over taste Laugier's theory adhered to the propositions of Charles Perrault for whom arbitrary beauty was considered secondary to the forms which could arise from positive reasons. In order to identify the principles inherent within essential beauty Laugier recalled the very origins of architecture. Believing in the continuous development of civilization, Laugier conceived of architecture as an historically progressing discipline. Architecture, he believed, had originated when primitive man built himself a hut in which the basic elements of architecture as well as its principles and rules of organization were set forth. In the primitive hut Laugier thought to find the first principles of building construction providing the foundation of architecture. Laugier's proposition herein conformed with Jean Jacques Rousseau's view that one should go back to the beginning of human history.

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[77] Wolfgang Herrmann, op. cit., p. 38.

[78] Laugier, *Essai*, op. cit., Preface, p. 3.

[79] " ... *le beau est tel que son empire s'augmente par la réflexion même.*" See Wolfgang Herrmann, op. cit., p. 41.

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Frontispiece of Antoine Laugier's *Essai sur l'Architecture* showing the rustic hut as the original source of architectural principles, 1753.

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Let us look at man in his primitive state without any aid or guidance other than his natural instincts. ... He wants to make himself a dwelling that protects but does not bury him. Some fallen branches in the forest are the right material for his purpose; he chooses four of the strongest, raises them upright and arranges them in a square; across their top he lays four other branches; on these he hoists from two sides yet another row of branches which, inclining towards each other, meet at their highest point. He then covers this kind of roof with leaves so closely packed that neither sun nor rain can penetrate. Thus, man is housed. Admittedly, the cold and heat will make him feel uncomfortable in this house which is open on all sides but soon he will fill the space between two posts and feel secure.[80]

From this rustic hut, which was illustrated in the frontispiece of the second edition of the *Essai,* Laugier deduced the rational justification for his ideas on architectural reform. The reference to the origins of architecture was not new; Vitruvius had recalled its early development when primitive man built himself a dwelling. Commentators of Vitruvius's *Ten Books,* including Claude Perrault, had illustrated the primitive hut, but "none had proposed that it be taken as the model of excellence in architecture."[81] Laugier declared the hut as the model from which the rules of architecture were to be extracted. This was possible since he had traced the

80 Laugier, *Essai sur l' Architecture,* Chapter I, pp. 11, 12.

81 Robin Middleton and David Watkin, *Neoclassical and 19th Century Architecture,* Electa Editrice (Milano), 1979, p. 21.

development of architecture to nature itself, for the hut was considered "the rough sketch which nature offers us."[82] Laugier had opened the first chapter of his treatise with the statement that "it is the same in architecture as in all other arts: its principles are founded on simple nature, and nature's process clearly indicates its rules."[83] Justified by natural law, absolute principles of truth determined what architecture is. In reference to the prevailing philosophy of the natural sciences, Laugier wrote regarding the field of architecture: "Such is the course of simple nature; by imitating the natural process, art was born."[84] So were the primary elements of architecture derived from an idyllic and natural state of human civilization. The vertical members of wood, Laugier declared, have given man the idea of the column; the branches placed horizontally on top of the columns led to the concept of the entablature; and from the inclining branches forming the roof, the pediment was derived.

Laugier's principle contribution to architectural theory lay in that he consciously deduced the primary components of architecture from primitive construction. As the vocabulary of classical architecture was identified with the very structure of building, so beauty was defined in terms of the rationality of construction seen in its most ideal state. *Venustas* and *firmitas* were closely related to one another as the values of beauty were considered referential to those of physical

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82 Laugier, *Essai sur l'Architecture*, op. cit., 2nd edition, Chapter I, p. 13.

83 Ibid., p. 11.

84 *"Telle est la marche de la simple nature: C'est a l'imitation de ses procedes que l'art doit sa naissance."* Ibid., p. 12.

reality, i.e. the means for achieving stability and durability. "From now on," Laugier declared, "it is easy to distinguish between parts which are essential to the composition of an architectural Order and those which have been introduced by necessity or have been added by caprice".[85] The essential parts of architectural form which were the cause of beauty were derived from the idea of constructional truth. The description of the primitive hut as a post and beam assembly provided the primary components of architectural form to which nothing further could be added to make the work more perfect:

I can only see columns, a ceiling or entablature and a pointed roof forming at both ends what is called a pediment. So far there is no vault, still less an arch, no pedestals, no attic, not even a door or a window. I therefore come to this conclusion: in an architectural Order only the column, the entablature and the pediment may form an essential part of its composition. If each of these parts is suitably placed and suitably formed, nothing else need be added to make the work perfect.[86]

Laugier was dealing here with an idea in abstraction according to which the beauty of form was determined by its representation of construction. His ideas presupposed the definition of architecture as conceived of columns, in which the column is an architectural element, and two columns establish a system of order, a module, and the organization for the entire building. Here was established a principle which

85 Ibid., p. 12.
86 Ibid., pp. 12, 13.

later during the nineteenth and twentieth centuries was to evolve as an integral part of building practice. Laugier's conception of building did not yet include doors, windows, and walls. He next introduced the concept of *licences*, a term commonly used within the architectural literature of the period.[87] Though not contributing to beauty, *licences* were admitted within architecture since they were considered to be of functional necessity. The wall, for example, was a *licence* satisfying man's need for shelter from the conditions of climate. Consequentially, the wall was restricted to its function as an architectural element within the enclosure system. While the column was to be articulated as a free standing member and the wall considered to be a protective 'skin', Laugier's theory implied the separation between structure and envelope which the Modern period later declared as one of its axiomatic principles.[88] Similarly, doors and windows were admitted as *licences* since a building, once it was enclosed, required openings for air and light.

All other parts which traditionally had been included within architecture, in addition to the *licences* and to those members contributing to essential beauty, Laugier asserted, were to be disregarded. The text of the *Essai* in this followed the ideas of Cordemoy and Frémin which "condemned every aesthetically unacceptable form as an abuse due to the heinous crime of

[87] See Wolfgang Herrmann, op. cit., p. 50.

[88] In the introduction to his translation of the *Essai sur l'Architecture* Wolfgang Herrmann mentions Le Corbusier's interest in the theories of Laugier. Of particular significance was Le Corbusier's reference to the primitive hut in which he thought to discover the principles for the development of a new style. See *Essai*, op. cit., p. xx.

caprice."[89] In making a distinction between the incidental and the necessary Laugier could clearly identify those forms which he believed could contribute to the perfection of architecture. While his theory favored naturalness and simplicity of formal expression, he rejected such elements as the pilaster, the niche, and the arch placed over columns. The use of pilasters was not encouraged since they were regarded as merely the representation or the imitation of columns.[90] The rejection of the niche followed logically from the functional rather than decorative purpose of the wall.[91] And the placement of arches over columns was questioned from a structural point of view as it was the role of the entablature rather than the arch to directly span from one column to another.[92] Laugier's vision of a new architectural style in which simplicity and clarity were favored disclosed a preference for *dégagement* allowing the truthful expression of architectonic components in their most elemental condition. The vocabulary of architecture was hereby determined from the image of a primordial construction which was to be expressed though the representation of form. The primitive hut was the paradigm supporting Laugier's conception of a new style which seemed more compatible with the Greek temple than the Gothic church. In the fourth chapter of the

89 Wolfgang Herrmann, op. cit., p. 51.

90 "*Pilasters are only a poor representation of columns. ... Pilasters are never necessary; wherever they are used, columns could be applied just as advantageously. They must, therefore, be regarded as a bizarre innovation, in no way founded on nature or authorized by any need, which can only have been adopted out of ignorance and is still tolerated only by habit.*" Laugier, *Essai*, op. cit., p. 16.

91 "*My aversion to niches is unshakeable, and until I have been shown their need and principle, I shall make a clean sweep of all niches which show up.*" Ibid., p. 34.

92 "*1. Fault: instead of giving the entablature the form of a true beam carried solely by free-standing columns, to support it by wide arches, ...*" Ibid., pp. 22, 23.

Essai, entitled "On the Style in Which to Build Churches," the vision of a new architectural vocabulary received its most detailed formulation. Explicit guidelines were put forth for the design of a church which embodied the ideal of a new architecture:

Let us choose the most common form, that of the Latin cross. I place all around the nave, transept and choir the first Order of isolated columns standing on low socles; they are coupled like those of the portico of the Louvre in order to give more width to the intercolumniations. On these columns I place a straight architrave ... and erect over this a second Order, consisting, like the first one, of free-standing and coupled columns. This second Order has its complete straight entablature and, directly over it without any sort of attic, I erect a plain barrel vault without transverse ribs. Then, around the nave, crossing, and choir, I arrange columned aisles which form a true peristyle and are covered by flat ceilings placed on the architraves of the first Order.[93]

After describing his ideal church Laugier went on to enumerate its advantages. First, he mentioned that such an architecture was "entirely natural and true," that everything had been reduced to simple rules and "executed according to great principles." Consequentially, the design of the church allowed "no arcades, no pilasters, no pedestals, nothing awkward or constrained." Furthermore, the whole structure was considered "elegant and delicate" since plain walls were "nowhere to be seen" and nothing superfluous had been included. The windows

[93] Ibid., p. 103.

were to be ordinary and large, placed in "the most suitable and most advantageous position;" the spaces between the columns were to be glazed.[94] To the "*dégagement*, simplicity, elegance and dignity of such a building," Laugier concluded, "splendor and magnificence could easily be added."[95]

The theory proclaimed in the *Essai* essentially attempted to establish for architecture what had been achieved within the natural sciences. But Laugier's propositions primarily aimed to resolve this correspondence between architecture and science at a purely formal level. It was precisely this priority for formal concerns which was criticized by Frézier. While Laugier searched for formal principles which would lead to absolute and essential beauty, Frézier, on the other hand, insisted on the relative nature of beauty. Technical matters of building construction where understood by Frézier in terms of their real condition from which architectural form resulted. Laugier instead primarily addressed construction as an image represented by architectural form. This attitude became more explicitly revealed in Laugier's second major work on architecture. In the *Observations sur l'Architecture* the task was undertaken to discover rational rules of proportion for the making of form.[96] The disagreement with Briseux was then to a certain degree reconciled.

94 See Kenneth Frampton, *Studies in Tectonic Culture*, publication of three lectures presented at the Graduate School of Design, Harvard University, Fall 1985, p. 4.

95 Laugier, *Essai*, op. cit., p. 104.

96 Abbé Marc-Antoine Laugier, *Observations sur l'Architecture*, Paris, 1765; republished by Gregg Press (Farnborough, England), 1966.

Proportional ratios, according to Laugier in the *Observations*, were to be applied not only to the classical orders but also to all parts of a building, for any rational operation always engaged the choice of precise dimensions. He believed that the use of specific dimensional relations provided architecture with meaning. Since proportion ultimately represented the ordered system of nature, architecture could essentially make this order perceivable. The ideal ratio of his *science des proportion* was the 1:1 relation; the square was declared the most appropriate geometric figure and the cube the most perfect volume in architecture.[97] Although Laugier's intention was to find a rational justification for beauty, he nevertheless recalled, by reference to an ideal system of proportion, the traditional belief that numerical ratios constitute universal values. In both treatises, the *Essai* as well as the *Observations*, formal considerations were emphasized. The reference to principles of construction as well as the search for numerical relations were attempts to provide a rational justification for the making of form. Technique, construction, and science were integrated within the discipline of architecture through the representation of form.

The Representation of Construction in Italy

Similar ideas to those expressed in France by Cordemoy, Frémin, Frézier, and Laugier were developed in Italy during the first half of the eighteenth century. Questions addressing the quality of materials and the functional properties of structure became integrated within formal considerations. Although these

97 "*Il fuit de-là, 1°. que le rapport de 1 à 1, ou le rapport dégalité fonde la plus belle de toutes les proportions ... ,*" ibid., p. 9.

propositions referred to the exigencies of construction, they were primarily addressed at a theoretical rather than practical level. The central figure of this development in Italy was the Venetian Franciscan friar Carlo Lodoli (1690-1761). A significant cultural exchange between France and Italy had existed for a long time. Lodoli probably had been influenced by the writings of Perrault and Cordemoy. Whether Laugier, who was significantly younger, had ever come into contact with Lodoli's theories is unclear. It is known that Laugier had been in Venice prior to the publication of his *Histoire de la République de Venice*, whose first volume appeared in 1759; and, some of Lodoli's disciples had frequently visited Paris. A line-for-line correspondence, however, between the development of architectural theory in both countries cannot be made; in fact, a divergence of opinion on some important issues existed.

Lodoli was an influential educator who started a small academy for the sons of the Venetian nobility. His teaching included the subjects of mathematics, languages, law, philosophy, and architecture, the latter of which he approached from a highly original theoretical position. Nothing is known to have been published of his writings during his lifetime. A few documents were released shortly after his death, notably some letters which he exchanged with the Neapolitan philosopher Giambattista Vico. Late in his life Lodoli worked towards an architectural treatise, only outline drafts of which have survived.[98] The ideas propagated by Lodoli, however, were not lost as his lectures had been recorded by his students.

The first publication referring to Lodoli's theories was Francesco Algarotti's essay *Saggio sopra l' Architettura* [99], printed in Venice in 1759. This document as well as Algarotti's *Lettere sopra l'Architettura* [100] commented critically on Lodoli's ideas. An additional publication followed in 1786, twenty-five years after Lodoli's death, by another of his students, Andrea Memmo. His book entitled *Elementi di Architettura Lodoliana* [101] was intended to clarify and correct Algarotti's point of view. Both, Memmo's and Algarotti's accounts, while disagreeing on certain issues, rendered a similar description of Lodoli's personality. Algarotti, rather than calling Lodoli by name, referred to him as the "philosopher", a master of discourse who challenged the Vitruvian doctrine through his "Socratic" technique of

98 Marco Frascari, "Function and Representation in Architecture", in *The Journal of the Design Methods Group: Design Methods and Theories*, California Polytechnic State University (San Luis Obispo), 1985, Vol. 19, No. 1, p. 202. Andrea Memmo included in the second volume of his *Elementi di Architettura Lodoliana* the outline of Lodoli's treatise, Zara, 1834, Vol. 2, pp. 50-62. For the English translation of this outline see Edgar Kaufmann, Jr., "Memmo's Lodoli," in *Art Bulletin*, Vol. 46, June 1964, pp. 162-166.

99 Francesco Algarotti, "Saggio sopra l'Architettura," first published in Venice in 1759 and not in 1756 as the dedication is dated; in *Opere del Conte Algarotti*, Marco Coltellini (Livorno), 1764, Vol. II, pp. 49-92.

100 Francesco Algarotti, *Lettere sopra l' architettura*, 1742-1763, in *Opere del Conte Algarotti*, Marco Coltellini (Livorno),1765, Vol. VI, pp. 171-278.

101 Andrea Memmo, *Elementi dell' Architettura Lodoliana; osia l'arte del fabbricare con solidità scientifica e con eleganza non capricciosa*, the first of two volumes was publishedin Rome in 1786, Stamperia Pagliarini (Rome), 1786; the second volume was released by Memmo's daughter and published in Zara (Zadar) in 1833-34.

conducting an argument.[102] Similarly, Memmo described Lodoli as the new Socrates. The frontispiece to the first edition of the *Elementi di Architettura Lodoliana* showed a portrait of the friar labeled "*il Socrate Architetto*." This illustration by Alessandro Longhi depicts a bust of Lodoli placed within an oval frame; above the oval the instruments of the geometer and surveyor were shown as emblematic symbols; below the frame the drafting tools of the architect were represented. The tablets on either side of the portrait recalled Jeremiah's prophecy: "to uproot" and "destroy" was written on one side and "to build and to plant" on the other.[103] Lodoli's position was here characterized as being at the threshold between the traditional and the modern worlds. The inscription within the oval, furthermore, summarized in a clear statement Lodoli's theoretical foundation: *Devonsi Unire Fabbrica e Ragione e Sia Funzion la Representazione*. This proposition which asserts that "building construction and reason must be unified and that function be the representation" was equivalently addressed in the subtitle of Memmo's treatise in which architecture was referred to as *l'arte del fabbricare con solidità scientifica e con eleganza non capricciosa* . Two of Lodoli's ideas were here outlined. First, the art of building was to be considered in reference to scientific principles. Secondly, elegance and beauty in architecture were to be achieved through the representation of function rather than the excess of

102 *"Autore di tal novità è un Filosofo, da cui tanto più ha da temere la dottrina di Vitruvio, quanto che feconda d'immagini ha la fantasia, ha un certo suo modo di ragionare robusto insieme e accomodato alla moltitudine; sa maneggiare con gran destrezza le armi socratiche."* Algarotti, *Saggio*, op. cit., pp. 52, 53.

103 *"As I watched over them with intent to pull down and to uproot, to demolish and destroy and harm, so now will I watch over them to build and to plant."* From "The Book of the Prophet Jeremia", 31: 28.

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Frontispiece of Andrea Memmo's *Elementi dell'Architettura Lodoliana.* The illustration by Alessandro Longhi shows the Franciscan friar Carlo Lodoli, 1786.

decoration. In all, Memmo as well as Algarotti clearly emphasized in their writings the "rationalizing and radical spirit"[104] inherent within Lodoli's theory.

