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Interdisciplinary Reflections and Deflections of Histories of the Scientific Revolution in Alberto Pérez-Gómez's Architecture and the Crisis of Modern Science

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Interdisciplinary Deflections

Histories of the Scientific Revolution in Alberto Pérez-Gómez's *Architecture and the Crisis of Modern Science*

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Alberto Pérez-Gómez's 1983 *Architecture and the Crisis of Modern Science* is used here as a vehicle for exploring the behavior of disciplinary boundaries in the context of crisis both historically and theoretically. Responding to his contemporaneous architectural crisis of the 1970s instigated by the rise of positivism, Pérez-Gómez uses Alexandre Koyré's history of the scientific revolution as a mirror to reflect the historical developments of architectural theory upon it. Although effectively circumscribed, his deliberate exposure to an interdisciplinary history nonetheless contributes to the opening up of a much richer constellation of perspectives that illuminate the nature of the disciplinary crisis he was trying to negotiate. These in turn open up new lines of interdisciplinary inquiry for the present condition and the new wave of positivism that haunts contemporary theories of parametricism in a novel moment of crisis.

While disciplinary accounts of crisis tend to portray it as a strictly "internal" affair in the history of modern professions, in this article, I opt to treat moments of crisis precisely as occasions for vocational cracks into interdisciplinarity. Unbound by artificially imposed disciplinary boundaries, phenomena of crisis can therefore be understood in their increased complexity as varying manifestations of common historical shifts. By exposing the only relative autonomy of each disciplinary field, these moments of uncertainty

thus blur their vulnerable boundaries, opening up alternative lines of inquiry that in turn enrich our vocational understandings. Often instigating both reflection and inquiry, moments of crisis thus acquire both historical interest and theoretical implications for the present.

Those broader questions relating to the behavior of disciplinary boundaries in the context of crisis can be both historically and theoretically elucidated by revisiting one of the most recent moments of disciplinary crisis,

instigated by the gradual rise of positivism, around the 1970s. At the moment when a new wave of positivism haunts contemporary architectural theories of parametricism, while other manifestations of crisis loom large (from the ecological to the epistemological plane), the act of revisiting Alberto Pérez-Gómez's 1983 *Architecture and the Crisis of Modern Science* as a historical case study is expected to lead to an essential reopening of lines of interdisciplinary inquiry for the present condition.

Architecture and the Crisis of Modern Science in the Historical Context of the Architectural Crisis of the 1970s

Architecture and the Crisis of Modern Science has certainly been a milestone in Pérez-Gómez's academic career. For instance, it was largely thanks to its original publication in Spanish in 1980, titled *La genesis y superacion del funcionalismo en arquitectura* (Genesis and overcoming of functionalism in architecture), that he became a fellow of the Mexican Academy of Architecture, an honor granted for his "outstanding contributions in the field of architectural theory." Shortly afterward, the Society of Architectural Historians characterized the 1983 publication of the book in English as "the most distinguished work of scholarship in the history of architecture published in North America between Nov. 1, 1981 to Oct. 31, 1983," granting its author the Alice Davies Hitchcock Book Award. The wider disciplinary recognition implicit in these institutional assertions may be better understood today when the book is situated within the



Figure 1. Alberto Pérez-Gómez's *Architecture and the Crisis of Modern Science* in the crossroads of Dalibor Vesely's phenomenological and Joseph Rykwert's historically oriented teachings at the University of Essex MA Program, in the context of the wider 1970s debates for meaning and a self-reflexive theory for architecture.

historical context of its production. In the final instance, what came to be globally known as *Architecture and the Crisis of Modern Science* is a slightly reworked version of Pérez-Gómez's 1979 PhD dissertation, supervised by Joseph Rykwert (but also closely followed by Dalibor Vesely) at the University of Essex.

Completed right after the University of Essex MA program closed its decade-long historical circle (1968–78), the dissertation is essentially the culmination of their long-standing academic relationship, which has clearly shaped Pérez-Gómez as a scholar in architectural history and theory. Originally trained as an architect in Mexico (1971), Pérez-Gómez followed the MA program in the history and theory of architecture at the University of Essex just two years later (1973–74). A mere mention of the titles of his theses and dissertations provides sufficient indication of the subsequent focal shift in his interests: Pérez-Gómez moves from the broader “Concept of Space as an Essential Element in Architecture” (honors thesis, National Polytechnic Institute

of Mexico, 1971) to “The Meaning of Geometry in Late 18th Century French Architecture” (MA thesis, University of Essex, 1975), and from there on to “The Use of Geometry and Number in Architectural Theory: From Symbols of Technological Domination” (PhD dissertation, University of Essex, 1979). The prevailing concepts in all those alternative theses and book titles of a scholarly interest, which is essentially shaped and stabilized in the mid-1970s, in turn summarize the understanding of the contemporaneous disciplinary crisis offered by the University of Essex MA program: functionalism represents a crisis of meaning in architecture, whose roots lie in the use of geometry and number as instruments of technological domination.

When Rykwert and Vesely set up the University of Essex MA program in 1968, they were in fact offering their own perspective on an emerging debate instigated by a new generation of British architectural theorists, critics, and historians. Irrespective of their subsequently divergent approaches, Charles Jencks, George Baird, Geoffrey Broadbent, Kenneth Frampton, Alan Colquhoun, and Nathan Silvers (to name just a few) all shared a common ground when they acknowledged a deep-seated crisis in the discipline around the 1970s. Not only did they acknowledge a crisis of meaning in their contemporaneous architectural production (that could only be intensified by the accompanying discussions of systems analysis, cybernetics, and an architecture of the great number), but they were also at odds with the status quo of architectural history and theory, especially as the latter was by then taught in British schools of architecture. Opposing an increasingly positivist technical education, an architectural theory that aspired to emulate the scientific method, and a linear understanding of architectural history as the progressive succession of monolithic styles, they advocated a self-reflexive architectural theory instead. The essays collected in the 1969 anthology, *Meaning in Architecture* (edited by Jencks and Baird),¹ discursively including the comments of the authors on each

other's texts, serve here as a useful crystallization of the debates of the period. This is precisely the broader context of British architectural discourse in which the University of Essex MA program is historically situated. But while Jencks, Baird, and Broadbent turned to linguistics and semiology in their attempt to reclaim the architectural qualities that render a space “communicative,”² Rykwert and Vesely proposed a turn to history, phenomenology, and hermeneutics instead (Figure 1).

