An Essay on Notation:
a speculative examination of what
and how architectural drawings
might mean

by

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ABSTRACT

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Every discipline represents the reality which concerns it by means of some formalization; in Architecture, the principal means of formalization is drawing. This thesis examines architectural drawings as notation systems. Plan, section, elevation, perspective and isometric projection, the kinds of drawing most used in architectural work, are discussed as generic types of images, each of which specifies a partial correspondence to the physical world by virtue of a particular logic and set of conventions. This logic and the associated conventions characterize each system and distinguish it from others.

Section 1 reviews a theory of visual perception on which a procedure for describing each notation system is based.

Section 2 presents an extended discussion of each system: the logic of each notation, its relation to our visual perception and the graphic conventions which it employs are examined, the potentials and limits of each system are suggested. Reference is made to the history of the development of each system and the traditions of its usage. The ways in which the several systems may be cross-referenced and combined to describe architectural space are considered, as are the conceptual devices scale, grid and key.

Section 3 outlines four principal contexts in which notation systems are used. Questions are posed as to the appropriateness of each system in each of the contexts. The section closes with a discussion of the role which notation systems play in design, especially as regards the introduction of metaphor to that process.

Thesis Supervisor: Julian Beinart

Title: Professor of Architecture

For Martha

to whom this thesis,
no less than its author,
owes far more than she imagines

I should like to acknowledge the critical insights and forbearance of my advisor and readers, Professors Julian Beinart, Gary Hack and, particularly, Dean William Porter;

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CONTENTS

INTRODUCTION

This is an essay about architectural drawings, especially those kinds which are most frequently made in architecture school and in practice--viz. plans, sections, elevations, perspectives and various isometric projections. Each of these kinds of drawings will be considered as a notation system, which is simply to say as a consistent and coherent means for displaying certain aspects of what we understand of buildings and space.

Several observations can be made at the outset. A very large part of architectural education (and perhaps an even larger part of architectural practice) consists in manipulating plans, sections and the rest; in interpreting or "reading" them, in evaluating them critically, and, not least, in making them. Such drawings are the currency of the profession: one need only reflect upon how much time and effort is spent translating what is observed or dreamed of spaces into a few rather precise and rather spare notation systems. Yet very little time is spent examining the assumptions and conventions upon which such systems are based.

Taken together as notation systems, all the various graphic means by which architectural space is modeled share several general aspects. Fundamentally, each is comprised of a set of elements and a set of rules which govern their use. Each system is a means of codification by which empirical phenomena may be formalized and expressed in a manner which is comprehensible to those who are familiar with the notation. Each system has been developed as a complex of conventions and is sustained in its usage by a general acceptance of those conventions--that is, a consensus on meaning. Each system is governed by an internal consistency or logic. Each proposes a particular veridicality--that is, a correspondence of the elements of the system to the actual phenomena which they describe.

Considered individually, however, each particular notation system is but a partial means of describing the experienced phenomena. The representation of any space in a given notation subjects the perception of that space to the "grammar" of the particular notation; it is a formalization, the imposition of an internally consistent structure on the material of experience. Such a formalization is, of necessity, a process of selection and organization: prominence must be given certain aspects of our perception over others, some must be ignored altogether. In short, we must, to a considerable extent, edit the material of experience to the particular requirements of the notation system in order to communicate impressions and ideas--indeed, to record them at all.[1]

What this essay proposes, then, is a kind of epistemology of architectural notation. It seeks to clarify how we know what we know from architectural drawings and, more specifically, what we know from examining one kind of drawing as opposed to another. To do so, we will try to describe for each notation system considered what kind of formalization is taking place. What assumptions are being made about what is experienced in order to make, for example, a plan of a particular space? What aspects of the real situation are being selected for representation in each notation and how are they being organized in the two-dimensional format? What kinds of consistency are posited by each notation system; what kinds of correspondence does it devise between its elements and their real aspects?

In pursuing this line of discussion, we hope to specify what kinds of information can and cannot be represented in any particular notation system. More particularly, what kinds of things may be known directly from a representation in a given notation; what kinds of things may be safely inferred, and on what basis are inferences to be made; and, no less, what kinds of knowing are completely excluded by each.

Similarly, a part of the discussion will address all the notation systems taken together as a whole--that which we may call generally "architectural drawing." We will ask how things known via one notation may be compared with things known by another, and whether the process of translation from one to another can be meaningfully characterized. Does an understanding formed on the basis of one mode preclude or reinforce an understanding formed on the basis of another? What are the terms of reference or the conventions of translation between systems?

Finally, we will turn from a consideration of notation systems as independent abstractions to a discussion of their role as integral parts of a design process--that is, the context(s) for their use. We will try to examine whether different design contexts influence or modify the meaning of particular notation systems; whether the assumptions and constraints which we will seek to demonstrate as being intrinsic to each notation system substantially influence, or are perhaps influenced by, their usage. Again, we will look here at notation systems individually and in combination. In this way, we hope to reach some general conclusions about the "potency" of notation systems in the various contexts in which they are used and perhaps offer tentative hypotheses as to the characteristics of potent systems.

These are both basic and abstract questions. They address the tools of the profession, the means by which it models the reality on which it seeks to operate. They ask, in sum, what it means to construct such an operational reality in much the same way that one might ask of a statistician what it means to array several discrete variables in terms of scattergrams and equations for curves, or of a biologist what it means to explain molecular structure in terms of certain diagrams, models and statements describing the behavior of basic elements, or of a poet what it means to express a relationship by means of metaphor and simile. The equation, the model, the simile all are tools by which certain correspondences and equivalences can be made manifest. Each arranges the stuff of experience--the material of inquiry--in a special form so as to reveal certain aspects, conceal others and allow for particular kinds of transformations in the effort to understand.

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Such issues admit to several kinds of investigation. One might undertake an historical analysis, one which sought to trace to its origins the usage of each notation system, to establish probable antecedents and patterns of usage in relevant periods of practice. Alternately, one might examine the contemporary professional contexts in which architectural drawings are used, contrasting--by a case studies method--the role which kinds of drawings play in the work of different individuals or groups. The former study would focus on particular drawings; the latter on the design paradigms which produced drawings.

The study which we propose might, by contrast, be called a speculative one. We shall examine the principles on which different kinds of drawings are based. In so doing, we hope to outline a critique of each notation system as an entity in and of itself, to suggest what its logic is and what its limits are. It is this characterization of limits, of capacity which, we believe, admits to direct description.

To be sure, the three methods are not mutually exclusive. We will introduce such historical evidence as we have been able to find in the literature to support several points; so, too, we will refer to some case study material. But our use of these sources will be of a secondary rather than primary importance; we have neither the time nor the training to emulate the historian's (or the social scientist's) method.

It might be observed that speculative inquiry recommends itself by virtue of the simplicity of its means. Yet it is, nevertheless, a means by which certain questions, important yet elusive to other methods of inquiry, may be posed and thoughtfully, if not conclusively, explored.

INTRODUCTION

Notes

1. This is clearly not a problem of architecture alone; these remarks apply to the use of notation systems generally, regardless of the particular field (cf. Goodman (20), Simon (40), and others). As Ivins has put it, "In order to have ideas about the returns given us about nature by our five senses, it is necessary to have some system of symbols by which to represent those returns and some grammar or rule by which those symbols are given logical relationships. Lacking such symbols, or a grammar for their use, the task of thinking becomes too onerous to be carried very far." Ivins (24), p. 7.

SECTION 1

Implicit in what has been said thus far is the notion that all drawing, and especially what we have called architectural drawing, is an arrangement of selected information which exists in the environment. This seemingly obvious and unobjectionable statement stands at the center of a long controversy in fields as diverse as perceptual psychology, art history and criticism, aesthetic theory and recent writing on "environmental meaning." It poses a dilemma for our discussion, for much of the debate in these fields is tangential or irrelevant to our purposes. And yet, any discussion of architectural drawings which seeks to deal with the content of drawings as information in the environment must eventually face several important and difficult questions: How is this information known to us? Does the process by which we come to know it influence the ways in which we represent it in drawings? And, once represented in drawings, what relationship does the process of understanding such information from drawings bear to the process of understanding the information in the environment itself?

It is this last question which has particularly engaged the attention of perceptual psychologists and historians of art, as well as several philosophers. Most of the argument has centered on the issue of illusionistic representation, those manufactured images which look "as if they were real."[1] This debate is clearly secondary to our purposes, although the discussion of perspective below will inevitably have to make reference to it. Yet we raise it here because much of the most significant recent theorizing on the nature of our perception and its relationship to our representations has been spawned by the insistent question of illusion.

We shall try to summarize briefly the salient features of a theory of perception which takes as its basis the notion of information in the perceived environment. We shall try to develop at the same time the consequences of such a theory for representation and particularly its significance for an understanding of the development and use of architectural notation systems. We hope to suggest, at least as a working hypothesis, what the information in the environment is, what the information in drawings is, what relationship the two have to each other, and by what processes we come to understand and make judgements about them.[2]

* * * * *

Our principal perceptual means of understanding space is visual, which is to say, in the context of the theory to be presented, the principal informational cues by which we understand spatial phenomena are visual.[3] It should be made clear that Gibson's theory is not confined to visual considerations, but extends to all the senses.[4] But it is primarily with vision that Gibson is concerned and it is only his discussion of vision which we will elaborate here.

Gibson describes visual perception as the discernment of structured information in the environment (environment is used in its original sense, viz. surround). This information consists in the "...formless and timeless invariants that specify the distinct features..." of objects and spaces.[5] At first this assertion may seem paradoxical: surely we don't see formless and timeless invariants in looking at objects or spaces but, on the contrary, variable forms which may vary in time. To develop his point, Gibson draws a distinction between two kinds of vision or, perhaps better, two kinds of visual realms and visual processes. These are the visual field and the visual world.

The visual field is the single aspect or view, that "...which seems to be experienced when one concentrates on what it feels like to see." The visual field is characterized by the fact that it seems to be displaced when moves one's eyes or head, appears to rotate when one lies on one's side, and has an apparent boundary "...between inner content and outer nothingness, or indeterminacy."[6]

The visual world, by contrast, is the phenomenal world which:

> "...has the property of being stable and unbounded. By stability is meant the fact that it does not seem to move when one turns his eyes or turns himself around...and that it does not seem to tilt when one inclines his head. By unboundedness

> is meant the fact that it does not seem to have anything like a circular or oval window frame. The phenomenal world seems to stay put, to remain upright, and to surround one completely. This experience is what a theory of perception must explain."[7]

Both of these--visual field and visual world--are parts of our visual perception; indeed, as we shall see, the former is in fact contained in the latter. But though they are difficult to distinguish in experience, the conceptual difference between them is crucial to distinctions which we will make between kinds of architectural drawings below.

The visual field may be considered as the product of "pure" vision, that which takes place when a fixed eye contemplates a fixed scene for a split instant, the registration of a visual image or aspect solely by visual means. The visual world, on the other hand, is a product of what might be called "composite" vision. We come to know the visual world by moving through it and correlating the visual stimuli we receive with other kinds of sense information, particularly tactile, haptic and kinesthetic (touching, holding and self-motion).[8]

These distinctions can be more clearly drawn by explication of the perceptual processes which are involved in experiencing the visual field and the visual world. The former is experienced by what Gibson calls "simultaneous grasping," for by definition all components of the aspect are registered by the eye at once. The visual world is experienced by "successive sampling," by which is meant the composite process we have described above, the correlation of discrete aspects with exploratory movement. Simultaneous grasping is a process of the apprehension of adjacencies in space. Successive sampling is a process of the apprehension of sequences in time. The same information may be apprehended by either process (an example which Gibson uses in a somewhat different context is the recognition of a word, first by seeing it written out [simultaneous grasping], then by having it spelled out orally by someone else, letter by letter [successive sampling]). The knowledge--that is, the information apprehended--is in both cases the same, although the material--that is, the information displayed--and the manner in which it is perceived are different. The two processes are therefore functionally equivalent yet conceptually distinct.

To return to the discussion of vision--in our experience, visual field and visual world are seldom, if ever, separate. Although we recognize the theoretical possibility of a single frozen aspect, we seldom actually perceive one. In the normal course of events we move our eyes, head and body with respect to what we are viewing.[9]

The same, of course is true of spaces with respect to our movement through them. Now, if the visual world consists of a successive sampling of visual information in association with exploratory movement, then the discrete parts of that visual information must be what we have called visual fields. Indeed, the two parts of visual perception now collapse into one or, to be more precise, the visual field may now be understood as contained in the visual world. The two parts of vision are reconciled as one process by which the phenomenal world is known.

It may be asked why the distinction between visual field and world is retained if the former is simply a part of the latter which alone is the whole of the process by which visual information is known. In his later writings, Gibson largely avoids the notion of visual field as unimportant because perceptually not experienced. Indeed, his larger theory is much more forcefully argued without it. We have retained it, and to some extent reinforced it, by the one-to-one association with simultaneous grasping (which Gibson does not explicitly do) because it has considerable explanatory power in an analysis of notation systems. Gibson acknowledges the value of the notion in this regard by suggesting that visual field was really the product of the development of a representational art. There was, he argues, no need and therefore no value in considering the information of vision as aspect until the problem of producing representational images on flat surfaces was posed. Thus, man did not see aspects until he made them.[10]

* * * * *

And what _is_ the visual information? Gibson argues that we use the process of visual perception purposefully to establish the identity of things and that identity consists in the constancies of objects and spaces which do not change when subjected to our visual scrutiny: "An individual who explores a strange place by locomotion produces transformations of the optic array for the very purpose of isolating what remains invariant during these transformations." And so, too, "...the individual who scans a strange room actively produces samples of the array so as to establish its permanent features."[11] In this respect, the visual field or aspect is not the visual information at all as it is always changing, never constant--indeed seldom, if ever, perceived. The visual information must rather be located in other parts of the composite process of successive sampling of the visual world; that is, in the tactile, haptic and kinesthetic correlates of our visual exploration.[12]

* * * * *

Perhaps we can now briefly and succinctly restate the essential elements of this theory. Environmental information consists in the invariants or permanent features of objects and spaces. Visual perception is the processing of the visual presentation of this information. It may be considered as having two component, nested parts--visual fields or aspects and visual world (it may be useful to call these "concepts" as distinct from "aspects"). There are two nested processes at work in making sense of visual information: simultaneous grasping and successive sampling. The first is a purely visual phenomenon while the second is a composite of visual with other sensation. It is by the latter process that we come to know the invariants of an object or space--that is, that we form a conception of what it is. But it is significant that we also have the capacity to "read" single aspects and to draw inferences and conclusions--that is, form knowledge about the invariants of objects and spaces on that basis alone.

The distinction between aspect and concept goes to the heart of how we form a visual understanding of the world. One of the implications of Gibson's theory is that it is our comprehension of concept which allows us to perceive aspect at all. It is, for example, our knowing that the trapezoidal void set in the undefined surface which we see is, <u>in fact</u>, a rectangular window in an orthogonal wall which enables us to see the window. In short, we <u>know</u> that the world is different from what we <u>see</u> of it, and it is knowing this which allows us to see the world "as it is." This has several consequences.

First, it means that we have the ability to relate any given aspect of an object or space to all other aspects in a consistent fashion. This consistency is key, for it is the test of our concept. The concept may be considered as an hypothesis which consistently and coherently explains all variability in appearance. Furthermore, it allows us to infer external conditions as the causes of variability in appearance. For example, I know that the elliptical opening of the coffee mug on the table in front of me is, "in fact," round; that its trapezoidal shape is, "in fact," cylindrical; that the irregularly curved, mobius-like strip on its side is, "in fact," a regularly curved handle of constant thickness. I understand all these apparent distortions in shape are a function of my particular position with respect to the mug. Furthermore, I know that although one side of the same mug appears to be a glossy purple, spotted and streaked with silver, and the other side a dull black that it is, "in fact," the same dark blue color over its entire surface. I understand that distortions in color are a function of directional illumination. Finally, I know that the two mugs across the room on the shelf which appear to be so much smaller than the one directly before me are, "in fact," the same size. I understand that distortions in size are a function of distance. Each of these distortions can be dismissed as attributable to external conditions which modify appearance: position, illumination, distance. By so explaining them away, what is seen remains consistent with what is known to be.

The understanding is, in each instance, an implicit test of the visual concept, the formless and timeless invariants of the mug--what it is--for it proceeds from the conviction that, were I to change the external conditions which create these distortions, I could indeed verify that the shape, color and size of the mug are what I know them to be. Indeed, the notion of the invariant identity of objects allows for a gauge or measure of the distortions: by apparent shape I can judge my position vis-a-vis the mug; by apparent color I can tell where the light is coming from and of what intensity it is; by the apparent discrepancy in sizes I can judge the distance between objects.

But this implicit test of verification between what is known and what appears bears further scrutiny. For if I were really in doubt as to the roundness of the elliptical opening, I would change my position with respect to it (or, more likely, pick it up and so change it with respect to me) and so "prove" to myself that the opening is round. Similarly, to establish the uniformity of surface color I would change the ambient illumination or hold the mug "up to the light" and so establish its color. So, too, I would get the mugs from across the room and put them next to the one before me and so "prove" the constancy of size. But there is something of a paradox here, for in each instance what I am really doing is changing the way in which the object looks--that is, I am changing its aspect to construct these "proofs." It would seem, therefore, as if certain aspects correspond with the visual concept better than others--or at least we treat them as if they do.

Let us confine the example to distortion of shape and the relativity of position: How can we know that the opening of the mug is round?[13] We have already demonstrated that the visual concept of the mug (that it has a round opening) satisfactorily accounts for all the perspective disortions (aspects) which may actually appear. Surely this means that every aspect must stand equally for all the others. If, however, I am in doubt as to whether the opening of the mug is actually round or not, I will make the test of verification explicitly by looking at the mug in a very particular way. I will hold it so that it is perpendicular to my line of sight, so that the opening is "facing me," which is to say so that its aspect is a circle, if indeed the opening is round. It seems that there is one particular aspect which conforms to the concept of a round opening--namely, when the outline of the opening is a circle. And that occurs only when the opening faces me.

To return to Gibson's terminology, it seems that there is a moment at which the visual world is contained in the visual field instead of vice versa and that this moment can be described by a very particular positional relationship. The visual concept may be verified by inspecting particular aspects; the formless and timeless invariants have, for certain purposes at least, a particular form. Thus we may say that there are some aspects which are homologous with the concept.

We have outlined above the composite nature of the experience of the visual world--the integration of visual sensory information with tactile, haptic and kinesthetic. It is all these sensory inputs together, we said, which create the visual world and the substance of our concepts. Yet our verification of roundness has not made mention of them. So far, we have only made a judgement about an aspect--that is, our test has only used the data of the visual field ("the outline is a circle, therefore the opening must be round"). How does the verification test of the roundness of the mug relate to these other sensory components of our knowledge of the visual world?

We might alternately test for roundness by holding the mug in cupped hands to find if it "feels round." Or, with greater accuracy, by running one finger around the opening: I will be convinced that the mug is round if I can move my finger all the way around the edge of the opening to the point at which I started without feeling any change of curvature. By yet another method, I might stretch my finger across the opening from one edge to the other and rotate the mug slowly with my other hand: if the mug touches my finger in the same two places as I turn it, then it is round. Of course, a somewhat less awkward way of accomplishing the same thing is to measure the distance across the mug in several places: after establishing that a sufficient number of these diameters are equal, I am again convinced that the mug is round. And, with a little basic geometry, I can avoid measuring so many diameters and achieve a more rigorous accuracy with only two measurements--one diameter and the circumference.