Algarotti's writings, according to the architectural historian Emil Kaufmann, provide the "fullest understanding of the far-reaching significance of Lodoli's doctrine."[105] Although Algarotti did not completely share the views of his teacher, he nevertheless attempted to outline the fundamental ideas of Lodoli's reform. The essential proposition for achieving a new architecture, better and truer than that inherited by tradition, was twofold. The first maxim was founded on the renewed interest in the functional aspect of building construction: "In Architecture only that shall show that has a definite function, and which derives from the strictest necessity."[106] The second axiomatic proposition asked for an architecture which was to conform with the "characteristic qualities and solidity of the component building parts" in

[104] For an excellent account on Lodoli's theory viewed within the context of eighteent century culture see: Joseph Rykwert,"Neoclassical Architecture," in *The First Moderns*, MIT Press (Cambridge), pp. 288-326. Rykwert addresses the "rationalizing and radical spirit" of the period. "The reform of architecture," he writes, provided "a field of practical activity in which rationality, the desire for a harmony of thought (of rational thought in particular) with action was possible, ..." See pp. 296 & 299.

[105] Emil Kaufmann, "From Alberti to Lodoli," in *Architecture in the Age of Reason*, Harvard University Press (Cambridge), 1955; Dover Publications (New York), p. 97.

[106] "*Niuna cosa, egli insiste, metter si dee in rappresentazione, che non sia anche veramente in funzione.*" Algarotti, "Saggio sopra l'Architettura", op. cit., p. 62. Translation from Emil Kaufmann, op. cit., p. 96.

agreement with "the nature of the materials" employed within construction.[107]

Algarotti, who was strongly attached to the classical tradition, saw in Lodoli's theories a fundamental questioning of the prevailing principles of architecture. Lodoli's argument was based on the premise that architecture must be truthful to the essential logic of a building assembly and consistent with the intrinsic properties of materials. The representation of one material with another, a traditionally accepted formal principle, was consequentially strongly criticized. Greek architecture, as explained by Vitruvius, originated from timber construction; for Lodoli, there was no justification in having transposed the forms of wooden structures into stone and marble: "This was sheer masquerade or, to put it bluntly, a lie."[108] From this Algarotti deduced that Lodoli had advocated the rejection of decorative ornamentation. With architecture truthful to structure and material, ornament seemed useless and inadmissable. As he understood them, Algarotti was not completely convinced about Lodoli's theorems. Timber had always been one of the primary materials used in building construction; consequentially, the forms given to ornament had originated from the techniques and applications of wood. If throughout history architects had been dishonest when

107 "*Tutto al contrario per appunto di quanto si pratica e s'insegna, tale esser dovrebbe l'Architettura, quale si conviene alle qualità caratteristiche, alla pieghevolezza o rigidità delle parti componenti, a' gradi di forza resistente, alla propria essenza in una parola, o natura della materia che vien posta in opera.*" Algarotti, "Saggio sopra l'Architettura," p. 66. See also Emil Kaufmann, p. 97.

108 "*Niente vi ha di più assurdo, egli aggiugne, quanto il far sì, che una materia non significhi se stessa, ma ne debba significare un'altra. Cotesta è un porre la maschera, anzi un continuo mentire che tu fai.*" Algarotti, "Saggio sopra l' Architettura", p. 66. See for the English quotation, Emil Kaufmann, p. 97.

transposing these ornamental forms into stone, then Algarotti concluded: "the lie may be more beautiful than the truth."[109] In recalling an understanding of architecture as a representative art, Algarotti reinforced the Baroque notion of beauty which favored illusion over reality. In remaining faithful to the tradition of architecture, Algarotti's ideological position revealed itself to being diametrically opposed to the views of his teacher Lodoli.

Emil Kaufmann was led to the conclusion that "Lodoli was the first advocate of functionalism."[110] In proposing a truthful expression of function and appropriate use of materials, Lodoli's objectives adhered rather to Francis Bacon's postulation of the unity of truth and utility. As clarified by Andrea Memmo's writings, Lodoli's philosophy was determined by the search for an understanding of the essential nature of building. The term *function* was used not in reference to convenience and commodity, as the contemporary meaning of the word implies, but instead pertained to the operational qualities of the parts used within a building assembly. Function was associated with the essential working mechanism inherent within objects and their constituent parts. Lodoli was therefore concerned with how the structure of a building worked according to the laws of statics and material qualities could contribute to the making of architecture.

109 "*Che del vero più bella è la menzogna.*" Algarotti, p. 91. For the translation see Rykwert, op. cit., p. 297.

110 Emil Kaufmann, op. cit., p. 95.

The new architecture advocated by Lodoli had to be visibly expressive of its ideology and therefore was considered 'true' architecture. Accordingly, the role of form was to represent the intrinsic properties of material and structure. It was essential that the functioning of a building be clearly revealed and thus made visible to the observer. The concept of representation was of great significance to the theory of Lodoli. Memmo wrote: "Representation is the precise and total expression resulting from the materials when they have been used in accordance to the geometrical-arithmetical-optical norms to reach a proposed end."[111] Formal representation was rationally justified by allowing the physical working of a building to be legible as related, for example, to the laws of statics. Memmo pointed out that Lodoli had made some experiments to test the strength of materials, the results of which he presumably summarized in the elaboration of charts. Such an approach, according to Memmo, allowed form to be representative of the properties of materials. Through the concept of representation, Lodoli had hoped to connect architecture with the scientific thinking of his period.

Function and representation constituted the foundation of Lodoli's theory. While the former concept referred to the techniques of building, the latter adhered to the forms of architecture. Memmo emphasized the importance of both concepts when he stated that: "straight function and representation are the two final scientific objectives of civil architecture."[112]

111 Andrea Memmo, op. cit., vol. II, p. 52. For the quote in English see Marco Frascari, op. cit., pp. 206, 207.

112 Andrea Memmo, ibid., vol. II, p. 59. For the translation of the quote see Alberto Pérez- Gómez, op. cit., p. 255.

Both the appropriate function and the proper representation converged into a single purpose which was for Memmo the visible manifestation of truth.

The relation between functional criteria and representational form is best illustrated in a small building by Lodoli, a remodeling of a hospice in San Francesco della Vigna. Memmo apologized for the insignificance of the project due to the lack of "generosity, magnificence, ... and elegance" of the architecture.[113] He nevertheless praised Lodoli for his ingenuity in devising new solutions for windows and doors. Of specific interest to him was Lodoli's use of the catenary curve for the design of the window sills. Memmo pointed out that window sills tended to break when made of one piece of stone as the weight bearing upon either end produced an unequal load distribution on that member. To avoid this problem, Lodoli initially divided the sill in three parts. This solution, however, which had been used previously, was not yet aesthetically satisfying, for the weight of the window jambs eventually led to the lowering of the end pieces of the sill. Consequentially, Lodoli bevelled the joints between the three parts whereby allowing the sill to act as one continuous beam. By applying the principle of the catenary curve to determine the form of the central stone piece of the sill, Lodoli could prevent its fracture. Form was here derived from an understanding of the system of forces contained within such a simple architectural element as the window. A connection between architecture and science was attempted; architectural form visibly decoded scientific principles.

113 Andrea Memmo, ibid., vol. II, pp. 152 f.

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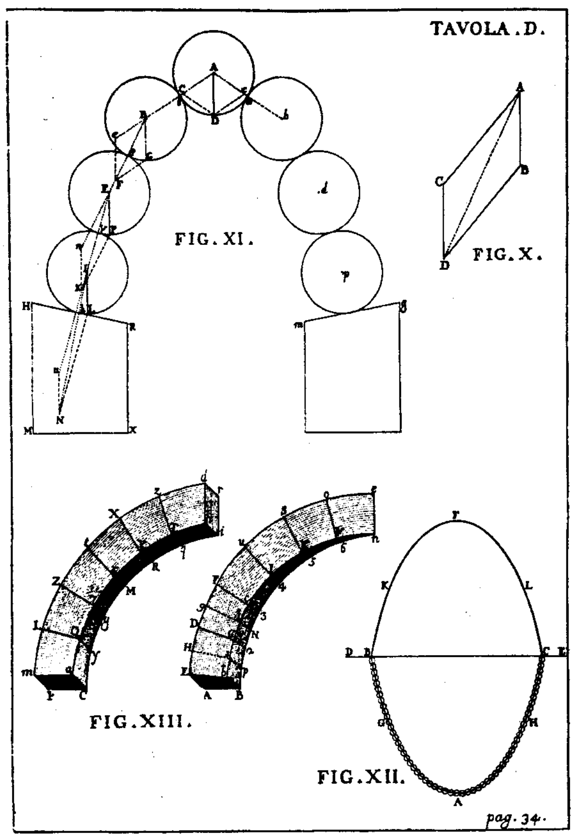

Illustration of the catenary curve and its application to masonry construction, after Poleni, 1748.

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Lodoli was informed about the development of structural engineering of his time. Experiments and theories regarding catenary curves had been made by engineers such as David Gregory, James Stirling and Giovanni Poleni. Gregory had published a paper entitled "Catenaria" in 1697 in which he analyzed the shape of hanging chains as a means of determining the most efficient structural configurations for the distribution of loads.[114] His work was further developed by Stirling, whose treatise published in 1717 included a discussion on the inverted catenary curve.[115] In 1748 Poleni's structural analysis of St. Peter's was published. Based on Gregory's and Stirling's work, Poleni investigated the properties of catenary curves in his search for a solution to make the dome construction of St. Peter's structurally sound.[116] Lodoli might have known the theories of Gregory and Stirling, especially as the latter had worked in Padua. But most striking was the similarity of ideas between Poleni and Lodoli. Mathematics, according to Poleni, was of great significance when applying the laws of mechanics and statics to architecture. He insisted, as Lodoli had done, on having knowledge of "the mechanical properties of building materials."[117] Poleni emphasized that the quality of materials as well as their appropriate use in construction were important parameters of architectural production. There was also a correlation of ideas between Poleni and Lodoli regarding the

[114] David Gregory, "Catenaria," *Philosophical Transactions*, 1697, no. 231, p. 637.

[115] James Stirling, *Lineae Tortii Ordinis Neutonianae*, Oxford, 1717.

[116] Giovanni Poleni, *Memorie Istoriche della Gran Cupola del Tempio Vaticano*, Padova, 1748.

[117] Ibid., pp. 30 f.

concept of representation. On this subject Poleni wrote: "The best method to know the works of Nature would be to imitate them, to give them - as it were- representations in which the same effects are produced by known causes when they are set in action."[118] Poleni was here primarily referring to the method of scientific experiments in which natural conditions were represented. He also encouraged the use of graphic representations to demonstrate structural and mechanical laws. Lodoli went a step further by transposing such graphic representations of scientific principles directly into architecture. The form was to decode the inherent functioning of its structure.

The three essential properties of representation within Lodoli's theory were, according to Memmo: "solidity, analogy, and commodity."[119] While *solidity* (firmness) and *commodity* (convenience) were determined by the real requirements of physical construction and human needs, *analogy* indicated how those requirements were to be integrated within formal expression.

The contribution of *solidity* to form lay in the correct use of construction which necessitated the study of the nature of materials and the laws of structural assembly. Since the principal materials were wood and stone, the knowledge of xylology (wood technology) and lithology (stone technology) was considered a prerequisite. The other essential element of formal expression was *commodity* which was considered a property

118 Ibid., pp. 76, 128. This quote is credited to Fontenelle.
119 Andrea Memmo, ibid., vol. II, p. 59.

of representation rather than a property of function. Convenience provided the structure for arranging architectural elements according to utility and economy of needs. Form was to be appropriate to the requirements of use. This property of representation is best revealed in Memmo's description of a chair designed by Lodoli.[120] A correspondence between the anatomy of the human body and the form of the chair was considered important. The design of the chair back was to be derived from the posture of a person and the position of the shoulders, while the shape of the seat was to be determined from a person's bottom. The relation between commodity and representation explained with the example of the chair was extended to the field of architecture. Buildings must provide a certain comfort and suit human needs.

Analogy, the third essential property of representation, was considered the operational mode for addressing function as well as the requirements of solidity and convenience within form. Lodoli emphasized that the functional working of a structure and its formal representation had to be analogical in their relationship: "Analogy is that proportionate regular arrangement of parts and the whole, which (in buildings) should result from the combination of stereometric-arithmetical theories with rational norms applied to the shape and measure of the elevations, the members, the openings and the architectural volumes."[121] It was through analogy that the connection between technique and form was made. This

120 Memmo, ibid., preface.

121 Memmo, ibid., pp. 59 ff.; see also Rykwert for the translation, op. cit. p. 325. Marco Frascari's essay "Function and Representation in Architecture" offers a more specific understanding of the term *analogy* within Lodoli's theory; op. cit., pp. 203 f.

proposition, which asked that the integral parts of architecture be revealed in their essential condition of existence as expressed in form, indicated a certain correlation with Charles Perrault's notion of "positive" beauty. Rather than confronting "positive" reasons with "arbitrary" beauty, Lodoli extended his understanding of form to the role of beautifying parts and ornamentation in architecture.

Lodoli was not rejecting the use of ornament, as Algarotti had suggested, but he instead advocated its appropriate and coherent application. A new understanding of ornament was to be developed resulting from the principles and laws of science. For achieving architectural beauty, the ornament was considered essential as long as it pertained to rational norms. Lodoli objected to the traditionally accepted understanding of ornamental organization which was based on historical reference and the free interpretation of formal precedents. He instead believed that the principles of wood and stone technology as well as the laws of structural assemblies could contribute to the form of the ornament. Although Lodoli's theory did not consider ornamentation the most important criteria within architecture, he nevertheless gave new meaning to its formal expression. The idea that form represented the principles inherent within solidity and commodity was similarly applied to the conception of the ornament. The forms as well as the disposition of ornaments were to be derived, Memmo wrote, "from mathematico-physical elements and by rational norms."[122] A reconciliation of ornament and structure was here attempted.

122 Memmo, ibid., pp. 51 ff.; see Rykwert for the translation, op. cit., p. 324.

While rationally justified, Lodoli's doctrine was carried by a symbolic intention. His theory argued in favor of an architecture that discloses the intrinsic properties of material and structure. In that, his ideas were motivated by the search for the inherent essences within things. The conception of architecture was to be directed by the symbolic revelation of the internal order and functioning mechanism of all the constituent parts of the building. The understanding of the static aspects of structure and the knowledge of the strength of materials were not guided by the interest to merely develop new instruments of technological domination; Lodoli's program was instead determined by the necessity to find a form of meaning in architecture which adhered to the development of modern science.

A correspondence of ideology between Lodoli and the Neapolitan philosopher Giambattista Vico (1668-1744) can identified. Lodoli, the younger of the two, was informed about Vico's ideas. Vico's vision of a 'new science' was paralleled by Lodoli's program for a 'new architecture'. The true science of man, according to Vico's philosophy, was history. It was through history that the origins of humanity as well as the gradual development and progress of civilization could be elucidated, an idea which a century early had been implied by Francis Bacon. Vico asserted that primitive man had learned to survive through the implementation of his imagination, ingenuity, and ability to make and produce. These traits, according to Vico, were man's poetic qualities; so was the act of building, originally, a form of *poesis*. Modern science's development could consequentially be understood as the manifestation of man's poetic will. Inspired by Vican philosophy, Lodoli advocated an architecture that pertained to the qualities of its making. The conception of building had to respond to the exigencies of construction, to the truth and simplicity of structure, as well as to the poetic potential of materials. From such a vantage point Lodoli objected to the Vitruvian description of the origins of architecture in which historically one material was represented by another. The new architecture instead was to be true to the essential aspects of building production. Modern science held herein a significant position as it contributed the knowledge of the intrinsic properties of construction material and principles of load distribution. Within the conception of architectural form, scientific knowledge was to be imaginatively applied, allowing architecture to be the visible representation of its inherent structures.[123]

Theories of Statics and Building Materials

The development of architectural theory in France and Italy during the eighteenth century led to an understanding of form as based on the principles of construction. As this interest was of academic nature, the reference to the exigencies of building production was primarily addressed in ideal terms through representational form. The traditional dichotomy between theory and practice was not entirely resolved, for the relation between form and technique remained within the realm

[123] The connection between Vico and Lodoli has been addressed by Marco Frascari in "Function and Representation in Architecture," op. cit., pp. 205-208. See also Alberto Pérez-Gómez, op. cit., pp. 255, 256.

of representation. Such condition, however, was gradually challenged during the period of the Enlightenment as an increasing interest evolved in the direct application of scientific theories to building practice. Significant research had been done by architects and engineers addressing problems of statics and strength of materials. Such theoretical contributions, in proposing mathematical formulae and precise calculations for the understanding of material and structure, offered the possibility of application to the practice of building. Architectural form, consequentially, could at least in part be determined according to technical considerations.

