CHAPTER 5

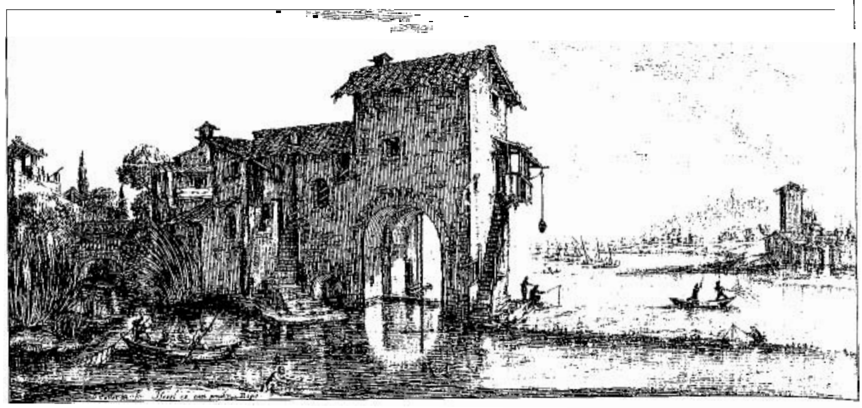
WHAT MAKES A GRAPHIC IMAGE WORK

In this chapter, we disassemble representational graphics to look at their parts. By analyzing the graphical and cognitive components of graphics, we try to understand how and why graphs work. Sheena Rogers (1) correctly called veridicality the property exhibited by representational drawings. The extraordinary diversity of graphic applications goes well beyond the pure representational function, however. The diagram presented in Figure 1.1, even if incomplete, offers an overview of this diversity. In this chapter, I survey the different threads of the diagram and their corresponding examples. I begin with thread number 2 and with a set of graphic representations for objects and scenes that are related to veridicality by stronger and weaker connections. These examples demonstrate how veridicality is not an "all-or-nothing" quality. Instead, it can possess different gradations, from the strong connection between a real object and its representation that one finds in trompe l'oeil to the absence of any correspondence that one finds in abstract drawing. Next, I discuss thread number **3.** In the drawings that belong to this thread, there is no relationship of veridicality between graphic productions and the represented segments of reality. There is, however, a visually compelling correspondence between nonvisual aspects of reality and the graphic symbols used to represent them. These symbols possess an intrinsic potential for communication, based on the functional properties of the visual system, but the communication does not require a correspondence between the drawing and the visible world.

VARIETIES OF VERIDICALITY

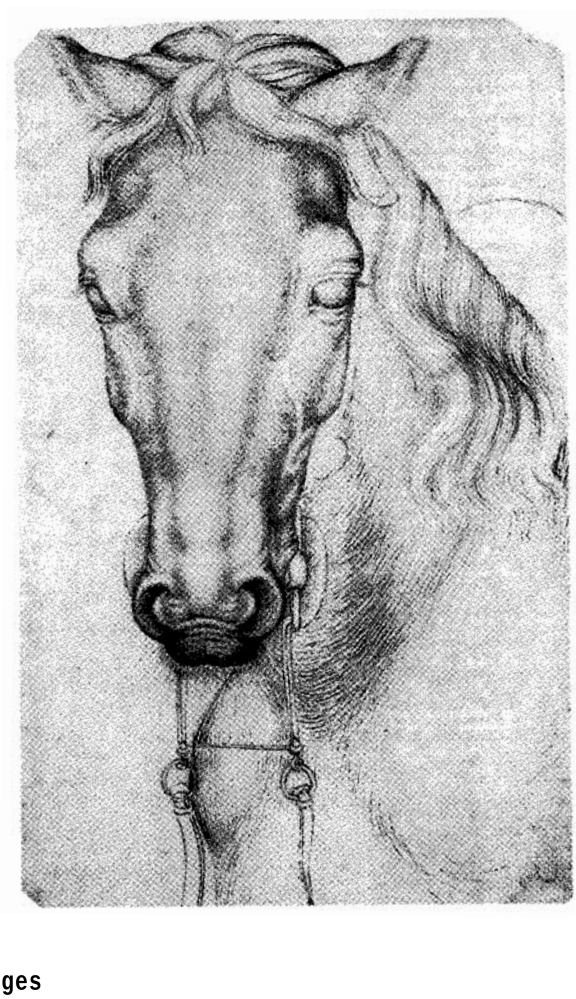
Figures 5.1, 5.2, 5.3, and 5.4 present four scenes exhibiting different degrees of correspondence with a physical layout of objects in the environment. Figure 5.1 represents a landscape by Callot. The experience of depth and three-dimensionality of the objects in the depicted scene is comparable with the experience one would have from the real scene observed from the appropriate viewpoint. To achieve this effect, the drawing contains several depth cues, including linear perspective, aerial perspective, shadows and