Thus, in a period when technological optimism and instrumental rationalism dominated the field, the University of Essex MA program aimed to reinscribe architectural history and theory in the tradition of the humanities, and the debates around the multifarious legacy of the Enlightenment—as well as its discontents. Rykwert's “Theoretical Literature of Architecture before 1800” module proposed a close reading of architectural theories “inevitably centre[d] on the Italian treatises of the XVIth and the XVIIth centuries, and the French literature of the XVIIIth,” as it moved forward in time toward the Enlightenment. It aimed to establish “a new relationship between the Ancients and the Moderns ... that questioned th[e] scientific organization of knowledge.”³ Vesely's “Phenomenology and Psychology of Perception; Their Implications for Methods of Design” module, on the other hand, explored issues of perception—especially in relation to memory, orientation, corporeality, and culture. His proposed reading list was almost exclusively comprised of fundamental philosophical treatises of phenomenology and hermeneutics, ranging from Edmund Husserl's *Crisis of European Sciences and Transcendental Phenomenology* and Martin Heidegger's *Being and Time* to Hans-Georg Gadamer's *Truth and Method* and Maurice Merleau-Ponty's *Phenomenology of Perception*.⁴ Vesely's module was complemented by “The Individual Building and the Total Environment” and “The Nature of Style and Language in Architecture” seminars, initially taught by George Baird, and later by Antoine Grumbach.⁵ In one of his later e-mail messages to Helen Thomas (April 7, 2003), Vesely explained

that his seminars intended to explore the “situatedness of consciousness”—especially in relation to “the role of the body, corporeal scheme and space (the move from Husserl to Merleau Ponty), and eventually interest in Heidegger and his notion of the structured world manifested in the most concrete form (manner) as situation.”⁷⁶

Even such a brief account of the seminars is enough to raise the question of a common ground or methodological consistency between Rykwert’s primarily historical interest in rereading European architectural treatises and Vesely’s philosophically motivated endeavors. Thomas suggests that their meeting point was to be found “in their intention to develop an understanding of architecture within a deep cultural context that connected the past to the present.”⁷⁷ Was that vaguely shared concern enough for their different approaches to cohere into, as it were, a distinctive ‘Essex School method’ of architectural history and theory, though?⁷⁸ The different, and mainly personal, answers to this question can most effectively be pursued in the work of their numerous disciples, from Robin Evans and David Leatherbarrow to Mohsen Mostafavi and Daniel Libeskind. For Pérez-Gómez, in particular, “their approach worked very well together. Joseph went ‘forward’ from Vitruvius to the 18th century, Dalibor ‘backward’ from phenomenology to the 19th century ending with Semper.”⁷⁹ Following his lessons from Rykwert, Pérez-Gómez’s book also goes forward from Claude Perrault’s architectural treatises of the late seventeenth century to Gaspar Monge’s late eighteenth-century functionalization of geometry and Jean-Nicolas Louis Durand’s early nineteenth-century version of functionalism in architecture; and, following his lessons from Vesely, his argument is hermeneutically informed by the present, that is, his contemporaneous concerns regarding the functionalist legacy of postwar modern architecture and the positivist reduction of architectural theory to a methodology of scientific building.

However, the actual intellectual

trajectory followed by the young PhD student seems to have been far more nuanced than this linear and harmonious story implied by Pérez-Gómez’s retrospective account. This is at least attested by the difficulties he faced when submitting his dissertation, a tension that was only resolved when Werner Oechslin was asked to intervene, and he did so to Pérez-Gómez’s benefit, indeed. The account of this trajectory suggests that his 1979 dissertation actually resembles a battleground, with the author anxiously struggling to find his own voice amidst the clashing strong influences of both his mentors. While Vesely’s hermeneutic influence seems indisputable—with Neil Leach even alluding to Plato’s relation to Socrates when he asserts that Pérez-Gómez’s book “eloquently articulates the central thesis behind Vesely’s outlook”⁸⁰—Rykwert’s, or, more broadly, the historically informed contribution to Pérez-Gómez’s thesis, does not yet seem sufficiently highlighted.

It is precisely in this context that I propose an alternative reading of *Architecture and the Crisis of Modern Science* that attempts to retrieve the peculiar role of history within it. Motivated by an interest in what this book, as a child of its own time, can possibly mean for the present concerns of the profession, I read Pérez-Gómez’s work as that of a scholar who attempts to work across a disciplinary border (from architecture to the history of science) precisely at the moment of a perceived disciplinary crisis. Attempting to associate the peculiar rise of functionalism in architectural theory with the epochal changing worldview, initially triggered by the seventeenth-century developments in science and natural philosophy, Pérez-Gómez aspires to no less than a total redefinition of our historical awareness of architectural modernity—which could in turn imply an overcoming of functionalism and its late twentieth-century discontents. My reading will focus on the way in which his architectural account may well reflect a broad historical mapping derived from the conclusions of contemporaneous historians of the scientific revolution, but it effectively

retains Husserl’s phenomenological diagnosis of crisis as its main interpretative undercurrent.

Interdisciplinary Reflections: Alexandre Koyré’s History of the Scientific Revolution as a Blueprint for Pérez-Gómez’s Architectural Account

It is significant to start this peculiar retrieval of interdisciplinary history in Pérez-Gómez’s book by noting that references to studies in the history of science represent only 0.01% in the total sum of the book’s 698 endnotes. With his 1983 English title clearly alluding to Husserl’s 1936 *Crisis of European Science and Transcendental Phenomenology*, Pérez-Gómez obviously insists on both the epistemological dimension and the phenomenological line of interpreting the theoretical developments that lie at the heart of his book. Hence, his narrative is not merely dominated by the return of geometry at the forefront of human knowledge about the world. Equally important is its gradual emptying from any symbolic or other metaphysical charge, as well as its concurrent conversion into a formal system that may well be internally consistent but is thenceforth clearly distinct from the lived world of quotidian experience. More than anything else, it is precisely this dimension in his work that both documents his lessons from Vesely and reveals its methodological origins in the philosophical tradition of Edmund Husserl’s phenomenology and Hans-Georg Gadamer’s hermeneutics.⁸¹ In this specific context, the fact that Pérez-Gómez selects Alexandre Koyré’s work as his major reference from the historiography of the scientific revolution is hardly surprising.⁸² For his is not only an important work that shares an approach of the scientific revolution as an episode in the history of ideas, but its author was also mentored by Edmund Husserl. And while the central figure for his study is probably Newton, Pérez-Gómez cannot stop referring to the “Galilean revolution” throughout his book—precisely

because therein lies the most systematic origin of the geometrization of nature; and this is precisely what both Husserl (1936) and his disciple, Koyré (1939), also do when they place Galileo at the turning point of their own approaches to the history of modern science.¹³