We have now tested for the roundness of the opening of the mug in three distinct ways. We have discovered a particular aspect in which the opening appears to be a circle; we have established by touch constant curvature, which is only true of circles; and, by measuring--a surrogate for touch--two critical dimensions and relating them by a formula, we have established circularity by yet another means. We have also demonstrated two of Gibson's basic tenets. Knowledge formed on the basis of "pure" vision (visual field) is equivalent to, though conceptually distinct from, knowledge formed on the basis of "composite" vision (visual world). There is a further equivalence between knowledge gained via simultaneous grasping and via successive sampling, although these two processes are conceptually distinct as well.

In discovering one aspect which has a direct correspondence to the haptic-tactile component of our knowledge--that is, one positional relationship between our line of sight and the object in which distortion is eliminated, we have in effect formulated a way of looking at things--indeed, the way of looking at things. The value of such a formulation is that it gives us not only a way of double-checking our haptic-tactile perception of familiar objects but also a prescription for understanding unfamiliar ones. We come to expect that what the object is is what it appears to be from a particular point of view perpendicular to it.[14] Thus objects can be compared and the unfamiliar described in terms of the familiar. By having a consistent position from which we agree that the aspects of objects in some sense correspond with their concepts, the way of knowing one thing becomes the way of knowing all.

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The correspondence of visual field and visual world and the equivalence of simultaneous grasping and successive sampling as perceptual processes are also significant notions in describing our perception of the built surround and, in one guise or another, figure in much of the literature. Lynch has written at length on what he calls "environmental image," the general framework of understanding which the individual forms of any given environment through his use of it, which undergoes constant revision and modification with increased familiarity.

Lynch sees the process of formulating such an image as firmly rooted in "purposeful way-finding,"[15] In his discussion of the five categories of elements which comprise the environmental image, Lynch attributes a dominant role to paths, "...which may be a principal resource in organization at the metropolitan scale [and] have intimate interrelations with other element types."[16]

Lynch's emphasis on path and the sequential nature of our perception of the environment echoes Gibson's distinction between simultaneous grasping and successive sampling as equivalent perceptual modes, as well as the interrelationship of visual field and visual world. What we see at any moment, Lynch suggests, we in turn relate to the image of the visual world which we have built up from a myriad of such discrete aspects in our movement through them. But the importance of movement and sequence in our understanding of the built environment points to one other component of the perceptual process to which we have alluded above, but which deserves more explicit consideration here--that is, the temporal element in our visual perception.

We referred earlier to the distinction between spatial adjacencies and temporal succession and their respective, and complementary, roles in perception.[17] In a discussion of architectural space (and no less in the discussion of notation systems), the importance of the temporal structure of our perception must be acknowledged. Indeed, it may be argued that the "structure of the time of our perception" plays an essential role in our aesthetic appreciation of a work of architecture. The "time of the work" may be seen as an element intrinsic to the work itself, a constituent part of its aesthetic significance.

Such a view casts the aesthetic discourse in the light of the paradox of perception of architectural space. We know that in its essence space is whole, contained, unchanging, yet in our experience of it--upon which aesthetic appreciation must ultimately rest--space is partial and transitory. The whole to which we aspire in understanding we must construct. The work of Souriau and others places the emphasis on the temporal succession of this process by which we construct or assemble meaning. The central question becomes that of what cues the object or space itself may provide which guide our exploration, our "view absorbing execution" of it.[18]

To be sure, in the plastic arts this temporal succession of a work cannot be determined or ordered in the same way as it is in musical or literary works. Still, any work of architecture must inevitably set up principal directions and patterns of choice vis-a-vis movement which will result in particular successions of aspects which then become the material to which a hierarchical order may be given.

Once such a condition is admitted, the range of devices which may be introduced to provide coherence or counterpoint to architectural space is limited only by imagination (that of the designer and the observor). We need not insist that meaning is created solely by temporal succession to nonetheless assign it a part, and potentially a very large one. The information presented in any individual aspect of a space may be given a designed relationship of a very particular sort to selected other aspects. To the extent that our inspection of the space reveals such relationships, we establish thematic connections between the successive aspects. These connections in turn may structure expectations about the aspects which follow and, in so doing, direct our attention to particular aspects as opposed to others.[19] And so, to the extent that we become conscious of and respond to such cues we enter, in Souriau's terms, the "universe of the work" and its "intrinsic time." These notions have a direct parallel in the information theory. The scanning process by which we build the visual world may be directed by the information in corresponding but separate aspects. And, we may add, to the extent that the particular succession of aspects influences the way in which we form the concept (the environmental image, the idea of the space), any artifice by which the succession of aspects is structured or one succession made more prominent, likely or meaningful than another, will influence our formation of concept and hence our understanding.[20]

This consideration of temporal succession bears on architectural drawings in two distinct ways. First, insofar as any particular drawing is an independent work, it too will have an "intrinsic time"--that is, the time in which we inspect the image will be structured to some extent by components of the drawing itself: the amount and clarity of detail; the use of shade and color; the general composition, and so on. We will suggest in the next section that different kinds of drawings, and different kinds of notation systems, have different kinds of "intrinsic time"--that the "reading" of a perspective, for example, engages the viewer in time in a way that is significantly different from the reading of a plan.

But insofar as architectural drawings--individually and particularly in combination--provide information about space in the visual world, the "intrinsic time" of the images has another significance. Souriau builds on Beaudelaire's notion of art as "the mnemonics of the beautiful"--that is, the direction and prolongation of the period of contemplation. Insofar as this is viewed as one of the bases of the aesthetic of the work, we may seek indications of it in the representation of the work as well; our reading of a group of drawings may communicate something of what we might expect of the "view-absorbing execution," the experience of the space itself. To this end, architectural drawings may be deliberately manipulated to simulate the temporal component of the work as it is designed (cf. Thiel (45) and (46), Lynch et al. (30)). But even if the "intrinsic time" of the space is not singled out for special study, the "intrinsic time" of the drawings which stand for the space may nevertheless condition our understanding of it.[21]

SECTION

Notes

1. It is difficult to state the issue without standing in one of the several camps; "look as if," "resemblance," "imitation," "depiction," are terms among many others which have become highly charged in the debate over the nature of illusion--indeed "illusion" itself has been appropriated.

2. The reader interested in the particulars of the debate on illusion will find the two extreme positions as well as a third alternative which is the crux of the information theory to be presented below well summarized in J.J. Gibson (15). The debate may be followed in Gombrich (18), Wollheim (48) and Goodman (20). See also Arnheim (6) and Black (19). A more general presentation of the competing theories in the psychology of perception and a rigorous argument for the information-based theory may be found in Gibson (16).

3. cf. Gibson (16).

4. On the role of auditory and other non-visual cues in spatial perception see ibid, pp. 52-55 and Ch. IV-VII.

5. Gibson (15), p. 31.

6. Gibson (16), p. 253.

7. Ibid.

8. "In the absolutism of the visual world, we are conscious of the invariant size and form of things and of their substantiality in their own right without relation to other objects. In the more relative visual field, we are aware of how things change in shape, size and proportion with respect to position and distance from fixed eyes, (and from each other)." Edgerton (14), p. 10.

9. "When one walks around an object, or sees it rotating, its optic array [the visual information it provides] undergoes perspective transformation and the whole family of perspectives is available to the eye so that the invariants are easy to see and the single perspectives are not; in fact, it is then almost impossible to see a single perspective. This is the normal way of seeing an object. On the other hand, when one holds still, it is easier to see the single perspective than when one moves around. But this is not the normal way of seeing an object. Gibson (15), pp. 31-32.

10. "I also believe that our primitive ancestors, before the discovery of pictorial representation by the cave painters, had never noticed the aspects of objects and the perspectives of the environment. They could only take the naive attitude toward the world. Why should the Ice Age hunters have noticed that the mammoth had a different

appearance from the front, the side, the rear and above. Why should they have observed that a thing appears to get smaller as it gets further away? What use would there be to have paid any attention to linear perspective and vanishing points and the optical horizon? But as our ancestors began increasingly to make pictures, they began to notice these appearances. They began to see aspects, perspectives, in short, forms. The man who painted the mammoth on the cave wall had to notice and remember one aspect (usually the side view), since the necessity of making tracings on a flat surface required it....And so it was, I think, that some men began sometimes to take the perspective attitude in viewing the environment. They began to be able to see the world as a picture...But they had to learn to do so." Ibid, p. 32. There is considerable evidence to suggest that an analogous process characterizes the development of learning to make images in childhood.

11. Gibson (16), p. 264.

12. "...the invariants of the object or the space provide for the detection of same thing along with the detection of different aspect. Locomotion thus eventuates in a sort of cognitive map, consisting of the invariants common to all the perspectives. This helps to establish the recognition of the objects contained in the perspectives." Gibson (16), p. 278.

13. The thrust of the arguments for illumination and distance would be the same but the mechanisms are different and to avoid confusion we shall look only at shape.

14. This is, of course, overly simplified for each perpendicular aspect presents but one side of the object; nevertheless, we understand the visual concept to accord with the sum of the aspects perpendicular to the sides of the object. We shall have more to say on this below.

15. "In the process of way-finding, the strategic link is the environmental image, the generalized mental picture of the exterior physical world that is held by the individual. This image is both the product of immediate sensation and the memory of past experience and it is used to interpret information and to guide action." Lynch (28), p. 4. See also Lynch (29), p. 219.

16. Lynch (28), p. 84. The others are node, edge, landmark and district. Although Lynch was not working explicitly with Gibson's model of perception, the latter's early work clearly informs much of the thinking; the five categories of elements, insofar as they are pieces of a mental image of the environment, are precisely analogous to what Gibson calls concepts and the visual world. Yet as actual entities in the environment, Lynch's elements are a mixed lot--landmarks, edges and, to a lesser extent, paths, have corresponding aspects; nodes and districts however are exclusively conceptual categories with no corresponding single aspects (see also Appleyard (4), Carr (10) and Thiel (46)).

17. "The idea that 'space' is perceived whereas 'time' is remembered lurks at the back of our thinking. But these abstractions borrowed from physics are inappropriate...Adjacent order and successive order are better abstractions, and these are not found separate....Even at its simplest, a stimulus has some successive order as well as some adjacent order....This means that natural stimulation consists of successions as truly as it does of adjacencies. The former are on the same footing as the latter." Gibson (16), p. 276.

18. See Souriau (42). In so far as it is offered to the sight, to the aesthetic appreciation, to the emotion or to the contemplation, the cathedral is successive: it delivers itself little by little in different spectacles which are never simultaneous. The cathedral of Chartres, seen from afar rising above the plain of Beauce, or from nearby when one is in the cathedral court; seen from a straight-front view or obliquely, or from the side; seen finally from the interior, according to whether one has just entered by the west door or whether through a series of changing perspectives one slowly approaches the choir;--presents with each aspect an artistic quantity which is absolutely different, and no one of them is seen simultaneously with any other.

"No doubt, the physical frame inclosing these successive aspects remains materially unchanging. No matter. The disc on which a musical composition is recorded also remains materially unchanging. The disc, however, is but an instrument for the orderly presentation of the work which itself is the structural law of the latter and which governs the musical execution. One must see in the same way the movement of the spectator around the statue or the architectural monument as a plastic or view-absorbing execution, which unfolds in order the various aspects which are held within the physical frame, and which are the aesthetic reason for that frame as it was planned.

"...the lover of cathedrals is held to an extremely set order which obliges him to regard in continuity and through a regular and sometimes irreversible succession, the various aspects through which an harmonious impression is established. He will proceed to the perspectives of the nave only after the main portal has been presented to him, like an opening chord; he will see the windows of the transept appear only as a kind of surprise of sudden modulation after the procession in regular harmony of the perspectives of the nave, modified at each step throughout its length. And who will dare to say that this ordered succession is unimportant, or that it has not been artistically foreseen by the genius of the architect?" Souriau, pp. 124-125

It may be objected that the cathedral is a singularly manipulative architectural creation with respect to sequence and time and that spaces with less formal directionality, less programmatic unity or a more plural range of symbolic associations would admit to far less by way of a significant ordered succession. Yet Souriau's point is subtler than at first might appear, for separations in space must of necessity structure temporal orders of succession and though we may be hard pressed to describe, in any given example, a single preferred or even a set of dominant orders, the fact that the temporal order conditions our perception of architectural space is inescapable.

19. Leo Steinberg's successive "readings" of S. Carlo alle Quatro Fontane of Borromini is an excellent example of this (Steinberg, (44)). On the role of expectation as a directive force in perceptual processes in general, see Gibson (16), pp. 266-286 and especially pp. 279-280.

20. On this last point several intriguing remarks are offered in Sauvage (35). She suggests that this may be a provisional temporality, cf. G. Brelet: "...at the moment when one becomes aware of the completion of the whole, the conscious mind loses the temporal movement which had been stimulated by the incomplete vision of the whole." I am not convinced that this is so--the mental image or concept ("completion of the whole") of some kinds of spaces clearly includes the element of meaningful sequence of succession of particular aspects, and there are buildings in which the idea is primarily one of structure as controlled sequence (the Guggenheim and Carpenter Center are obvious contemporary examples; see also N. Wu's interpretation of the approach to the Forbidden City in Peking). Sauvage suggests that there are four kinds of time, or temporal modes, present in various combination and in varying degree in every work of art. These are: T1, historical time (aging, "clock time"); T2, the time required to perceive the work and the ways in which the work may structure our perception of it in time (this is what we have discussed above); T3, which is the complex of temporal significations of the thing represented, or "time evoked" (Sauvage is primarily concerned with representational art and so intends, for example, the ages of the persons represented in paintings, the presence of a tomb, as a reference to those who had lived before, etc. A corollary in architecture might be found in what is often called historicism, the self-conscious reference by detail or even in plan to earlier buildings--for example, a contemporary architect's use of the classical orders; indeed, the Renaissance use of the orders represents the evocation of a particular time); T4 is seen as time itself represented as the subject of the work.

21. Lowenthal and Prince (27) amplify this point: "Works of art are not wholly congruent with everyday experience, as the words distill and encapsulate imply. Selecting and crystallizing, highlighting some features and shadowing others, they resemble landscapes of memory more than those of actuality. This is a function not only of the work itself, but also of our involvement with it. When we look at a picture, we suspend our normal sense of time and place to enter imaginatively into another realm, just as we do when we consciously recall our own past; and we attend to this other mode of being for its own sake rather than for some practical purpose...", p. 126. Architectural drawings are not, in this sense, works of art--they are most often attended to for some "practical purpose." Yet something of that same suspension of normal time characterizes our engagement of them.

SECTION 2

We are now ready to turn to a direct discussion of architectural drawings. As outlined above, we start with the premise that such drawings are an encoding of parts of the information which we do actually, or may potentially, perceive in the environment. As such, drawings are representations (in the most literal sense of that word) of the things we know about space, either the concepts of the visual world or the aspects of visual fields. That which is systematic in the notation concerns the correspondences which it makes to these two components of our visual perception, what information is selected and how it is displayed. The system may be thought of as the logic by which the visual world and the visual fields are represented in the drawing.

The value of the information theory we have presented in Section 1 in the discussion of systems of notation is that it provides a means by which to proceed in an analysis of the logic and conventions of each. The question of how space is understood in a particular drawing may be rephrased in terms of what kind of information the system (of which the drawing is but an instance) is structured to represent. As we elaborate this question with others, a method of analysis is developed. Does the information represented in the system correspond to a visual field or to the visual world, and so is the particular drawing representing "pure" or "composite" visual information? What are the <u>terms</u> of correspondence between the drawing and its referent (i.e., the rules of the system): Which constancies in the space represented are constant in the representation, which distorted, and how? What parts of the space are being shown and in what relationship do these stand to one another as represented in the drawing? What are the particular graphic conventions of the notation system which accomplish this? What is the position of the viewer (and the maker) of the drawing--that is, from where is it to be seen? What cues does the drawing provide which give us an understanding of the third dimension? What does it tell us about time?

In this section we will provide a description of each notation system based on answers to the set of questions which we have just outlined. To the extent that it seems relevant, we will try to say something about the history of each notation system, its development and dissemination as a technique for the representation of architectural space. We will also consider several ways in which different notation systems can be combined and cross-referenced to each other. Finally, we will discuss those conceptual devices by which the information of the notation systems is indexed to other kinds of information about the space they represent.

ORTHOGONAL SYSTEMS

First we shall consider those systems which collectively may be termed orthogonal: plan, section and elevation. These systems share fundamental assumptions, a method of construction and a set of conventions with respect to the way in which space is represented. Plan and section are, in some sense, reciprocal images while elevation may be taken to be a special instance of section. Taken together, the orthogonal systems provide a "complete" description of any space--complete, at least, in a very particular sense, with respect to certain kinds of information. This descriptive complimentarity has a long tradition and particular historical precedents, which we will outline below. Considered separately, however, plan, section and elevation each have a distinct and dramatically different significance which determines, in large measure, the utility and potency of each system as a representation of space.

Orthogonal systems provide an image of a given space as if viewed from an infinite number of hypothetical vantage points, each perpendicular to every represented feature. All space-defining elements--that is, planes, surfaces and objects--are drawn in terms of the outline of their edges, rendered as if they were equidistant from the observer, without any of the visual distortions that would be present in an image made from a single, actual viewpoint. Hence, the position of the viewer with respect the space represented in orthogonal images is located in some abstracted "outside"--above the space of the plan, in front of the space of the section and elevation. There is no actual point at which we stand: we find ourselves at no real distance from the image. The space of the drawing exists without reference to the position from which we engage it.

In each case, the features of the space are drawn as if they were reflected directly onto an imaginary plane. For the plan, this plane is parallel to the surface of the ground; for section and elevation it is perpendicular. In each case, the surface of the page is taken to be coincident with this imaginary plane, a kind of screen upon which all the edges of the space-defining elements below or behind it are traced.

Orthogonal drawings are pre-eminently representations of the visual world, translations of composite visual information--indeed, they contain no purely visual information whatsoever. Thus, they are an encoding of haptic and tactile sense perception, a visualization of metric relationships. The lines of the plan represent length, breadth and position; those of the section and elevation, height, breadth and position. In each case there is no relation to any real visual field, hence the colloquialism of "top view" for plan and "side view" for section is a misnomer. Orthogonal representations are very particular concepts (in the sense in which we have defined that term in Section 1); they represent the information of the visual world without reference to any visual field.

The orthogonal systems show us things as we know them to be: the metric relationships in plan, section and elevation correspond to the metric relationships in the dimensions of the space represented in each case. We may say that there are isomorphisms of measure and angle between orthogonal images and the spaces they represent; each angle between lines in the image is identical to the corresponding angle between edges of contiguous surfaces in the space. So, too, the lengths of the lines in the representation correspond by direct ratio to the measure of the surfaces in space.