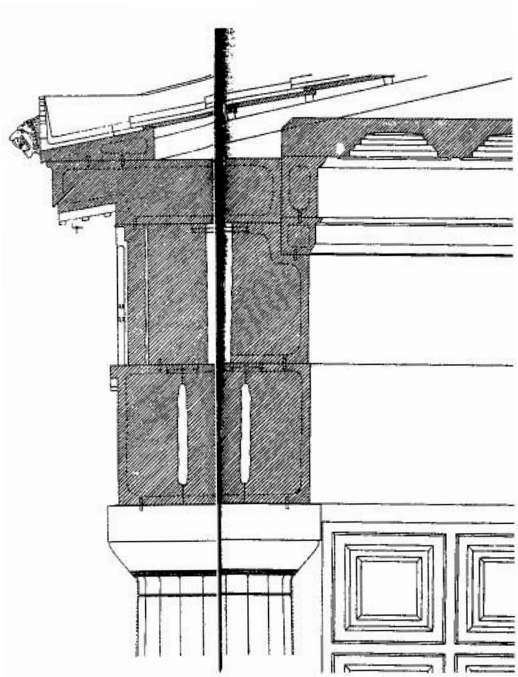
5.1. Landscape. Callot, The Water Mill. From Callot's Etchings, *1974,* by H. *Daniel, Dover 1974. (Reprinted with permission)*



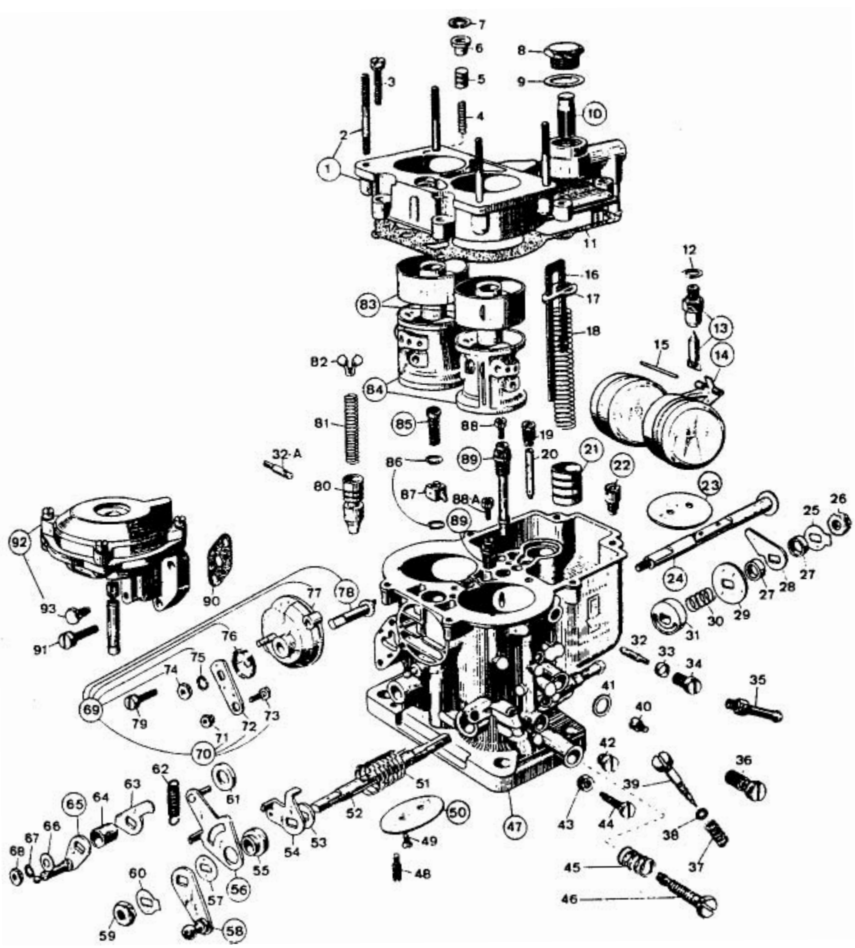
shading, interposition, relative size, and texture (2). In terms of veridicality Figure 5.2, a horse's head drawn by Pisanello, is similar to the scene by Callot, but its phenomenal impact is substantially different. Although the overall impression of three-dimensionality is strong, the head of the horse emerges from the white paper in the space between the paper and the eyes of the observer. The phenomenal position of the head presumably depends on the absence of a naturalistic background. In Callot's image, in contrast, phenomenal space