By effectively reflecting the conclusions of Husserl and Koyré in the domain of architecture, the main thread of Pérez-Gómez's own hermeneutic historical narrative consists of the gradual rationalization or "functionalization" of architectural theory. Already ascendant in the mid-seventeenth century, these tendencies for a rationalized theory of architecture culminate in the early nineteenth-century work of Jean-Nicolas-Louis Durand. Separated from wider cosmological or philosophical systems, at this point in time, architectural theory becomes a self-referential and internally consistent system governed by the laws of mathematics that acquires its meaning "internally" by this mathematical system itself. At the same time, this mathematical system lends architectural theory its epistemological legitimation, since it proves successful in addressing the modern demands for a scientifically objective theory. In this epistemological context, any other external reference can only be considered inexorably subjective. Durand thus moves architecture away from art and closer to science. Therein lies the gap between "the eternal and immutable dimension of ideas [and] the finite and mutable dimension of everyday life."¹⁴ It is the same gap that Alexandre Koyré's mentor, Edmund Husserl, had already highlighted as characteristic of the crisis of modern science in 1936. By opposing the modern tendencies of identifying theory with a mere methodology for technical and constructive efficiency, and a sum of general rules for any conceivable purpose (as opposed to a specific and meaningful teleology), Pérez-Gómez intends to foreground the significance of a historical horizon of meaning for architecture. The functionalization of architecture, the reduction of almost every aspect of it to a formal system of relations,

whose value remains unchallenged, and the conversion of questions concerning value and meaning into parameters that can functionally define form, are the main features of Pérez-Gómez's perceived crisis in architectural theory, along the lines of Husserl's diagnosis of the crisis of modern science. This is precisely the point where the history of the scientific revolution enters his own study, indeed: "modern architecture, and the crisis it faces, has its roots in a historical process touched off by the Galilean revolution."¹⁵ This process involves the gradual foregrounding of number and geometry as fundamental factors in architectural theories of the period. Pérez-Gómez argues that this is the case indeed, since these are both factors that have been endowed with value and meaning by Newton's natural philosophy, and its underlying Platonic cosmology that leads to a geometrization of nature¹⁶—as already argued by Koyré.

According to Koyré, science is not a predominantly empirical process relying upon the mere accumulation of observational data, and the subsequent generalizations extrapolated from them through induction. Scientific novelty arises instead from a priori changes in the scientific spirit, which primarily take place in the field of metaphysics (or philosophy). In science, the a priori element precedes the empirical; the latter is actually constructed and experimentally tested in response to the claims of a specific theory, and in the terms of its language.¹⁷ These presupposed a priori changes, which also render the scientific revolution as a rupture from the scientific practices of the ancient and the medieval world before it, are "the destruction of the Cosmos" and the "geometrization of space."¹⁸ "Destruction of the Cosmos" stands for the gradual replacement of the ancient Greek world picture with that of a modern universe. The enclosed and hierarchically ordered whole of the ancient world, whose elements were driven to their natural place in the inferior terrestrial or the superior celestial sphere, is gradually replaced by a homogeneous open universe, in which there is no place for

limits between ontologically different areas (*topoi*) and their accompanying teleology. This infinite universe is only bound by the common laws of nature that inexorably govern all its elements via forces of attraction and repulsion. "Geometrization of space," on the other hand, stands for the crucial intellectual transition to an equally homogeneous Euclidean space, in which every position can be quantitatively defined. This comes in sharp contrast to the Aristotelian conception of space (organized around the succession of qualitatively different *topoi*) that constituted the ancient world of quotidian experience. Hence, there is a direct link between these two major a priori changes, since the Euclidean conception of space also implies the abolishment of a deeply established hierarchical ontological (and, in the last instance, value-laden) distinction of the terrestrial from the celestial area.

Pérez-Gómez repeatedly resorts to a common general interpretative schema for many of the architectural theorists that parade throughout his study. In almost every case, he usually foregrounds the internal tension developing between their positivist tendency toward an absolute formalization of architectural theory, in the image of contemporaneous developments in mathematics (and, especially, algebra and descriptive geometry), and their need for retaining a residue of symbolic meaning through an ultimate reference to an external element. This intellectual trajectory is in turn similar to the one followed by Koyré in his *From the Closed World to the Infinite Universe* (1957). There, the transition to the idea of an infinite universe is realized through the gradual magnification and subsequent explosion of the bubble of the ancient world in the work of natural philosophers and protoscientists of the period.

Koyré's work also allows Pérez-Gómez to trace the crucial differences in the architectural debates between a mainly Newtonian Perrault and a mostly Galilean François Blondel.¹⁹ According to Koyré, Newton's primary focus lies on the mathematical description of reality through a series of experiments that will inductively

lead to the suggestion of a theory. While such a theory cannot avoid including hypotheses as fundamental axioms (concerning the particle nature of light, for instance), these are legitimate and acceptable as long as they result or derive from the specific quantitative experimental data. Perrault's intention to separate the conceptual dimension of number and architectural proportion on a level that is different from, and simultaneously underlies, our common everyday experience of buildings casts him as a Newtonian figure. Pérez-Gómez argues that the core of the Blondel-Perrault debate lies in the possibility of relativizing the very values that used to bestow any architectural creation with meaning and aesthetic value. Inasmuch as he moves closer to the Platonic tradition of mathematics, Blondel is also closer to a Galilean figure: "Relying on the traditional belief that our perceptual world is a projection of the human body, Blondel maintained that geometry and proportion, being transcendental entities, guaranteed the highest architectural meaning, apart from the specificity of ornament or style."²⁰ This is Blondel's only way out of the relativization of architectural meaning that was incipient in Perrault's work that came before him. In his work there is no space for a distinction between mere technical efficiency and empirical sufficiency from the absolutely invariable cause and purpose of architecture. Hence, not only the book of nature but also the book of building is written in the language of geometry.