Amédée-François Frézier had recognized that by means of geometry and mathematics an understanding of building structures could be attained. In his treatise *La Théorie et la Pratique de la Coupe des Pierres et des Bois*, published in 1737, Frézier asserted the importance of scientific theories for architecture. Such theories were intended to be practically applied as the subtitle of the treatise indicates: *Traité de Stereotomie à l'Usage de l'Architecture*. Frézier's intention was to provide a general theory of wood and stone cutting techniques that could direct the work of engineers, architects, and craftsmen. Frequent reference to mathematics and geometry was made, for these disciplines provided the means for the implementation of technical operations. Theory was conceived as a technical instrument. Frézier was interested in identifying the load distribution within arches and vault structures while referring to principles of Euclidean geometrical configurations. In the third volume of his treatise, the determination of arch thrusts and dimensions of piers were attempted. Frézier also recorded the results of experiments which were made for testing the structural properties of arches. Architecture was here subjected to the theories of mechanics, which encompassed the fields of dynamics and statics. Such an approach to architecture illustrates Frézier's position as being firmly embedded within the epistemological framework of eighteenth century science.

The writings of Frézier repeatedly emphasized the importance of theory and its application within practice. However, Frézier believed that propositions of theoretical significance could scientifically be determined without necessarily requiring recourse to traditional practice. Structural problems, for example, could more successfully be resolved within the realm of abstraction offered by theory. A position too close to practice, Frézier believed, could very likely confuse the issues involved. Traditional practice, respectively, was successful without reference to theory. Frézier admitted that the experience of craftsmen commonly sufficed for solving problems of building construction. This paradoxical condition indicated a distance between theory and practice, and although theoretical axioms were intended for practical application, both theory and practice were addressed as autonomous entities.

A similar dichotomy is to be observed within the relation between architectural form and theories of technical implication. In 1738, Frézier appended to his treatise the *Dissertation Historique et Critique sur les Ordres d'Architecture* in which the question of architectural beauty was addressed in relation to the role of scientific theories.

Beauty in architecture was considered to be founded on rational principles. This assumption presupposed that a correspondence between the natural laws of science and the principles of architectural beauty must exist. Frézier asserted that "the universal rule of the orders should be founded on the imitation of Natural architecture."[124] From the point of view of eighteenth century science, nature was considered to be founded on simple and straightforward principles; accordingly, the rules of architectural composition were to reflect the simplicity of natural reality. Architecture had not only to be physically determined according to the logic of natural laws but required above all that the principles of solidity and stability be visibly depicted.

The proportional system underlying the orders, Frézier believed, was to be in accordance with the relation between the dimensions of the column and the load it carried. Such proportions, however, were not determined from specific calculations but rather from the notion that man possessed a natural sense for structural relationships. Buildings were not only to be structurally sound but to be perceived as being solid, in agreement with man's sense of solidity. In other words, the principles of statics were not directly applied in defining form but instead provided the intellectual justification for the natural and thus beautiful arrangement of parts. Similarly, the dimensions of doors and windows were derived, Frézier wrote, "from a natural sentiment through which we relate everything to the dimensions of our body and to our

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124 Amédée-François Frézier, *Dissertation Historique et Critique sur les Ordres d'Architecture*, Strasbourg, 1738, p. 8.

needs, even before reason has determined their convenience."[125] The connection between beauty and the laws of nature was here established in ideal terms. While beauty was founded on natural principles, its manifestation within architectural form embodied scientific rules. Beauty addressed the theory of science at a symbolic level without requiring the real application of its laws. Eighteenth century architecture was confronted with this dichotomy between form and technique which paralleled the above mentioned discrepancy between theory and practice.

Frézier was not the first to point to the difficulty in relating scientific theories to the reality of practical matters. Several decades earlier, similar observations were made by Philippe de la Hire (1640-1719), a well-known French engineer and architect. De la Hire was a member of the *Academie des Sciences* and the successor of François Blondel in 1687 when appointed professor at the Royal Academy of Architecture. In his lectures, De la Hire introduced questions pertaining to the fields of statics, stereotomy, surveying, and mensuration. He was interested in geometry and its application as a technical means for solving complex structural configurations. In his treatise *Traité de Mécanique, ou l'on Explique tout ce qui est Necessaire dans la Pratique des Arts*, published in 1695, De la Hire asserted that the traditional arts necessitated an understanding of the science of mechanics for their practical application.[126] He pointed out, however, that a certain

[125] Ibid., p. 35.

[126] Philippe de la Hire, *Traité de Mécanique, ou l'on Explique tout ce qui est Necessaire dans la Pratique des Arts, & les Propriétés des Corps Pesants lesquelles ont un plus grand Usage dans la Physique*, Paris, 1695.

incompatibility existed between real phenomena and abstract theories. This divergence between practice and theory became explicitly clear to De la Hire in his research on the structural performance of arches.

In order to identify the load distribution within arches from which De la Hire hoped to derive the specific configuration of piers, a conceptual model was conceived assuming a frictionless condition between the different parts, or voussoirs, of a semi-circular arch. The load that could be taken by each voussoir could thus be determined by resolving the forces into vectors of a force polygon. De la Hire concluded that the weight acting on the voussoir at the springing line of the arch was infinite. Consequently, an arch conceived independently of cohesion, assuming no friction between parts, could not stand on its own. Practice could therefore not exactly follow theoretical calculations but only use theory as a guide.[127] De la Hire's method was founded on sound geometrical principles and led later to valid theoretical results; but since his hypothesis was based on the assumption of frictionless conditions, his theory seemed not to be applicable to practice. This distance between the theory of statics and the reality of physical conditions was a problem which repeatedly came to be addressed during the eighteenth century. Dissatisfied with the concept of frictionless voussoirs, De la Hire further investigated the structural performance of arches and formulated propositions more closely representative of actual conditions. In 1712, he presented to architects of the academy his geometrical method

[127] For a description of De la Hire's method see Jacques Heyman, *Coulomb's Memmoir on Statics, an Essay in the History of Civil Engineering*, Cambridge University Press (London), 1972, pp. 82-84.

for calculating the stress produced by the thrust of an arch. Such a method, which took into account the height of piers as well as the radius and weight of the arch, offered the possibility for determining the dimensions of supporting piers.[128] The method advocated by De la Hire brought theory and practice closer. Theoretical propositions of scientific nature could now be regarded as instruments for practical application within architecture.

De la Hire's theoretical propositions were generally accepted by architects and engineers of the eighteenth century, regardless of the relative discrepancy between hypothetical assumptions and physical phenomena. Frézier as well as the engineer Bernard Forest de Bélidor (1697-1761) repeatedly referred to De la Hire's theory on the structural properties of arches. While De la Hire's work primarily focused on the formulation of general principles, his theory remained specific to certain structural problems. It was Bélidor, several decades later, who first conceived of engineering within an overall theoretical framework. Bélidor, a member of several European scientific societies, was a mathematics professor and author of significant writings. His treatise *La Science des Ingénieurs*, published in 1729, constituted one of the first attempts to methodologically address questions of construction in view of scientific principles.[129]

[128] Philippe de la Hire,"Sur la Construction des Vôutes dans les Édifices," in *Mémoires de l'Académie Royale des Sciences, 1712*, Paris, 1731.

[129] Bernard Forest de Bélidor, *La Science des Ingénieurs dans la Conduite des Travaux de Fortification et d'Architecture Civil*, Paris, 1729. Bélidor's treatise was published in several editions, two of which were annotated by Louis-Marie-Henri Navier in the nineteenth century.

Bélidor's treatise was divided into six books addressing the knowledge, or science, which the engineer was to have.[130] In the first book, entitled *de la Théorie de la Maçonnerie,* simple principles of statics were explained and applied for determining the dimensions of masonry retaining walls. These propositions primarily pertained to the construction of fortifications, for they constituted the largest and most difficult works of eighteenth century engineering. The second book with the running title *de la Mécanique des Voûtes* specifically examined the thrusts of arches. Partially following De la Hire's hypothesis, Bélidor offered general principles by which to calculate the supporting piers of different types of vaults and arches.[131] The third book, *de la Construction des Travaux,* offered a detailed analysis of building materials. Quantitative data as well as detailed notes on qualitative properties were provided. The unit weight, for example, was given for a range of materials, including metals, sand, clay, brick, stone, and wood. Such materials were to be assembled according to described methods and building procedures of construction. This book also contains a significant number of tables for determining the dimension of retaining walls in relation to height, width, and spacing of structural piers. With such methodically organized information, Bélidor intended to relieve the engineer from repetitive and tedious calculations. In the fourth book, *de la Construction des Edifices Militaires & Civils,* Bélidor provides practical

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130 For a clear summary of the six books of *La Science des Ingénieurs,* see Jacques Heyman, op. cit., pp. 84-88.

131 Bélidor, op. cit., Book II, Chapter 2, 3, and 4.

rules for the design and construction of different types of military and civic buildings. As the construction of most buildings required an understanding of timber technology, some experimental results on the strength of wooden beams were presented. The primary intention of this book, however, was of more general orientation. Bélidor hoped to provide architects and engineers with examples of functional building types, their spatial organization and construction. The fifth book, *de la décoration,* was included in the treatise, for Bélidor strongly believed that engineers were to have knowledge of the principles of architectural form and composition. He was well aware of the fact that engineers were mainly preoccupied with technical problems, their field being so vast that they could hardly also have time to address questions of beauty.[132] Notwithstanding this fact, Bélidor argued that engineers must address the laws inherent within beauty, for mathematics was the foundation of classical proportion. Bélidor implied a certain equivalence between the role of mathematics as a scientific tool and the traditional concept of mathematics as symbolic expression. However, aesthetic considerations, especially the proportional rules of the classical orders, were treated by Bélidor as decorum. He did not present his own opinion but instead offered a historical outline in which traditional concepts of the orders were described. In referring to Palladio, Vignola, Scamozzi, Chambray, Perrault, and Blondel, Bélidor could assume a certain objectivity regarding

132 Regarding aesthetic considerations Bélidor wrote: "*Je sai bien que la plûpart des ingénieurs s'y attachent peu, les autres parties de leur métier étant assés étendues pour les occuper entierement ...*" Ibid., Book V, Chapter 1, p. 1.

the rules of aesthetic order.[133] Technique had clear priority, whereas formal elements in architecture were considered as applied layers. The interest in a precise understanding of all parameters pertaining to construction and building procedures is again revealed in the sixth and last book of *La Science des Ingénieurs* with the title *de la maniere de faire les Devis*. Bélidor dealt here with cost estimations and the preparation of specifications which he considered part of the science of building.

The primary intention of Bélidor's treatise was to assemble technical information based on a scientific approach to the art of building. Such a body of knowledge could be applied by architects and engineers to the realization of their work. From the very beginning of the treatise, the conflict between a theory "intentionally postulated as *ars fabricandi* and an eminently traditional practice" is explicitly made by Bélidor.[134] He observed that traditional craftsmanship engaged in the resolution of technical problems by means of experience as founded in practice without recourse to theory. This condition, Bélidor believed, should be overcome by subjugating the decision making processes of production to the rational structure of scientific theories. With exception of specific formal rules, he asserted, the field of architecture did not rely on clear principles. *La Science des Ingénieurs* was

133 *"L'Art de décorer les édifices renferme tant de choses interessantes & utiles, que j'ai cru ne pouvoir me dispenser d'en donner un petit traité, qui contint succinctement les maximes les plus approuvées des meilleurs architecte. ... ce n'est pas moi qui vais parler, plûtot, Vitruve, Palladio, Vignole, Scamozzy, Chambray, Perrault, blondel, Daviler, ..."* Ibid., Book V, Chapter 1, pp. 1, 2.

134 Alberto Pérez-Gómez, *Architecture and the Crisis of Modern Science*, op. cit. p. 216.

conceived as a contribution to surmount this deficiency, offering a theoretical base for the practice of architecture. For solving technical problems of construction, according to Bélidor, axioms and rules could be formulated which could guide the making of building. Based on mathematics and geometry, the laws of statics, for example, could be applied for determining the dimensions of structural members. The knowledge of material properties offered a better understanding of tectonic considerations. And, the preparation of specifications allowed a precise evaluation of the quality criteria of the work to be performed as well as providing an attempt to achieve an economy of means for the construction of buildings. Bélidor's treatise was guided by the conviction that a rational framework of theory must inform the experience of practice, recognizing the necessity to conceive of architecture within the understanding of building as science.

Building Science: The Unity of Theory and Practice

The difficulty in uniting the seemingly incompatible realms of theory and traditional practice as discussed by De la Hire, Bélidor, and Frézier became most apparent in the disputes concerning the construction of Ste.-Geneviève in Paris during the second half of the eighteenth century. Ste.-Geneviève, since the French Revolution of 1789 called the Panthéon, was the first major building in France which was considered to have come closest to Laugier's ideal model of a church.[135] The architect, Jacques-Germain Soufflot (1713-1780), was interested

[135] Laugier himself praised the design of Ste.-Geneviève as "*le premier modéle de la parfaite architecture, le véritable chef-d'oeuvre de l'architecture française.*" From the "Discours sur le rétablissement de l'architecture antique," Lyon, Académie des Sciences, MS 194.

in the reconciliation of aesthetic and technical considerations. The projects which he proposed embodied the lightness and transparency of Gothic structures as combined with the pure vocabulary of Greek architecture.[136] Soufflot's design was primarily marked by the use of the detached and free-standing column, for he considered it superior to all other building elements. In agreement with Laugier's theory was also the articulation of the perimeter walls which were conceived as a continuous colonnade with a window in each of the intercolumnations. Soufflot's aesthetic vision was guided by the conviction that architecture must formally express the clarity and lightness of its structure. The design was not only determined by formal concerns but disclosed the architect's interest in a rational understanding of construction.

The unity of form and technique as proposed by Soufflot was at its base an attempt to reconcile the traditional and modern foundations of architecture. In a lecture presented to the Académie in Lyon in 1744, Soufflot raised the question whether architecture primarily depended on the notion of taste or on

[136] Soufflot was interested in the lightness of Gothic architecture which he sought to combine with the trabeated system of the classical orders. His pupil Maximilien Brebion wrote: "Le principal objet de M. Soufflot en bâtissant son église a été de réunir, sous une des plus belles formes, la légèreté de la construction des églises gothiques avec la pureté et la magnificence de l'architecture grecque." See Jean Mondain-Monval, *Soufflot: Sa Vie.- Son Oeuvre.- Son Esthétique (1713-1780)*, Librairie Alphonse Lemerre (Paris), 1918, p. 423. Soufflot's interest in Gothic architecture was clearly stated in a lecture which he delivered to the Académie des Beaux Arts in Lyon in 1741. Jacques-Germain Soufflot, *Mémoire sur l'Architecture Gothique;* reproduced in: Jean Mondain-Monval, ibid., pp. 424-431. While Soufflot's spatial vision recalled the inherent transparency within Gothic architecture, the formal vocabulary was exclusively a manifestation of the classical orders. See Michael Petzet, "Soufflot et l'Ordonnance de Sainte-Geneviève," in *Les Cahiers de la Recherche Architecturale: Soufflot l'Architecture des Lumières* , C.N.R.S. (Paris), 1980.

the application of scientific rules.[137] He wrote: "*Le goût est né de la raison de plus en plus éclairée, les règles sont nées de la raison; on ne peut pécher contre l'une sans blesser les autres, et cela prouve bien leur identité* ."[138] The identity of taste and rules addressed by Soufflot resulted from the belief in the unity of beauty and science. Both aesthetic and scientific rules pertained to the concept of a mathematically ordered nature. Beauty based on architectural proportion transcended the inherent order within nature. Science, similarly, proposed absolute laws for disclosing the structure of natural phenomena. Consequently, the argument summarized that architectural rules of form and composition were to be in agreement with the propositions of scientific theories.