5.2. Pisanello, Horse's Head *(Département des Arts Graphiques, Musée du Louvre, item 2360). (Reprinted with permission)*





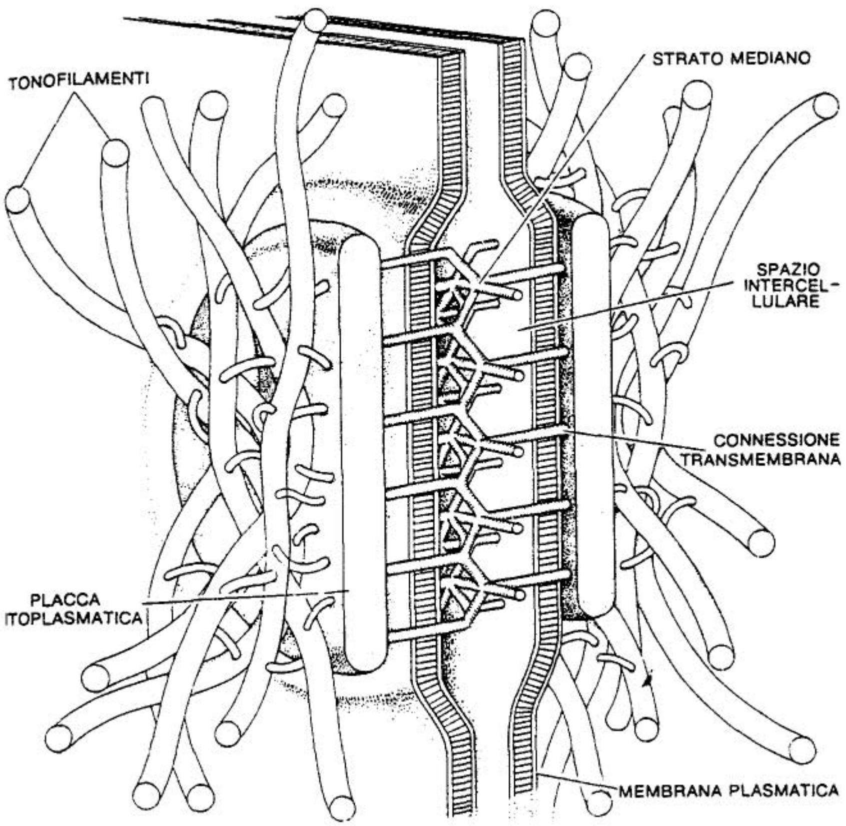
5.3. Supporting beams in the Parthenon. From Tecnica del Disegno, 1982, by L. Benevolo, Bari: Edizioni Laterza. (Reprinted with permission)



5.4. A Weber carburetor, axometry. (Reprinted with permission) extends entirely beyond the sheet of paper and away from the eyes of the observer. This difference will be discussed in greater detail in the next paragraph. Without depth cues to articulate the drawn background, the effect that perspective theorists called sfondato cannot materialize. The surface of the drawing sheet remains the farthest spatial frame of reference, so that the depicted object necessarily appears in front of it. The example presented in Figure *5.3* is also a representation of a real object, namely, part of the entablement of the Parthenon. But this representation demonstrates a deliberate departure from veridicality. All the depth cues that could produce an experience of three-dimensionality are missing, and the image has an abstract quality because of the precise marks drawn using graphic instruments. The depicted three-dimensional object is flattened into two dimensions and shown from a theoretical viewpoint that could not be occupied in practice—a viewpoint at an infinite distance from the object. Finally, the example in Figure 5.4 is detached from veridicality in another way. It shows a Weber carburetor through a set of "exploded" views and in section. All the parts are shown as detached but not independent components of the object. The core of the object is placed at the center of the picture and drawn using an isometric axonometry. The constituent parts of the object are parallel to the three orthogonal axes of space, so that the main axis of each convex part coincides with that of the concavity that will be fitted to that part. This way of representing objects must take into account the perceptual articulation of the whole and its parts. Any object of some complexity is a whole made up of different parts, divided up in an arbitrary way. Consider Kosslyn's thoughts on the subject: "Although we talk easily of objects and parts, the line between them is not clear. Is a face an object or a part? In some sense, it is both" (3).