Clearly each orthogonal system only encodes information about two dimensions of space. Because in each instance two dimensions are represented visually without the distortions of parallax, the third dimension (vertical for plan, horizontal for section and elevation) is necessarily "flattened." The logic of construction of the systems does not provide for any way to gauge the distance of a given edge from the imaginary plane on which it is represented. In plan, for example, the sill of the window is ostensibly part of the same plane as the floor. Such ambiguities are, in each case, most clearly resolved by making reference to drawings of another sort, an aspect of the complimentarity of such images. However, in each system a number of graphic conventions have been developed to assist the immediate visual reading of the absent third dimension from the individual image. Customarily, the edges of the surfaces through which the imaginary plane is "cut" are rendered darker than those which are deeper in the space of the drawing. In plan and section, the thickness or void of the wall is often shaded or otherwise coded. Continuous surfaces--horizontal in plan, vertical in section and elevation--may be toned so as to suggest their relative distance from the plane of the cut and their continuity beneath or behind objects closer to the plane which may partially obscure them.[1]

Such devices are sometimes also used to describe attributes of space-defining elements on "the other side" of the plane--that is, above the level at which the plan is taken as, for example, the representation in broken outline of a vaulting pattern in the ceiling or of a structural overhang. (An analogous convention is sometimes used in section, although it is usually more straightforward simply to make another section. Elevations may sometimes include indications of the attributes of the space behind the plane which is shown.)

All of these graphic devices are designed to enrich the total understanding which may be derived from orthogonal images by visually differentiating information according to the level at which it occurs and thus giving some indication of the third dimension. Such "depth," however, does not have the same correspondence to actuality as does the information presented for the other dimensions: it is always approximate and illusory. The overriding conventions and the rules of construction of the systems collapse the space--vertically or horizontally as the case may be--and provide no means for measuring real displacement.[2]

These, then, are the consistent logic and conventions of the orthogonal notation systems. As far as we have gone, the systems are identical.

The differences in their individual significance therefore do not follow from theoretical or structural differences in the assumptions of each, but rather from the differing significance of the dimensions of space and the space-defining elements which each system represents.

PLAN

A plan represents the surface of human action in space, the plane of movement. This is fundamental to an understanding of its significance as a system. The plane of movement has a curious quality of seeming ever unique: although there may be places in a given setting where transparency, void or juxtaposition create an awareness of several potential planes of movement simultaneously, there is, nevertheless, a tendency to experience the given plane on which one stands as singular and discrete. Furthermore, a plan represents this plane of movement with a completeness which is not achieved by any other form of representation. The singularity and completeness of the plane of movement as an experiential fact is reinforced by the logic of the plan representation itself: the absent third dimension and the other layers of the space (other plans) are not read as incompletions or inconsistencies of the image at hand, but rather as other domains, separate from what is represented. (As we shall argue below, this is not true of sections.)

For these reasons, the plan accommodates several different interpretations simultaneously. Because the continuous enclosing perimeter of the space is clear as the outer edge of the plan image, we may read the entire space as an isolated and identifiable figure with respect to its surround. In this sense, the plan may be seen as a kind of diagramatic emblem of the space, a statement of its essential form. Indeed, plans may be greatly simplified, even distorted, and yet retain this quality of standing for, of conjuring, the whole. There is a fundamental sense in which the plan is synonymous with the idea.[3]

At the same time, the plan illustrates the relationship of the figure (space, idea) to its surround and to other such figures insofar as these are part of the surround. Thus, we may read the relationship of one figure to others; the plan represents the interrelationship of built ideas. We may also read the ground between such figures (negative) as a figure itself (positive); thus the plan represents the reciprocity of built and unbuilt ideas.

Alternately, we may read our way "through" the plan, following in mind's eye each of the possible paths by which the plane of movement could be transversed. The significance of the plan here is that it represents all conceivable paths--all possible movement--in a single image.

Finally, a plan is a representation of invariant relationships, of separations and continuities in space. It is significant in this respect that a plan has no "correct" orientation, no top or bottom. The absence of any specified orientation vis-a-vis the space represented in the drawing allows us to rotate the plan at will, to consider it from any angle. The information which it is designed to convey is indifferent to our vantage.

SECTION

Whereas a plan shows us the length and breadth of the plane on which we move and the location of the vertical surfaces which confine movement, the section shows us the length (height) and breadth of the vertical surfaces which confine movement and the vertical location of the plane(s). Such a formulation reveals the absolute complimentarity of the two notation systems, considered as abstractions. But in terms of our actual experience of the dimensions of space which plan and section represent, the inversion of priorities in section which creates theoretical complimentarity at the same time undermines any possibility of a complimentary experiential significance. For, inasmuch as it is true that at any given moment we experience but a single plane of movement, it is equally true that we are aware of a multiplicity of vertical surfaces which confine movement and contain space. For this reason alone a single section can never present a space with the same conceptual clarity as a single plan. But the difference runs deeper than this.

As we move through space, we are aware of the section of the space changing in a way that the plan never does (or, at least, that we are never aware of in the same way). For example, the plan of a longitudinal cathedral with nave, transept, side aisles and central altar is customarily flat, except at the crossing; in any case, the entire plane of movement can be represented in the plan. The section above this datum is, however, quite varied: low vaults over the side aisles; higher vaults, perhaps vaults of a different kind, over the central nave; a dome of yet another height over the crossing, with yet another section in its pendentives; the vaulting of the apse; and so on. To move through the church is to experience these changes in section (indeed, there are those who argue that it is precisely this modulation of section that gives meaning to the space (Arnheim (7), Souriau (42)). No one sectional image can, however, fully represent these changes; the cut along any one line will invariably exclude some. To the extent that we are familiar with the particular space represented, or even with the kind of space represented, we may well be able to anticipate many or all of the successive changes and so "read" the whole space from one section, but it cannot be represented in a single sectional image.

The section is further distinguished from the plan in that it has a specific orientation--the floor or ground is always the bottom of the image. Hence, there is a visual equivalent for gravity and weight. Furthermore, of the two dimensions presented (and the absent one which it partially suggests), only the information of the vertical is complete. Thus any section is--in a manner not true of plans--dependent on all other possible sections; completeness of sectional information can be achieved only to the extent that any section can be visualized in relation to all others. The plan, to be sure, does not show all the variety of the space nor does it fully explain its experiential qualities, but it does show everything that can be shown <u>in plan</u> in one image.[4]

As we have noted above, the section, like the plan, collapses the space it represents, offering no structural cues as to the presence of depth, although these cues may be added. But this collapsing, too, has a different significance in section than in plan, for the ambiguity which it creates here concerns the possibility and the extent of our lateral movement through the space (the limits of our movement into the space of the section, as it were). Furthermore, because habitable space must be comprised of continuous ground and discontinuous vertical surfaces, a representation in section will almost invariably occlude the character of distant vertical surfaces behind those that it represents. (In the example, the longitudinal section of the nave hides the pilasters on the walls behind the columns; in spaces of less symmetrical regularity, the surfaces behind what is shown in the section may give no cue as to what is behind it.)[5]

There is yet another respect in which the section is an ambiguous representation. Sections, like plans, are constructs of metric--that is haptic and tactile--information; they relate to the visual world. But unlike plans, sections have a curiously visual, or "aspectual," quality. They don't look just like what we see of a space, yet they seem to resemble something we think that we might see.[6] Thus there is a tendency to deal with sections as if they were purely visual information and a consequent, albeit curious, sense in which the section may be taken to bridge, at least in part, the gap between the thing as it looks and as it is. But it is this very resemblance to the glance that makes the section, finally, less significant as a representation; glances (aspects) are plural--they change as we move and it is only the sum of many aspects which bears any full relationship to, and has any power to evoke, our concept of space.

ELEVATION

Elevation may be considered as a special case of section, alike in every regard as a notation system, but taking as its object only the exterior of the building. For this reason, however, the elevation is not limited by some of the shortcomings of the section. We are not primarily interested--in looking at an elevation--with what is located behind the surface which is represented, but only with that surface itself. The elevation is the image of the side or facade of the building and it is customary, although by no means necessary, to "take" the elevation parallel to the side of the building being shown. We tend to assume, therefore, that there are as many elevations as there are discrete sides to the building--a limited and self-apparent number--whereas, as outlined above, the number of significant sections is by no means so limited, nor so apparent.

Elevation, like section, is ambiguous with respect to depth and offers no cue by which a jog in plan may be immediately read although, as with plan and section, a set of secondary devices may be added to give some sense of this absent depth. Like section, too, elevation has a tendency to be read as a view--that is, to closely resemble and hence come to stand for something which we think we might see. However, somewhat paradoxically, the elevation becomes a more potent image by this confusion. Elevation is primarily a compositional device, drawn so as to compose (or discover, as some design ideologies would have it) the form of the exterior surface--the disposition of the functional and decorative elements in the plane of closure. As such, it has a preeminently visual function, even though the elevation per se does not correspond to any view of the facade we actually see. But this ability to be taken for the "thing as seen" is, therefore, especially appropriate. As a representation, and as a system, elevation bears a close resemblance to the significance of the component of the experience for which it stands as a surrogate.[7]

The ambiguity of the elevation, its tendency to stand for a purely visual image of the surface, seems to enhance its potency as a representation. Indeed, the principal elevation--most often the entrance facade--may come in mind's eye to stand for the building as a whole. This is clearly, and intentionally, the case for many buildings of the Renaissance and for Gothic cathedrals, for example, but it is to a greater or lesser extent true of all buildings. The act of entering constitutes, at some point, the penetration of a surface and our image of that surface is likely to stand, at least in part, for an understanding of the building per se. The elevation may thus become closely correlated with the concept of the space--the "formless and timeless invariants" of the visual world.

One other, associated respect in which an elevation closely resembles a plan is the quality of its completeness as a figure standing against a surround. The elevation reveals the vertical edge--the continuous perimeter of the built space in the other dimension--and so allows us to visually understand its position with respect to other edges and the singular identity of the building as an independent form. The same reciprocity of figure/ground that we cited as true of plan is true here, and this may further add to the significance of the elevation as a representation. Again--as with plan--the absent other sides, like the other floors, are not experienced as, or read in the drawing as, incompletions; each drawn elevation, as each drawn plan, is largely self-sufficient.

* * * * *

The history of the orthogonal representations as generic types of images would seem virtually impossible to trace.[8] However, the history of the development of a particular kind of plan--one which is complementary to, if not the sole precedent for, the use of plans in architectural practice--has been documented. This is the kind of drawing which Pinto has called the ichnographic city plan.[9]

The development of the ichnographic plan must be seen in the context of cartographic experimentation in the second half of the 15th century. Two other kinds of city images predated its appearance in the western European tradition: the iconic map and the view. The former were most often circular images in which a group of monuments were chosen to typify the city. (The circular format is a characteristic which these medieval images share with "world maps" and "heavenly maps," which date back to the 8th century.)[10] Indeed, the iconic map may be seen as a kind of local cosmography, presenting the city as an idealized arrangement of symbolic abstractions. It was the translation of this symbolic hierarchy onto the page which was of greatest importance in these images: no systematic representation of scale and distance--that is, of real space--is to be found.

The views, by contrast, were renderings of greater or less accuracy of the city as seen from a single vantage point; sometimes a nearby mountain or town, more often a fictive, celestial perch. The problems of constructing such views were formidable. Even with the later adaption of perspective technique, the intrinsic limitations of any view remained; the various illusionistic devices which created the apparent spatial effect at the same time confounded an understanding of actual spatial relationships. Even to the extent that such difficulties could be overcome, the view remained a selective representation of purely visual information, an image which corresponded with appearances.

It was, on the other hand, just such an understanding of actual spatial relationships that the ichnographic city plan provided. One of the very first was Leonardo's plan of Imola of 1502.[11] What most concerns us here is that such a drawing represented a complete departure from the logic and conventions, as well as the substantive priorities, of the earlier images--a wholly different kind of abstraction. This new plan was a visual construct based on metric rather than visual information which made a correspondence with the physical reality of things and did so, moreover, by a coherent systematization of the drawing process. This was a representation of the city from without rather than within and at the same time a framework from which both the general layout and the configuration of its component parts would be understood.[12]

PERSPECTIVE

Whereas plan, section and elevation are all "conceptual" systems--representations of and constructed from the information of the visual world--perspective is, above all, a visual or "aspectual" system. Its referent is "pure" vision and its conventions are determined accordingly. It is the antithesis of the three systems we have thus far presented.

A perspective is a view, an image of appearances. The lines on the page are drawn in such a way as to exactly replicate the edges of the planes and surfaces in the scene as it would appear from a fixed vantage point. A perspective is a visual field and thus, unlike the orthogonal images, the space of the perspective representation has a precise correspondence with one position in the space outside of the image. It is this point from which the image is made and from which, ideally, it is to be seen. Thus, the position of the observer is known and fixed.[13] The perspective may thus be seen as a conditional explanation of visual spatial relationships--"what things look like from <u>here</u>." It is in this condition that both the great power and the great limitation of the system lie.

In the discussion of the orthogonal systems, the question of which planes and surfaces of any given space are to be presented in an image is answered by the rules of each system, without reference to the particular space or image under consideration. Inclusion of more or less information becomes therefore simply an issue of whether the plan, section, or elevation is more or less complete. In perspective representations, however, how many planes and surfaces are to be shown and which particular ones become questions to be answered less by an a priori set of rules about perspective than by the selection of the point of view. A perspectival image of a square interior may show five of the six space-defining surfaces (floor, ceiling and three walls), whereas a perspective of the exterior of a building will show two exterior walls. Thus, the relative quantity of information is a function of the vantage point, rather than--in the sense it was before--an intrinsic limit of the notation system itself.

The primacy of vantage point affects the quantity of information in a given perspective image in yet another way. Since the path of vision follows a straight line, any point of view will set up juxtapositions of planes and surfaces in which near objects will obstruct the sight of far ones behind them. This much was, of course, equally true of sections and the orthogonal systems generally. But since the perspective is but one of an infinite number of possible perspectives and given the ability to select a vantage point, we may accordingly select from among an infinite set of of juxtapositions. If we want to represent the axial relationship of the pilaster and the column which was impossible in section, we need only choose a position oblique to their axis from which to make the perspective.

There is also a question of what was termed correspondence of the drawing to its referent. We noted that plan, section and elevation are all isomorphic to their referents with respect to measure and angle. Clearly this is not the case with perspective. But we cannot so easily formulate a rule for all perspectives to serve as counterpart to this isomorphism of orthogonal representations, because the degree of visual distortion (diminution of size with distance, apparent parallax of parallel edges and so on) is itself a function of the position of the observer. For any particular view, the relative distortion may easily be found and for all possible perspective views the method of finding it is the same, but the particular vantage point is the critical variable determining for each representation the apparent measure and angle of the lines. Hence, the making of the drawing becomes an implicit part of the drawing; the act of representing is, in some sense, itself represented. It is in this respect, finally, that perspective is most unlike the other notation systems and most clearly an artifact of "pure" vision.[14]

The utility of perspective representations is, of course, in their suggestion of "true" depth, the illusion of space. Perspectives are the most immediately accessible of architectural drawings; they require no special effort to read. The great visual power of the perspective image proceeds from the fact that the coordinates which create its illusionistic space can be projected "out toward" the observer as well as "in away" from him, so organizing all space in its logic of appearances. One correctly drawn perspective becomes, in a sense, a visual representation of the entire world.

Yet when we want to know "how things are," perspectives tell us much less, though they are not altogether mute. As we observed in Section 1, there are certain moments and certain positions in which the concept of an object seems to be contained in a particular aspect. So, too, there would seem to be certain perspective views which explain more--or rather, in which more can be read--than others. For example, a bilaterally symmetrical building will appear so in a perspective if our point of view is in line with the central axis. What occurs is a kind of visual recognition of symmetry: the two parts look identical and, given the location of the vantage point, we know that they would only appear to be so if, in fact, they were. But making such a visual inference--this act of recognition--depends once again on an understanding of our position in space with respect to the scene. To verify such an inference we must, as before, resort to other kinds of information and so, to other kinds of representations.

So far we have confined our discussion to what is strictly termed linear perspective. This is the basic framework on which the images generally called perspective are based: the principles of construction which prescribe the angles and measures of lines and the regular diminution of apparent size of objects as they recede from our vantage. But there are two other components of perspective vision which reinforce our reading of depth in the perception of visual fields and are themselves the basis of graphic techniques which may be used to clarify and enhance the reading of depth in perspective images. There is the perspective of color or light, whereby surfaces and objects at a greater distance appear to be darker in tone and there is the perspective of resolution whereby surfaces and objects at a distance reveal less quantity and clarity of detail. As graphic devices, these rules (i.e., farther=darker and farther=vaguer) are the equivalent for perspective of the depth devices we lister earlier for the orthogonal systems.[15]

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In contrast to that of the orthogonal systems, so much has been written on the history of the discovery (or as some whould have it, the invention) of perspective and its dissemination as a technique from the Renaissance on that little purpose would be served by its repetition here. Yet, a few remarks on events and theory surrounding its development will help to clarify its significance as a notation system in architecture.

We have thus far not mentioned what is, in many ways, the most important attribute of perspective as a notation system--that is, its basis in mathematical relationships and therefore in "objective" fact. This was, of course, the chief claim for the new system among its early propagandists and the subtle minutia of that basis took the greater part of two centuries to fully resolve. Perspective was, as in the title of W. M. Ivins' wonderful essay, the rationalization of sight. Prior to its development, there was a currency of realistic images, realistic in the sense that they served as credible simulacra of the people, places and events which they purported to describe. The significance of perspective was in the fact that it systematized image-making and made its tenets and techniques a logical extension of the laws which described other phenomena.[16] Visually "correct" images could thenceforth be directly, mathematically related to their real, three-dimensional referents. Conversely--and more importantly from the standpoint of making images--objects and settings could now be understood in a way (seen in a way) which permitted their translation into a particular, mathematically rigorous, representation.

Ivins credits this as the single most important occurrence in the history of the Renaissance (over, for example, the fall of Constantinople, the discovery of the New World, the Reformation and the development of moveable type and printing, to name but a few) and his argument is quite convincing. He interprets the development of perspective as a manifestation of a shift in modes of knowing the world which posed a new problem of translation, and it is especially in this regard that his interpretation bears on our discussion.

In examining the tradition of "space intuitions" prior to the Renaissance, he summarizes Euclidean geometry: "...the origin of which in tactile muscular intuition is shown by its nearly complete pre-occupation with metrical problems and its essential dependence upon congruence." The dominance of the tactile-muscular intuition brought with it "...failure of that geometry to take account of visual intuition."[17] He illustrates the limits of this single-intuition reasoning with the famous problem of parallel lines: the returns of the two space intuitions are contradictory (by sight the lines meet; by touch they don't). Perspective therefore represents the substitution of a visual space-intuition for a tactile-muscular one made possible by the elaboration of "...the hitherto missing grammar or rules for seeing both the logical relations within the system of symbols employed and a reciprocal...metrical correspondence between pictorial representations of objects and the shapes of those objects as located in space."[18] Description and representation were thus unified—the visual world and the visual field shown to be a continuum.[19]

It is important to emphasize that perspective imagery is based upon, and constructed from, the same haptic and tactile sense returns which form the basis of the orthogonal systems, but this metric information is used to a different end. In perspective the metrical representation is implicit but transformed in the final image; it is the means to making an immediate, visual impression--an aspect. In the orthogonal systems, the metrical representation is itself explicit--directly represented in the image--while the visual impression is implied, but must be derived by a translation on the part of the viewer. (We shall expand on this notion of complimentarity below.)