Soufflot believed that through scientific experiments and observation quantitative results could be attained. These would lead to the formulation of absolute laws providing architects with a thorough understanding of structural problems. During the long period of construction of Ste.-Geneviève Soufflot collaborated with different engineers. He worked with Jean-Rodolphe Perronet (1708-1794), the *Inspecteur Général des Ponts et Chaussées* and the founder of the École des Ponts et Chaussées, on machines to test the compressive strength of stone. With the help of a young engineer, Émiliand-Marie Gauthey (1732-1808), Soufflot and Perronet assembled quantitative data from which equations were deduced and applied

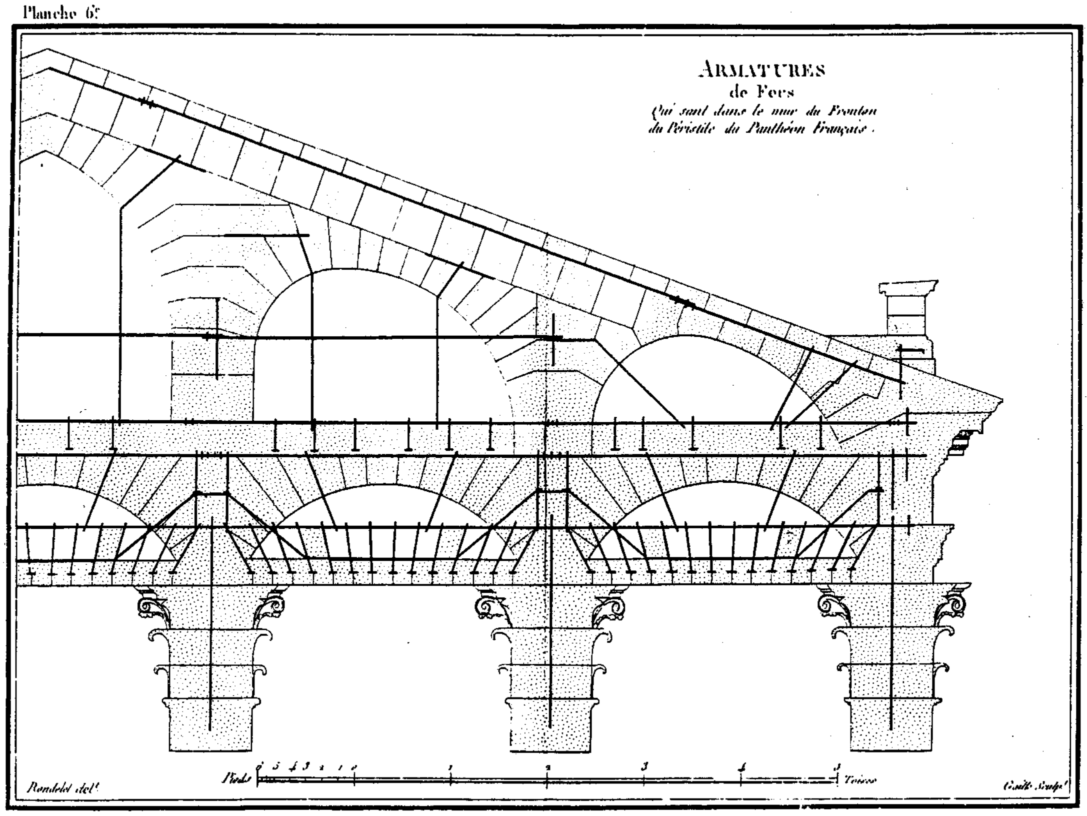
137 Soufflot's lecture was entitled: *Mémoire pour servir de solution à cette question: savoir si dans l'art de l'architecture le goût est préférable à la science des règles ou la science des règles au goût.* See Michael Petzet, *Soufflots Sainte-Geneviève und der Französische Kirchenbau des 18. Jahrhunderts,* Walter de Gruyter (Berlin), 1961, pp.142-147.

138 Ibid., p. 145.

for determining the structure of the building. Later, Jean-Baptiste Rondelet (1734-1829), a pupil of Soufflot, was put in charge of the completion of Ste.-Geneviève. Soufflot was of the conviction that architecture depended for its realization upon scientific observations and theories. The involvement of engineers during the phases of design and construction indicates the necessity to have conceived of the building in terms of scientific propositions. In order to realize the vision of structural lightness and to achieve an architecture primarily dominated by columns, as Cordemoy and Laugier had proposed, Soufflot required an understanding of statics and material properties.

Ste.-Geneviève, however, reveals certain inconsequences from a structural point of view as resulting from formal intentions. The contradiction between the concealed buttresses and the open frame of the internal peristyle as well as the fact that the semi-circular vaults were non-load bearing and suspended from timber trusses are both indications that the technical means were not entirely compatible with the formal concepts of the work. Such dichotomy between form and technique became even more apparent during construction when a series of structural problems occurred, delaying the completion of the church until after Soufflot's death. The various attempts to resolve the technical problems encountered during the construction process evidently compromised the purity of Soufflot's vision. The reinforcement of the stonework involving an excessive amount of iron cramping revealed the incompatibility of Soufflot's formal intentions regarding the technical means at his disposal. Of greatest consequence was the infill of the perimeter windows

Planche 6e



Detail showing the reinforcement of the stonework by means of elaborated iron cramping techniques. From Jean-Baptiste Rondelet, *Mémoires Historique sur le Dôme du Panthéon Français,* Paris, 1797.

(circa 1800) in order to strengthen the walls so that they could resist the lateral thrust of the structure.

Soufflot's theoretical approach to problems of construction was sharply criticized as the technical difficulties were encountered during the erection of Ste.-Geneviéve. When problems were discovered due to settlement of the masonry, Soufflot and his collaborators were required to justify their methods and procedures to members of the academy. A polemic arose which continued long after Soufflot's death when the main piers were found to be cracking. The strongest critique was formulated by Pierre Patte (1723-1814) before the construction of the dome structure had even begun. Patte was an architect, engraver, and author of the period, interested in the technical problems of building construction.[139] From 1757-1759 Patte had worked on the engravings of the *Encyclopédie* illustrating the methods and techniques of the traditional trades. He also completed the last two volumes of Jacques-François Blondel's *Cours d'architecture*, devoted to building materials and construction. Patte's concern with the techniques of building production constituted the foundation of his criticism, which questioned Soufflot's inherently theoretical approach for determining structure and materials in architecture.[140]

139 For a thorough description of Pierre Patte's life and work, see Mae Mathieu *Pierre Patte, sa Vie et son Oeuvre*, Alcan Presses Universitaires de France (Paris), 1940.

140 See "Le Conflit entre Patte et Soufflot a propos de l'Église Sainte-Geneviève," ibid., pp. 181-284. The debate between Patte and Soufflot within the eighteenth century understanding of theory and practice has been addressed by Alberto Pérez- Gomez in "Soufflot, Patte, and the Piers of Ste.-Geneviève," op. cit., pp. 258-267.

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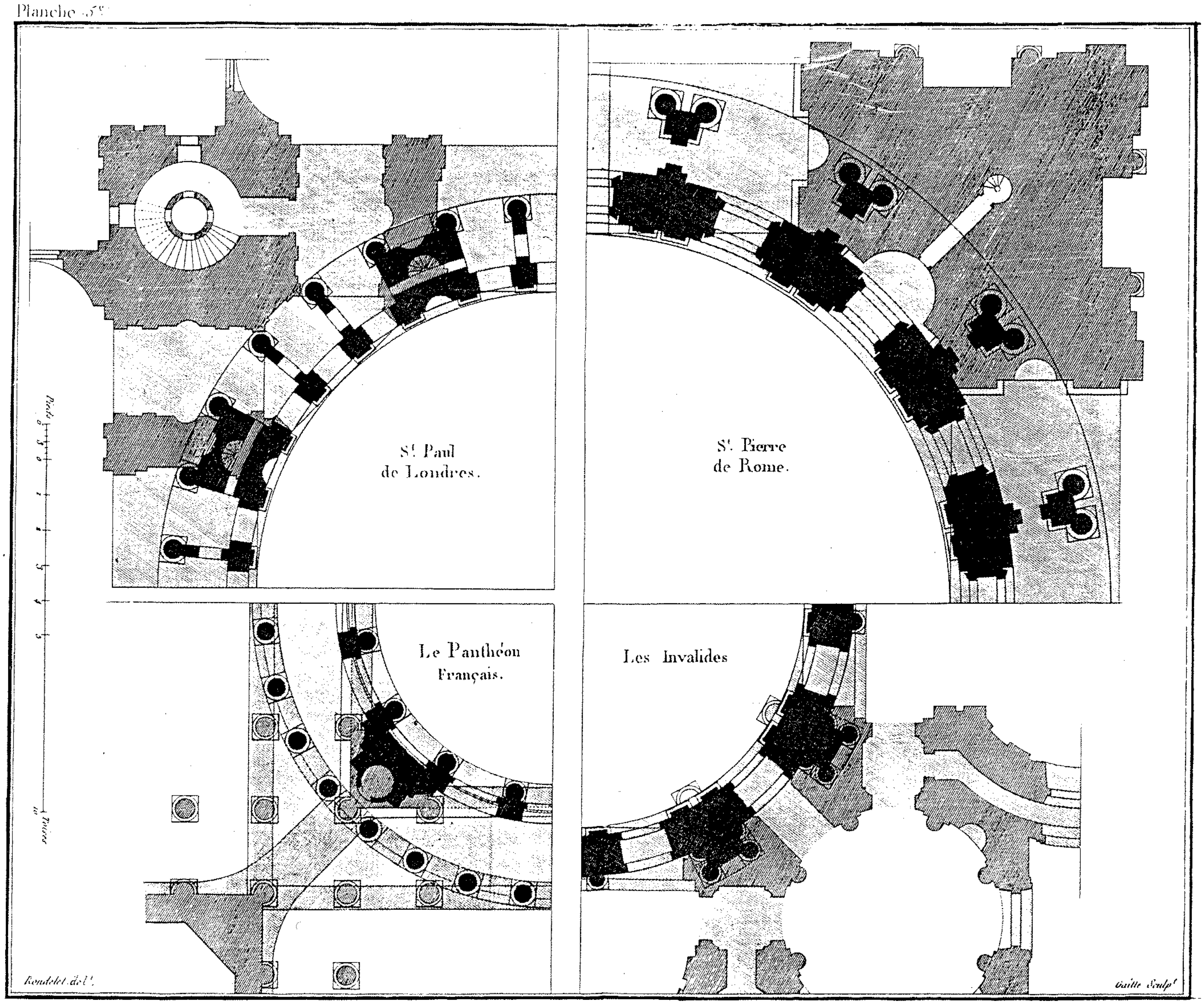

The piers of Ste.-Geneviève as compared with the dome structures of St. Peter, St. Paul, and Les Invalides. After Patte's *Mémoire*, 1770; from Jean-Baptiste Rondelet's *Mémoire Historique sur le Dôme du Panthéon Français*, Paris, 1797.

In 1769 Patte emphasized in his work *Mémoires sur les Objets les Plus Important de l'Architecture* that building construction constituted the most essential part of architecture.[141] The reference to considerations of building practice formed, consequently, the base of his critique of Soufflot's design for Ste.-Geneviève. In 1770 Patte published the *Mémoire sur la construction de la coupole projettée de l'église Sainte-Geneviève*. He asserted that the piers, which at the time were under construction, could never support the significant load resulting from the weight of any proposed dome structure. He argued that Soufflot had determined the dimensions of the piers through theoretical calculation alone, thus having neglected the conditions of reality to which building practice is unavoidably subjugated. Patte was aware of the limitations of theory which De la Hire, Bélidor, and Frézier had revealed in their attempts to apply the principles of statics to construction. He did not at all reject the use of mathematics and scientific principles for architectural production; he stressed, however, that theoretical rules must take into account all the practical contingencies of construction. Patte's criticism was guided by the conviction, as he asserted in Blondel's *Cours*, that historically practice had always preceded theory.[142] The art of building, according to Patte, was based on experience. Rules of construction were traditionally established through the repeated and successful application of building techniques.

[141] Pierre Patte, "Introduction," *Mémoires sur les Objets les Plus Important de l'Architecture* (Paris, 1769); see A. Pérez-Gómez, op. cit., p. 72.

[142] Pierre Patte, in J.F. Blondel *Cours d'Architecture*, Vol. 6, pp. 1, 2.

Although in disagreement regarding the relation between theory and practice, both Soufflot and Patte were essentially interested in the role of technique in architecture. Soufflot believed in the *a priori* nature of scientific laws which were to be physically implemented. In contrast, Patte's position was determined by an empirical approach to problems of structure and construction. Accordingly, Patte's critique regarding the dimensions of the piers of Ste.-Geneviève was based on empirically assembled information; he compared Soufflot's proposal for the dome construction with such structures as St. Peters in Rome, St. Pauls in London, and Les Invalides in Paris. From this comparison Patte deduced that the proposed structure of Ste.-Geneviève was inadequate. Construction for him was based on the straightforward application of techniques as they had evolved through the experiences of practice. His approach was nonetheless founded in scientific inquiry, for modern science required empirical methods from which experience could be gained in research and experimentation. Patte was, however, critical of scientific theories when those were not in agreement with the facts of reality. He strongly believed that theory had to address practice; only from such a vantage point could a theoretical approach be significant for the field of building construction.[143]

Soufflot's position was defended by Émiliand-Marie Gauthey and Jean-Batiste Rondelet, both involved as engineers in the project of Ste.-Geneviève. Gauthey argued that Patte had ignored certain significant parameters as, for example, the adhesive property of mortar. In considering such factors

143 Ibid., pp. 5, 6.

Gauthey's calculations led him to conclude that Soufflot's proposed structure could support a dome of even greater dimension.[144] Rondelet shared Gauthey's interest in solving structural problems through deductive reasoning and by means of calculations. He assigned, however, a greater importance to the practice of building construction. His *Mémoires Historique sur le Dôme du Panthéon Français*, published in 1797, dealt in detail with materials and specific building procedures.[145] He not only examined the structural properties of the walls and the points of support of the dome but also analyzed the failures of the structure as observed during the construction process.[146] Rondelet was equally interested in theory and practice, for he was conscious of the interdependence of their respective operations. His understanding of the problems both at the theoretical and the practical levels gave him the information necessary to structurally reinforce the piers of the dome, making the completion of Ste.-Geneviève possible.

The unity of theory and practice was the guiding concept of Rondelet's treatise *Traité Théorique et Pratique de l'Art de Bâtir,* published in 1802.[147] He expressed that the art of building was to be considered as the physical and material application of the theoretical sciences: "L'art de bâtir consiste dans une heureuse application des sciences exactes aux

144 Emiland-Marie Gauthey, *Mémoire sur l'Application des Principes de la Mécanique à la Construction,* Paris, 1771.

145 Jean-Baptiste Rondelet, *Mémoire Historique sur le Dôme du Panthéon Français,* Du Pont (Paris), 1797.

146 See the fourth part of Rondelet's *Mémoire* which addresses "*le détail exact de tous les accidens qui se sont manifestés,*" ibid., pp. 76-115.

147 Jean-Baptiste Rondelet, *Traité Théorique et Pratique de l'Art de Bâtir,* 1802; Firmin Didot Frères (Paris), 1867.

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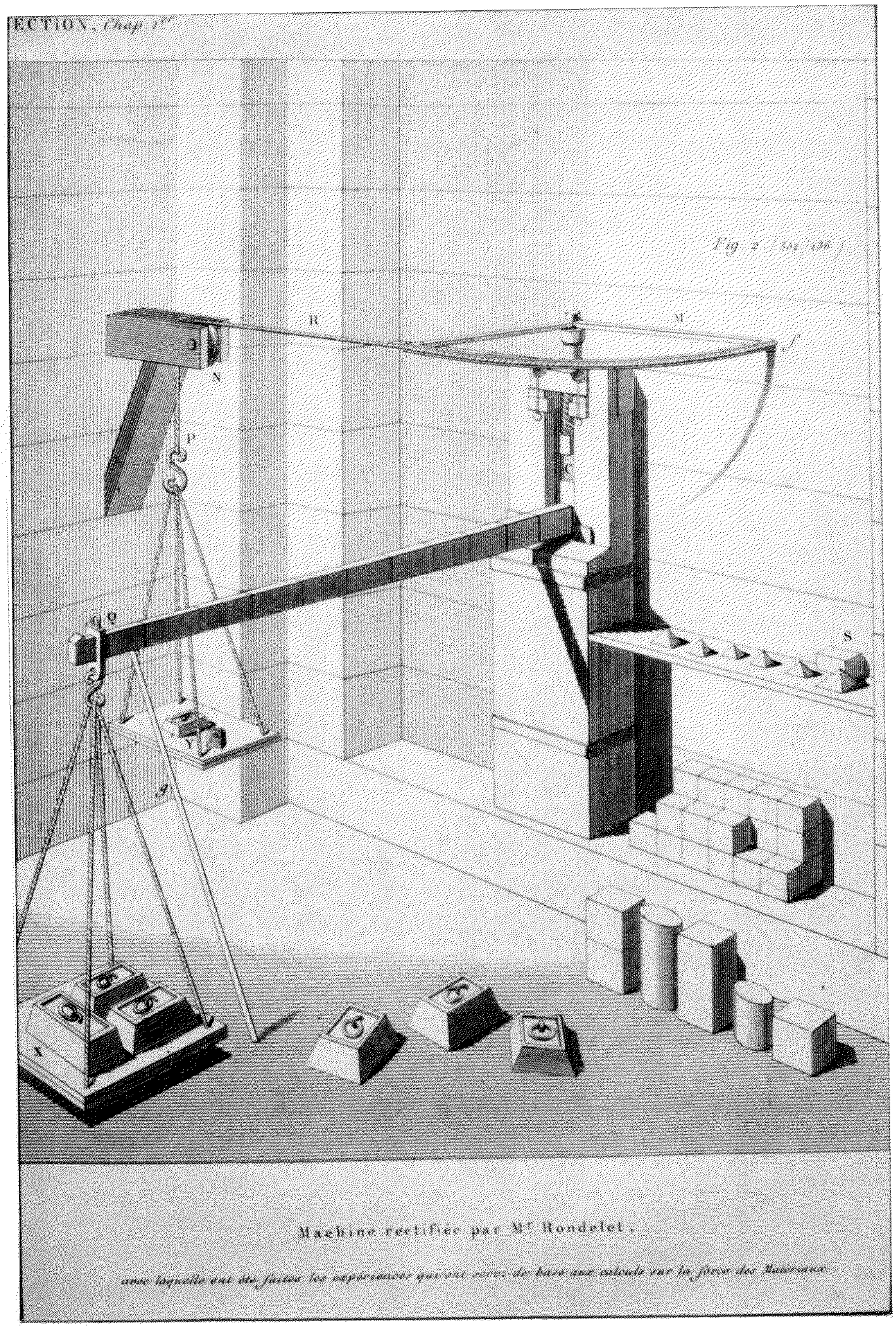

Machine for testing the strength of materials; from Jean-Baptiste Rondelet's *Traité Théorique et Pratique de l'Art de Bâtir*, 1802.