For the purpose of our discussion, the important feature of this type of drawing is its ability to show how objects are made up of both external and internal parts. Exploded views and sections depict objects as one would need to imagine them when thinking about their assembly or their construction. The simultaneous presentation of wholes and parts and of the appropriate spatial relationships between them makes available information that is invaluable for the purpose of guiding actions. Figure 5.5 depicts a hypothetical model of the three-dimensional structure of a cellular component. The drawing has the character of veridicality because of the attention devoted to the correct depiction of spatial relationships in the object. This is a paradoxical veridicality however, because the depicted part of reality cannot be observed directly. This paradox introduces a theme, that of the relationship between veridicality and observability, which will be discussed in greater detail in the next chapter. At present, it is important to realize that the degree of veridicality of a drawing can be gradual. The general purpose of a drawing is to convey information through the visual medium. Sometimes this purpose can be reached more effectively moving away from veridicality rather than striving for it.

Figures 5.6 and 5.7 are two examples drawn from a vast subset of graphic productions that have nothing to do with veridicality. The subset was represented in Figure 1.1 at nodes 17 (optical–geometrical illusions) and 18 (paper-and-pencil perceptual research). These drawings represent nothing but themselves. They are not drawings of objects; they are themselves visual objects. A quick perusal of most books on the graphic arts or on the psychology of visual perception reveals a large number of examples

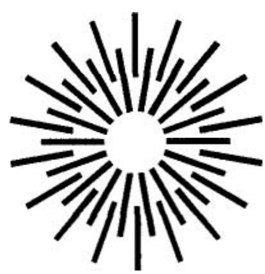


5.5.* Hypothetical model of the three-dimensional structure of a cellular component. In Staehelin L. A., & Hull B., Junctions between living cells,** Scientific American ***1978. (Reprinted with permission)

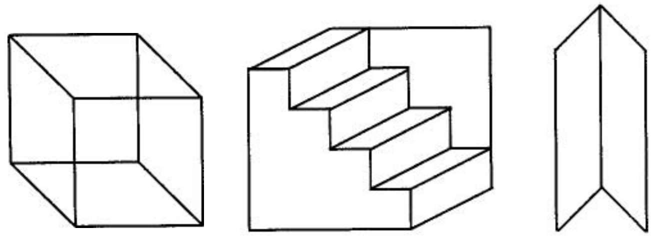
of such objects, which are considered interesting for their ability to intrigue viewers.

Figures 5.8 and 5.9 present two depictions of displacement. A displacement may be decomposed into two parts: an object and its trajectory in time. The object can be shown, as in the two cases of Figure 5.8, or it can be implied, as in Figure 5.9, which shows the trajectories of bikers performing a mass exercise during the Worker's Olympics of 1925. The direction of the lines representing trajectories is intuitive or is represented explicitly by arrows. In this way, the drawing becomes a tool to represent not only figures and spatial patterns of objects and scene, but also spatiotemporal properties of an event. Figure 5.10 represents such an event. Any transformation necessarily implies a temporal dimension: In this case, the temporal variation of a quantity, the value of stocks in the London and Paris markets. A sudden peak or a downward fall would represent traumatic events with great precision. Diagrams such as that of Figure 5.10 provide immediate and comprehensive information because they exploit general and automatic perceptual processes, not only to extract optical information at the early stages of the process, but also to extract higher level properties such the Gestalt psychologists "expressive qualities" or Gibson's "affordances" (4). Gibson created the neologism ***affordances*** to define characteristics that allow us to decide what is good or bad in the things with which we come in contact. The word *affordance* expresses, for example, the idea that air allows us to breathe and that the ground is a support on which we can rest. It allows us to recognize that water does not allow respiration, but does allow us to