ISOMETRIC PROJECTION

The last notation system which we will consider is that of the class of representations which may be called isometric projection. Called variously isometric, axonometric and plan oblique, these images all share the basic characteristic of preserving scaled, dimensional relationships along two or three of the axes. An image thus constructed creates the impression of a three-dimensional reality by suggesting depth without, however, adopting the compensating optical distortions of the scenographic perspective system and at the same time allows for an "objective" scrutiny--that is, a measurable one. It was this combination of visual illusion and metric accuracy which was the impetus to the development of the system, and its application to architecture. However, if isometric projection combines the seeming advantages of both orthogonal and perspectival systems, it also lacks elements which are essential to each.

Despite the illusion of three-dimensional space--of depth--isometric images are representations of the information of the visual world. They correspond to no possible aspect for the reason that their construction depends on no actual vantage point. Rather, as with orthogonal images, the position of view is relative to a plane.[20] And, as with plan, section and elevation, the information of the isometric projections is the haptic and tactile returns of perception, but only in part. In order to create the illusion of depth, isometry sacrifices the isomorphism of angle which was a cardinal virtue of the orthogonal aystems. With isometry, measure is constant, but angle is distorted. Thus, circular apses become elliptical segments, square columns take a diamond shape, and so on. This distortion is systematic--that is, it can be translated to the real (i.e., plan) formulation by a simply algorithm (but a curious one; angles drawn as 60°, 90° and 120° may all be equal to 90°, as in Choisy's drawings).

At the same time, isometric projections--like sections and perspectives--obstruct some portions of the information by the representation of others. This problem may be ellided if the building represented is bilaterally symmetrical (as were so many of Choisy's examples); the observer can mentally complete the rest of the space. But with asymmetrical and irregular plans, isometric images become quite confusing. The observer cannot so easily, or cannot at all, "complete the space." (This explains, at least in part, the tendency of so many of the de Stijl images to look as if they were all exterior surface, with an implied and apparent but finally incomprehensible spatial depth.) Furthermore, unlike perspective in which the occluded portions of space or surface could be logically referred to actual appearance from a real position in space, the vagaries of isometric images have no such visual explanation. The system imposes restraints--which the draftsman may use to advantage--but there is no a perceptual logic to guide his choice.

One final ambiguity which isometric projection poses is the relationship of the image with respect to the page. As noted above, in the orthogonal systems the page may be considered as a screen which corresponds to an imaginary cut either parallel or perpendicular to the ground plane. In perspective representation, the page may be thought of as a screen which stands in front of the viewer, perpendicular to his line of sight (Alberti wrote of a veil of fine cloth which artists should imagine before them; Durer's famous engravings of the artist and his model make the imagined veil a literal piece of gridded glass). In isometric projection the page has no such actual or imaginable correspondence to the space represented--the image or, to be more precise, the spatial meaning of the image and the surface upon which it is drawn, are discontinuous. (It is perhaps for this reason that isometric representations so often seem to be floating or ungrounded images.)

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The history of isometric projection as a formal notation system is an intriguing one. The essential principles were applied, with varying degrees of precision, to problems in a wide range of fields--painting, stonecutting, construction and engineering--before their application to architectural problems, and the use of such images to which we are accustomed today represents something of a blending of several traditions.[21] In architectural practice, there are instances of the use of illusionistic representational systems which approach isometry dating back to the 16th century in the drawings of Peruzzi and others active in the fabrica of St. Peter's.[22]

What we know today as isometric drawing had its origins in the work of Gaspard Monge, the 18th century mathematician who formulated the basis for descriptive geometry.[23] Monge was instrumental in founding the Ecole Centrale des Travaux Publics of Paris in 1794, which was renamed Ecole Polytechnique the following year. Its charge was not only the preparation of students for all aspects of civil and military construction but, under Monge's direction, the pursuit of the general, theoretical foundations of all technological fields.[24]

From its inception, the Ecole included one professorship and several courses of courses of instruction in architecture. Unlike the Ecole Speciale de l'Architecture (the forerunner of the Ecole des Beaux Arts)--in which theoretical issues in design, composition and history were emphasized--the program of the Polytechnique focussed on construction and the history of its techniques. This was exemplified in the treatises of one of the best known of the Polytechnique's architects, Auguste Choisy. Exactly one hundred years after Monge's Geometrie Descriptive, Choisy published his two-volume L'Histoire de l'Architecture (1899), which applied Monte's principles to the illustration of architectural space in a methodical way for the first time. His text compares buildings of all ages from the "prehistorique" to his own, with a central view to issues of construction. It was as much this particular emphasis, we may suppose, which recommended the use of isometric projection as the author's position in the school which preserved the legacy of Monge's work. In an introductory note to volume 2, he comments that the system has "...the clarity of perspective and lends itself to direct measurement."[25] The visual persuasiveness and therefore the value of Choisy's system stem primarily from the particular use to which he put it: his was above all an illustrative text intended to facilitate comparison of diverse building technique. The "abstract figuration of plan, section and elevation" which he sought to supplant with images "as lively as the edifice itself" was, of course, precisely the abstraction which, three centuries earlier, Raffaello had proclaimed as essential to the architect's art. This juxtaposition of views points to the larger issue of the use of the notation systems severally, in combination, superposition and succession. To this issue we now turn.

* * * * *

We have suggested that isometric projection combines information available in the orthogonal systems with some approximation of the characteristics of "visual space" to be found in perspective. (It could be argued that isometric representation could be derived from a progressive distortion of the principles of perspective construction, along the lines of the cavalier perspectives, discussed above.) Certainly as Choisy posed it, isometry was a combination of plan section and elevation so contrived as to produce illusionistic qualities. The components of each of the orthogonal systems were transformed in a way which preserved some essentials of the information and yet made explicit the coordination of the separate planes which had previously been hidden. Moreover, the method of combination resulted (unlike the cavalier perspective) in a systematic means for the construction of such images, one which was entirely independent of viewpoint, actual or imaginary.

There is a sense in which perspective itself may also be regarded as a combination, or superposition, of the orthogonal systems. In his critical analysis of Alberti's text, Ivins makes use of a simple, visual model--a box-like "peep-show," similar to the sort which Alberti himself is believed to have used in his famous demonstrations and which so amazed his contemporaries.[26] With the aid of this device, Ivins demonstrates quite convincingly that the original formulation of perspective construction published by Alberti may be derived from the superposition of the section (of the visual "cone of rays" from the fixed eye to the square in plan) rotated 90 degrees onto the elevation (of the same cone of rays). What is thus produced, without recourse to mathematical theory or the abstraction of vanishing points (which, as Ivins rightly points out, would have made no sense at all a century and a half before Kepler's postulate on parallel lines), is quite simply Alberti's first diagram by which the square is thrown into a "correct projection." Thus it may be argued that as the theory of perspective representation follows from a mathematical manipulation of extant physical relationships, so too the mechanics of the perspective notation follow from a manipulation of the orthogonal systems which represent those relationships.[27]

By a rather circuitous route, we have come back to the assertion which we made in Section 1--that the visual world and the visual field were in every sense reciprocal components of visual perception which could, under particular circumstances, be directly cross-referenced and, indeed, substituted for each other. The systematization of perception has a precise analogue in the systematization of representation. Ivins' unraveling of perspective shows that the representation of an aspect (any aspect) is indeed a process of transforming the information of the visual world and its representations. So, too, once we have Alberti's formulation, we may reverse the process and derive the haptic and tactile information components from any aspect.

Such an interpretation of perspective also helps us to make sense of several other kinds of images which combine different notations, especially the so-called section-perspective. A section-perspective is a device used primarily to explain the apparance of interior spatial relationships.[28] Like the section, this kind of image represents the space as if bisected by an imaginary vertical plane but with all space behind the plan rendered in one-point perspective. Conversely, such images may be seen as full perspective representations which have been "sliced" at some known distance from the vantage point of the observer--the plan thus created at that precise distance rendered in scaled (i.e., metrically accurate) fashion.

Ostensibly such a combination of notations violates the logic and conventions of each: the section as notation assumes the observer to be at an unspecified (infinite) distance while the perspective, by definition establishes the observer's precise vantage point. Visually, however, there is no contradiction--the image appears to make sense. The reasons for this are several. First, the two sets of notational conventions are working in separate parts of the drawing, impinging upon one another only at the interior edge of the section so there is no apparent (visual) contradiction. Next, as we have observed before, the section has a curiously aspectual quality, an ability to seem a plausible view of the thing as seen, and this is exploited to advantage here. But most importantly, such an image again attests to the interrelation of visual and tactile/haptic sense perception and representation, for the perspective may be conceived as an infinite number of parallel sections marching to the horizon's vanishing point. At any given point, we may remove those before us to a certain depth in the image; what remains will be a section-perspective, with a "face" which can be accurately measured and an image of what is beyond it.[29]

With a discussion of the succession of images and its impact on the understanding of architectural space, we turn from a consideration of how the component parts of the space may be understood from discrete representations to the larger question of how a space may be understood in its entirely from a particular set of images. We outlined in Section 1 a theory which explains the processes by which we come to an understanding of space on the basis of sense perceptions. Implicit in what we have said in Section 2 is the idea that the representations we make of space must be based on that same information of sense perceptions, and we have tried with each notation system to outline the ways in which those sense perceptions are translated and structured into graphic images. With the question of the impact of a particular succession of images on our understanding, we must address the issue of what similarities there are between our understanding of space from our representations of it and our understanding as based on our experience of it.

We have made several references to Raffaello's letter to Pope Leo X of 1519 in which a particular view of drawing and of the appropriate use of kinds of drawing was forcefully articulated, a view which we have said has become the paradigm for an understanding of architectural space from representations. What Raffaello prescribed, as Lotz explains, was the systematic separation of plan, section and elevation, and their scaled interrelation in the representation of architectural space.[30] Implicit in this view of orthogonal representations was a particular notion about how architectural space should be understood and what set of representations was to be considered as complete.[31] It also presented a very particular way of thinking about space in drawing (or "reasoning about space," to use Poincare's phrase) which was, we may suggest, altogether different from the way in which we reason about space in our experience of it. Let us pursue this contrast.

In our experience of space, we start with a series of aspects and work toward a concept which embodies our cumulative understanding or knowledge. We may call this process inductive--assembling fragments until, either gradually or with a sudden start of realization, we understand the space in its entirety (of course, we may in fact never reach that point for a particular space). At that moment we can, in theory at least, create for ourselves on the basis of our concept along an image of every possible aspect of the space, even those which we have not yet experienced. We know the space. (The particulars of this inductive process will vary with each person's experience, but the form of the process--from fragments to whole, from aspects to concept--will be the same.)

In coming to an understanding of space from representations of it, we may in principle start with the counterpart to such aspects, i.e. perspectives and mimic to some extent the inductive process we have just described. After all, just as it specifies a vantage point, a perspective specifies a temporal position in an implicit succession of images or, more precisely, a single temporal position which may be part of many possible successions of images. But, in fact, we seldom follow this method in dealing with representations.

The particular succession of interrelated representations specified by Raffaello structures our knowledge of space in an altogether different way, a process which might be called deductive. We confine our inspection to the orthogonal systems. Customarily, we start with the plan which, as we have observed, is in one sense an outline of the entire space--it anticipates the concept, as it were. As we move to sections and elevations, we may add new, even surprising information to our understanding, but it is largely anticipated in the plan. However, the plan is itself an image of information which could, in experience, only have been discovered from a succession of views (aspects). It represents a portion of that same composite information by which we inductively build concepts, but in a completely new form--as a single image, seen simultaneously. Thus, the process which is characterized in experience by a directed exploration in time is here translated into an image which is immediately apparent. The inductive process of correlating discrete aspects by which space is known in experience is replaced by a deductive one in which images of composite information, presented successively to view, must be conceptually interrelated.[32]

The point is a difficult and ambiguous one and it is perhaps best not to hang too much on it. This much is clear: the processes of knowing space in experience and knowing it in drawings are conceptually distinct; both processes utilize similar information in particular temporal arrangements but in very different ways.

* * * * *

Havings suggested some of the ways in which drawings may be combined, it remains to discuss several concerns common in one guise or another to all the notation systems we have examined which may be grouped under the headings of scale, grid, and key. These devices, in each case, correlate information which is technically outside the domain of the notation system to the drawn representation. Together, they provide the framework by which information contained in one representation may be compared with or transferred to another and, finally, the means by which the knowledge in drawings may be extended to knowledge in its other forms.

SCALE

Scale has three aspects. It is first a means of relating dimensions by a set ratio; a particular scale simply specifies that so many units drawn shall stand for so many units as seen or built. Hence, it provides a means of preserving proportional relationships while manipulating the absolute size of the representation. Next, scale is a device for bringing to bear on drawings what we know of numerical relationships in general. Scale allows us, therefore, to express graphic equivalences as numerical ones and so establishes a reciprocity between representational thinking and numerical (arithmetical) thinking. Finally, scale permits the relation of drawn information to certain dimensional absolutes which, for any of a variety of reasons, we may hold to be of significance. We shall look briefly at each of these in turn.

Even if there were no other reason, architectural drawings would utilize scale for sheer practicality; that a plan of a space drawn full size would be unmanageable is too obvious to require discussion. Hence, one benefit of scale is the potential to miniaturize and one benefit of miniaturization is convenience: the absolute size of the image is reduced to manageable proportions. But this convenience is not achieved without consequences.

Though proportion be preserved, absolute size counts for something: images alike in every detail save size do not, cannot, have the same significance. Levi-Strauss has remarked that the tendency to make the depiction smaller than the object invites the viewer first to comprehend the entirety of what is presented and only secondarily its components. (Miniaturization in this sense accomodates deductive thinking; we are given the whole and surmise what we do of the parts in relation to that given.)[33]

The qualitative simplification produced by quantitative diminution of which Levi-Strauss writes has an actual as well as a metaphorical truth. Given a constant capacity of resolution, a smaller image must contain less information than a larger one. This observation provides a kind of normative axiom in looking at, and in making representations. The scale at which the plan is made is taken to prescribe both the quantity of the information included in the drawing, and the quality of its resolution (or the completeness with which it is drawn). The four ways in which a plan may be read which we outlined above correspond, in large measure, to different levels of quality and quantity of information. (Indeed, some portion of the plan may even get to be the full size of the detail which it represents and thus become a template or pattern.)[34]

In its second aspect, scale seems also at first blush a purely pragmatic device: it is the formalization of measure. Having drawn a line to scale we may find the measure of the surface which it represents and so measuring the drawing becomes a way of measuring the space. Scale keeps the laws of spatial relationship in the drawing constant with the laws of spatial relationships in the visual world.

By using the "language" of numbers in drawings, however, scale also provides us with numberical shorthands for describing spaces. The graphic configuration which we see in plan may be formalized as an "x sq.ft. space." The two are not, of course, strictly equivalent because the "x sq.ft. space" may take an infinite number of actual configurations. But this is, in a way, just the point. Scale allows us, for better or worse, to think about space in the far more abstract terms of arithmetic and geometrical relationships.

In this regard, also, scale has a strictly operational function. It allows us to relate the separate representations of plan, section and elevation to one another--to gauge, for example, equivalences in the openings shown in each and so on. Often, we need only know that two drawings are "to the same scale" (or even to different scales as long as we also know what the ratio of the two scales is) in order to read the information of each in terms of the other. This "reading" is a visual exercise, but it is the numerical scale relationship which assists, indeed permits, it.

Finally, there is the question of dimensional absolutes. Regardless of what all else we may read in a drawing, at some point we wish to know how the space represented relates to our size. This, of course, may be expressed in various ways from the specification of precise dimensions based upon experimental analysis of human activity, to the elaboration of dimensioning systems based upon proportions and ratios which have a particular significance.[35]

GRID

"Lack of scale," as Lotz wrote, "is a correlate of the perspective construction; as we know, the section through the optical pyramid provides no clue to the true dimensions so long as there are no human figures in the picture."[36] For this reason, our discussion of scale has been necessarily confined to the orthogonal systems. We now turn to the consideration of grid, a device which performs an equivalent function in perspective, but the ultimate significance of which is not confined to that end alone.

Lotz might have added that a geometric surrogate for the human figure would do nearly as well and it is indeed just this which Alberti's construction of perspective provided for scaling perspective images, almost inadvertently. The grid--a matrix of uniformly spaced perpendicular lines--had a widespread use as a practical device in the transfer of cartoon sketches for fresco and the execution of sculpture, perhaps even architecture, in the early Renaissance.[37] The presence of the grid was built into Alberti's derivation of perspective construction.[38] Whatever its source, its consequence was that once the viewer could find any object in the image the size of which could be determined (often a human figure), he could, simply by judging the size relationship of that object to the grid, immediately comprehend the dimensions of the entire space, as <u>the grid was a constant</u>. If the image was accurately made, therefore, the measure of the space could be taken.[39]

We have already mentioned Alberti's gridded veil and Durer's gridded glass, which were the heuristic devices for the artist engaged in making the perspective image. It may have been the notion of this imagined vertical plane interposed between scene and eye which was the impetus to the use of the grid on orthogonal images, or it may simply have been the result of the kind of scaling process which Raffaello recommended for the preparation of such images in his letter of 1519, which amounts to laying out a grid.[40] However, once the grid was applied to plan and section, the ability to translate between orthogonal and perspectival representations was provided with a visual shortcut. As long as the dimension of one side of one square could be verified in each of the images, the representation of space in the visual field and the visual world was visually reciprocal.

KEY

Finally, we turn to key or legend. A key is simply any device which makes a translation of graphic information into written language. Thus a key permits us to relate representational thought to verbal thought in the same way that scale relates representational to numerical thought. At its simplest level, this process amounts to the identification of the parts of the image: we see some part of the space in plan, the key tells us what it is called--a kind of formalization of labeling. The presumption is that the written information underscores or may add to the information we surmise directly from the graphic image.

It is interesting to note that key is customarily used with plan, sometimes used with section, scarcely used with elevations and isometrics, and almost never with perspectives. There is, it seems, a tendency to make greater use of verbal information as the representation is less immediately visual. This may perhaps be because verbal notions help to provide substance to visual concepts which do not have an "aspectual" character--but conversely, it seems more probable that verbal information may intrude less, be more of a kind with visual material that is more conceptual in nature.

As we suggested might be true of numerical thought with scale, so too verbal thought may as much obstruct as enhance the information we understand from the image itself. Verbal information defies the graphic conventions of the notation system--which convey a visual sense of the qualities of space--by substituting instead a verbal concept, a name. Words may not speak louder than the images for which they serve as captions, but they often speak more quickly and always in a different voice. To the extent that seeing is a struggle to identify something (and our engagement with architectural drawings an attempt to identify the space visually), naming may preempt seeing; at least it will condition it. The grafting of verbal to visual thought is a topic well beyond the scope of this essay, but we may suggest that the particular meaning of such combination for architectural drawings is likely to be found in the resonances, or patterns of association, which certain spatial concepts have in verbal, as opposed to visual, representation.

SECTION 2

Notes

1. The darkening of farther surfaces in section and elevation is an adaption of perspective devices, as we shall see.

2. The authority of this conceptual organization is absolute; in plan, for example, the occasional oblique surface (e.g., ramp or roof) is rendered as a rectangle with its higher and lower edges seemingly in the same plane. To accomodate the irregularities of natural terrain, the plan uses the abstraction of contour lines which locate the hypothetical intersection of the landscape surface with a series of imaginary planes referenced to some arbitrary height.