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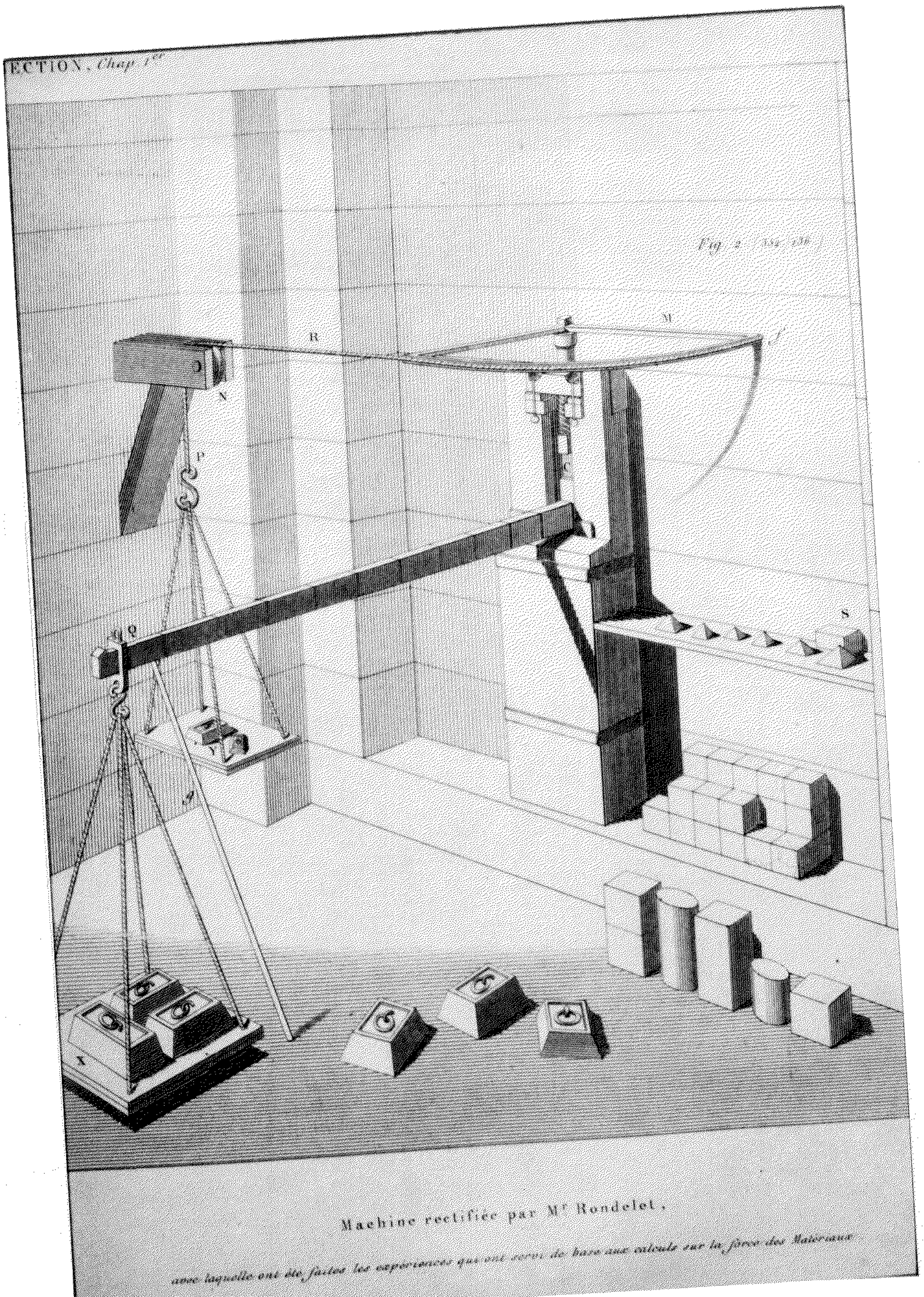

Machine for testing the strength of materials; from Jean-Baptiste Rondelet's *Traité Théorique et Pratique de l'Art de Bâtir*, 1802.

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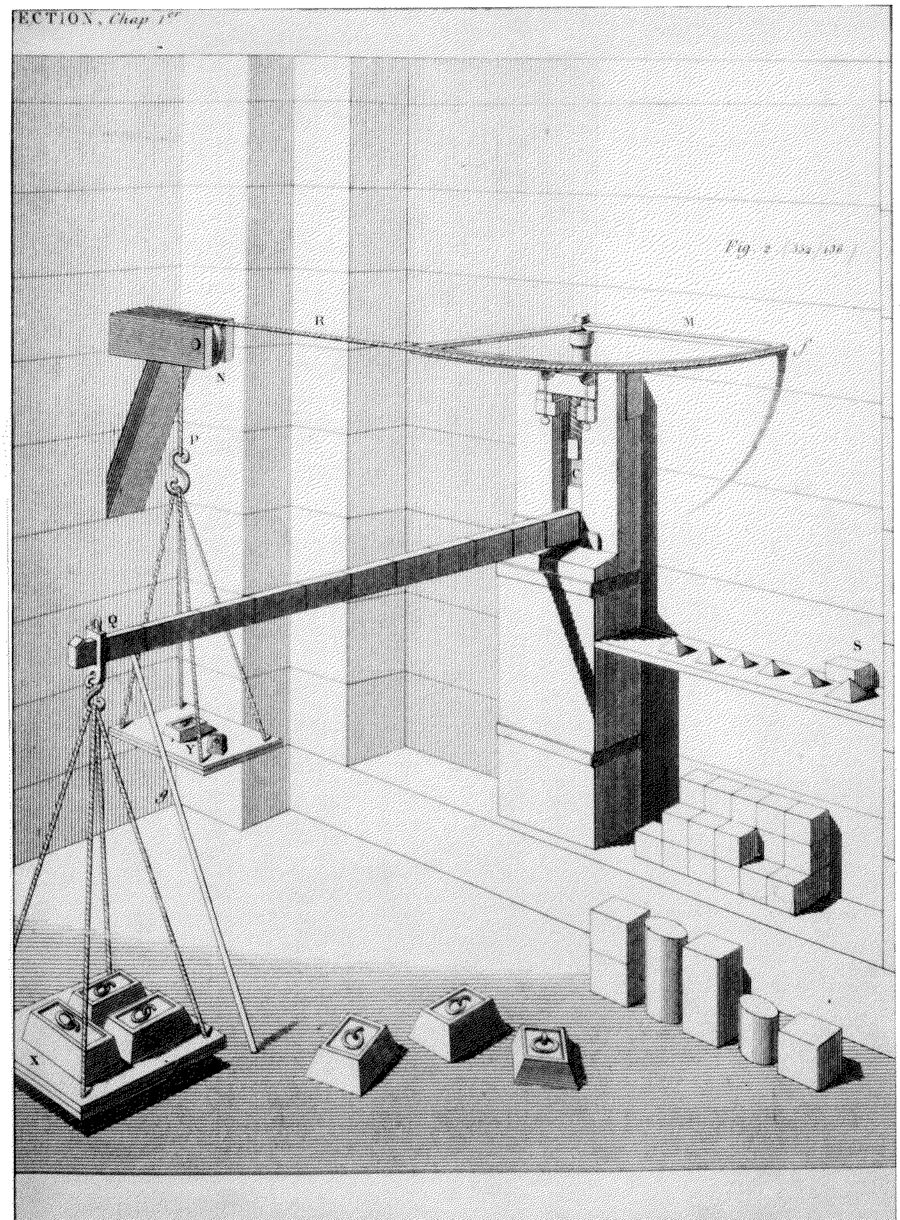

Machine rectifiée par Mr Rondelet,

avec laquelle ont été faites les expériences qui ont servi de base aux calculs sur la force des Matériaux

Machine for testing the strength of materials; from Jean-Baptiste Rondelet's *Traité Théorique et Pratique de l'Art de Bâtir*, 1802.

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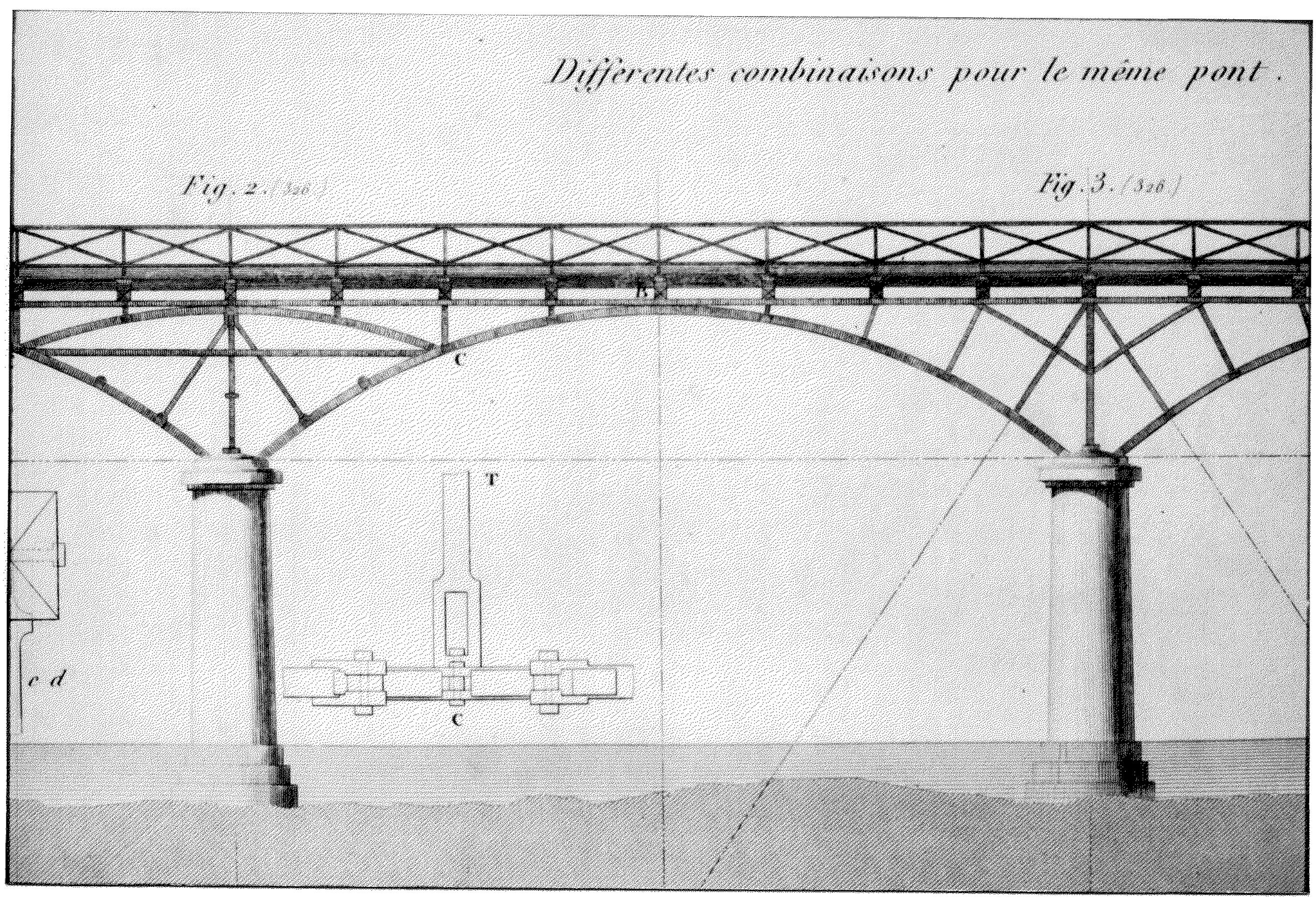
propriétés de la matière."[148] Such an understanding of construction, according to Rondelet, was reflected in Giovanni Poleni's analysis of the dome of St. Peter's as well as in Soufflot's construction of Ste.-Geneviève. Such projects revealed the significance of theories of statics and building materials for architecture. Rondelet wrote his treatise with the intention to disclose the primary importance of theory within the field of construction. This idea which advocated a theoretical foundation for the practice of architecture was expressed at the beginning of the book:

On appelle théorie le résultat de l'expérience et du raisonnement, fondé sur les principes de mathématique et de physique appliquées aux différentes combinaisons de l'art. C'est par le moyen de la théorie qu'un habile constructeur parvient à déterminer les formes et les juste dimensions qu'il faut donner à chaque partie d'un édifice, en raison de leur situation et des efforts qu'elles peuvent avoir à soutenir, pour qu'il en résulte proportion, solidité et économie.[149]

Rondelet not only emphasized the necessity to provide a theoretical foundation for practical operations, but he also indicated that the creation of form in architecture was to be in accordance with the technical means of construction. The discipline of architecture was considered for him primarily a building science rather than a representational art. He thus defined the art of building as an application of the exact sciences to the properties of matter. Construction, according

148 Ibid., Vol. 1, Introduction, p. xxvi.
149 Ibid., p. xxviii.



Bridge construction in iron; from Rondelet's treatise, 1802.

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to Rondelet, could only evolve as an art form when theoretical and practical knowledge were conjoined: "La construction devient un art lorsque les connaissances de la théorie unies à celles de la pratique président également à toutes ses operations."[150] The five volumes of the *Traité* were therefore conceived as a textbook on construction providing rules for solving technical problems. Building materials were analyzed in terms of their properties and strength; construction techniques were described as to their application; and, methods for calculating the cost of building were provided. The plates and text of the treatise offered detailed accounts of all the building trades: stereotomy, masonry, carpentry, cabinetry, locksmithing, and roofing. Rondelet included information on iron as a material to be used in building construction. He illustrated various bridges in iron which recently had been built in France and England offering suggestions as to their improvement. In all, Rondelet's work was guided by the intention of forming an extensive body of technical knowledge which he considered as the foundation of architecture.

Architects were to be versed in all aspects of building in theory and practice. Rondelet saw in geometry and mathematics the means for establishing the link between theoretical and practical considerations. For determining the configuration and dimensions of building parts, Rondelet proposed the methodical application of geometry and mathematics. By means of geometric projections, for example, the form of stairs, vaults, or roof structures could be precisely identified. Mathematics constituted the base for solving equations in order to

150 Ibid., p. xxvi.

quantitatively understand the structure of buildings. Such methods, from which the form and size of building parts were determined, constituted the foundation for a theory of construction. Rondelet was well aware of the difficulty which engineers such as De la Hire, Frézier, and Bélidor had encountered when attempting to apply principles of statics to reality. Theoretical assumptions within the field of construction could not pertain solely to the abstract, but instead must conform with the circumstances as found in practice. Experience and empirical data were therefore, according to Rondelet, as important to construction as were the rules of scientific laws.

The information assembled in the treatise not only reveals Rondelet's extensive understanding of construction but also discloses his dedication to providing a framework for technical knowledge. The *Traité* was conceived as an encyclopedia of architectural construction; in that, Rondelet's work coincided with the intentions underlying Diderot's project of the *Encyclopédie*. Rondelet's interest in the development of technical knowledge was founded on the belief that the advancement of science constituted the progressive realization of human kind. Consequently, the treatise revealed the same symbolic dimension previously implied by the encyclopedists. As the encyclopedia offered a general framework of human knowledge, similarly Rondelet's treatise showed the intention to provide a rational structure for the specific field of architectural construction. The constant reference to geometry and mathematics, constituting the base of scientific theories, was made with the intention to disclose the rationality evident in natural order. The application of theory within building construction was an attempt to reveal the order of nature and expressing its 'truthful' condition. Rondelet's objective was to bring forward this order inherent within the processes of production while proposing an understanding of technical knowledge.

With the increasing development of technical knowledge, Rondelet believed, architecture could attain a level of perfection from which ultimately beauty would result. This concept which advocated a precise relation between technique and formal expression was clearly stated in the introduction of the *Traité*: "En effet, c'est le mérite de la construction qui constitue à tous les yeux le premier degré de beauté d'un édifice; et la perfection qu'il tient de l'art de bâtir excite surtout notre admiration par cela seul qu'elle devient le garant d'une plus longue durée."[151] Construction, according to Rondelet, leads to beauty and constitutes its first principle. This idea adhered to the concept of "positive" beauty as was expressed by Claude and Charles Perrault more than a century earlier. Technique in these terms was not only the means for the realization of architecture but constituted the foundation of beauty as formally expressed. Constructional logic and tectonic quality thus provided architecture with meaning. The art of building essentially disclosed the conditions from which the conception of architecture was determined.

151 Ibid., p. xxvi.

The Ontological Structure of Technology

The concept of construction as a building science led to a new understanding of technology within the field of architecture. Rather than conceiving of building techniques merely as the instrumental means for realizing a specific and predetermined formal intention, technique was instead understood in terms of its ontological dimension. Technology in general and construction technology specifically were viewed as being related to man's condition of existence, for technique could not be separated from human endeavor. This view, which developed with the emergence of scientific thought during the seventeenth and eighteenth centuries, was the foundation for understanding technology as a modern discipline.