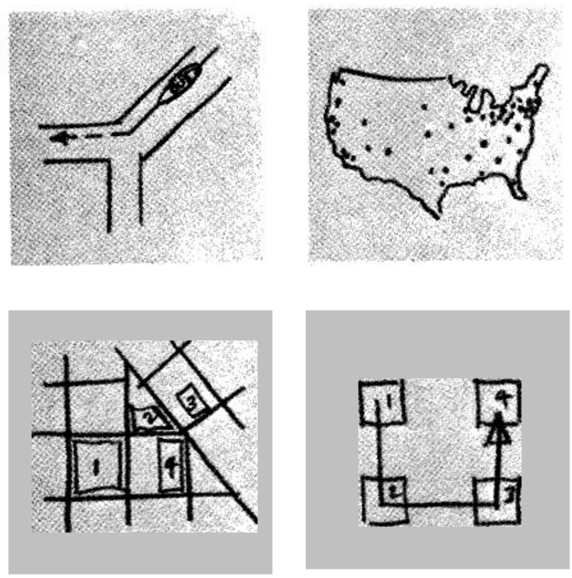
5.6. *Trademark by G. Meidinger. Catalogo Associazione Grafici Italiani, Alfieri, Venezia, 1974.*



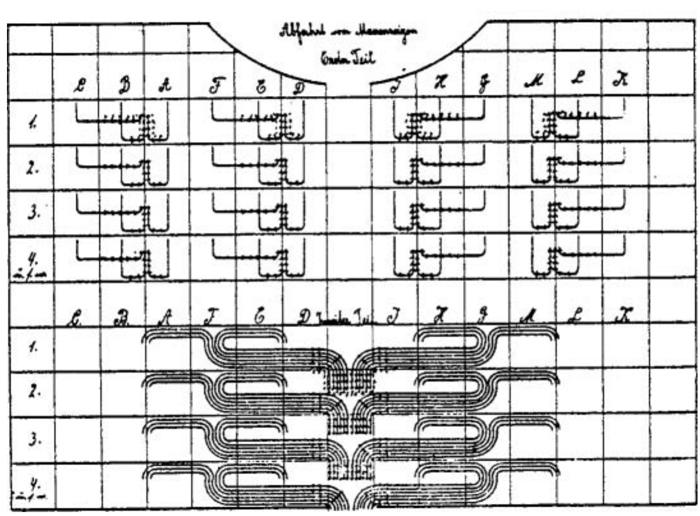
5.7. ***Drawings of geometric constructions.***

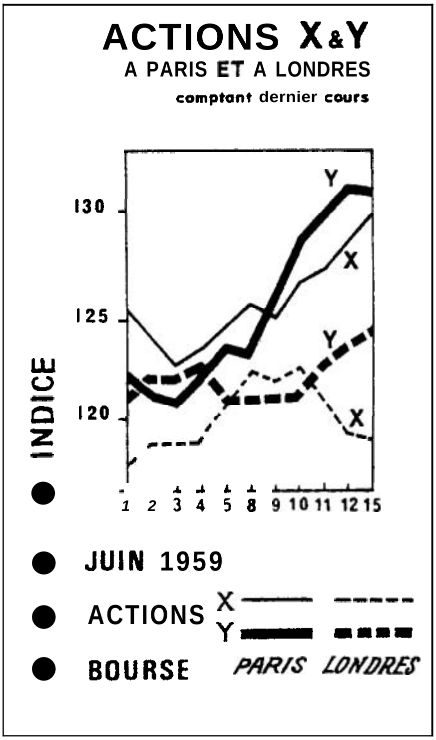


5.8. ***Trajectories of object displacements. Note. From W. J. Bowman,*** Graphic communication, ***Reprinted with permission from John Wiley and Sons Inc., New York. (Reprinted with permission)***



5.9. ***Trajectories of workers cycling. The Worker's Olympics, Frankfurt, 1925. In Buonfino, Cacciari, Dal Co,*** Avanguardia Dada Weimar. ***Venezia, Arsenale Cooperativa Editrice, 1978.***





5.10. A diagram of the evolution of prices of two stocks at the Paris and London stock markets. From Sémiologie graphique, *by J. Bertin, 1967. Villars: Mouthon Gauthier. (Reprinted with permission)*