Examples like these constantly recur in Pérez-Gómez's account. His overview of the developments in architectural theory of the period consistently highlight a prevailing ambivalence regarding the status and nature of geometry and number, as well as their special contribution in establishing a desirable (e.g., cosmic) harmony. Obviously following Koyré's interpretation again, he traces this ambivalence within Newton himself: "On the one hand, and on a practical level, Newton attested that

geometry derives from mechanics; on the other hand, the geometrical order of his Platonic cosmology was a primordial symbol of God's participation in Being, confirming the significance of human action in an infinite universe."²¹ In other words, Newton's work, with its strong a priori assumptions, can still guarantee the ties that bind the world of science, which describes the reality of absolute movement in the language of mathematics, with the world of everyday experience and relative movements.²² According to Pérez-Gómez, it is precisely these "external" metaphysical commitments of the Newtonian worldview that provide the ultimate horizon of meaning to Newton's scientific practice. Hence, his mathematics of absolute space and time is not strictly formal in the positivist sense, since its legitimation derives from the absolute reality of a world where God is still present as the final guarantor of the validity, normality, and harmony of the natural laws.²³

Newton's subtle metaphysical assumptions in turn exert an influence of their own in architectural theories of the period. As long as the Newtonian model prevails, the technical can coexist with the aesthetic dimension of architecture in the context of a whole that is not utterly self-referential.²⁴ Pérez-Gómez contends that this is precisely the accomplishment of neoclassical architecture, which should not be conflated with a spirit of eclecticism between alternating formal styles and systems. And from that partial reinterpretation of a specific architectural style, he concludes with a broader redefinition of architectural modernity, claiming that "modern architecture did not appear around 1750 and that it was not simply generated by the Industrial Revolution. The process of transformation of theory into an instrument of technological domination started with modern science itself."²⁵

To sum up Pérez-Gómez's interdisciplinary foray into Koyré's history of science, there are probably four main ways in which the

scientific revolution exerts its influence on architectural theorists of the late seventeenth and early eighteenth centuries.

- (a) Macroscopic epistemological influence: after the scientific revolution, architectural theories are developed within a totally different epistemological model that opposes traditional theories. Architectural theorists adopt the main thesis of Newton's natural philosophy as a strong conviction of their own. Assuming the definite existence of a mathematical law that correlates quantifiable (geometric) sums, their scientific task lies in discovering it through empirical research. In a similar fashion, they attempt to found the objectivity of architectural theory upon an invariable constant underlying the superficial succession of historical styles and orders.
- (b) Microscopic epistemological influence: in this case, architectural theory production is understood as part of the wider cultural fermentations of the period. It is the specific work of distinct figures from the history of the scientific revolution that exerts its influence upon architectural theorists, thus leading them to different approaches and critical debates. The aforementioned example of the Perrault-Blondel as analogous to the Newton-Galileo debate is a characteristic case in point.
- (c) Superfluous influence: in this case, the mere mention of Newton's name as an indubitable authority lends its gravitas to various assumptions of architectural theorists. See, for instance, Charles-Etienne Briseux, who used Newton's name as a means of legitimizing his

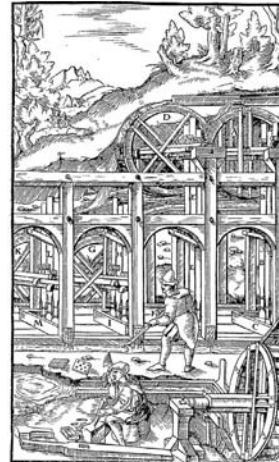


Figure 2. The illustrations of Georgius Agricola's 1556 treatise on metallurgy, *De re metallica* (from left to right, 391, 72, and 181) are indicative of the impressive technical achievements of the practitioners of the period. According to Zilsel, key figures of the scientific revolution, like William Gilbert and Galileo Galilei, benefited greatly from their contact with this previously disregarded world of master craftsmen and artisans.

own “insights” concerning nature, harmony, and the arts.²⁶

- (d) Methodological influence: in this case, it is the experiment as a main feature of the modern scientific practice that drives the appearance of proto-experimental methods in architectural theory—manifest in an increased emphasis on collecting empirical data. Marc-Antoine Laugier, who documented the existence of inherent and essential aesthetic qualities in architecture through a peculiar “experimental” confirmation of his thesis (i.e., an empirical study of the impressions caused to himself and others by specific buildings) is a characteristic example here.²⁷ Same goes for Nicola Carletti, who regarded architecture as a science that could use Newton’s analytical methods.²⁸

Meanwhile, the pure geometrical volumes of the Platonic solids and the empty homogeneous spaces in the architecture of Étienne-Louis Boullée and Claude-Nicolas Ledoux attempt to render the absolute space and time of Newtonian natural philosophy a tangible everyday reality—reconciling human ends with an “external” Nature that is thenceforth regarded as independent

from the human project. However, their conviction that the artistic and scientific dimensions of architecture are still reconcilable can only be fully accomplished in the perfect sphere of architectural drawing—and not through their imperfect realization in building.²⁹ Thus, they unwittingly contribute to a widening gap between theory and practice, which in turn is a rather unexpected consequence of Koyré’s “destruction of the Cosmos.”

Yet while Pérez-Gómez’s conclusions certainly retain their validity for the field of architecture, they appear rather circumscribed when viewed from the perspective of histories of science. By constantly returning to the same concepts and interpretations derived mainly from Husserl, and often indirectly through Koyré, Pérez-Gómez circumscribes what initially seems like an opportunity for a variegated opening to interdisciplinary histories. Often acting as an intermediate, Koyré’s history of science can only serve as an alibi for an interdisciplinary history of architecture, when in the final instance it practically echoes and reinforces Husserl’s dominant line of interpretation. That is to say, as an interdisciplinary history, Pérez-Gómez’s account is in the final instance overtheorized, hence circumscribed. In other words, while *Architecture and the Crisis of Modern Science* revisits many of the architectural treatises discussed in the context of Rykwert’s seminar, it is indubitably Vesely’s teaching

that prevails in Pérez-Gómez’s study, setting the phenomenological-hermeneutical tone of interpretation of his historical material. In Husserl’s light, Pérez-Gómez’s study appears as a natural development of this particular phenomenological line of thought, through its reflective extension from the domain of science to that of architectural theory.

However, this process of reflection works as a double-edged sword. On the one hand, it provides Pérez-Gómez with strong conceptual and methodological tools (from interpretative categories to a sense of orientation for his historical narrative) that allow him to understand the work of established figures in the field of architectural theory in the context of a broader cultural shift signaled by the scientific revolution.³⁰ On the other, the a priori reflection of a ready-made interpretative framework hinders other possible interdisciplinary deflections, as it were, that remain latent in the multifarious historical accounts of the same period. Readily available to the author at the time of writing, and already widely debated during the late 1960s, those alternative perspectives on the historiography of the scientific revolution can serve as a useful launchpad for further exploration of those possible interdisciplinary deflections. The added challenge to current understandings and the disciplinary boundaries they entail—alongside Pérez-Gómez’s significant, albeit predominantly philosophical, opening to interdisciplinary



Figure 3. Subsequent depictions of the figure of the architect gradually leaving behind the tools of manual labor and excelling in the theoretical knowledge of the orders and the proportions of harmony. The illustrations are in line with the agenda of the Parisian Academie d'Architecture (1671–1717) that intended to move the architect away from the mess of the construction site.

histories of the scientific revolution in architecture—opens up a constellation of possible historiographical perspectives, which may also allow us to follow these threads of an epistemological crisis that still runs unbound up to the present moment.