3. This notion--plan as idea--has, of course, been explicitly proclaimed during certain periods of architectural history (and at other times as vigorously denounced). Its origins, however, I think run much deeper; it is not simply fortuitous that our word plan has the double meaning, also connoting strategy, design or idea; it is consistent in its etymology through other languages to its Latin root "planus." This association of diverse meanings reflects, I think, this same quality of completeness as a representation of the realm of action.

4. It may be objected that in our example the plan would not reveal the presence of the catacombs and crypt or of the walkways above the aisles; again, these multiple plans do not constitute a part of our momentary experience of the space as we stand before the transept, whereas the multiple sections do.

5. There is, I believe, a particular habit of mind in looking at plans and sections, explication of which may further characterize the distinctions made here. There is a general tendency to read the third dimension in both kinds of images by mentally "extruding" the image given along the absent third axis. If this is true, there is generally a much greater correspondence between the mental image thus created and the fact when one extrudes the plan vertically than when one extrudes the section horizontally. In most spaces (although certainly not all), the mental exercise in plan will provide a fairly accurate picture; we don't know from the image how high the space is or where, for example, the vaulting may begin to constrict it, but this extruded plan image will be accurate as far as the location of all the space-bounding vertical surfaces is concerned. It approximates a passable concept of the entire space, a working hypothesis to which subsequent information can be added--the plan anticipates the concept. The extruded section, and the section itself, achieve no such analogous approximation.

6. We can, with only a slight effort, imagine the section from the aspect--the glance; indeed, a section can often be drawn from a single photograph.

7. This ambiguity between the elevation as drawn and the facade as seen in actuality may itself become a part of the formal composition of the building as a whole. In his text on Beaux Arts drawings, Drexler describes a project of F. Duban, a Customs and Tollhouse of 1823. The major approach was to the narrow end of a long hall which was to be flanked some sixty feet or more behind by twin wings and some sixty feet or more behind these, transected by a tall and very wide main hall. The person approaching the entrance would have been aware of a low masonry wall with a single entrance and, at some depth, a second set of flanking walls--perhaps a vague impression, at some very considerable depth--of the main hall. But in drawn elevation, except for a shadow cast by the entry gate, the entire facade reads as one wide, continuous surface with no dislocation in depth, thus creating a singularly imposing aspect, all the elements integrated on a truly monumental scale. Drexler writes: "...the visual difficulty of indicating relative depths is actually incorporated into the conception and used to generate its thematic development....A model or perspective would make the relationships easier to understand, but would omit just those juxtapositions, fictitious but conceptually decisive, that are inseparable from the language of elevation drawings." Drexler (12), pp. 33-34 (emphasis added). We see here an instance of the role that the conventions of the notation systems can play in directing the elaboration of the design concept--a theme to which we will return in the final section.

8. Because of the extent to which it accomodates abstraction and distortion while still maintaining its essential character plan, for example, may be given a very broad interpretation. H. Pirenne writes that the Egyptian hieroglyph for city was a kind of idealized plan image; diagramatic plan-type representations of cosmographies may be found in many cultures, dating back millenia. It would seem a hopeless task to try to organize a hierarchy or find limits for the historical use of the plan image per se.

9. Pinto (31); "ichnographic" is derived from the Greek for trace or outline and writing; the use of the term as a rough synonym for ground plan goes back to Vitruvius. See also Schulz (38).

10. Ibid., p. 36.

11. Ibid.; details of its construction and the tools wich which it was made, pp. 38-43. See also Heydenreich (22).

12. Ibid., p. 50. (especially on the exigencies of Renaissance city design and fortification which influenced this development.) The ichnographic city plan by no means supplanted the production of views or of iconic maps--indeed, its diffusion throughout Europe was relatively slow. The Renaissance audience for these new plans was, in any case, a rather select one: administrators, engineers and armies--the only audience for whom a comprehensive image of the physical reality of the city was a matter of vital importance. Schulz develops a somewhat analogous interpretation of the material, but with a different cate-

gorization--didactic v. geographical images. "Broadly speaking, the known material can be divided into two categories. One consists of maps and plans of a narrowly cartographic intent, the function of which must have been simply to report geographical and topographical facts. The other comprises maps and views with an ideal content, material that must have had a didactic intent. Drawings of the second group sometimes make use of data drawn from those of the first and vice versa, so that cartographically these two groups are inter-related, but in function they differ clearly." Schulz (38), p. 443. Schulz is primarily concerned with the construction of view, especially the much celebrated one of Jacopo da Barbero, made of Venice in 1500. It may be argued that it is in the view that the components of all three kinds of drawing may most workably be combined: symbolic relationships may be expressed both by the selection of vantage point and by distorting somewhat the prominence of distant objects; so, too, physical relationships may be generally inferred from a view provided that important particulars are not obstructed. Hence, within the reality of appearances, the reality of symbolic hierarchies and of metric absolutes may be alluded to, if not decisively shown. For this reason, the distinction between kinds of intent (i.e., didactic or reportorial) is particularly appropriate to the discussion of views.

13. This is particularly important when the image is intended to be a highly illusionistic one--one which "looks real." Many of the early perspective theorists prescribed the point from which their images were to be viewed for such an effect. Alberti wrote, in this regard, that no picture can resemble the truth if it is not seen from a certain distance ("Cosa niunta dipinta mai parra alle vere, dove non sia certa distantia a vederle." Delle Pittura, 1.3 as per Janitschek ed. of original, quoted in Ivins (24),p.15.) See also Edgerton (14), Gombrich (17), and White (47) on this point.

14. Once again, because the information which perspectives contain/encode is completely different from that of the orthogonal systems. "The puzzle of perspective is that it makes things look right by doing them wrong," as Arnheim has put it. But the solution to this puzzle is implicit in the terms of its statement: perspectives look--plans do. Or, to put it a little less cryptically, perspectives encode "pure" visual information and simultaneous grasping; orthogonal systems encode the composite information of the visual world and successive sampling. The "normal" mode of perception ("doing them right") is the latter. Of course, just what is "right" in looks and dos may itself sometimes be questioned. Arnheim includes a very instructive illustration: a rectangular pond surrounded by trees of equal height, equally spaced is shown in two representations--one perspectival, the other a kind of "Egyptian" plan (the pond is in plan, the trees are seen in elevation with their trunks correctly placed with respect to the pond's edge). The modern Westerner and the ancient Egyptian are asked to jusfity these images. The Westerner replies that the perspective looks just like the scene, whereas the other image has the trees "knocked over," pointing in four directions--some upright,

some upside-down, etc.--and that the outline of the pond is seen as if from the air. The Egyptian counters that, in his representation, the pond is shown to be rectangular--as indeed it is--the trees are evenly spaced and all of the same height--as indeed they are--whereas in the perspective the pond is skewed, the trees are of different heights and some are in the water, some outside, and some on top of each other. Arnheim (6), p. 96.

15. Ironically, conventions used in the orthogonal systems are to some extent derivative of the perspectival conventions: farther=vaguer is often used on sections and often more distant surfaces are rendered more darkly although strictly considered, this contravenes the basic premise of the orthogonal systems which, as we have shown, are not related to purely visual concerns at all. Edgerton documents a similar confusion of graphic depth conventions in the history of pre-perspectival painting: space rendered in oblique, non-perspective fashion was apparently thought to be made more realistic by the addition of "naturalistic" shading (Edgerton (14), p. 10). The use of shadow in section and elevation to increase legibility of depth is also in a sense a misappropriation of perspectival conventions: in orthogonal images, the light no more than the observer can have a real location with respect to the space represented. However, the logical weakness of this mixing of conventions does not seem to undermine its visual effectiveness.

16. "A system of symbols without logical schemes, both for its interrelations and combinations within itself and, if it symbolizes external fact, for its two-way, or reciprocal, correspondence with external fact, is...of very limited usefulness. Ivins (24), p. 7. Perspective provided the systematic rationalization of that reciprocal correspondence.

17. <u>Ibid</u>., pp. 7-8.

18. <u>Ibid</u>., p. 8. Kepler's statement of the mathematical proposition that parallel lines meet at infinity 150 years later was, in Ivins' view, "...recognition of an operational fact implicit in Alberti's construction and represented the final shift from tactile-motor to visual schematization as it marks modern from classical geometry." p. 10.

19. The extent to which Ivins' essay anticipates Gibson in its insistence on the primary significance of tactile-muscular v. visual intuitions in understanding systems of representation is remarkable. It may be relevant to add here the thoughts of yet another writer, some 60 years before Gibson: "Thus representative space in its triple form--visual, tactile, and motor--differs essentially from geometrical space. It is neither homogenous nor isotropic; we cannot even say that it is of three dimensions....Our representations are only the reproduction of our sensations; they cannot therefore be arranged in the same framework--that is to say, in representative space. It is also just as impossible to represent to ourselves external objects

in geometrical space, as it is impossible for a painter to paint on a flat surface objects of three dimensions. Representative space is only an image of geometrical space, an image deformed by a kind of perspective, and we can only represent to ourselves objects by making them obey the laws of this perspective. Thus, we do not represent to ourselves external bodies in geometrical space, but we reason about these bodies as if they were in geometrical space." Poincare (33), pp. 56-57.

20. As Lotz has observed, isometric projection"...might be described as perspective with an unlimited number of vantage points." Lotz (26), p. 38. In the illustrations of Choisy, to which we will refer below, the observer most often finds himself situated under the ground, looking up through a removed floor into the vaults which were of greatest interest. In the de Stijl use of axonometric, the observer is customarily floating in the heavens, looking down.

21. Isometric-like images have a long tradition in pre-perspective painting, a non-rigorous use which may be termed crudely illusionistic (cf. White (47) and Edgerton (14)). The principles of isometry may have been used by the builders of the Gothic cathedrals in the cutting of stone; this tradition was extensively refined in late Renaissance and Baroque treatises on stereometry.

22. See Lotz (26). It was the problem of visualizing and executing an enormous interior space which most clearly posed the limitations of scientifically "correct," scenographic perspective; such experimentation sought to overcome these limits. Peruzzi's famous "ideal plan" of St. Peter's of ca. 1515 is an example; the method employed was an adaptation of a technique known as "cavalier perspective" or "bird's-eye view," a bastardized perspective construction which utilized multiple vantage and vanishing points which were not mathematically coordinated. This earlier method may be traced to Filarete's treatise of 1465 and had a subsequent tradition of use of its own in, for example, the drawings of Serlio and particularly the later production of city views--for example, the map of Rome undertaken by Peruzzi's son in 1564. Lotz sees, in this extremely fecund period of representational experiment, something of a struggle between the positions of those whose background emphasized the problems of painting as opposed to architecture and construction at just that moment when the two endeavors were for the first time being clearly distinguished as separate fields. It was, paradoxically in this regard, Raffaello--preeminently a painter--who articulated the method of representation thenceforth considered appropriate to architecture which renounced all illusionistic systems in favor of separate, metrically coordinated orthogonal images--plan, section and elevation. On this we will say more below.

23. Monge developed the system while a student in military academy to address complex problems in forticiation and ballistics, an alternative to the vastly more complicated analytic methods by which such problems had customarily been solved. In later life, however, Monge sought to establish his theory as a part of general mathematics, with-

out reference to its many potential applications.

24. See Chafee in Drexler (12).

25. Quoted in Drexler (12), p. 18. The passage continues: "In this system one single image, as lively and as animated as the edifice itself, takes the place of abstract figuration, broken into plan, section and elevation....The reader has under his eyes at one time the plan, the exterior of the edifice, its section and its interior dispositions." As Drexler observes, Choisy's method realy trades one abstraction for another: "...his own being better suited to a conception of architecture which would not have occurred to those whose buildings he analyzes."

26. See Ivins (24), and Edgerton (14).

27. For the demonstration see Ivins (24), pp. 16-21.

28. Its use dates to the 15th century and its Renaissance development is extensively documented in Lotz. Contemporary usage has extended the device to exteriors as well.

29. Such a device could be used in many ingenious ways which retained a visual credibility while defying sense: Lotz gives an example of a drawing by Sangallo in which a section taken along the aisle of a church outlines three chapels, the interior space of each of which is rendered in separate, one-point perspective.

30. See Lotz (26). The letter concerns the representation of the architectural treasures of ancient Rome of which Raffaello had completed an exhaustive survey. It was written during his tenure as master of the fabbraca of St. Peter's, and it is Lotz's thesis that the view enunciated in the letter influenced the preparation of drawings in the fabbrica as well. The full text is to be found in V. Golzio, Raffaello, pp. 82-92; parts of a translation are in Lotz (26).

31. A view distinctly different from that of Alberti, which had held sway over a previous generation of practitioners with the injunction to rely on ground plan and model alone, with occasional reference to the "expedient" of perspective.

32. It would be tempting to suggest that orthogonal images in general and plans in particular are concepts as far as representation goes, and that we deduce the qualities of space from them. While such a formulation may in fact describe some of the ways in which orthogonal representations are used, as a generality it is too neat. Plans can in no way be thought of as concepts; they are rather some intermediary from which aspects may be deduced, but from which the real three-dimentional concept must be worked back to.

33. Writing of models, Levi-Strauss continues, "...the smaller the totality of the object, the less redoubtable it appears; by being quantitatively

diminished it seems qualitatively simplified. More importantly, this quantitative transposition increases and diversified our power over an analogue of the thing, by means of which the thing itself can be taken hold of, weighed in the hand, comprehended with a single glance." C. Levi-Strauss, The Savage Mind, quoted in Arnheim (7), p. 124. The statement applies equally well to drawings; drawings are, in a sense, less complete analogues than are models (although there are models of many kinds); drawings, even more than models, seem to lend themselves to "comprehension with a single glance." In a very different way, Bachelard has made an anologous point. Miniaturization challenges the imagination; it invites the kind of "reverie" which engages us--ourselves also imagined as miniaturized--in the space represented. We see ourselves at once within the space and outside, watching. It is as if the view of the whole defies the single glance and presents a new possibility for reasoning and the desire to engage the parts. "One might say that these houses in miniature are false objects that possess a true psychological objectivity....Miniature is one of the refuges of greatness." Bachelard (8), p. 148 and 155. For Bachelard, the truth of miniature is a function of the larger relationship between Representation and Imagination (his capitals), in which absolute size plays a critical role. For both Levi-Strauss and Bachelard, the notion of the power and omniscience of the observer in relation to the miniaturized environ is very strong.

34. The oft-repeated injunction to students of design to "jump scales" or "take it up the scale" is a reflection of the assumption that larger absolute size means the manipulation of quantitatively more, and qualitatively different, issues.

35. In this regard, Alberti argued that the only actual dimensions that the architect need specify were those of the principal measurements (the "proportion" and "diviso") of the ground plan; all subsequent dimensions, in every plane of the structure, had a purely geometrical derivation. In his chapter on "the problem of harmonic proportion in architecture," Wittcover cites the correspondence of the 18th century architects F.M. Preti and T. Temenza. The former argued for the existence of an absolute set of universal ratios by which buildings should be harmoniously design and regulated in all their parts. The latter argued for the relatively of ratios on two grounds; first that the eye was incapable of comprehending all three dimensions of space at once and hence incapable of comprehending the ratios; second, that all proportions in architecture should be judged from the angle of vision at which the building is actually seen. Wittcover characterizes this as a shift from the "objective truth of the building to the subjective truth of the perceiving individual." Each of the disputants claimed that his approach to proportion was the rational one. But each of these truths may also be seen as a claim for one kind of representation of design over another. Preti's position takes a conception of architecture best expressed in orthogonal representations (essentially a restatement of Raffaello's position). Temenza, on the other hand, espouses a truth which depends upon a completely different representation of architectural space, a perspectival one. There are

continuous traditions to be found for each of these positions in writing and practice back to the early Renaissance, following Alberti's statement of a rudimentary theory of ratios in the four books of Architecture. See Wittcover (49), pp. 102-154 and especially 146-147.

36. Lotz (26), p. 15.

37. See Edgerton (14), pp. 287-290.

38. See Ivins (24). Why Alberti chose a gridded square--checkerboard--for his demonstration is open to speculation. These subdivisions of the principal figure (Alberti writes that he wants to throw a square into correct projection) serve as a check on the accuracy of the diagonals in the first diagram so they may have been simply auxiliary parts of the process. Alternately, Alberti may have started, consciously or otherwise, with the problem which has so long thwarted the efforts of painters: the correct rendering of a floor surface of an interior, which was often tiled in a grid pattern.

39. "Whatever the configuration of a grid-divided surface, the observer is able to comprehend all of its continuity as long as he can relate to the side of at least one undistorted modular square which represents the true unit of measurement for judging the whole." Edgerton (14, p. 287. Edgerton believes the development of the perspective grid had an impact on what he called processes of "space structuration" as a whole. He quotes a 15th century text of the Florentine historian Gio. Cavalcanti: "Thus the eye is the ruler and compass of distant regions and of longitudes and abstract lines. Everything is comprehended under the geometric doctrine, and with the aid of the arithmetic art, we see that there is a rule for measuring... with the eye," in ibid, pp. 114-115.

40. Lotz (26), p. 21.

SECTION 3

Thus far in our description of notation systems we have been concerned with what kind of information is available in drawings, to what kind of information in the world it refers, and how it is structured--in short, the points of correspondence between drawings and their referents. Our discussion has been largely a comparative one, but comparison is a relative endeavor and must finally be made specific to some purpose. The relationship between things compared must be characterized actively, as it were, with respect to the ends which the points of correspondence serve.

What we hope to provide in this section is a framework in which the distinctions drawn between notation systems in Section 2 can be appraised on the basis of the contexts for use of those systems. The differences which we have described suggest certain intrinsic potentials and limits in each system. We suspect that these potentials and limits condition the appropriateness or effectiveness of each system in a given context. But to make that point and thus further characterize the differences between systems (and combinations of systems), we must first say something about the possible contexts in which they may be used.

We have taken some care in the previous section to restrict the vocabulary which we have used in describing the particular notation systems, especially the terms which describe what drawings do. We have for the most part used terms which have broad and ambiguous meanings--for example, "represent." But it will be instructive to consider, for a moment, some of the other kinds of things that are said of drawings and particularly the many other verbs used in speaking of (and thinking of) drawings for which "represent" is a general substitute.

Drawings describe, they denote and depict; drawings resemble and "look like"; they display, portray and reflect; drawings identify; drawings encode and organize; drawings conjure, "call forth," and envisage; drawings instruct, they specify; above all, drawings show (hows and whats); and, finally, drawings mean.

This is not idle semantics. Each of these verbs, and many others besides, conditions the way we think about the simple statement, This is a drawing of that. Each verb creates a very particular understanding of the drawing, the referent and, above all, their relationship. Each verb qualifies the correspondence of drawing and referent with respect to some process. It is such processes about which we hope to say something in this section.

We shall argue that there are four generic uses to which architectural drawings are put. These are projection, specification, display, and portrayal. The first two--projection and specification--may be thought of as generative; the second two--display and portrayal--may be thought of as representative.[1] We shall briefly describe this entire organization with some general remarks and then present a more detailed exposition.