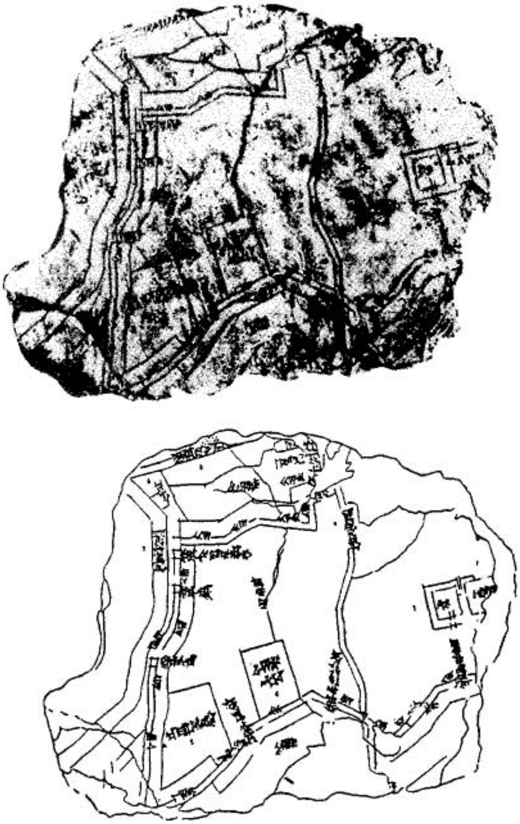
drink; and because it is fluid, it can be collected in a container and used for washing, but it is not a good support for heavy bodies. The optic information of water is well specified by the features of its surface, especially by its rippling fluctuations. The visible features of solid objects show instead the possibility of being manipulated, modified, modeled, and so forth. Every substance, every surface, every arrangement allows something in favor of or at the expense of something else. Gibson stated that the central problem for a theory of affordances does not concern whether these exist or not, but the understanding of ***how*** does environmental light convey this specific kind of information. Because the same stimulus provides information both for the perceptual outcome of formal–dimensional–positionalfeatures and for affordances, it is possible, according to Gibson, that two classes of invariants are working at different levels, providing simultaneously both types of information. One can think about a low-level class of invariants, such as those concerning formal and spatial characteristics, and about a high-level class of invariants, such as those concerning affordances. Diagrams are an excellent example of the interaction between top-down and bottom-up processes. "Reading" a diagram requires the activation of a data-driven process, which is responsible for registering the position of dots relative to the two-dimensional framework on the drawing surface. At the same time, however, a conceptually driven process is activated to assign a specific meaning to each of the dimensions and to appreciate their contribution for a specific position. The construction of diagrams, and the interpretation of them, represent two faces of an interesting perceptual and cognitive problem *(5)*.

A special form of drawing is the geographic map. Maps are special because they represent specific portions of the real world, but they are nonetheless essentially free from concern with verisimilitude. This is so because what one observes on a map is not a replica of an environment seen from a potential viewpoint, but what one would see from an artificial satellite high up above the area. Of course, one could in theory occupy such high viewpoint, but maps have a much older history than satellite launching and human space flight. Mapmakers and geographers seem capable of conceptualizing and representing the equivalent of satellite-based imaging, but this process is not grounded in verisimilitude. In mapmaking, the viewpoint chosen to construct the projection of the represented region is of great importance. In fact, the choice of where to position the virtual viewpoint of the projection is decisive in making the map reliable. If, for instance, the region that must be represented is very large, then the mapmaker faces the problem of the distortions of the spherical surface of the planet when this is projected into two dimensions. One the must make choice. If the map must represent distances reliably, then a parallel projection is needed, and the viewpoint must be placed at infinity. This will distort the outlines of the represented regions. If, instead, the map must represent forms, and distances are not crucial, one would choose a polar projection. Geographic maps are obvious examples of the processes and the decisions involved in communication through images: The choice of viewpoint and the dialectic between emphasis and exclusion. Think about the differences between a political and a physical map of the same region, or between a road map and an orthographic map.

Another choice a mapmaker must consider is the scale. This choice provides a value for the particular trade-off between represented area and the number of details included. The larger the represented area, the smaller the number of details that can included per unit area of the paper. An analogical coding of a very limited portion of the terrestrial surface is called a topographic map. Topographic maps are a very old form of diagram, as is shown by the examples of Figure 5.11. They date approximately to 2000–1500 BCE, that is, more than 1,000 years before Anaximandrus (610–547 BCE) is said to have produced the first geographic map. Apparently, it took a long time to make the conceptual leap from two-dimensional representations of directly perceivable terrain to those of large areas that cannot be experienced in a unitary way, but must nonetheless be represented coherently.