Interdisciplinary Deflections: Toward Other Histories of Science and Architecture

Effectively limited to the realm of a history of ideas, Pérez-Gómez's study does not discuss the significance of "external"/wider social and political developments in relation to the "internal"/intellectual developments during the long period of the scientific revolution. However, different social groups and their shifting relations, as well as those between wider political formations and institutions, inexorably play a crucial role in the propagation of the scientific revolution as a historical process.³¹ This "external" history of science involves both the tensions associated with the reconciliation of the scientific with the religious world-image and the specific attitudes encouraged by the prevailing spirits of Protestantism and Catholicism,³² as well as the interactions between specific social groups that gradually shape scientific communities and their practices. The social dynamic that both supports and legitimates science as a novel mode of knowledge production is therefore an equally significant part of a historical

understanding of the scientific revolution.³³ What are the possible implications of all this for novel architectural histories and theories of the period, though?

In response to all of the above, Pérez-Gómez could of course follow Koyré in arguing that social forces cannot adequately explain exceptional figures like Newton. Even if one accepts this as a valid point, though, without contesting the very concept of the individual genius, it seems that it is precisely these social forces—and their complex interactions through politics—that explain both the decisive acceptance of Newton's work as a culturally dominant factor of modern life and the wider dissemination and social legitimation it enjoyed afterward. Or, in the words of Barry Barnes, and in a supposed absence of a sociological account of the history of science, the history of ideas alone cannot adequately explain itself.³⁴ That is to say, it cannot explain the way in which those specific changes in the metaphysical assumptions of each period, which are indeed tirelessly diagnosed and mapped by historians of ideas like Koyré, actually take place. If one would additionally consider the fact that hardly ever are there conclusive arguments for or against any metaphysical thesis, it is rather obvious that the question concerning the dominance of certain assumptions on the scale of a whole epoch refers to a very complex phenomenon. It is clearly impossible to exhaust the latter in a process of completely disinterested and

rational evaluation of the available arguments for and against opposing views. Nonetheless, Barnes agrees that the scientific revolution can still be legitimately approached as an episode in the history of ideas, precisely because this is still a period when the boundaries between philosophy and science have not been institutionalized, nor can they be retrospectively defined.³⁵

In that sense, Pérez-Gómez's study retains its indubitable significance as well. However, if one follows Barnes's argument further into the field of architectural theory, then an intellectual history of architectural developments during the scientific revolution can only be a necessary first step toward a more comprehensive understanding. If the developments in the history of science since 1930 are anything to go by, indeed, then the latent potential of such architectural studies seems enormous. Pérez-Gómez's study might then anticipate its successors inasmuch as the fundamental transition from the "more-or-less" world of craftsmen to the quantifiable precision of the world of academics, retraced by Koyré, could only be read alongside a complementary sociological approach of the same phenomenon, like the one carried out by Edgar Zilsel, for instance.³⁶

In his equally influential historical studies, Zilsel intended to highlight characteristic social structures that could be associated with certain systems of knowledge and their modes of production. According to Zilsel,

the main features that needed to be combined in order to produce the scientific method pertained to different social classes, whose special education enabled them to develop only a specific set of those skills. In other words, the boundaries that had to be overcome were not only intellectual but also social. The scientific revolution was therefore possible only when the restructuring of social relations, due to the gradual shift from a feudal to a capitalist economy, led to a redefinition of previous class boundaries. It was this ongoing social process that initially created meeting points and gradually facilitated the interaction between university scholars and humanistic literati (who were trained to methodically develop their abstract thinking, cultivating the intellectual skills necessary for rational argumentation), on the one hand, and artisans (who excelled in empirical observations and devised original proto-experimental techniques, along with the instruments those required, but lacked a corresponding training in rationalist methodologies), on the other. There was a social barrier between the artisans, whose manual/material contact with the world enabled them to empirically deduce rules of thumb for their practice, and the literati who could easily use those rules as initial steps for proceeding to abstract generalizations and inductions in the language of mathematics. However, this was not merely a matter of training but a matter of specific mental habits and attitudes as well. University scholars and humanistic literati held manual labor in such a low esteem that they could have never developed anything remotely like the experimental methods cultivated by the artisans. Thus, the social and intellectual osmosis that lies at the origins of the modern scientific method was indeed accompanied, and further facilitated, by an unprecedented cultural shift toward a reappraisal of the significant value of manual work. Thus, modern science is born precisely at the moment when a certain level of technological progress, combined with an overcoming of derogatory prejudices regarding manual work,

allows the academic literati to adopt the artisans' experimental methods and recuperate them within their rationalist ways of thinking. In their hands, the practical rules of the artisans can now be reformulated as laws of nature. According to Zilsel, this successful recuperation is characteristically exemplified in the cases of Galileo Galilei, Francis Bacon, and William Gilbert. In their major treatises, all three of them express their deep appreciation for, and refer extensively to, the remarkable empirical technological feats of their contemporaneous naval, metal, and military artisans and engineers (Figure 2). Thus, these major figures in the history of science practically embody the bridging of a social gap, as in the case of Galileo and his lessons from the Venetian arsenal.³⁷

This social process is embedded within the progressive development of an early capitalist economy that weakens collective mentalities and discourages prejudice, while reinforcing the secular, rational-causal way of thinking, along with a spirit of individualism. According to Zilsel, the critical scientific spirit is directly associated with economic competition; that is precisely why it has never appeared within social formations that are not structured around it, that is, outside the Western European sphere of influence of the seventeenth century. The rise of quantification is also difficult to be disassociated from the rational calculus required by the members of capitalist economies. Even the revival of Greek mathematics was made possible by the increased needs of the new social organization for calculus and measurement. What gradually came to be known as the "Zilsel thesis" has even further historiographical implications, though. If the development of modern science coincides with the transition from feudalism to capitalism, indeed, then historical research needs to move away from Koyré's conventional periodization of the scientific revolution (from the publication of Copernicus's *De Revolutionibus Orbium Coelestium* in 1543 to Newton's *Philosophiæ Naturalis Principia Mathematica* in 1687) to an altogether different time span, ranging

from the end of the Middle Ages to the late sixteenth century.