The traditional, or Aristotelian, concept of technology considered technique as a neutral means by which to achieve a specific end. Tools, instruments, and machines as well as methods of production were not thought to have any meaning in themselves; the value of technique was rather determined by the view that it served and made possible the attainment of human ends. While technique was traditionally defined in instrumental terms, it was considered to be external to man, extrinsic to his natural condition. The modern conception of technology on the other hand viewed technical matters as being inherently connected with the human condition and part of man's existential structure.

Modern science, as made explicit by the work of Galileo, Pascal, and Newton, revealed the essential conditions of natural phenomena. Laws, axioms, and principles were formulated allowing man to gain an understanding of the structure of the natural environment. Such scientific knowledge was essential to guide man in the making of his world which was considered as an extension of nature. The search for truthful and natural conditions as applied to the production of artifacts offered a meaningful base for the creation of man-made objects. This search contained an *a priori* stipulation of the essence of the object and therefore of objective truth. Herein lay the metaphysical justification of man's material world, allowing him to understand and conceive the physical structure of his environment.

The proposition of Francis Bacon to write a history of the mechanical arts as well as the succeeding work of Félibien, Diderot, and Rondelet gave renewed priority to techniques and methods of production. Their attempts to systematize the knowledge pertaining to manufacturing processes were guided by the search for truth which was considered inherent within the material world. While primary emphasis was placed on practical and pragmatic considerations, this ideological search was nevertheless determined by a symbolic intention, i.e. to disclose the essential meaning of human existence. As technical matters were understood in terms of man's condition of being, technology came to address the theories of technique in terms of its ontological dimension.

In order to consider the man-made object in terms of its condition of existence, priority was given within technology to the processes which led to the creation of artifacts. This importance assigned to manufacturing and production was paralleled by the significant role given to *process* within scientific inquiry. In architecture, the concept of *process* was similarly valued; the increasing reference to the exigencies of building construction during the seventeenth and eighteenth centuries was an indication that considerations of production gradually became understood as constituent factors of architectural design. Rather than conceiving of architecture exclusively in terms of formal concerns, a new approach to the architectural object emphasized the processes of its making. The understanding of form in view of the parameters of construction was made possible, thus preparing the foundation for an expression of modern aesthetics.

CONCLUSION
Towards a Modern Concept of Unification

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"In the intellectual revolutions of the past, architecture has been a point of fusion: the most sensitive point at which new ideas in science and a new conception of the arts have crossed and influenced one another. Men have learned both, unconsciously, from the daily sight of great buildings. Today the architect bears the same responsibility for making science as well as art visible and familiar, and for having each influenced and enter into the other. Architecture remains the crossroads of new science and new art. "

Jacob Bronowski, "Architecture as a Science & Architecture as Art."[1]

Building Art, the Unity of Form and Technique

The increasing interdependence of theory and practice led to an unprecedented development of technical knowledge during the first half of the nineteenth century. The application of scientific theories to practical issues as well as the verification of hypotheses through experiments offered the possibility for technical innovation. New techniques and methods were gradually introduced into all fields of production, contributing to the development of the industrial revolution. The priority assigned to technique in general was fundamental to architecture, allowing new possibilities of formal expression. Architectural form had been traditionally

[1] Jacob Bronowski, "Architecture as a Science & Architecture as Art," in *The Visionary Eye, Essays in the Arts, Literature, and Science*, MIT Press (Cambridge, MA), 1978.

founded on the predetermined rules of a classical vocabulary whereby a dichotomy existed between form and technique. This view was challenged by the new importance given to technique. An approach to the making of form gradually emerged in which the reconciliation of formal and technical concerns was attempted.

As the traditional concepts pertaining to the understanding of architectural form were re-examined during the nineteenth century, theories were formulated in which an integration of technique within architecture was advocated. Importance was given to craftsmanship and construction from which new aesthetic principles were deduced. The writings of such authors as John Ruskin in England, Eugène-Emanuel Viollet-le-Duc in France, and Gottfried Semper in Germany addressed the exigencies of building construction within the general understanding of architecture as an art form. Such theories did not advocate a direct correspondence between technique and form in which formal expression was exclusively derived from technical consideration; instead, priority was placed on architectural form which received its justification from an abstract and ideal understanding of the processes of production. Although building construction involved the application of scientific theories, the discipline of architecture was still considered primarily as an art form. Architectural theory continued to address the question of beauty as its primary subject matter.

While suggesting different conceptions of architecture, the writings of Ruskin, Viollet-le-Duc, and Semper offered essential contributions for understanding the relation between architectural form and technique during the mid-nineteenth century. The increasing reference to questions of utility and construction which had occurred during the eighteenth century became integrated into theories of architectural aesthetics. A new understanding of form evolved. Formal expression was not considered independent from technical means, nor was architectural form seen as being representational of technique; instead form was to embody technique. Architecture was to be the truthful manifestation of the principles inherent within construction. Such an understanding, in which form was considered the poetic expression of the process of building, adhered to the concept of the unity of truth and utility. This idea had been previously advocated within philosophy by Francis Bacon, Denis Diderot, and Giambatista Vico, for example, and gradually became integrated into the field of architecture. The search for truth inherent within craftsmanship, construction, and building techniques constituted the metaphysical and spiritual foundation of architectural form.

That form was to be the embodiment of both technique and aesthetic considerations differentiated the position of the nineteenth century authors from those who had come before. It is in this sense that a historical and theoretical division can be made in the investigation of architectural form and technique in the mid nineteenth century. The following discussion of the writings of Ruskin, Viollet-le-Duc, and Semper will briefly describe their positions and thus attempt to clarify the understanding of architectural aesthetics at the outset of the Modern Movement.

The theoretical work of John Ruskin (1819-1900) reveals an understanding of form wherein the unity of truth and utility is asserted as a moral principle.[2] Although Ruskin did not formulate a coherent architectural theory which could be specifically abstracted from his writings, his work nevertheless addressed certain significant ideas pertaining to the relation between formal expression and technical execution.[3] In *The Seven Lamps of Architecture*, published in 1849, Ruskin offered an approach to architectural aesthetics in terms of its ethical foundation.[4] The Lamps of Sacrifice, of Truth, of Power, of Beauty, of Life, of Memory, and of Obedience are all primarily evocative qualities, not strictly confined to architecture. It was within such a context that Ruskin understood the concept of utility. He did not conceive of architecture as pertaining exclusively to pragmatic considerations of functional and technical necessity but instead as an art form transcending matters of utility and entering the realm of poetic expression.[5]

2 For a thorough analysis of Ruskin's life see the biographies by Joan Evans, *John Ruskin*, Oxford University Press, 1954 and J.D. Rosenberg, *The Darkening Glass*, New York, 1961.

3 Graham Hough wrote that Ruskin's "individual judgements are so capricious that to establish his real and substantial view is always a matter of sifting and collating: to quote any one passage as final lays open to the charge of being as arbitrary as Ruskin himself." Graham Hough, *The Last Romantics* (London), 1949; quoted from Kristine Ottesen Garrigan, *Ruskin on Architecture*, The University of Wisconsin Press (Madison, Wisconsin), 1973, p. xiii.

4 John Ruskin, *The Seven Lamps of Architecture*, 1849; Farrar, Strauss and Giroux (New York), 1981.

5 The connection between poetry and architecture was made by Ruskin in his early work, in the collection of papers *The Poetry of Architecture* (1837-38), which he had written in his youth and published under the pseudonym "Kataphusin" in J.C. Loudon's *Architectural Magazin*.

The difference between the merely technical aspects of construction and its manifestation as a fine art was made in the beginning of the first chapter of *The Seven Lamps of Architecture* with the distinction between *Building* and *Architecture*. Ruskin wrote: "It is very necessary, in the outset of all inquiry, to distinguish carefully between Architecture and Building."[6] The factual and instrumental aspects of construction as well as questions concerning the accommodation of use belonged to the realm of *Building* for they were considered basic requirements. *Architecture*, on the other hand, was the manifestation of an artistic will. Ruskin writes: "Architecture concerns itself only with those characters of an edifice which are above and beyond its common use."[7] Building, according to Ruskin, becomes architecture when the technical and functional considerations are resolved and the pragmatic aspects of production are taken to the level of poetic expression.

This process of transcending *Building* toward *Architecture*, Ruskin believed, was deeply rooted in the work of the craftsman in that his role in architecture corresponds to that of the artist within art. Ruskin's theory of architecture proves to be founded on his conception of art. As the artist's work evokes beauty, so architecture depends on "that spirit which is given by the hand and the eye of the workman."[8] A significant role is assigned to the builder and his processes of production for it is the craftsman who gives life to the work he produces. This

6 John Ruskin, *The Seven Lamps of Architecture*, "The Lamp of Sacrifice," p. 15.

7 Ibid.

8 Ibid., "The Lamp of Memory," p. 184.

was an idea which was later to become important for the Arts and Crafts movement. Ruskin juxtaposed the work made with the help of machines, which he regarded with contempt, to the work made by men. An inherent quality, he believed, existed *a priori* within craftsmanship: "so long as men work *as* men, putting their hearts into what they do, and doing their best, it matters not how bad workmen they may be."[9] The effect of the work achieved through the practice of the craftsman, "as compared with the same design cut by a machine," Ruskin believed, "will be like that of poetry well read and deeply felt to that of the same verses jangled by rote."[10]

The work of artists and craftsmen was in so far superior to machine production as that the making of art was thought to be guided by the constant search for truth. "Speaking truth," Ruskin asserted, "comes only by practice."[11] In the second chapter of *The Seven Lamps of Architecture*, entitled "The Lamp of Truth," Ruskin offers an understanding of construction as the truthful expression of the craftsman's work. He writes: "Do not let us lie at all."[12] A connection was here established between building construction and its influence on form. The violation of truth, which 'dishonors poetry,' was to be avoided; three principles were suggested by Ruskin to be critically followed within the making of architecture. The first proposition pertains to the formal consequences of the structural system; "the suggestion of a mode of structure or support, other than the true one" was considered a false

[9] Ibid., "The Lamp of Life," p. 162.
[10] Ibid.
[11] Ibid., "The Lamp of Truth," p. 36.
[12] Ibid.

assertion of the real conditions. The second principle addresses the quality of building materials as revealed in the treatment of wall surfaces; "the painting of surfaces to represent some other material than that of which they actually consist" was to be avoided for the nature of material had to be respected. The third proposition is concerned with the operative aspect of the process of creating form; "the use of cast or machine-made ornaments of any kind" was rejected for truthful expression could only result from the craftsman's work.[13] Although the three architectural deceits mentioned by Ruskin seem not to be logically on the same plane, they nevertheless reveal a distinctive understanding for the integration and manifestation of construction within form.

The qualities of structure, material, and building process, according to Ruskin, contributed to formal expression. Specific emphasis was given to ornament, which Ruskin believed to be the "principal part of architecture."[14] Ornamentation was not directly derived from technical considerations but offered the possibility for visibly demarking the building's underlying construction. Ruskin asserted that ornament, while not necessarily subordinate to the structural system, should essentially not contradict structure. This relationship between architectural form and building construction, which offered a certain visual accessibility of the object, was addressed in *The Seven Lamps of Architecture*:

13 Ibid., p. 39.

14 See Ruskin's *Lectures on Architecture and Painting* (1854), reprint of the 1854 edition by Wiley (New York), 1978, p. 89.

The architect is not bound *to exhibit structure; nor are we to complain of him for concealing it, any more than we should regret that the outer surfaces of the human frame conceal much of its anatomy; nevertheless, that building will generally be the noblest, which to an intelligent eye discovers the great secrets of its structure, as an animal form does, although from a careless observer they may be concealed.*[15]

This reference to architecture and observer was also the guiding factor for Ruskin's preoccupation with surfaces and the materials of which they were made. Importance was given to the visible layer of the architectural object for a building was considered to be constructed of a series of planes. Ruskin's conception of building was founded on an understanding of veneer construction. An inherent beauty lay within the nature of materials which was expressed by the external layer of the building. From this Ruskin deduced that a "falsity of assertion respecting the nature of material" was a violation of truthful conditions. Both veneer construction and building materials were understood in reference to their essential qualities. This idea was addressed by Ruskin in the discussion regarding the facing of brick walls with precious stone:

It is well known, that what is meant by a church's being built of marble is, in nearly all cases, only that a veneering of marble has been fastened on the rough brick wall, built with certain projections to receive it; and that what appear to be massy stones, are nothing more than external slabs. ... If it

[15] Ruskin, *The Seven Lamps of Architecture*, "The Lamp of Truth," op. cit., p. 40.

be clearly understood that a marble facing does not pretend or imply a marble wall, there is no harm in it; and as it is also evident that, when very precious stones are used, ... there is no resource but this of veneering; ...[16]

Such application of building materials as surface veneer was considered by Ruskin "as simply an art of mosaic on a large scale."[17] The treatment and articulation of a building's visible surfaces was the primary task of the craftsman. It was within such work that the essential qualities of human labor were revealed allowing the understanding of architecture as an art form. Ornamentation as applied to walls and façades was thus compared to the making of sculpture and painting. In the preface to the second edition of *The Seven Lamps*, Ruskin asserted that the fine arts were constituted only by sculpture and painting. "Architecture," he added, "is only the association of these in noble masses." For Ruskin, it was this combination of building construction with art production which provided the basis for what he called the "artistical and rational admiration" of architecture.[18]

The Gothic style, which Ruskin so much respected, embodied all the characteristics that he considered to be good within architecture. Ruskin admired Gothic construction for it implied a truthful understanding of structure. The articulation of surfaces and the sculpting of building materials, which brought

16 Ibid., p. 53.

17 Ibid., p. 54.

18 This quote is taken from the 1855 preface to the second edition of *The Seven Lamps of Architecture*. See Kristine Ottesen Garrigan, *Ruskin on Architecture*, op. cit., p. 49.

beauty to architecture, were within the realm of art. Above all, the Gothic represented the work of craftsmen. Gothic architecture was for Ruskin *Living Architecture*, it encompassed the life which the work of masons and carvers gave to the building.[19]

Ruskin hoped to determine the power of *Mental Expression* in relation to the *Material Form* of Gothic architecture. He wrote in "The Nature of Gothic" that good architecture embodies the unity of *external forms* and *internal elements*. As the "chemist defines his mineral by two separate kinds of character; one external, its crystalline form, hardness, lustre, etc.; the other internal, the proportions and nature of its constituent atoms," architecture for Ruskin was similarly understood in terms of its *external forms* and *internal elements*.[20] The artistic and "mental tendencies of the builders" constituted, for example, internal conditions which contributed to the beauty and poetry of Gothic form. For Ruskin, this synthesis of material and mental expressions was particularly visible within the articulation of details. The architectural detail was considered the formal and legible manifestation of *internal*

[19] John Ruskin, "The Nature of Gothic," in *The Stones of Venice*, 1851-53; edition Bellew & Higton Publishers (London), 1981, pp. 118-139. In "The Nature of Gothic" Ruskin outlined his conception of the Gothic in terms of qualities of labor. Such characteristics of artistic expression were, for example, *rudeness, imperfection, changefulness, rigidity,* and *redundance.* The *rudeness* of manual work as expressed in *imperfection* recalled for Ruskin the "state of progress and change" to which the process of architectural production was constantly exposed. The concept of *changefulness* was significant in that it demonstrated the freedom of the craftsman's work and 'the perpetual variety' of building parts. *Rigidity* pertained to the formal manifestation of structure as "the communication of forces from part to part" and its expression "throughout every visible line of the building." And, *redundance* was the revelation within craftsmanship of "the wealth of its labor" and of the "fullness and wealth of the material universe."

[20] Ibid.

elements. Such a proposition was characteristic of Ruskin's approach to architecture. His writings reveal the search for identifying the conditions inherent within the processes of making architecture. The repeated reference to structure, surface, materials, and craftsmanship discloses Ruskin's interest in the fundamental elements of building production. To bring such components of construction into the realm of art, or poetry, was the resultant of realizing *internal elements* into *external form*.

Ruskin's theoretical position was biased in favor of traditional craftsmanship. Although the understanding of material qualities and production processes was considered essential to the art of building, Ruskin nevertheless disregarded the technical and industrial advances of the nineteenth century. The use of iron and glass as a building materials as well as the application of machine production within construction were regarded by Ruskin with contempt. He polemically criticized the new iron and glass structures of the railway stations which were built in England during the mid-century: "Better bury gold in the embankments than put it in ornament in the stations."[21] Railway stations exemplified non-architecture; in 1880, he added a footnote to the first sentence of *The Seven Lamps,* which defined architecture as an art form: "This separates architecture from a wasp's nest, a rat hole and a railway station."[22]

[21] John Ruskin, *The Seven Lamps,* op. cit., "The Lamp of Beauty," p. 117. See also N. Pevsner, *Some Architectural Writers of the Nineteenth Century,* op. cit., p. 155.

[22] See the publications by Nikolaus Pevsner, *Ruskin and Viollet-le-Duc,* Thames and Hudson (London), 1969, p. 33, and "Ruskin," in *Some Architectural Writers of the Nineteenth Century,* op. cit., p. 155.