STRUCTURAL COMPONENTS OF DRAWINGS

I have argued that veridicality is neither the sole nor the most important connection between a drawing and reality. I have shown, furthermore, that drawings can portray temporal transformations and that they can synthesize in a single representation the main spatial features of a large geographic environment. To understand how graphics, despite their extreme material poverty, manage to represent such a variety of things and concepts, we must do three things. The first is to analyze graphic art in its elementary components. The second is to understand how these different components are combined to reach specific communicative goals. The third is to list the rules that apply, in different contexts, to these combinations. For the purpose of analyzing graphics into components, an initial distinction can be drawn between two families of constituent elements. I will call these the "primary" and "secondary" components. The distinction between them is purely operative, in that none of the two components can exist without the other in a concrete drawing.



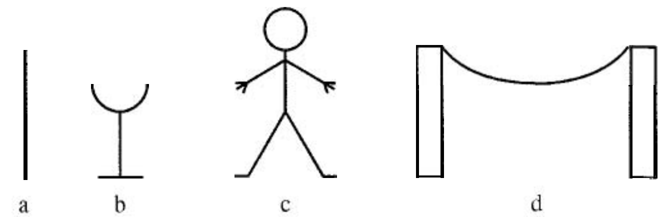
5.11. ***Topographical Map of the City of Nippur, 2000–1500 a. C. In Benevolo, Storia*** della ***Citth, Bari, Laterza, 1976. (Reprinted with permission)***

Primary components. Primary components have to do with the material aspects and the perceptual–cognitive implications that are common to all graphics in all cultures. They are (a) the characteristics of graphic marks, (b) the kind of relationship that one can establish between the surface of the drawing paper and the surfaces of the portrayed objects, and (c) the modalities through which the communicative goals of the artist influence the process of emphasis and exclusion.

Secondary components. Secondary components, in contrast, are those that depend on the place, time, and culture that are the environment for the production of a drawing; in addition, secondary components also depend on the personality and style of the artist. The number of these components is large, for they differ by historical period, country, and artist. At a sufficiently detailed level of analysis, one could say that they differ in each new drawing. The secondary components of graphics are the subject matter of the history of art and of art critics. I am interested in these only marginally.

The objects of my study are the primary components, which are fundamental to investigate how graphic notations are formed. In contrast to secondary components, the primary ones are easy to define and finite. Graphic marks, which can be subjected to an infinite range of variations, constitute the most basic class of primary components. As anticipated in the first chapter, any time I talk about "lines," "traces," or marks, I refer to symbols produced by a human-controlled tool on any surface, aiming at communicating some content. In the 1974 edition of Art and Visual Perception, Arnheim discussed three ways of using a line to achieve specific phenomenal

5.12. *Examples of object lines.*



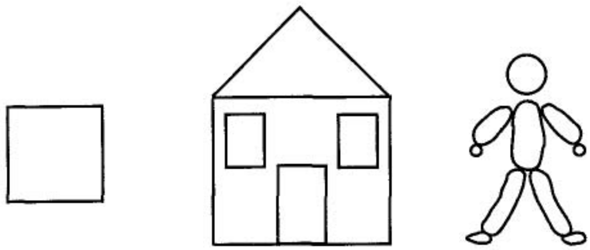
effect. These are lines as objects themselves, lines as edges of surfaces, and repeated lines that produce the effect of texture on a surface.

In my own analysis of graphic productions, I reached similar conclusions (6). Lines can indeed function as objects, as margins, and as texture elements. Going beyond Arnheim's classification, however, I found that lines also can be classified along another dimension, that of the mode of production which has, on one end, lines that are drawn perfectly by mechanical means or with the aid of instruments and, on the other end, lines drawn freehand with all the related imperfections. Recently, I worked on a further development of my work on the use of graphic lines (7), adding a fourth type of line, the line as a crack in a surface. This four-way classification exhausts the basic elements of any possible type of drawing.