- Projection refers to all those uses of drawings by which spaces imagined, conjured and dreamed are given form and developed. Projective drawings may be said to be those which carry the imagination forward.
- Specification refers to all those uses of drawings by which instructions are given about how a thing (object, building, space) is made.
- Display refers to all those uses of drawings by which the images projected (conjured, dreamed) are fixed and formalized, made into distinct statements. Display drawings may be said to be those which carry the imagination to the present.
- Portrayal refers to all those uses of drawings by which information about things (objects, buildings, spaces) which exist is recorded and presented. (They may explain how a thing has been made.)[2]

It will be useful to see these four generic uses as falling into two general realms. The first may be called the design realm; it includes projection and display. The second realm is harder to name; we will call it "built" for the moment: included here are specification and portrayal.

Grouped this way, we may observe that each of the generic uses in a realm is complimentary to (or a reciprocal of) the other. Thus in the design realm, display is a formalization of projection--a commitment to a decision about an order of things which has been discovered in projection. Projection, in turn, is a development of new themes, ideas, elaborations on the basis of the previous display. So, too, in the built realm. specification and portrayal both have to do with the fit or match between drawing and object: specification goes from drawing to object as, e.g., a working drawing; portrayal goes from object to drawing as, e.g., a measured drawing of an existing space.

The value of making such distinctions between the realms is that they allow us to generalize the description of the generic uses with respect to kinds of purposes or ends. For example, what we will say below about projection and display is based upon a particular way of thinking about processes of design which will be described; identifying the two generic uses--projection and display--as constituent parts of the design process will, we hope, clarify that description. Similarly for specification and portrayal as parts of the built realm.[3]

* * * * *

We shall now elaborate the definitions of each of the four generic uses of drawings. We are describing drawings here with respect to processes. What this means in a general way is that drawings play a role in a set of actions of a particular sort; the role includes supplying certain kinds of information which are needed in the process, allowing certain kinds of questions to be posed, and providing answers of a kind appropriate to the actions to be taken. So, in trying to describe how drawings in general would accord with each of the generic uses, we shall describe what kinds of actions in the process would make use of the drawing, what kinds of questions it would pose and what kinds of answers it would give. We shall try to abstract prime criteria for the drawings--that is, statements which characterize how the drawing must perform--and we will list some examples.

SPECIFICATION

As we have said, this is any drawing which directs the production of its referent; the drawing must accord with the thing in every respect which concerns its manufacture; it must also fit the manufacture--i.e., have an appropriate place in the particular scheme of making. Its conventions must be shared or readily graspable by all those involved in the production process. Hence, if the maker understands and can carry out all the actions which are involved in making the thing, then the role of the drawing is to specify the precise end of each of those actions or steps and provide a basis for judging if the step has been correctly performed. Thus the drawing will "answer" questions of the sort, I know that this needs to be fastened to that; where should the connection be made, how should the connectors be fastened?, etc. The test of this ability to direct action is in the resemblance of the thing made to the image specified. Thus the question of significant detail is very important. Resemblance will likely be broken down into the resemblance of successive states in the completion of the object. Drawing(s) must highlight each step and provide straightforward, easily recognized checks on successive states; image must not be open to much misreading (and should also perhaps point to likely mistakes or anticipate trouble-signs in some way). The efficacy of such images is very much tied to users' familiarity with the processes at hand. Examples include working drawings, model-airplane kit instructions, repair manuals of all sorts, gadget assembly instructions, etc.

PORTRAYAL

Portrayals are of two sorts: a kind of drawing which records a place, "shows us what it looks like"--i.e. creates visual expectations on the part of the viewer which will accord with the space represented; therefore answers questions of the sort (and to varying levels of detail), If I'm standing here, what will I see of the space? or If I move around or measure the space, what proportions or juxtapositions of elements, etc., would I find? Alternately, the drawing may stand for the space in a completely separate context of ideas or images, comparison of church plans in an architectural history seminar, for example. In the latter case, we are not interested in the drawing's accord with visual expectations vis-a-vis the place, but rather the extent to which the drawing adequately represents (stands as a credible surrogate for) the space in terms of the salient feature or idea being described. In the first case, the drawing must be readable in a way analogous to the space; in the second, the image must not be open to misreading on the salient feature, but otherwise is quite flexible. The most important criterion by which portrayals are judged is the quantity and accuracy of information. Examples: illustrations in texts, travellers' sketchbooks, painters' life-studies, drawn (or photographed) project presentations in architectural periodicals, etc.

PROJECTION

A kind of drawing which gropes toward the form of a thing--which can express the essentials of formal and functional relationships--and comes therefore, as close to some image of the concept of a space as possible. In general, projections must pose and answer questions which characterize the design process, which have a general form of, What if x, then a,b,c,... and some evaluation--for example, If what I want to do here is something like this, what will it look like, be like, etc? and What are the consequences of doing that? The drawings must facilitate thinking, imagining, dreaming and yet still pose images about which normative judgements can be made at some point; must be open to multiple, even conflicting, readings--"richness"; must abstract and simultaneously present diverse kinds of information--must be "information-dense"; detail is not a prime consideration; conventions need not be shared beyond designer(s). Examples: sketches, scratches, doodles on trace, etc.

DISPLAY

A display is a kind of drawing which formalizes a set of projected relationships, and hence culls the essential elements from the projection and displays them as a new problem statement/point of departure for projection--the next set of what-ifs. Responds to questions of the sort, Having decided to do this and that, what does it mean in terms of (all the relevant elements being manipulated at the moment)? Thus a display must achieve a balance between a sensitivity to the richness of the previous projection and the clarity and "objectivity" (or "degree of fixedness") required to facilitate a new direction of thinking. Examples: site plans, preliminary designs, "design development" drawings, etc.

* * * * *

In the remaining part of this section, we shall try to outline a discussion of the design realm so as to provide the context for the uses of drawings we have called projection and display.[4]

The underlying notion is that design is a sequence of metaphorical transformations of representations of a given reality.[5] Schon sees the design process as an exercise in language--that is, a combined verbal and graphic "language game" between the designer and others and, even more importantly, the designer and himself. The dialogue is an iterative one which arranges a series of statements, queries, consequences and judgements so as to produce new statements, queries, consequences and judgements until a preferred state is achieved. Effective designing involves finding effective and efficient strategies for producing such dialogues. We shall argue for the primacy of representations in this process.

Let us examine this process in greater detail. There exists for every design problem a set of relevant issues or "normative design domains." These include, for example, siting, program/use, technology, form, cost, precedent and so on.[6] Some of these domains will be relevant to every kind of architectural design problem; others may be specific to a very few. For every problem, however, such a set will be articulated. Each domain separately brings certain criteria to bear on the problem; the interaction or interrelation of domains produces still others. Judgements about the steps in designing will be made on the basis of these normative criteria.

The particular set of domains and the criteria which follow from them reflect, in every case, the specifics of the problem as defined and the priorities which the particular designer chooses to emphasize in working on it. Thus, for the same problem some designers may give great consequence to issues of very little concern to others.[7] The criteria have implications for each move that the designer may choose to make and every decision will be evaluated in terms of them. The process of decision and evaluation sets up a discipline--a logic of consequences and priorities--by which the designer chooses to be bound.[8]

The action of designing consists in what Schon calls a series of "thought experiments." These are, as we shall see, very much drawn experiments. The action takes the following general form:

- A statement is made about the problem. It is (provisionally) accepted as a given.

- A proposition (or "what-if") is made with respect to the statement. This represents a potential design move.
- The implications of the proposition are studied for each relevant domain. Groups of such implications are seen as consequences ("thens") of the potential move.
- The proposition, with its implications and consequences, is evaluated in terms of the criteria which pertain to each relevant domain.

These three steps may be repeated several times, as there may be many feasible propositions for any provisional statement; the competent designer may have to hold many such parallel chains of propositions, implications and evaluations simultaneously in mind.

At some point, for a variety of reasons, a judgement is made and the designer chooses one proposition, its associated implications and consequences. (Schon calls this a conversion from the "what-if" stance to a "stance of commitment.") The move thus selected is then represented as a new statement (i.e., a transformation of the previous statement) and becomes the basis for the next set of propositions. (Schon calls the selected moves "nodes for further designing"; their implications become binding on subsequent moves.[9] Thus is design seen as a transformation of representations of reality.

The representations are most often drawings and, insofar as the process is a drawn one, the generic uses which we have outlined above are its fundamental parts. The statement with which the process begins may be either a portrayal or a display. (At the outset of the process the drawing is likely to be a representation of existing conditions--for example, the site; this is a portrayal. Alternately, a designer might start with some schematization of functional relationships, either based on precedent or on some prior analysis of the problem at hand. This would be, in our terms, a display.) The set of propositions which ensues is part of projective drawing; each "what-if" explores some rearrangement of the drawn elements of the statements (portrayal or display). Each such exploration recasts the elements so that an evaluation may be made. Drawing after (or on top of) drawing will be made until the designer is prepared to take a "stance of commitment." At that moment, a new drawing is made which formalizes the results of the exploration. This drawing is a display; it becomes a new statement, and so the process begins again.

This transformation process may be characterized by its use of metaphors (what Schon calls "generative metaphors"). These are families of familiar ideas which contain implicit normative stances which the designer may invoke when confronted with an unfamiliar situation. Metaphors are simple notions which stand for complex relationships between ideas and it is this aspect of complexity in simple form which makes them powerful as parts of the design process. The imposition of a metaphor on a design problem recasts the elements of a new situation so that they accord with a familiar one; in this manner the new situation becomes amenable to the normative criteria which are implicit in the metaphor. Indeed, the metaphor may be seen as a distillation, a succinct encapsulization of a particular hierarchy of relationships between design domains. The metaphor suggests both a way of conceptualizing the problem and a set of possible paths toward its solution. Thus, it provides a way of guiding the exploration which we have described above, of seeing how the given representation will respond to moves of various kinds.[10]

When we say that an unfamiliar situation is described in terms that are true of a familiar one, what actually happens is that we treat the representation of the problem as if certain familiar relationships--relationships true of the representations of another situation--were true here. To put it more emphatically, we make representations of the new situation as if it were (like) the familiar one. Metaphors, then, direct the production of representations--the making of drawings.

This raises several interrelated questions. Where do the particular metaphors used in design come from? What are the characteristics of a representation which allow it to be influenced by metaphor? What forms do metaphors take? Most fundamentally, from whence this potential for metaphor; what aspect of the design process itself allows for or invites metaphors?

The potential for metaphor is intrinsic to the means of representation. In the definition of metaphor in a very old Webster's, the example "the ship plows the sea" is given. This metaphor in written language has nothing to do with the possibility of taking ships out of water or of actually seeing oceans filled with earth (although it may conjure these as images). The metaphor is an aspect of the rules of sentence structure which allow us to combine the subject "ship" with the verb "plows" in describing its relationship to its direct object "sea." To be sure, the content of the metaphor is significant, especially in appraising its quality: "the ship punches the sea" is a weaker metaphor; "the ship whistles the sea" is obscure and nonsensical, but both are metaphors nonetheless. The potential for metaphor is in the structure of the sentence. We shall argue that just as the literary metaphor is intrinsic to the structure of verbal notation, so metaphors in design are intrinsic to the structure of drawn notation.

What are the sources for particular metaphors in the design process? In his discussion of social services, Schon cites two sources: particular metaphors exist in the language generally (he calls this a "semantic" source) and particular metaphors exist in the practice (he calls this a source which draws on the "sociology of ideas").

By the semantic source is intended all verbal language. Schon introduces the metaphor of fragmentation in his discussion of service delivery (as in "social services are fragmented; policy must be devised to make them whole again"). The semantic source for the metaphor is in our habituation to describing all kinds of things--from broken china dishes to the plots of bad movies--as fragmented. In this sense, fragmentation is "in the language."

The second source reflects ideas in good currency in the field--in Schon's example, social policy analysis. In the instance of service delivery being described as fragmented, the use of the metaphor reflects the history of individuals and movements which have taken a particular view toward social reform. Thus, "an inquirer may find himself thinking of fragmentation and coordination when he thinks of service delivery, without knowing how he came to do so, because that metaphor has become powerful for thought and action in the special society of which he is a part."[11]

We would suggest that the second source may be seen as a refinement of the first. The metaphor which is powerful in the special society of which the policy analyst is a part is simply a particular historical usage of the language in a special way. In other words, the metaphor of fragmentation in the general language has <u>as well</u> a particular pattern of usage and associations in social policy studies. To apply the metaphor to a particular problem in social policy analysis then may reflect the general language use of the metaphor or the particular society's use of the language (and, most likely, both).

Certainly this is the case in architectural design. Architecture too makes use of the fragmentation metaphor. Buildings, users' needs, programs, even sites may be described as fragmented. As before, the usage in part reflects the use in the general language (our habituation to speaking of things other physical objects as fragmented). But the use of the metaphor in an architectural discussion would also reflect values specific to factions within "architectural society" (there are those for whom fragmentation is a term of utmost derision and those for whom it is, in some sense, the desired end of design). To describe a particular building as fragmented is, knowingly or otherwise, to stand in one of several historical campes and with or against one of several contemporary design ideologies. Thus, we shall argue that the source of metaphor in architectural design is simply in the language, both general and architectural.

Let us examine a particular metaphor from architectural practice. "The house is a machine to live in"--LeCorbusier's famed dictum of 1923--has been one of the most variously interpreted metaphors in modern architecture. First, the statement is rather sweeping and not without a certain ambiguity: <u>the house</u>, not this house or any particular house, but the house in general, the archetypal house, all houses are machines to live in. But this was no more true in 1923 than it is today; we know from the context in which the statement appeared that it carried an implicit prescriptive sense: all houses should be machines to live in. What might such a statement be taken to mean?

At the level of all houses (or all future houses to be built) the metaphor may prescribe a way in which houses should be made (i.e., more like machines are made), or perhaps that house manufacture should utilize more machine processes; it may also prescribe something about how houses are to be used. Thus the metaphor may affect ideas about the production of houses.

At the level of a house as a building type, the metaphor suggests that living should be accomodated by houses as, for example, movement is by automobiles or wheat threshing by a harvester. Such an interpretation suggests a very particular way of looking at living, an analysis which clarifies a hierarchy of related functions which the house should accomodate and optimize. Thus, the metaphor may affect ideas about the significant elements of habitation.

At the level of a particular house or part of a house, the metaphor may be taken to suggest that houses as objects should be more machine-like in actual design--that, for example, the details of furnishings ought to be articulated in a way which connotes machinery (either by literal resemblance or by qualitative association--e.g., streamlined, stripped of ornament, functional, etc.). Thus, the metaphor may affect ideas about aesthetics of the decor of houses.[12]

These are but three of the many ways in which LeCorbusier's metaphor can (and indeed has) been construed. A powerful metaphor will thus have an application to the problem at several scales, from the organization of our thinking about the problem as a whole in its broadcast context down to the consideration of its smallest parts. (It may be salutary or disastrous to actually apply a single metaphor to every scale of the design problem; the point is only that potent metaphors are those which are not restricted a priori to a particular level of the design process.)

From a machine to live in it is but a short step to "mechanical" and "mechanistic" and in turn a whole set of metaphorical adjectives which become evaluative design terms. The operative metaphor is thus elaborated into a group of affiliated concepts which allow us to organize our thinking not only about the object of design (i.e., the house), but also about aspects of the process which produces it (as in, The process is "too mechanistic"--i.e., not sufficiently responsive to non-rational considerations--or Should be "more streamlined"--i.e., strictly reasoned and causally explicit). In time, we may come to see the metaphor not simply as a view of houses but of design itself.

What of the form of metaphors? In literature, the expression of metaphor is a written array of words; in social policy--indeed, in most fields--the expression of metaphor is written language. (The consequences of metaphor may have non-written results; in Schon's example, the new policy may be to place all the offices of the services physically under one roof, but the only way that a social policy analyst can express the metaphor of fragmentation is in written language.) So, too, architecture may make use of written language. However, in architecture metaphor has another and quite different expression: metaphors are expressed in drawings.

To return to the house as machine example, the metaphor may influence the representations which are made of the house in several ways. The details of the house may be drawn so as to emphasize the component parts and the steps of their assembly. The metaphor may influence the style of drawing in, for example, the degree of precision and uniformity in lines and the choice of medium (e.g., ink as opposed to pencil and wash). Values implicit in the machine metaphor may be transposed to the representations themselves and we may prize clear, reductionist images with a look of elegance and efficiency. The metaphor may even influence the choice of notation systems in which the building is portrayed in presentation drawings.[13]

But these are relatively superficial influences. The strong metaphor will have a much more profound impact on the development of the design itself, an influence made manifest in the impact it has on the representations which are part of the design process, especially that portion of the process we have called projection. Here a wide variety of things may happen: the initial display may be modified by additions and deletions, prominent elements may be softened or further articulated, entire sections of the image may be rearranged, whole new figures may be introduced and juxtaposed, and so on.[14]

It seems that there are two general ways in which a particular metaphor could come to play a normative role in this projective phase. First, we may imagine a point at which the representations are sufficiently "soft" and ambiguous that a multiplicity of readings may be imposed. At such a point, a metaphor from the general language may "occur" or "be discovered" in the drawing as a means of organizing further representation along some explicit line. The structure of the metaphor galvanizes the drawing as it were, making clear which elements need to be fixed, which eliminated and what the direction of further development might be. (The description of this "occurrence" would be an exercise in the psychology of invention and discovery; we won't attempt such an explanation.) This might be called the realization of a metaphor.

Alternately, a metaphor may be consciously selected. We may imagine another representation, one in which a great deal is fixed and clear at a given moment, and a particular reading is beginning to emerge. A designer may then deliberately turn to a metaphor which is contained in another example, making a selection from architectural precedents on the basis of certain similarities between the representation at hand and the historical example. This may take the form of a matching procedure in which it is now the "hard" and explicit elements of the display which guide the imposition of a metaphor. Also, in this instance it would seem that the metaphor would more likely be taken from the architectural language--that is, that it would have an extant exemplar in another representation (a portrayal of another building, for example).

If these are plausible options, we might further suggest that in the second, the group of available metaphors, or range of attachable ideas, is more likely to be a function of the particular notation system in which the representation is made--that is, the matching procedure (or however it might best be described) would operate on the basis of similarity of images. Hence, projection made in plan might be associated with metaphorical precedents represented in plan.

But this may go too far. In order to study such possibilities further, we would now have to look at another set of questions. What influences do the conventions and logic of particular notation systems exert on the representation of particular metaphors? Are some classes of metaphor more vividly "seen" in some notation systems? (Is the machine metaphor especially conducive to axonometric expression, for example?) Conversely, does a particular metaphor cast the logic and conventions of the notation system in a certain light and thus direct the form in which the next display of the problem statement is made? Or perhaps in a given design endeavor (or a given designer's oeuvre) kinds of drawings and classes of metaphors. become so closely associated in practice that the threads which we have tried to disentangle become indistinguishable. And, if so, do certain ways of drawing take on an implicit metaphorical content? Do certain metaphors come to dictate the use of certain notation systems and thus the production of an increasingly refined and narrow group of representations?

These are the kinds of questions which future inquiry must address. We have probably long ere now overrun the limits of a speculation such as the present work. But in concluding this section, we may perhaps take a step back and simply point again to those elements which, it seems, would have to be the subject of any further examination of the processes we have tried to describe.