But Zilsel's crucial historiographical challenge is not limited to a question of an alternative periodization that would shift the architectural historians' attention to what has already been touted as the "first scientific revolution" of the fourteenth-century late medieval world.³⁸ Discussions about an alternative periodization could have already been instigated without veering off the realm of intellectual histories of science, indeed. In treating the scientific revolution in terms of continuity—instead of rupture—with the past advances of science, Pierre Duhem's 1908 history of science had already inscribed the scientific practices of Galileo and Copernicus into a longer line of tradition that went back to the late Middle Ages.³⁹ By studying the work of natural philosophers like Jean Buridan and Nicole Oresme at the University of Paris, Duhem highlighted the reappearance and retainment of fourteenth-century concepts in seventeenth-century science, arguing for the medieval practitioners' contribution to an understanding of fundamental concepts that still underlay the subsequent mechanics later elaborated and further developed by the likes of Galileo, Descartes, and Newton. A turn to Duhem's alternative timeline of developments is also corroborated in the case of architecture by the short time lapse between the constitution and identification of the community of architects before that of the scientists. Such an approach would then help the scholar in architectural history associate the developments in an early architectural and an early scientific community, putting the architectural repercussions of the scientific revolution into a long-term perspective.⁴⁰ Last but not least, and inasmuch as Pérez-Gómez's main concern still revolves around the dissemination of epistemological developments in natural science in other disciplines, his study could have also benefited from the later works of Eduard Jan Dijksterhuis (1950). Largely sharing Koyré's view that the crucial shift during the scientific revolution lies in the processes of mathematization

of the world picture, Dijksterhuis attempted to extend his research from physics in other domains, like chemistry and the life sciences.⁴¹ However, this was also the point where the limits of this interpretative schema appeared very clearly. Mathematics were not as important in the development of other sciences, where Koyré's and Dijksterhuis's main thesis started to feel more like a straitjacket than a historically informed account. Could this also be the case for architectural developments of the period? Pérez-Gómez's strongly theorized historical account definitely didn't leave room for exploring similar questions. Reflecting rather than deflecting Koyré's account, Pérez-Gómez practically leaves it unchallenged, precisely at the moment when architecture could start acquiring its own peculiar sort of agency through an active contribution to (instead of a rather passive reflection of) the scientific developments of the period. Offering a radical deflection, Zilsel's crucial challenge pushes further in this direction.

Inasmuch as architectural historians are fascinated by intellectual histories of science, they tend to perceive the historical developments in the scientific domain as blueprints for the subsequent architectural ones. However, the gradual autonomy gained by a community of master craftsmen who start practicing architecture as a liberal art, and their contemporaneous distinct depictions as figures who thenceforth hold only a drawing, a ruler, and a compass, do indeed predate the constitution of the first scientific communities (Figure 3). If those historical signs are anything to go by, then "external" social and political factors may well play an even more significant role in the developments in architectural theory of the period—although the point in time when natural science adopts the cultural role of serving as a model for organizing and producing human knowledge still retains its indubitable significance. Yet, if Zilsel is right to assume that figures like Galileo and Gilbert benefit from their direct social contact with the classes of the craftsmen and the engineers who

have already developed practical solutions to difficult problems following their hands-on method of empirical experimentation, then the image of the intellectual historians of science is reversed: the architects and engineers of the period become the central focus of attention, with the scientific community following and learning from their achievements. Who are all those relatively anonymous figures of artisans and master craftsmen, and what are the crucial microhistorical shifts of their rising social status, as they gradually become autonomous professionals? It is the task of architectural historians to retrace these stories, and in doing so, they can inform our understanding of the scientific revolution, this time from the side of an active disciplinary contribution to it. In other words, and rather paradoxically so, the most useful interdisciplinary study for exploring the historical relations between architecture and the natural sciences is the one that focuses on the specific achievements of the discipline itself as it is gradually shaped during the same period. Zilsel's potential deflection in the historiography of architecture would allow historians of science to rethink the scientific revolution in a slightly different way, much closer to the logic of "the architecture of science."⁴² What is gradually being sketched here is an approach where Pérez-Gómez's study would unexpectedly end up meeting historiographical approaches of architecture like the ones propagated by Spiro Kostof, Mary Hollingsworth, and Elizabeth Mays Merrill on the microscale, and even by Manfredo Tafuri (1992) on the macroscale.⁴³ It would also herald the moment when histories of science and architecture both need to open up to histories of technology of the same period,⁴⁴ widening the interdisciplinary potential for further historiographical reflections and deflections of crisis.

Novel interdisciplinary interpretations of architectural developments in a period that still needs to be historicized can only raise contemporary architects' awareness of an epistemological crisis whose diverse repercussions still rock the cradle of our modern world. While

interdisciplinarity allegedly prevails in many registers at the present moment, very often induced precisely by diagnoses of crisis, the sometimes cryptic and only nominal forms of interdisciplinarity upon which these diagnoses are built need to be as closely scrutinized and identified. At the moment when another dominant form of modernist discourse, like parametricism, presents itself as the autonomous all-inclusive universal metalanguage for the architecture of the future, the interdisciplinary legacy of the "Essex School" of architectural history and theory needs to come out of its "historical cocoon" through a radical deflection.⁴⁵ If Patrik Schumacher's "autopoietic" parametricism is only the most recent neopositivist child of the postmodern condition,⁴⁶ then a novel breed of self-reflexive architectural theory for the 2010s needs to reopen such lines of interdisciplinary inquiry (Figure 4).