A similar critique was formulated by Ruskin when Joseph Paxton's design for the Crystal Palace was realized for "The Great Exhibition of Industry of All Nations" in 1851. The Crystal Palace, a structure of glass and steel, was a manifestation of the technical advances developed from engineering and the industry of the period. The concept of the structural skeleton, the use of glass for determining the building envelope, and the understanding of building construction as an assembly process offered new possibilities of formal expression which Ruskin only partially recognized. His position was contradictory and ambiguous; he wrote:

The quality of bodily industry which the Crystal Palace expresses, is very great. So far it is good. The quantity of thought it expresses is, I suppose, a single and admirable thought ... that it might be possible to build a greenhouse larger than ever a greenhouse was built before. This thought and some very ordinary algebra are as much as all that glass can represent of human intellect.[23]

Ruskin also criticized the application of steel for determining the structural framework of the Cristal Palace. Iron could not contribute to *Architecture* since traditionally the art of building and the laws of structure had been based on the material qualities of clay, stone, and wood. Ruskin believed that "the entire or principal employment of metallic framework would, therefore, be generally felt as a departure from the

[23] Pevsner, *Some Architectural Writers of the Nineteenth Century*, ibid., p.154.

first principles of the art."[24] He realized, on the other hand, that those new methods of production could offer the possibility for an entirely different understanding of architecture. Ruskin sensed this potential for a new approach to architectural aesthetics when he wrote that "the time is probably near when a new system of architectural laws will be developed, adapted entirely to metallic construction."[25] Although an indication was here given to the possible future development of architecture, he did not attempt to address the formal consequences which new construction techniques might have suggested. Ruskin's theories of architectural form included ideas pertaining to structure, building materials, and manufacturing processes; his propositions, however, remained within the realm of traditional practice, thus not considering modern methods of construction within his search for a new aesthetic sensibility.

In contrast, a new approach to architectural form as based on the principles of nineteenth century technology was attempted by the French architect, restorer, and writer Eugène-Emanuel Viollet-le-Duc (1814-79). He was a passionate defender of his own age, of engineering, and of the new materials and techniques which he sought to integrate in a new and expressive vocabulary of architectural forms. The unity of truth and utility, while for Ruskin belonging to the creative sensibility of the craftsman's work, was for Viollet-le-Duc a matter of rational thinking as it pertained to the intellectual ability of the designer. This emphasis on rationality was advocated in

[24] Ruskin, *Seven Lamps*, op. cit., p. 43.
[25] Ibid., p. 44.

Viollet-le-Duc's two operative works: the *Dictionnaire raisonné de l'architecture française* of 1854-68 and the *Entretiens sur l'architecture*, published in two volumes in 1863 and 1872.[26]

Viollet-le-Duc wrote his Dictionary, to which the term 'reasoned' was attached, in order to provide a theoretical framework and systematic understanding of architecture. The *Dictionnaire* offered an analysis of medieval monuments of the eleventh to the sixteenth century, yet its primary goal was to disclose the principles and logical structure inherent within building construction. The choice of using a dictionary as the form by which to structure his writing had a didactic intention, an idea clearly expressed in the preface to the *Dictionnaire* :

The dictionary form ... seemed to meet my requirements most adequately because of the multiplicity of examples in my work. It would do justice to the complicated but strictly logical divisions into which the compositional aspects of our medieval monuments fall, because it forces one to dissect, as it were,

26 Eugène-Emmanuel Viollet-le-Duc, *Dictionnaire raisonné de l'architecture française du XI ^{e} au XVI ^{e} siècle*, ten volumes, Paris, 1854-66; see *Viollet-le-Duc, Le Dictionnaire d'architecture*, edited by Philippe Boudon and Philippe Deshayes, Pierre Mardaga (Bruxelles), 1979. Eugène-Emmanuel Viollet-le-Duc, *Entretiens sur l'architecture*, two volumes, Paris, 1863 and 1872, reprinted by Gregg Press (Ridgewood, New Jersey), 1965.

each building, as well as to describe the functions and applications of all the component parts.[27]

Throughout his writings Viollet-le-Duc upheld the excellence of Gothic architecture. He believed that the truth inherent within a formal style, such as Gothic, lay in the extent to which the hidden order of relationships responsible for the construction of the architectural object was made manifest. While Ruskin's approach to the Gothic style was primarily emotional, it constituted for Viollet-le-Duc a clear expression of rational construction.[28] In his *Dictionnaire* he undertook the task to 'prove' the rationality and ingenuity of Gothic construction. The reference to Gothic architecture, as demonstrated by Robin Middleton, had already played a significant role within French architectural theories of the sixteenth to the eighteenth centuries; the work of Philibert de l'Orme, Derand, Cordemoy, and Frézier had addressed Gothic construction in rational terms.[29] Viollet-le-Duc continued this line of development; he understood, as his predecessors had recognized, that the system of Gothic ribs formed a structural skeleton and that the webs

27 *"Ces raisons, notre insuffisance peut-être, nous ont déterminé à donner à cet ouvrage la forme d'un* Dictionnaire. *Cette forme, en facilitant les recherches au lecteur, nous permet de présenter une masse considérable de renseignements et d'exemples qui n'eussent pu trouver leur place dans une histoire, sans rendre le discours confus et presque inintelligible. Elle nous a paru, précisément à cause de la multiplicité des exemples donnés, devoir être plus favorable aux études, mieux faire reconnaître les diverses parties compliquées, mais rigoureusement déduites, des éléments qui entrent dans la composition de nos monuments du moyen âge, puisqu'elle nous oblige, pour ainsi dire, à les disséquer séparément, tout en décrivant les fonctions et les transformations de ces diverses parties."* Viollet-le-Duc, *Dictionnaire*, preface, vol.I, p. vi.; see also *Viollet -le-Duc, Dictionnaire d'architecture*, op. cit., p. 16.

28 Nikolaus Pevsner, *Ruskin and Viollet-le-Duc*, op.cit., p. 42.

29 Robin Middleton, "The Abbé de Cordemoy and the Graeco-Gothic Ideal: A Prelude to Romantic Classicism," in *The Journal of the Warburg and Courtauld Institute*, vol. 25,1962 and vol. 26, 1963.

could be considered as infill. From such observations Viollet-le-Duc attempted to derive the basic principles of construction underlying Gothic architecture.

Viollet-le-Duc, however, realized that if his propositions were to have any impact on the course of architecture in France he would have to put forward a theory wider in scope than one based on the Gothic alone. Following the rationalist tradition of the seventeenth and eighteenth centuries, he sought to show that good architecture in general was founded on a rational system of organization. This concept was not to be merely confined to an analysis of Gothic architecture but could also be interpreted within the context of the nineteenth century, as Viollet-le-Duc suggested in the *Entretiens*, to formulate a new style. This new architecture, *l'architecture de l'avenir,* was to take into account the new materials and production methods which the nineteenth century development of technology had made available. Architects were encouraged in the *Entretiens* to search for new forms as derived from the qualities of iron and its manufacturing processes.[30] Viollet-le-Duc also recognized the possibilities resulting from industrial production and the prefabrication of parts. Various building components could now be entirely made in the factory or *atelier* and assembled on site.[31] This was a concept which had already been of guiding

30 "*Mais, si le fer est* prescrit, *non* proscrit, *entendons-nous bien, - il faut trouver les formes qui conviennent à ses qualités et à sa fabrication; nous devons le montrer, et chercher ces formes convenables jusqu'à ce que nous les ayons trouvées.* " Viollet-le-Duc, *Entretiens sur l'architecture,* op. cit., vol. II, p. 125.

31 "*Il est évident que ces sortes de constructions demandent à être conçues et exécutées entièrement à l'atelier avant d'être montées, ce qui ne serait pas d'un médiocre intérêt.*" Ibid., p. 336.

significance for the realization of Joseph Paxton's project of the Crystal Palace.

In Viollet-le-Duc's writings a great importance was assigned to the role of building construction, for it revealed the logical structure governing the arrangement of parts within an architectural unity. For Viollet-le-Duc architecture was determined, in its foundation, by the reality of physical construction. He believed that an alliance between architectural form, function, and the means of construction must be achieved. Consequently, the architect had to be truthful to the procedures of production and "employ building materials according to their qualities and properties."[32]

Viollet-le-Duc's theories, while concerned with the reality of building practice, went still further in proposing a systematic approach to architectural construction. He was interested in researching the interrelation between building components, their assembly, and entire systems of construction. The relationship between parts constituted the essential structure of an architectural entity. The very idea of a *system*, as applied to architecture, implied the breaking down not only of the constructed whole into its constituent elements but also of each of these elements into their component parts.[33] In

[32] Viollet-le-Duc, *Habitations Modernes*, Paris, 1875, p. 2.

[33] As described in a recent article by Hubert Damisch entitled "The Space Between: A Structuralist Approach to the Dictionary," Viollet-le-Duc's method discloses certain traits of structural thinking. Damisch writes that "it is not difficult to detect the language of modern structuralism in Viollet-le-Duc's work, for the text of the *Dictionnaire* is full of references to elements and functions, systems, logic and structural equilibrium, reasoning, deductions, reactions and counteractions." Hubert Damisch, "The Space Between: A Structuralist Approach to the Dictionary," in *Architectural Design: Viollet-le-Duc*, Vol. 50, No. 3/4, 1980, pp. 84-89.

attempting to indentify the logical principles from which the unity and cohesion of the Gothic system could be understood, Viollet-le-Duc's approach adhered to a method of analysis which was rooted in scientific thinking. This structured model, however, was not limited to its analytical application but constituted in itself a conception of architecture. The structure of relationship between architectonic parts in its ideal and formal terms was determined by the very physical structure of building construction. This was an idea which became fundamental to a new sense of architectural aesthetic.

The connection between the inherent structures of an object and its visible form was clearly asserted by Viollet-le-Duc. "Architectural construction," he wrote in the *Dictionnaire*, "is the employment of materials according to their quality and their adaptability, with the idea of satisfying a want [un besoin] by the most simple and solid means, giving to the constructed object the appearance of durability and proper proportion, subject to certain rules imposed by the senses - reason and human instinct."[34] The reference to "reason" and "human instinct" was in so far of significance as that it offered a definition of construction encompassing the concepts of science and art. To understand the techniques, methods, and principles of building production meant for the architect to conceive of construction as a body of knowledge, or science. Construction, furthermore, was considered an art for it encompassed the form of production expressing the creative will

34 Viollet-le-Duc, *Dictionnaire*, op. cit., p. 106; see for the translation *Rational Building being a translation of the article "Construction" in the Dictionnaire raisonné de l'architecture Française of M. Eugène-Emmanuel Viollet-le-Duc* by George Martin Huss, Macmillan (NewYork), 1895.

approach to architecture as being primarily concerned with the formal appearance of buildings. Such tradition, according to Viollet-le-Duc, had excluded from its consideration the essential logic on which the art of building is based. From this point of view, the theory of architecture was not to be *a priori* concerned with questions of appearance, representation, and transcendent principles, but instead engage in a thorough investigation of the physical conditions which contribute to the essential structure of a work of art.

Architecture as opposed to construction recalled the concept of beauty which in itself implied the idea of truth. As the logic governing architectural forms was to be informed by the reality of physical construction, Viollet-le-Duc essentially suggested a unity of truth and utility by giving equal value to formal and technical considerations. The laws of structural mechanics, the qualities of building materials, and the principles of construction methods could thus contribute to the definition of a formal order. Beauty in these terms was not considered apart from the concrete and necessary parameters of building production but instead derived its very meaning from the order underlying the physical creation of the architectural object.

A similar understanding of the relation between architectural form and building construction was developed in Germany by Gottfried Semper (1803-79). The relation between art and industry was for Semper one of the significant questions to be addressed by nineteenth century theories of aesthetics. His most important written work, entitled *Der Stil in den technischen und tektonischen Künsten oder praktische Ästhetik,* of the maker. In other words, construction addressed both the realms of science and art. This unity was asserted in the opening sentence of Viollet-le-Duc's article "Construction" in the *Dictionnaire raisonné* :

Construction is a science; it is also an art - that is to say, the constructor must have knowledge, experience and a natural gift. Some are born constructors; science which is acquired, can but develop the germs already deposited in the brain of those destined to give useful employment and permanent form to rough materials. [35]

A further distinction was made between *architecture* and *construction*, the former belonging to the realm of formal expression and the latter addressing considerations of building production. "Architecture and Construction," Viollet-le-Duc wrote, "must be taught, or practised simultaneously; construction is the means, architecture is the result."[36] Although historically architecture and construction were periodically considered as autonomous entities, their interconnection was for Viollet-le-Duc of primary significance. His writings did not treat the subject matter of architecture in exclusively formal and compositional terms but instead emphasized the necessity to establish the connection between form and technique. He criticized the traditional, or academic,

35 *"La construction est une science; c'est aussi un art, c'est-à-dire qu'il faut au constructeur le savoir, l'expérience et un sentiment naturel. On naît constructeur; la science qu'on acquiert ne peut que développer les germes déposés dans le cerveau des hommes destinés à donner un emploi utile, une forme durable à la matière brute. "*

36 *"L'architecture et la construction doivent être enseignées ou pratiquées simultanément: la construction est le moyen; l'architecture, le résultat; ..."*

involved the question of style within the technical arts.[37] The expression 'practical aesthetic' used in the title of Semper's work indicated the essential bond between form and technique which was later to evolve as one of the clearest tenets of a Modern conception of architectural aesthetics.

The unity of truth and utility, a concept discussed above in relation to Ruskin's and Viollet-le-Duc's writings, was a guiding idea of Semper's theory. Function, material, and technique which belonged to the realm of utility not only contributed to the creation of a work of art but essentially constituted its very meaning. Form in these terms was not conceived as an autonomous and independent entity but instead was placed in relation to the determining factors of purpose, material qualities, and manufacturing processes. Semper's interest was directed towards an understanding of the art work as the product or result of a process, a creative act which takes into consideration a whole series of parameters. This idea, suggesting that the art work was to be considered a function of an unlimited number of agents or forces, was summarized by Semper in the formula Y = F (x,y,z etc.).[38] Such variables not only included material and technical considerations by also the unknown factors pertaining to the

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37 Gottfried Semper, *Der Stil in den technischen und tektonischen Künsten oder praktische Ästhetik - Ein Handbuch für Techniker, Künstler und Kunstfreunde*, München, 1861-63; reprinted, with an introduction by Adrian von Buttlar, Mäander Kunstverlag (Mittenwald), 1977.

38 "*Jedes Kunstwerk ist ein Resultat, oder, um mich eines mathematischen Ausdruckes zu bedienen, ist eine Funktion einer beliebigen Anzahl von Agentien oder Kräften, welche die variablen Koefficienten ihrer Verkörperung sind. Y = F (x.y.z etc.)* "; see "Entwurf eines Systems der vergleichenden Stillehre," 1853, in *Kleine Schriften*, edited by Manfred & Hans Semper, Verlag Spemann (Berlin and Stuttgart), 1884, p.267.

creative act of making, i.e the search for ideas, symbolic expressions, or truths.[39]

Although using a formula for describing the dependency of art on other factors, Semper nevertheless understood the work resulting from art production as an entity which could not be analyzed into a series of independent factors. The concept of the unity of the art work, including architecture, was for Semper of cosmological significance; he wrote in the "Prolegomena" of *Der Stil* that the work of art "is man's response to the world which is full of wonder and mysterious powers, whose laws man thinks he might understand but whose riddle he never resolves, so that he remains forever in unsatisfied tension." In order to come to terms with this "unattained completeness man conjures into play by building a miniature universe for himself."[40] This world created by man was inherently artificial and while conceived in reference to a cosmological order nevertheless was understandable to man.

Semper's classifications and his precise taxonomy pertaining to the conditions under which artifacts, form, and style are generated propose a structure for understanding man's artificial world. From such a perspective Semper identified,

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39 "*Die Stillehre ... fasst das Schöne* einheitlich, *als Produkt oder Resultat, nicht als Summe oder Reihe. Sie sucht die Bestandtheile der Form* die nicht selbst Form sind, *sondern Idee, Kraft, Stoff und Mittel; gleichsam die Vorbestandtheile und Grundbedingungen der Form.*"; see *Der Still*, op. cit., p. vii.