There are three significant components in the action of design, particularly in the phase of projection. One is the information of the problem statement; one is the notation system and the conventions and logic of the particular system in which the problem statement is represented; and one is the metaphor. These terms are co-equal; each contributes its influence to the process of design. Each influences the others--indeed, together they form a kind of knot of influences within which three cross-influences may be discerned. There is the interrelation of the notation system and the information of the problem; of the information with the metaphor; and of the metaphor with the notation. Of the first we have said something in Sections 1 and 2. Of the second, we have tried to suggest something in this section. The third, in some ways the most important, we will leave for a section yet to be written.

* * * * *

For the most part, we are accustomed to dealing with images as if they possessed some of the qualities of their referents; this has been called the efficacy of images. Thus we examine architectural drawings in the conviction that from them we will ascertain some understanding of the real relationships of things in space. The greater part of this essay has been concerned with describing the details of this efficacy, the kinds of correspondence or veridicality that a given image may make with its referent. Indeed, we have tried to characterize whole notation systems on the basis of the classes of correspondence they structure by virtue of their logic and conventions.

Yet finally, all images are also independent statements which prescribe how a set of things <u>ought</u> to be seen. Architectural drawings are acts of visual exhortation and persuasion; they establish associations between ideas and things, and they do so as much by what they conceal as reveal. Each drawing becomes a set of instructions which tells us what to look for and how to see it. The significance of this prescriptive or editorial component of architectural images is at least as strong as their actual veridicality, for it reverses the standard notion of their efficacy. Thus, instead of seeking the qualities of the real in the image, we come to attribute the qualities of the image to the real.

There is, then, an inherent tension between the image as record and the image as statement--between the dictates of the thing seen and those of the way of seeing. To the extent that representation in architecture is the creation of an equivalent or surrogate which stands for its referent in a particular context, this tension must be evident. Each individual image resolves the tension between these poles and each notation system commends some general method for its resolution. But the tension itself lies at the heart of thinking about drawing and thinking about design.

SECTION 3

Notes

1. By representative, here, we intend something rather more specific than the way in which we have used the term thus far, which we will try to clarify below.

2. Display and portrayal are terms introduced to distinguish between two kinds of depiction in M. Black's essay in Gombrich et al. (19). As Black presents it, portrayal is the depiction of actual events, persons, places, etc. (e.g., Washington crossing the Delaware); display, on the other hand, is the depiction of imagined or fictitious events, persons, etc. (e.g., Orpheus crossing the Styx).

3. The reader may observe that what we have outlined here is really a 2 x 2 matrix of the form:

		categories	
		generative	representative
realms	design	projection	display
	built	specification	portrayal

This demonstrates that the reciprocities we have described within domains are symmetrical--that is, specification : portrayal as projection : display. We hesitate to make use of such a matrix in the text; it is a bit too neat, and the form of the matrix itself lends an authority to the distinctions which we are not convinced that they merit. As soon as the distinction between realms is made, it must be qualified, for the facts that we hope to explain by it groan as we force them into one slot or the other. The names of the realms are not altogether satisfactory; indeed, the very separation that two realms implies is misleading, for at some moments they must be seen as ends of a continuum. For example, a project which is designed and subsequently built: there is a moment in which the last display (formalization of projection) in the design realm must become a specification in the built realm in order for the project to be realized. Similarly, the projection process must start with something, as we conceive it. This may be a previous display of some sort, but it often takes the form of some representation of existing consitions--of a site, for example--and this, then, is a portrayal. So it may be well to hold in mind another figure, with as much authority as the matrix:

projection

portrayal display

specification

with the possibility of a continuous, circular interconnectedness which may, in theory at least, commence at any state. We raise these qualifications here because the classification on which these figures are based are themselves difficult and not altogether satisfactory. In so doing, we hope to warn the reader (if, indeed, he needs any warning) to treat with skepticism the generalizations which follow.

4. We shall make extensive reference to two unpublished manuscripts by D.A. Schon (36,37). The former is an analysis of a "protocol" from a survey study of architecture curricula; it develops a commentary on two design "crits" of student work, which are presented as transcripts of the conversation between student and professor, as well as some tentative interpretive remarks on the nature of the design process as it can be generalized from these particular instances. The earlier piece is a discussion of the design process in its most general sense. It begins with a critique of the writings of several design theorists (Simon and Alexander, among others) and proceeds to a presentation of a substantially different formulation. Specific illustrations are drawn from the design of service delivery systems as an aspect of Social Policy Planning.

5. This statement builds on a definition first advanced in Simon (40). Simon considers all design primarily in terms of problem-solving; solving a problem, in its most basic sense, is taken to mean representing it so as to make the solution "transparent" (see page 77 and note #16). Architectural design neither can nor should be reduced to Simon's problem solving terms, but the role of representation of problem statements is nonetheless crucial. The value of Schon's thesis is that it begins to examine the role of representations in design problems for which single--i.e., "correct"--solutions, or even single classes of solutions, may not be appropriate.

6. The phrase, normative design domain, is Schon's; he defines these as "...groupings of terms which describe elements, features and relations of design phenomena."((37), p. 10). For the particular protocol which Schon is analyzing, he lists 12 design domains, p. 11.

7. Here lies part of the basis of styles, schools and movements--the relative priorities which individuals or groups of designers assign to relations between domains in addressing a problem. Of course, such priorities often have an influence on the problem statement per se, so the notion of identical problems is itself problematic. This is, however, a minor point in the present discussion.

8. Thus, designing involves a continuing interaction between the designer's free choice of moves, on the one hand and, on the other,

the discipline set up by the implications of his moves....But the designer does not know the meaning of his moves until he discovers their consequences (including their implications) across the range of normative domains."(37) pp. 13-14.

9. Schon presents the model we have summarized here (37) pp. 10-15 and, in greater elaboration, pp. 51-65.

10. "The generative metaphor provides a selective representation of the new situation and a set of values for its transformation. The representation permits investigation of the ways in which the situation would respond to various interventions. The values for transformation set the criteria for the direction of intervention." (36) p. 34.

11. Ibid., p. 41.

12. The metaphor may be taken very literally on a grand scale which combines all of the levels we have raised, as in Archigram's walking city, in which all houses become a machine to live in. The visions of Fuller, Soleri and NASA all reflect a similar interpretation of the metaphor.

13. Thus Drexler writes of J. Stirling's 1964 Cambridge University History Building, published as a hard-lined axonometric: "Where architecture seeks to emulate the look of machinery, with complex shapes, chamfered corners and moveable bits of hardware, the axonometric seems to generate its own design solutions. A model can include more information, but only by sacrificing schematic elegance." (12) p. 21, note.

14. Note, too, the role that the notation system plays here: the designer may make modifications to the representation which is the original statement (if, for example, it is a plan, he may move all the elements around in plan, concentrating on such evaluations as are best facilitated by the conventions of the plan system). Alternately, a different kind of representation of the initial statement may be made, for example, a section or perspective, in which the original display is modified and evaluated on the basis of its content as shown by the conventions of these other systems.

BIBLIOGRAPHY

1. Abercrombie, M.L.J. The Anatomy of Judgement (New York: Basic Books, 1960).

2. ______________. "Perception and Construction" in Design Methods in Architecture, G. Broadbent, ed., AA Paper #4, 1969.

3. Ackerman, J. "Architectural Practice in the Italian Renaissance," J.S.A.H., Vol. XIII, #3, 1954.

4. Appleyard, D. "Notes on Urban Perception and Knowledge" in Image and Environment, R.M. Downs, ed. (Chicago: 1973).

5. __________. "Understanding Professional Media," reprint #150, Institute of Urban and Regional Development, University of California at Berkeley, 1976.

6. Arnheim, R. Art and Visual Perception (Berkeley: University of California, 1967).

7. ________. The Dynamics of Architectural Form (Berkeley: University of California, 1977).

8. Bachelard, G. The Poetics of Space (Boston: Beacon, 1969 [1958]).

9. Bruner, J. On Knowing, Essays for the Left Hand (Cambridge: Harvard).

10. Carr, S. "The City of the Mind" in Environmental Psychology, H. Proshansky, ed. (New York: 1970).

11. Cassirer, E. "The Expression of Space and Spatial Forms" from The Philosophy of Symbolic Forms, Vol. 1, New Haven, 1953, in Modulus Vol. 9, University of Virginia.

12. Drexler, A. The Architecture of the Ecole des Beaux Arts (New York: Museum of Modern Art, 1977).

13. Edgerton, S.Y., Jr. "Florentine Interest in Ptolemaic Cartography..." J.S.A.H., Vol. XXXIII, #4, 1974.

14. ______________. The Renaissance Rediscovery of Linear Perspective (New York: Basic Books, 1978).

15. Gibson, J.J. "The Information Available in Pictures," Leonardo, Vol. 4, #1, 1971.

16. __________. The Senses Considered as Perceptual Systems (Boston: Houghton-Mifflin, 1966).

17. Gombrich, E.H. Art and Illusion (Princeton: 1960 [1956]).

18. ______________. "The Evidence of Images" in Interpretation: Theory and Practice, C. Singleton, ed. (Baltimore: Johns Hopkins, 1969).

19. Gombrich, E.H., J. Hochberg and M. Black. Art, Perception and Reality (Baltimore: Johns Hopkins, 1972).

20. Goodman, N. Languages of Art (Indianapolis: Bobbs Merrill, 1968).

21. Gregory, R.L. Eye and Brain (London: Weidenfeld and Nicolson, 1966).

22. Heydenreich, L.H. Leonardo Da Vinci, 2 volumes (New York: MacMillan, 1954 [1928]).

23. Hochberg, J.E. Perception (Englewood Cliffs: Prentice-Hall, 1964).

24. Ivins, W.M., Jr. On the Rationalization of Sight, Paper #8, Metropolitan Museum of New York, Da Capo 1973 (1938).

25. Langer, S.K. Feeling and Form (New York: Charles Scribner's Sons, 1953).

26. Lotz, W. Studies in Italian Renaissance Architecture (Cambridge: MIT, 1977).

27. Lowenthal, D. and H.C. Prince. "Transcendental Experience" in Experiencing the Environment, S. Wapuer, ed. (New York: 1976).

28. Lynch, K. The Image of the City (Cambridge: MIT, 1960).

29. _________. Site Planning, 2 ed. (Cambridge: MIT, 1971).

30. Lynch, K., D. Appleyard and J. Myer. The View from the Road (Cambridge: MIT, 1964).

31. Pinto, J.A. "Origins and Development of the Ichnographic City Plan," J.S.A.H., Vol. XXXV, #1, 1976.

32. Prak, N.L. The Visual Perception of the Built Environment (Delft: 1977).

33. Poincare, H. Science and Hypothesis (New York: Dover, 1952 [1905]).

34. Ruskin, J. The Elements of Drawing (New York: Dover, 1971 [1857]).

35. Sauvage, M. "Notes on the Superposition of Temporal Modes in Art" in Reflections on Art, S.K. Langer, ed. (Baltimore: Johns Hopkins, 1958 [1953]).

36. Schon, D. "The Design Process," unpublished manuscript, 1974.

37. Schon, D. "Learning a Language: Learning to Design," unpublished manuscript, 1977.

38. Schulz, J. "Jacopo de Barbari: Map Making, City Views and Moralized Geography...," Art Bulletin, Vol. LX, #3, 1978.

39. Seckler, E. and W. Curtis. LeCorbusier at Work (Cambridge: Harvard 1978).

40. Simon, H.A. The Sciences of the Artificial (Cambridge: MIT Press, 1969).

41. Sims, W. Iconic Simulations..., unpublished PhD dissertation, MIT, 1974.

42. Souriau, E. "Time in the Plastic Arts" in Reflections on Art, S.K. Langer, ed. (Baltimore: Johns Hopkins, 1958).

43. Steinberg, L. "The Eye is a Part of the Mind" in Reflections on Art, S.K. Langer , ed. (Baltimore: Johns Hopkins, 1958 [1953]).

44. ____________. Borromini's San Carlo Alle Quattro Fontane (New York: Garland, 1977 [1960]).

45. Thiel, P. "Movement in Japanese Environmental Representation," Urban Planning/Development Series #3, Washington State U., 1969.

46. ________. "The Problem of Sequential Connectedness in the Urban Environment," Urban Planning/Development Series #1, Washington State University, 1962.

47. White, J. The Birth and Rebirth of Pictorial Space (London: Faber and Faber, 1967).

48. Wollheim, R. On Art and the Mind (Cambridge: 1974).

49. Wittkower, R. Architectural Principles in the Age of Humanism (New York: Norton, 1971 [1962]).

ILLUSTRATIONS

1 Plan

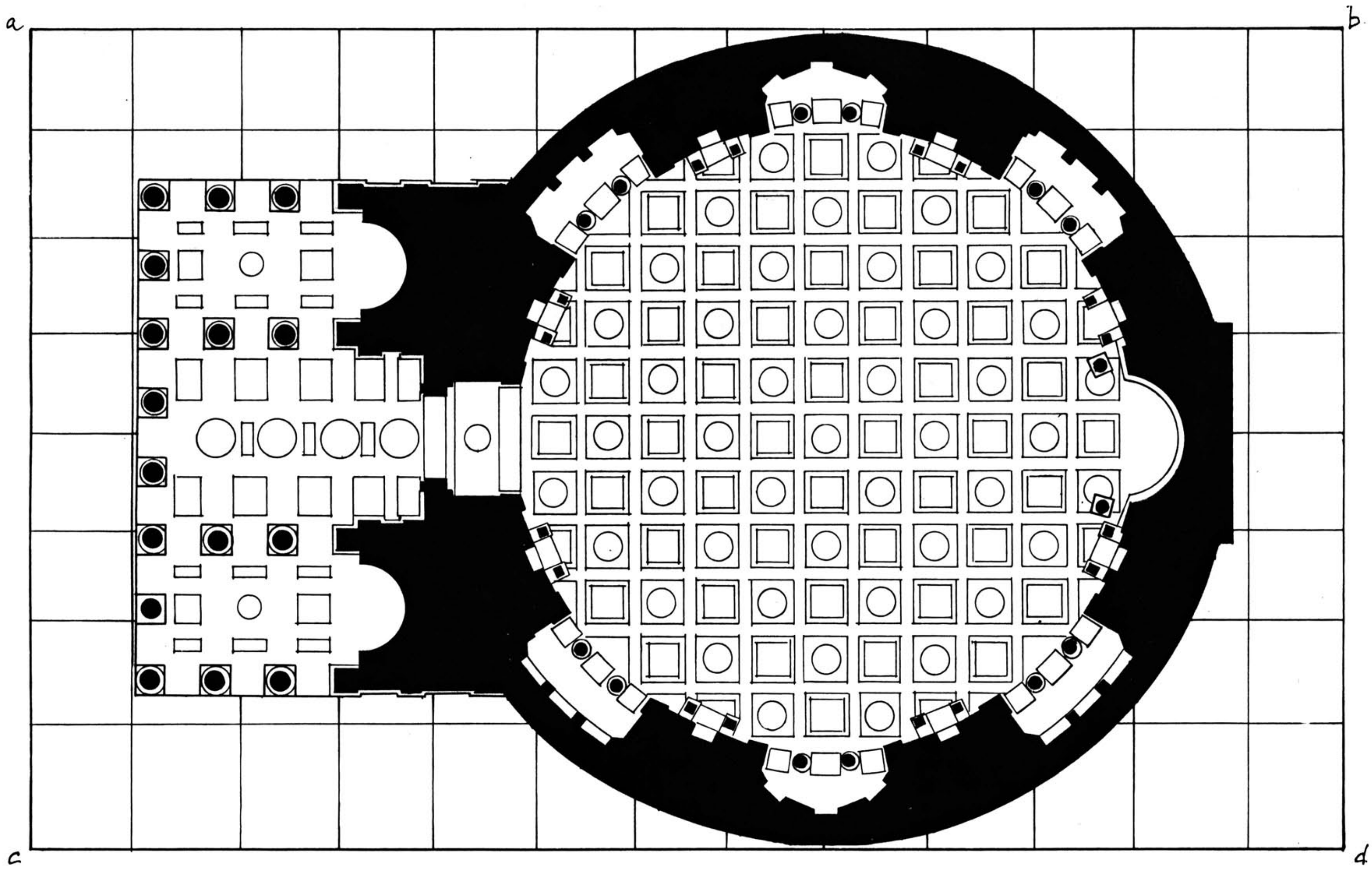
2 Section

3 Elevation

4 Isometric

Each illustration presents a simplified plan of the Pantheon in accurate, two-point perspective with the corresponding image above. Plan and section after R.M. Boyle reproduced in W.L. MacDonald, The Pantheon Design, Meaning and Progeny, (Cambridge: Harvard, 1976); isometric after plate in L. Benevelo, Storia della Citta, (Rome: Laterza, 1975).