Such an approach can considerably help both qualify the epistemological claims of parametricism and reveal the complex power issues, alongside the economic, political, social, and pedagogical agendas behind it. Since contemporary scholars have already started revisiting the work of early modern philosophers as a reply to the architectural challenges left unaddressed by parametricism,⁴⁷ the need for a proliferation of such interdisciplinary deflections seems ever more relevant for the present moment, when similar examples of crisis unbound certainly abound. IT and its role in the production of knowledge was already there right from the start in 1979 in Jean-François Lyotard's account of the postmodern condition, anyway. In other words, the most recent crisis of the modern world, the crisis from which Pérez-Gómez himself starts writing, is diagnosed to pertain once again to the epistemological plane of knowledge production, this time instigated by the advent of IT.⁴⁸ However, recent debates about the contribution of big data in contemporary knowledge production hark back not only to Lyotard's 1979 discussion but also much further back to Francis Bacon's 1627 *New Atlantis* and the constantly renewed



Figure 4. Greg Lynn, Patrik Schumacher, and a new rise of positivism in contemporary architectural theory, whose epistemological assumptions need to be traced back, qualified, and contextualized in their long historical trajectory.

legacy of his thoroughly empiricist methodology of intensive data collection. And if one follows a different thread from Bacon's *New Atlantis* (1627) and the accompanying vision of man's domination of the natural world to the present, then the current ecological crisis could also be illuminated in its historical and cultural depth—but also in its more recent social, political, and architectural dimensions, as they were developed by activists and artists of the 1960s and the 1970s, like Rachel Carlson and Agnes Denes.⁴⁹ The list of similar examples could certainly go on and on, by first and foremost including the technocratically narrow concept of sustainability through reduced carbon emissions usually offered as a reply to a larger social, economic, and political set of questions regarding the ecological crisis. Biomimicry and other recently fashionable trends of computer-aided architectural design (that often refer exclusively to similar sources with much different “anti-Cartesian” conclusions)⁵⁰ can also be similarly contextualized and reinterpreted in terms of their much longer cultural histories. However, the main point should be clear by now. By challenging both our temporal and our disciplinary

parochialism, interdisciplinary historiographies can certainly offer thoroughly incisive and insightful diagnoses of our contemporary manifestations of crisis. While it remains to be seen whether they can also inspire rigorous ways out of it, the latent potential for their development definitely remains the most significant legacy of Pérez-Gómez's and the Essex School method of architectural history and theory from the 1970s to the present, and from one instance of crisis to another.

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Notes

- 1 See Charles Jencks and George Baird, eds., *Meaning in Architecture* (London: Barrie & Jenkins, 1969). Alan Colquhoun's variant of a self-reflexive architectural theory is further explicated in his *Essays in Architectural Criticism: Modern Architecture and Historical Change* (Cambridge, MA: MIT Press, 1981).
- 2 For a comprehensive discussion of this sort of linguistic turn in architectural theory and criticism of the period, see Andreas Kourkoulas, “Linguistics in Architectural Theory and Criticism after Modernism” (PhD diss., Bartlett School of Architecture UCL, 1986).
- 3 Helen Thomas, “Invention in the Shadow of History: Joseph Rykwert at the University of Essex,” *Journal of Architectural Education* 58, no. 2 (2004): 39–45, 40.
- 4 Although Graham Livesey is right to note the “greater availability of phenomenological writings translated into English” in the 1980s and early 1990s—see his “Changing Histories and Theories of Postmodern Architecture,” *Building Research and Information* 39, no. 1 (2011): 93–96, 95—some of the most important texts of this philosophical tradition were readily available in English in the 1970s, including Edmund Husserl's *Crisis of European Sciences and Transcendental Phenomenology*, trans. D. Carr (Evanston, IL: Northwestern University Press 1970), Maurice Merleau-Ponty's *Phenomenology of Perception*, trans. C. Smith (London: Routledge & Kegan Paul, 1962), Martin Heidegger's *Being and Time*, trans. J. Macquarrie and E. Robinson (Oxford: Blackwell 1962), as well as his “Building, Dwelling, Thinking,” trans. A. Hofstadter, in *Poetry, Language, Thought* (New York: Harper & Row, 1971), 143–161; and Hans-Georg Gadamer's *Truth and Method*, trans. and ed. G. Barden and J. Cummin (New York: Seabury, 1975).
- 5 For a more detailed account of Rykwert's and Vesely's University of Essex MA program (1968–78), see Thomas, “Invention” (note 3). Joseph Bedford is currently focusing his in-progress PhD dissertation at Princeton University on the same MA program.
- 6 *Ibid.*, 45, note 21.
- 7 *Ibid.*, 41.
- 8 While Thomas is right to highlight both the “deliberate intention toward practical application” (*ibid.*) behind Vesely's seminar and the “understanding of the design process” that was considered “integral to the approach to the academic material of the course” by Rykwert (*ibid.*, 42), she is also quick to subsequently ponder “whether the Essex master's course unwittingly enabled the release of architectural theory from