40 "*Umgeben von einer Welt voller Wunder und Kräfte, deren Gesetz der Mensch ahnt, das er fassen möchte, aber nimmer enträthselt, ... zaubert er sich die fehlende Vollkommenheit im Spiel hervor, bildet er sich eine Welt im Kleinen, worin das kosmische Gesetz in engster Beschränkheit ... hervortritt.* " Ibid., p. xxi. See for the translation Joseph Rykwert, "Semper and the Conception of Style," in *Gottfried Semper, gta 18,* Schriftenreihe des Instituts für Geschichte und Theorie der Architektur ETH Zürich, 1974/75, p. 73.

within the first pages of *Der Stil,* those considerations which seemed to him essential in all processes of creative production. The first determining factor governing the fabrication of objects and, thus the making of architecture, was necessity, for Semper considered that the production of artifacts was always the result of a need, whether "physically experienced or raised to a symbolic plane."[41] The second consideration which essentially determined the condition of the artifact was that of the materials used in its fabrication. He included within this the actual processes of production, for instruments, tools, and techniques significantly contributed to the final form of the man made artifact.[42]

Functional, material, and technical considerations essentially contributed to form. Semper's interest was here directed towards the truthful expression of function and the materials' constructive qualities for which he used the terms *functionsgerechte* and *materialgerechte Form.* An early text written in 1834 already pointed to the relation between formal expression and material properties which later evolved as a guiding concept of Semper's theory: "Es spreche das Material für sich und trete auf, unverhüllt, in der Gestalt, in den Verhältnissen, die als die zweckmässigsten für dasselbe durch Erfahrung und Wissenschaft erprobt sind. Backstein erscheine als Backstein, Holz als Holz, Eisen als Eisen, ein jedes nach

41 "... *erstens das Werk als Resultat des* materiellen Dienstes *oder* Gebrauches, *der bezweckt wird, sei dieser nun thatsächlich oder nur supponirt und in höherer, symbolischer Auffassung genommen; ..." Der Stil,* op. cit., p. 8. See also Rykwert, op. cit., p. 72.

42 "... *zweitens das Werk als Resultat des* Stoffes, *der bei der Production benutzt wird, sowie der* Werkzeuge *und* Proceduren, *die dabei in Anwendung kommen." Der Stil,* ibid.

den eigenen Gesetzen der Statik."[43] Important in this idea was not the visible appearance of the materials *per se*, but rather the revelation of their essential constructive qualities as, for example, disclosed by the laws of statics.

Semper's proposition regarding the role of function, material, and technique as formal determinants was not limited to the traditional crafts but also pertained to modern materials and processes of industrial production. He did not regard the influence of machines with contempt as Ruskin did but allowed his theory to also address the conditions created by the new manufacturing processes. Although Semper repeatedly criticized nineteenth century industry with its division of labor and speculation, he nevertheless hoped that a new aesthetic sensitivity might evolve. The remarkable paragraphs on vulcanized rubber in *Der Stil* reveal how receptive Semper was to new inventions.[44] His description on the properties, applications, and formal consequences of rubber has rightly been called "an apotheosis of synthetic material a hundred years in advance of his time."[45] Also, Semper's comments on the Great Exhibition of 1851 disclose his belief that a new understanding of form would evolve from the technical

43 Gottfried Semper, "Vorläufige Bemerkungen über bemalte Architektur und Plastik bei den Alten," 1834, in *Kleine Schiften*, op. cit., p. 219. Vor an analysis of Semper's *Vorläufige Bemerkungen* see Rudolf Zeitler, "Semper's Gedanken über Baukunst und Gesellschaft in seiner ersten Schrift: 'Vorläufige Bemerkungen über bemalte Architektur und Plastik bei den Alten.' 1834," in *Gottfried Semper, gta 18*, Schriftenreihe des Instituts für Geschichte und Theorie der Architektur ETH Zürich, 1974/75, p. 18.

44 G. Semper, *Der Stil*, op. cit., vol. I, pp. 112-119.

45 "*...; eine wahre, um 100 Jahre verfrühte Apotheose der Kunststoffe.*" Hellmut R. W. Kühne, "Über die Beziehung Sempers zum Baumaterial," in *Gottfried Semper, gta 18*, Schriftenreihe des Instituts für Geschichte und Theorie der Architektur ETH Zürich, 1974/75, p. 113. See also Wolfgang Herrmann, *Gottfried Semper: In Search of Architecture*, MIT Press (Cambridge, MA), 1984, p. 87.

achievements of the industrial revolution: "May the inventions, the machines, and the speculators stir up things with all their might; they will thus prepare the mixture out of which constructive science will mold the new form."[46]

Although Semper emphasized the influences of function, material, and technique on form, his approach was not guided by positivistic nor materialistic interests. Semper was explicit on this issue; he stated that his position principally opposed modern materialism within art. The "contructive-technical understanding of the origins of basic forms in architecture," he wrote in *Der Stil*, "had nothing in common with the crude materialistic notion according to which the essence of architecture was nothing more than developed construction, as it were, an illustration and illumination of statics and mechanics, simply a display of material."[47] The reference to "constructive-technical" considerations as well as the importance assigned to function and materials were determined by Semper's search for the origins of architecture. His theory traced the archetypal principles underlying architectural production, for he believed that *a priory* rules existed within all manufacturing processes. Architecture was in these terms not historically understood as an autonomous discipline with

46 *"Mögen die Erfindungen, die Maschinen und die Spekulanten nur wirken, was sie vermögen, damit der Teig bereitet werde, woraus die konstruierenden Wissenschaften, ..., die neue Form gestalten könnte."* Gottfried Semper, *Wissenschaft, Industrie und Kunst*, 1851; reprinted in "Neue Bauhausbücher" (Mainz & Berlin), 1966, p. 47.

47 *"Die ... konstructiv-technische Auffassung des Ursprungs der Grundformen der Baukunst hat nichts gemein mit der grob-materialistischen Anschauung, wonach das eigene Wesen der Baukunst nichts sein soll als durchgebildete Construction, gleichsam illustrirte und illuminirte Statik und Mechanik, reine Stoffkundgebung."* G. Semper, *Der Stil*, op. cit., p. 7. See also Wolfgang Herrmann, "Was Semper a Materialist?," in *Gottfried Semper: In Search of Architecture*, op. cit., p. 121.

its own rules and principles but instead essentially connected to the traditional crafts and mechanical arts.

Basic aesthetic laws, Semper asserted, were first developed within the fields of the practical arts and from there brought into architecture. "The industrial arts," he wrote, "are therefore the key to understanding architectural as well as artistic form and rule in general."[48] This idea, as Wolfgang Herrmann recognized, was developed by Semper during his years of exile (1849-1855), probably as a response to what he had seen at the Great Exhibition of 1851. Herrmann asserts that this exhibition was "the decisive influence" on Semper from which the theoretical framework of *Der Stil* might have been inspired.[49] Semper's interest was not exclusively directed towards Joseph Paxton's structure of steel and glass, but most importantly focused on the exhibited objects. Regarding the display of industrial products, he observed a decline in artistic taste as a result of a pretentious and tasteless application of machine production. Semper admired instead the objects of primitive civilizations which had been included within various stands of the exhibition. The objects produced within primitive cultures demonstrated a high standard of artistic achievement based on a sense for materials and techniques as applied to art. Semper asserted that in order to improve on the artistic value of modern industrial production,

48 "... ; *es sind daher die Werke der Industrie die Schlüssel zum Verständnis architectonischer (so wie allgemein künstlerischer) Form und Regel.* " Gottfried Semper,"Theorie des Formell-Schönen, Einleitung (Ms. 179)," See Wolfgang Herrmann, *Gottfried Semper, Theoretischer Nachlass an der ETH Zürich, Katalog und Kommentare, gta 15,* Birkhäuser Verlag (Basel), 1974, p. 221.

49 Wolfgang Herrmann, "The Great Exhibition of 1851 as Inspiration for *Der Stil,*" in *Gottfried Semper: In Search for Architecture*, op. cit., pp. 84-87.

modern man was to do consciously what primitive civilizations had done instinctively, i.e. study and respect "the properties of the materials and the requirement of the task."[50]

From such observations the structure of *Der Stil* and Semper's classifications of the technical arts can be understood. The origins of architecture were considered to be found in the principles underlying craftsmanship and traditional manufacturing processes. Consequently, Semper did not open his treatise by propagating the rules governing the discipline of architecture but instead addressed those principles which he considered inherent within the different branches of the traditional arts. The four primary classes distinguished by Semper were determined by the arts of textiles (textile Kunst), ceramics (keramische Kunst), carpentry (Tektonik), and masonry (Stereotomie).[51] Metalworking, which he considered to have developed from the previous arts, was later added as a fifth category. Important for Semper was the search for archetypal conditions within which artisans had traditionally worked and from which principles could be determined. These principles, primarily pertaining to considerations of function, material, and technical processes, were to be applied to the industrial and, thus, modern arts. Herein lay the foundation of Semper's concept of a "practical aesthetics."

The archetypal model from which architectural principles could be developed, Semper believed, was the primitive hut for it

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50 "... *die Anforderungen der Stoffe und in die Bedingungen der Aufgabe* ..."; *Der Stil*, op. cit., p. 124; see also Wolfgang Herrmann, op. cit., p. 85.

51 Semper, *Der Stil*, op. cit., vol. I, p. 10.

disclosed an application of the various branches of the technical arts into architecture. As Laugier and other authors had previously done, Semper adopted the concept of the primitive hut as the model of reference for supporting his theoretical propositions. He did not consider the hut in ideal terms as the origin of Greek temples but sought instead to investigate its construction as real structure. Semper had seen a model of what he called "a Caribbean hut" at the Great Exhibition of 1851. From the analysis of this structure, which was considered to represent an architectural system, four constructive elements of architecture were deduced: the hearth, the base, the roof, and the walls.[52] Semper wrote later in the second volume of *Der Stil* that within the Caribbean hut "all elements of ancient architecture appear in their most original and unadulterated form: the hearth as center, the mound surrounded by a framework of poles as terrace, the roof carried by columns, and mats as space enclosure or walls."[53]

A correspondence existed between the constructive elements of architecture and the primary branches of the technical arts. Weaving, belonging to the art of textiles, was considered the technique for making walls and partitions. Ceramics, the art of moulding and burning clay, pertained to the hearth. Carpentry and joinery were the crafts necessitated for the construction of the roof and the framework of the base. Masonry, or

52 The concept of the four primary elements of architecture was first mentioned by Semper in a manuscript entitled "Die vier Elemente der Baukunst," a year prior to the Great Exhibition of 1851.

53 "*An ihr treten alle Elemente der antiken Baukunst in höchst ursprünglicher Weise und unvermischt hervor: der* Heerd *als Mittelpunkt, die durch Pfahlwerk umschränkte Erderhöhung als* Terrasse, *das säulengetragene* Dach *und die Mattenumhegung als* Raumabschluss *oder* Wand." *Der Stil*, op. cit., vol. II, p. 276.

stereotomy, was of significance as it historically replaced joinery in building substructures and later was used for making walls. Lastly, the techniques of metalworking offered new possibilities for the articulation of constructive elements.[54] Such propositions exemplify his search for primary and archetypal forms in architecture. The essential configuration of the different components of a constructional system evolved from the conditions which underlie their production. Semper's approach towards the question of 'style' essentially advocated a unity of functional, material, and technical considerations within architectural form.

The relation between form and technique in Semper's theory, however, was not exclusively founded on pragmatic concerns. Form had to emancipate itself from the purely material and functional aspects of architecture transcending physical construction into the realm of symbolic expression.[55] The discussion of textile arts in *Der Stil*, for example, is an indication for Semper's interest in the use of color and pattern as meaningful decoration. As the *wall* in its archetypal origin was made of woven materials, pertaining to the art of textiles, its function was not only that of protection and enclosure but also of artistic expression. Semper used the term *Bekleidung* to identify the external covering of buildings, for the concept of the wall in architecture was considered in analogy to the role of clothing

54 See Joseph Rykwert, "Semper and the Conception of Style," op. cit., p. 75.

55 "... *Emanzipation der Form von dem Stofflichen und dem nackten Bedürfniss, ...*" *Der Stil*, op. cit., p. 445.

for man.[56] With the principle of *Bekleidung*, which proposed a unitary origin for all the arts, Semper's theory established the connection between the realms of necessity and symbolic intention. Beauty pertained as much to the objective unity of truth and utility as to the subjective will of the maker.

At one extreme, beauty was considered inherent within the internal structures of natural phenomena; Semper, for example, examined snow-flakes, flowers, and astronomical patterns to understand the order of beauty in symmetry, proportionality, and unity of movement. Similarly, the beauty of man-made objects lay within their essential structures as determined by the functions, materials, and techniques underlying artificial production. This concept of beauty, while being defined as the truthful expression of internal structures, addressed the concept of art as a system of production. At the other extreme, beauty pertained to the creativity of the maker, revealing subjective values, ideas and truths. This latter concept of beauty belonged to the realm of artistic expression. Architecture, or *Baukunst*, addressed both the concepts of art as a system of building production as well as that of artistic expression; within the field of architecture a mediation was achieved between the categories of art and craft, between *Kunst* and *Kunstgewerbe*. In this lay the foundation of Semper's understanding of *style* as the formal unity of technical parameters with meaningful contents. As his contemporaries John

56 The understanding of the building envelope as a thin layer applied to the structure of the building had already been realized in Paxton's Crystal Palace; significantly, however, was the fact that this principle of cladding was later further developed by such as Otto Wagner and Adolf Loos to become a guiding concept of modern architecture.

Ruskin and Eugène-Emanuel Viollet-le-Duc addressed the unity of truth and utility within the understanding of architecture as an art form, so was Gottfried Semper equally guided by the intention to unify form and technique.

The theoretical work of Ruskin, Viollet-le-Duc, and Semper disclosed a search for a new conception of architectural aesthetics. The emergence of modern science and the increasing influence of rational thought on all fields of human knowledge gradually led to an unprecedented development of new methods and techniques of production during the nineteenth century. As this development had its effect on the specific techniques of building production as well as on the theories of architectural construction, a new approach to the question of form consequently resulted. An understanding of architectural aesthetics evolved in which formal and technical considerations were mutually addressed. Whereas form was not to be considered an independent entity, the integration of technique within architecture became increasingly advocated. The making of building, however, could not exclusively be limited to technical exigencies and the application of scientific principles. The new approach to architectural expression, formalized in a modern theory of aesthetics, united both realms of science and art.

The understanding of construction techniques in their ontological dimension, a concept resulting from the search for truthful conditions advocated by scientific thinking, was integrated into the theory of form. While the traditional and classical relation between form and technique was essentially representational in its structure, assuming a priority of formal over technical concerns, the modern conception of architecture instead offered a reconciliation between the means of production and the realm of visible expression. However, as architectural theories continued to address questions of aesthetic nature, architecture remained an art form. Within this conception of building as art, the search for a new foundation of architectural aesthetics disclosed the interest in an unity of form and technique, an unity achieved in theory while awaiting the modern movement for the possibility of its realization into practice.

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Education	- Candidate for Doctor of Technical Sciences, Swiss Federal Institute of Technology, to be completed: July 1987 - Diploma in Architecture (M-Arch), 1973-79 Swiss Federal Institute of Technology, ETH-Zürich - Mathematics Diploma, 1968-73 Mathematisches Naturwissenschaftliches Gymnasium, Zürich
Current Teaching	- 1983-87 Assistant Professor in Architecture Graduate School of Design, Harvard University Design Studio, 1st and 4th Semester 4th Semester Construction Course Seminar on Theories in Architectural Technology
Previous Teaching	- 1986 Visiting Professor Rhode Island School of Design One semester Design Studio - 1982-83 Instructor in Architecture Graduate School of Design, Harvard University Design Studio, 1st and Second Semester, and seminar - 1979-82 Assistant Professor, ETH-Zürich, Chair of Prof. Herbert Kramel Design and Architectural Technology
Administration	- 1984-85 Director of the Master in Architecture Program, Harvard Graduate School of Design
Membership	- SIA (Swiss Engineer and Architect Association)
Languages	- English, French, German

Academic Honors
- Scholarship, ETH/Zurich
  for travel and study in the United States, 1980

Design Awards
- First "Ankauf", University of Zurich
  Faculty of Law and Economics Competition
- "Ankauf", Housing Project for Young Families
  Uitikon Competition
- "Ankauf", Office and Housing Building
  Basel Old City Competition

Research
- Theories in Architectural Technology
  The relation between technique and formal expression in architecture, 1983-87
- Study of Effects of Office Automation on Design Criteria for Office Furniture
  Development of workstation prototypes for the enclosed and open office space, 1984-85, HGSD and IBM
- The Evolution of Museum Building Types
  A model demonstrating a typological approach to the history & language of architecture, 1980-1985
- The City: Sabbioneta - A Formal Analysis of Renaissance Urban Space,
  Lehrstuhl Prof. H. E. Kramel ETH Zürich 1981
- The Development of the Modern Building Process
  The Britania and Convay Bridge, United Kingdom, 1979
- Participation and Reuse: The Role of "Participation" in Relation to Form and Space
  Group exhibition at the ILAUD 1978

Professional Work
- 1982-87 Principal, Angélil/Graham Architects
  Boston, Massachusetts
- 1979-82 Principal, Gysin /Angélil Architects
  Duebendorf, Zurich
- 1976 R. Zuercher, M. Schuepp, R. Kottler, ZH
- 1975 Basil Powell, Johannesburg, South Africa
- Executed Work:
  Apartment Interiors, Frank Foster, Boston
  House Addition Shafroth, Aspen, Colorado
  Laboratory for Construction Technology at Harvard;
  Penthouse Addition and Office Interiors, Cambridge;
  Apartment Building Renovation, Boston;
  Apartment Building Renovation, North-End, Boston;
  Office Furniture, IBM;
  House Addition Brandin, Lexington;
  Remodeling Residence Baumer, Kilchberg;
  Casa Giovanni Piccioni, Biasca.