The illustrations are not referenced to particular parts of the text but rather attempt to provide a visual equivalent for the arguments which are put forth in Sections 1 and 2.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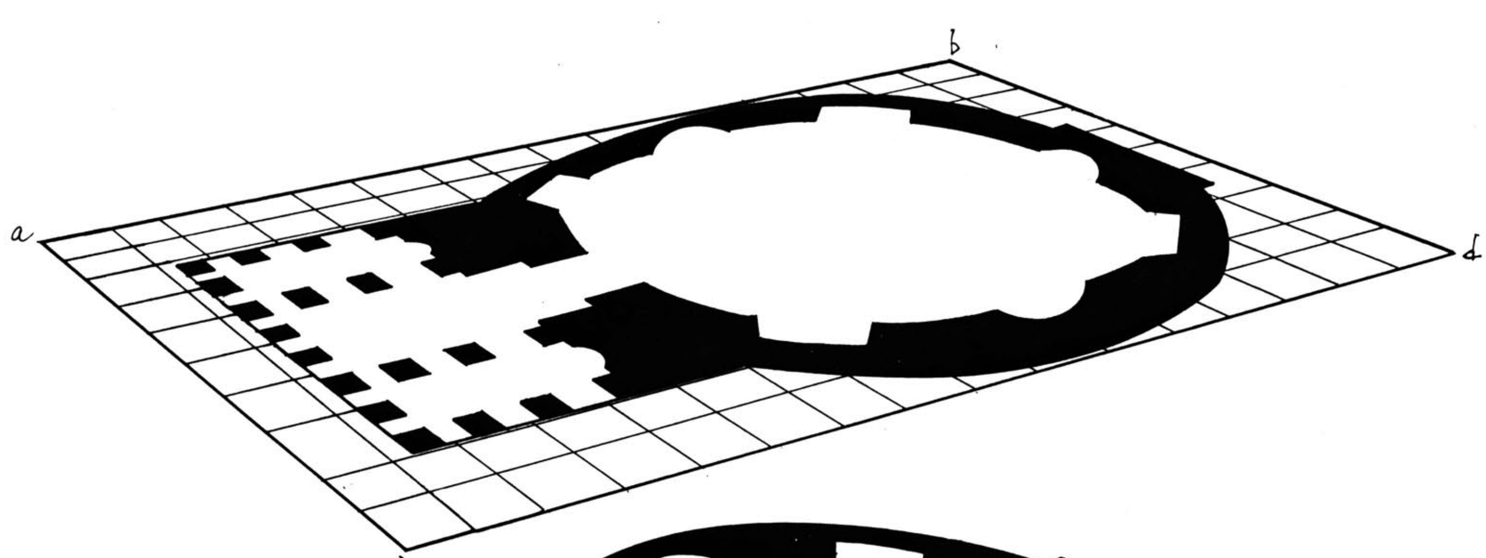
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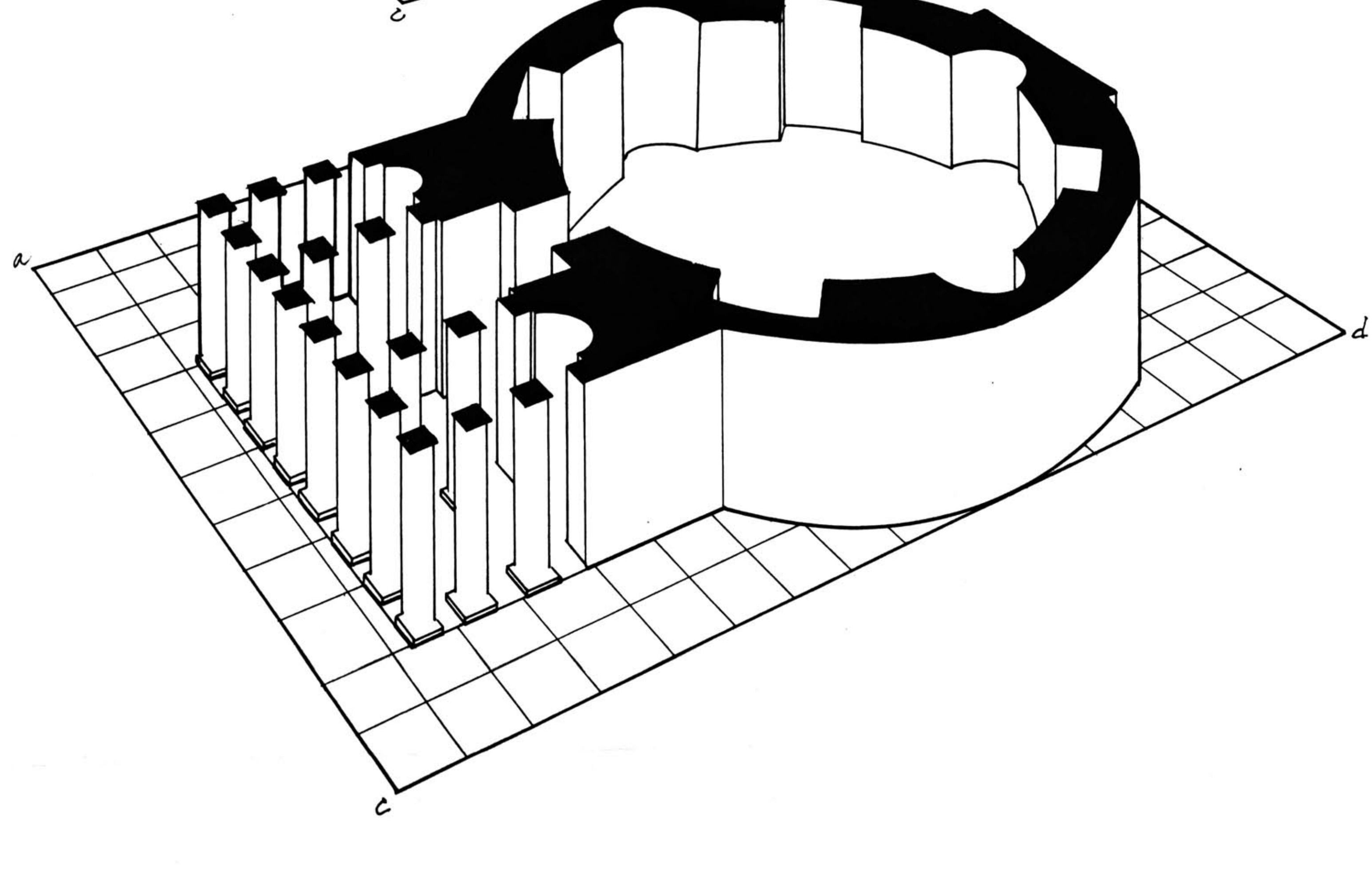
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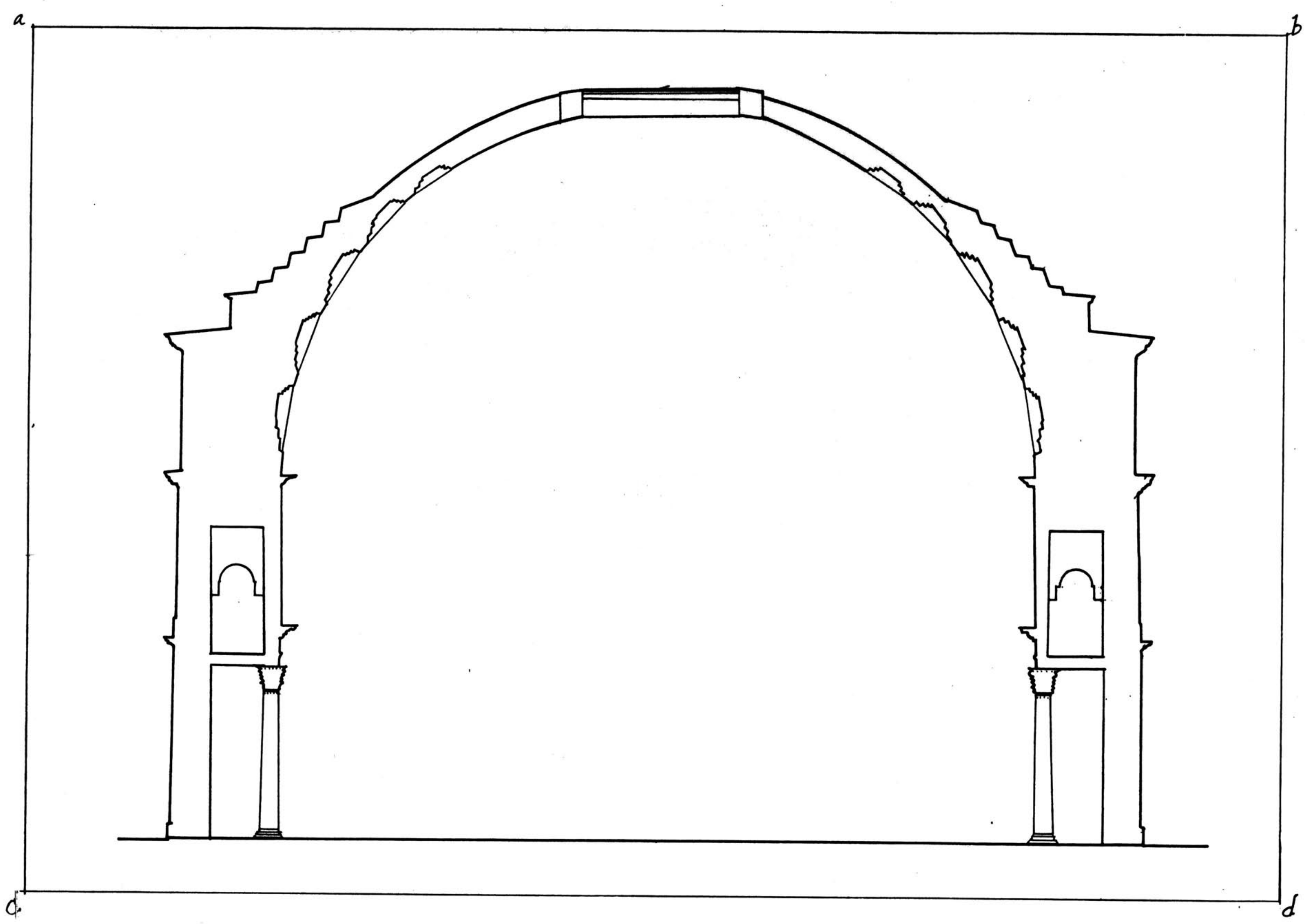
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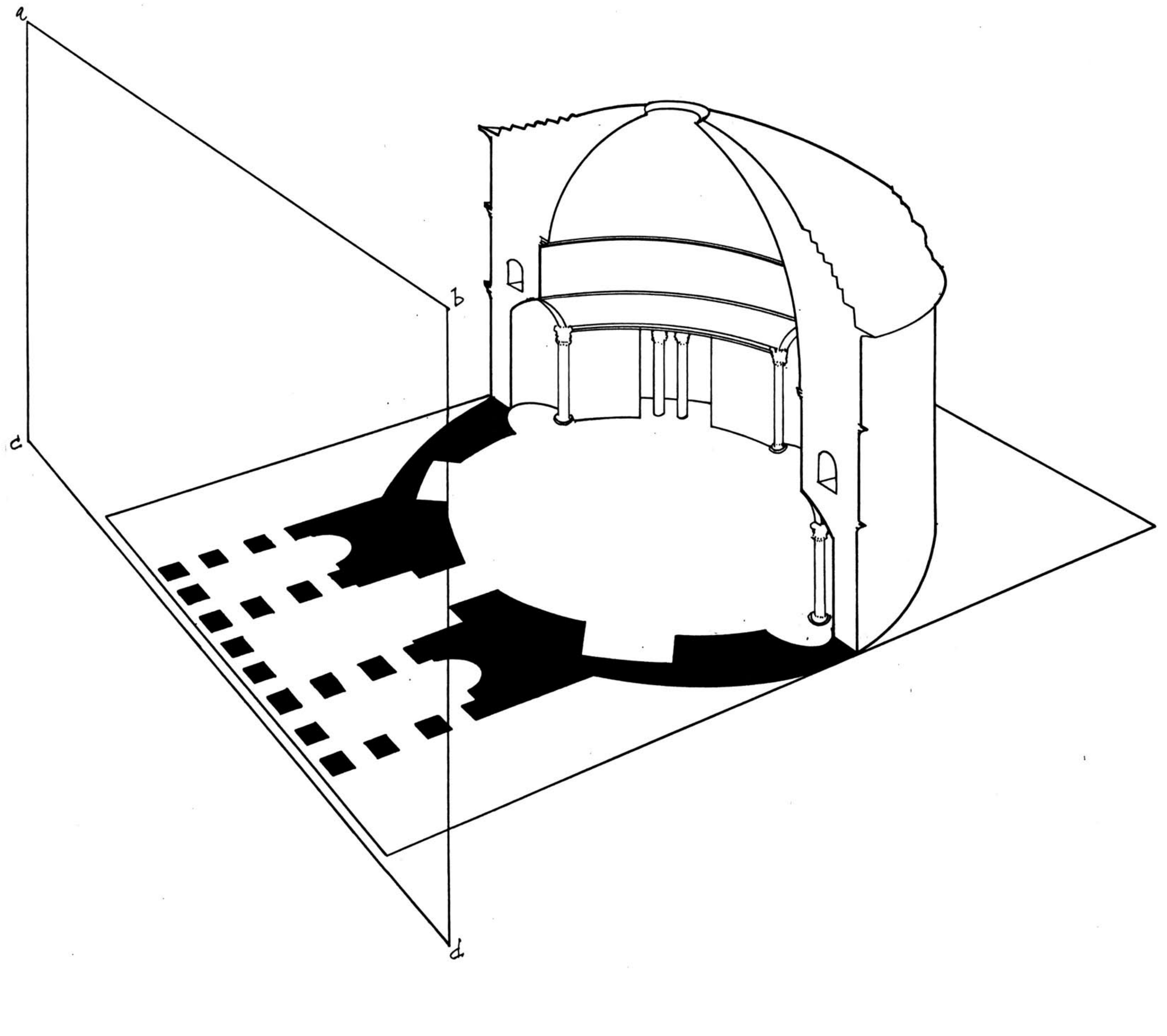
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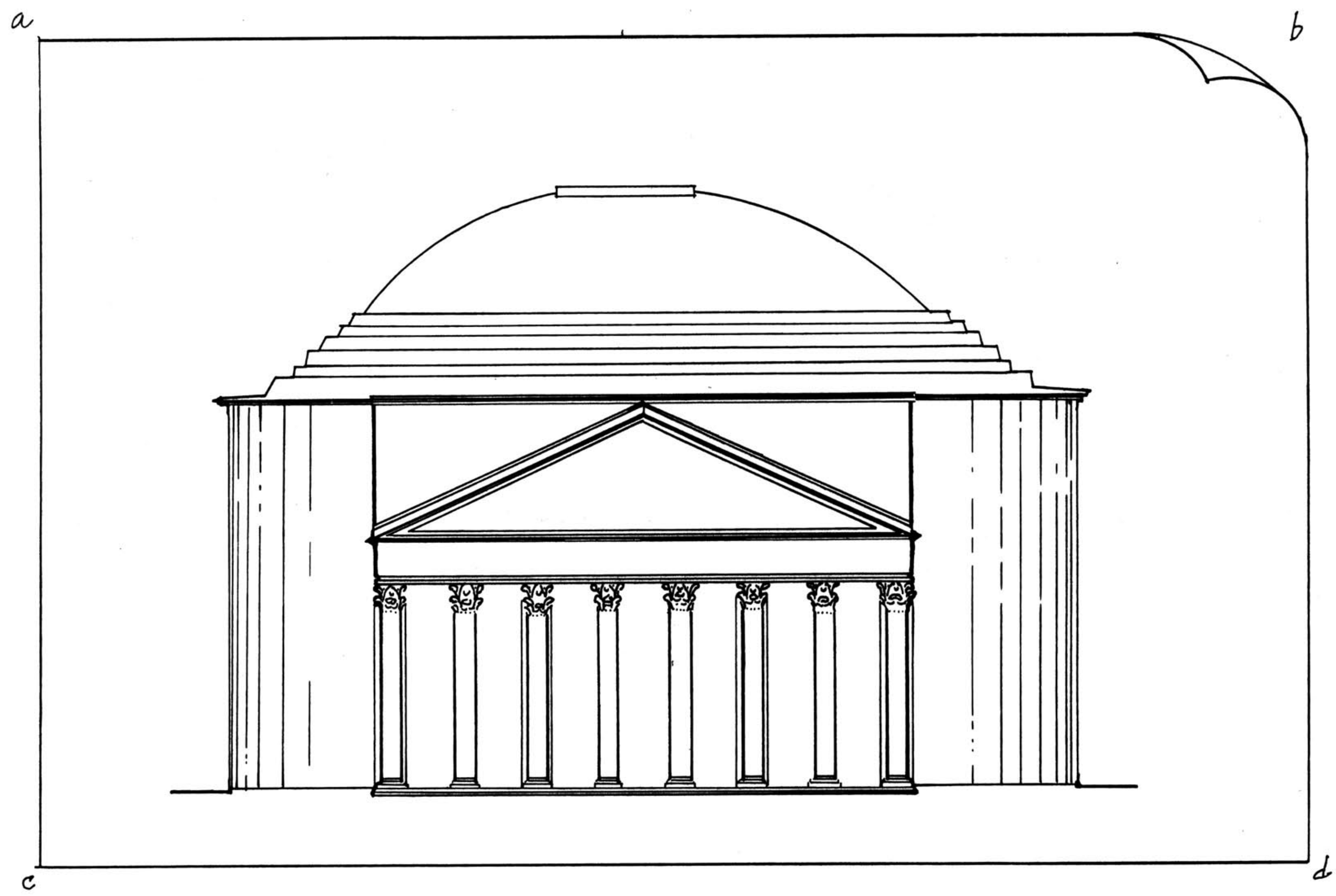
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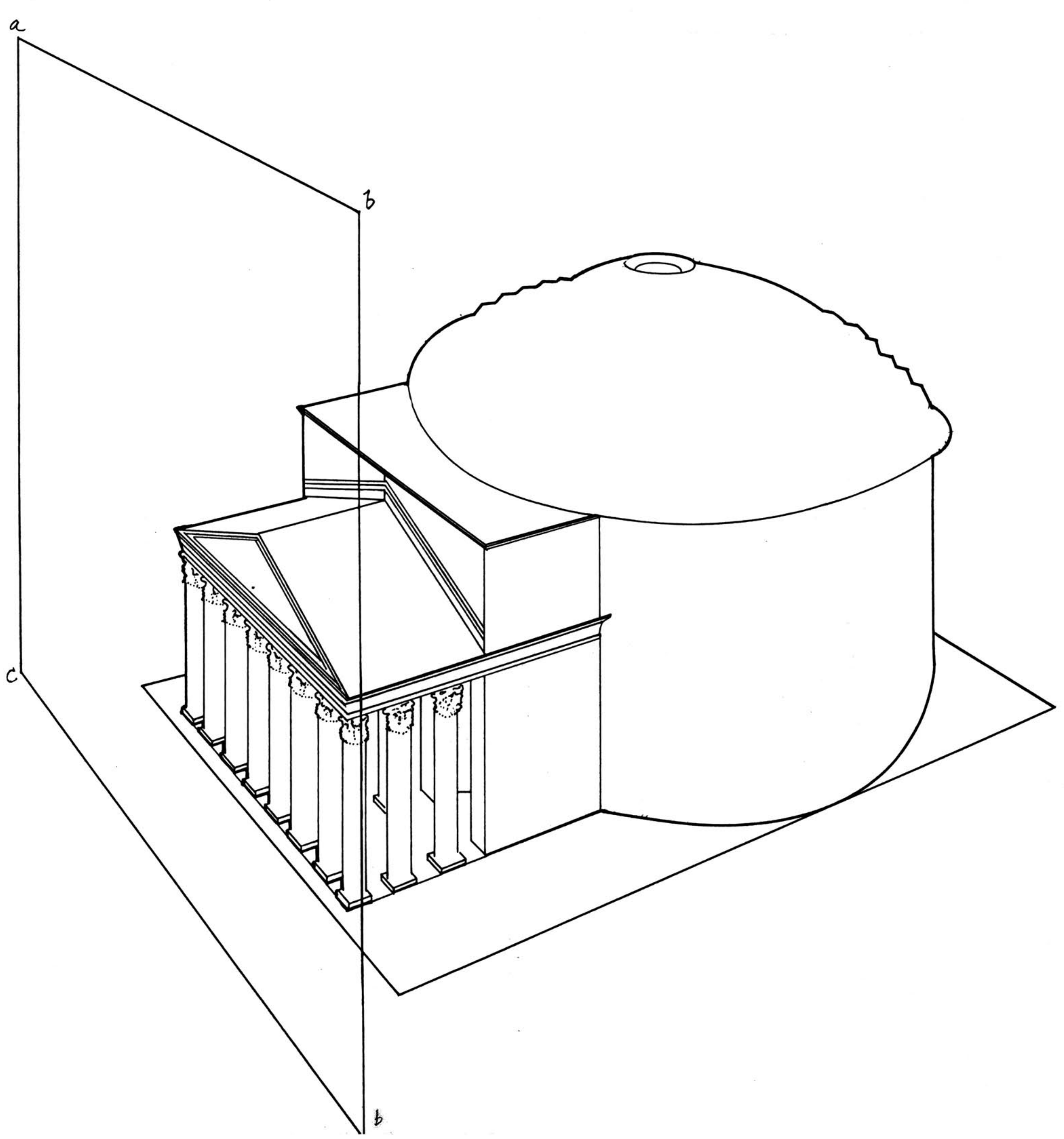
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