- the practice of architecture at the moment of its tenuous integration with it," based on Porter's 2001 account (ibid., 43). See David Porter, "Letter to the Editor: Lost in the Backlash," *Architectural Research Quarterly* 5, no. 1 (2001): 5. If that is indeed the case, then it is definitely possible to wonder about the specific characteristics of a distinctive "Essex School" method of architectural history and theory, as I do here, irrespectively of the originally intended practical orientations of both Rykwert and Vesely. The main intentions and concepts behind the design studio offered by Vesely at the Architectural Association in the same period are further explained in Dalibor Vesely and Mohsen Mostafavi, *Architecture and Continuity* (London: Architectural Association Press, 1982), while Rykwert's legacy is discussed in George Dodds and Robert Tavernor, eds., *Body and Building: Essays on the Changing Relation of Body and Architecture* (Cambridge, MA: MIT Press, 2002). Equally illuminating in the same context are Joseph Rykwert, *On Adam's House in Paradise: The Idea of the Primitive Hut in Architectural History* (New York: Museum of Modern Art, 1972), and Joseph Rykwert, *The First Moderns: The Architects of the Eighteenth Century* (Cambridge, MA: MIT Press, 1980).
- 9 Thomas, "Invention" (note 3), 40.
 - 10 Neil Leach, "The Limits of Poetics," *Building Research and Information* 33, no. 4 (2005): 382–85, 382.
 - 11 See Alberto Pérez-Gómez, *Architecture and the Crisis of Modern Science* (Cambridge, MA: MIT Press, 1983), 3–14.
 - 12 While Pérez-Gómez's references also include works of somewhat peripheral relevance to the interests of his study (like Yates's 1964 and 1972 studies on the occult and the hermetic tradition or Burt's 1924 study on the role of Neoplatonism in the rise of modern science that is later elaborated in the work of Alexandre Koyré), along with Dijkstra's very important 1950 study on the scientific revolution and the mechanization of the world picture, he hardly ever refers to, or comments upon, them in the main body of his text. Hence, it is only Koyré's history of science that substantially informs Pérez-Gómez's study. See Edwin Arthur Burt, *The Metaphysical Foundations of Modern Physical Science* (London: Routledge & Kegan Paul, 1924); Frances Yates, *The Rosicrucian Enlightenment* (London: Routledge & Kegan Paul, 1972); Yates, *Giordano Bruno and the Hermetic Tradition* (Chicago: University of Chicago Press, 1964); and Eduard Jan Dijkstra, *Mechanization of World Picture: Pythagoras to Newton*, trans. C. Dikshoorn (Oxford: Clarendon, 1961).
 - 13 See Edmund Husserl, *The Crisis of European Sciences and Transcendental Phenomenology*, trans. D. Carr (Evanston, IL: Northwestern University Press, 1970), and Alexandre Koyré, *From the Closed World to the Infinite Universe* (Baltimore: Johns Hopkins Press, 1957).
 - 14 Pérez-Gómez, *Architecture and the Crisis of Modern Science* (note 11), 4.
 - 15 Ibid., 10.
 - 16 Ibid., 10–11.
 - 17 Alexandre Koyré, *Metaphysics and Measurement: Essays in Scientific Revolution* (London: Chapman & Hall, 1968), 75–76, 80.
 - 18 Ibid., 19–21.
 - 19 Ibid., 39–40.
 - 20 Ibid., 45.
 - 21 Ibid., 121.
 - 22 Ibid., 77.
 - 23 Ibid., 78–81. However, see also Rykwert's own take on Newton in *The First Moderns* (note 8).
 - 24 Koyré, *Metaphysics* (note 17), 83.
 - 25 Pérez-Gómez, *Architecture and the Crisis of Modern Science* (note 11), 83.
 - 26 Ibid., 59.
 - 27 Ibid., 62.
 - 28 Ibid., 112–16.
 - 29 Ibid., 160–61.
 - 30 It is precisely the wider framework of Pérez-Gómez's study that allows him to interpret not only the role of architects, like Boullée and Ledoux, but also the development of whole architectural currents, like neoclassicism, in a light completely different from other scholars of the period—such as Emil Kaufmann. See Kaufmann, *Three Revolutionary Architects: Boullée, Ledoux and Lequeu* (Philadelphia: American Philosophical Society, 1952).
 - 31 Even when he refers to clearly technical fields (like fortifications and gardening), or the establishment of institutions (like the Royal Academy of Science and the Royal Academy of Architecture), Pérez-Gómez's main concern remains with the changes in metaphysical and epistemological assumptions that are aligned with the corresponding changes in the central stage of the history of the scientific revolution.
 - 32 See, e.g., Robert King Merton, "Science, Technology and Society in Seventeenth Century England," *Osiris* 4, pt. 2 (1938): 360–632.
 - 33 See H. Floris Cohen, *The Scientific Revolution: A Historiographical Inquiry* (Chicago: University of Chicago Press, 1994), 314.
 - 34 See Barry Barnes, *Scientific Knowledge and Sociological Theory* (London: Routledge, 1974), 99–124.
 - 35 Ibid., 114. In other words, Barnes believes that Koyré's approach is right for the wrong reasons. His intellectual history makes sense precisely because Galileo's practice, for instance, bears almost no relation to normal scientific practices that come before him—at a moment in time when science has not yet been institutionalized as such.
 - 36 See Edgar Zilsel, "The Sociological Roots of Science," *American Journal of Sociology* 47, no. 4 (1942): 544–62.
 - 37 See Cohen, *The Scientific Revolution* (note 33), 347.
 - 38 See Anneliese Maier, *Die Vorläufer Galileis im 14. Jahrhundert: Studien zur Naturphilosophie der Spätscholastik* (Rome: Edizioni di Storia e Letteratura, 1949).
 - 39 Duhem's study originally developed in response to Ernst Mach's 1883 positivist thesis of a total rupture between modern science and similar practices of the past. See Pierre Duhem, *To Save the Phenomena*, trans. E. Doland and C. Maschler (Chicago: University of Chicago Press, 1969), and Ernst Mach, *The Science of Mechanics: A Critical and Historical Account of its Development*, 6th rev. ed., trans. T. J. McCormack (London: Open Court, 1960).
 - 40 While Pérez-Gómez's mentor, Dalibor Vesely, did cover some ground in this direction, the era is ripe for further historical research. See Vesely, *Architecture in the Age of Divided Representation: The Question of Creativity in the Shadow of Production* (Cambridge, MA: MIT Press, 2004).
 - 41 See Dijkstra, *Mechanization of World Picture* (note 12).
 - 42 See Margaret J. Osler, ed., *Rethinking the Scientific Revolution* (New York: Cambridge University Press, 2000); Antoine Picon and Alessandra Ponte, eds., *Architecture and the Sciences: Exchanging Metaphors* (New York: Princeton Architectural Press, 2003); and Peter Galison and Emily Thompson, eds., *The Architecture of Science* (Cambridge, MA: MIT Press, 1999).
 - 43 See Spiro Kostof, ed., *The Architect: Chapters in the History of the Profession* (New York: Oxford University Press, 1977); Mary Hollingsworth, "The Architect in Sixteenth-Century Florence," *Art History* 7 (1984): 385–410; Elizabeth Mays Merrill, "The Trattato as Textbook: Francesco di Giorgio's Vision for the Renaissance Architect," *Architectural Histories* 1, no. 1 (2013): 20; and Manfred Tafuri, *Interpreting the Renaissance: Princes, Cities, Architects*, trans. D. Sherer (New Haven, CT: Yale University Press, 2006).
 - 44 An important first step in this direction has already been made in Antoine Picon, *French Architects and Engineers in the Age of Enlightenment* (Cambridge: Cambridge University Press, 1991).
 - 45 Leach, "The Limits of Poetics" (note 10), 385.
 - 46 See Patrik Schumacher, *The Autopoiesis of Architecture*, 2 vols. (Chichester: Wiley, 2010–12).
 - 47 See Peg Rawes, "Spinoza's Geometric and Ecological Ratios," in *The Politics of Parametricism: Digital Technologies in Architecture*, ed. Manuel Shvartzberg and Matthew Poole (London: Bloomsbury Academic, forthcoming).
 - 48 See Jean-François Lyotard, *The Postmodern Condition: A Report on Knowledge*, trans. G. Bennington and B. Massumi (Minneapolis: University of Minnesota Press, 1984); and Stylianos Giamarelos, "Have We Ever Been Postmodern? The Essential Tension within the Metamodern Condition," in *Re-thinking the Human in Technology Driven Architecture*, ed. Constantin Spyridonidis and Maria Voyatzaki, *Transactions on Architectural Education* 55 (2012): 408–19, www.enhsa.net/Publications/AR2011.pdf (accessed October 24, 2014).
 - 49 See Peg Rawes, ed., *Relational Architectural Ecologies: Architecture, Nature and Subjectivity* (Abingdon: Routledge, 2013).
 - 50 See Greg Lynn, *Animate Form* (New York: Princeton Architectural Press, 1999).