Lines as Objects

In Figure 5.12a, we see a black segment, or a pole; Figure 5.12b is something that looks more or less like a fork. Figure 5.12c depicts the body of a schematic man. In Figure 5.12d, an object suspended on a rope attached at one of its extremities (8). This kind of mark is isomorphic to objects that are thin and that extend in one direction only. These objects are not uncommon. Consider, for instance, Figure 5.1, where we can see a rope holding a bucket, the masts of sailboats in the background, and the rope attached to the net on the foreground. In addition, the line object is useful to represent abstract geometric elements, such as the "rays" in Figure 5.6, or the lines that form the pattern of an optical–geometric (Figure 5.7). Finally, line objects are useful to represent virtual lines, such as the trajectories of Figure 5.8, or the unfolding of a transformation over time as in Figure 5.10, or a curve graphing a function. Object-lines are drawn through space but do not divide space into parts. Regions on either side of the line object are interpreted as belonging to the same background. Furthermore, line objects always represent an object that is "in front" of the picture plane. Therefore, they are always phenomenally "closer" to an observer. Line objects are usually open, that is, they are not connected to other lines, and they tend to be open on both ends. For this reason, the background usually completely surrounds object lines. In Figure 5.13a, we see four segments that meet forming right angles, but intersect in ways that leave their extremities unconnected. Note that the rectangular region, even if completely enclosed by the segments, does not

5.13. *The difference between object lines (left) and edge lines (right).*



5.14. *Examples of edge lines.*

appear segregated from the background (Figure 5.13a). Instead, we see four independent intersecting line objects. Note also that the segregation of the rectangle takes place in Figure 5.13b, where a continuous edge appears to have a rectangular shape.

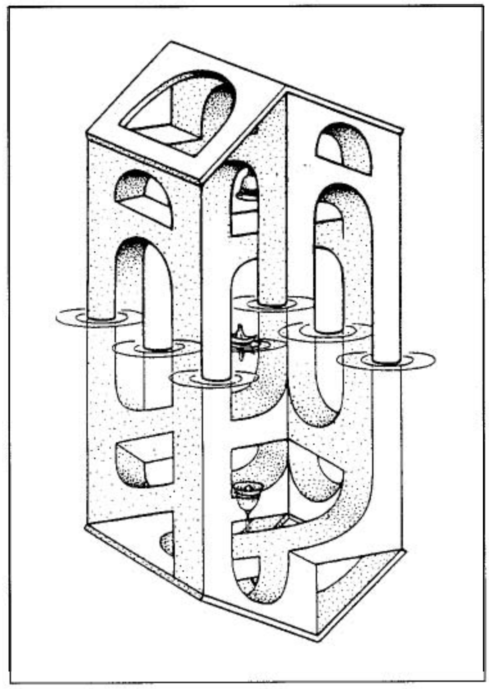
Lines as Edges

In the cases shown in Figure 5.14, objects are no longer represented simply by lines. Rather, they correspond to surfaces that are delimited by graphic marks. The lines now become edges that belong only to figures; that is, they acquire a "unilateral" function (9). Backgrounds lack edges and therefore appear to continue behind the figures. A perceptual split takes place in the perceived third dimension, despite the fact that the regions drawn on paper are physically on the same depth plane. With regard to phenomenology, the area delimited by a closed contour does correspond to a gap in the background. Thus, the region on one side of the edge line is completely different from the region on the other side (10), meaning that the "inner" region appears to be a different egocentric distance than the "outer" one. The edge line becomes the contour of an object, and this forces the enclosed region to appear closer to the observer. Typically, the terminators of edge lines are not isolated, but they intersect other edge lines or bend to form a closed contour. In many multistable patterns, edge lines are connected in such a way that there can be an inversion of border ownerships along lines. This intriguing effect is exemplified by the so-called impossible figures (see Figure 5.15) (11).

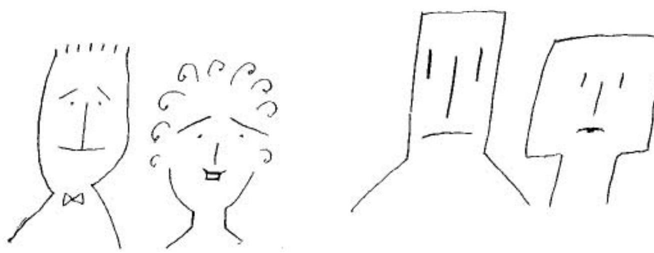
Lines as Cracks

Drawn lines can sometimes represent splits or ruptures on a surface (12). Crack lines are edges that belong to both sides of the surface, for they separate two parts of the same object. Examples of crack lines are the fissure that separates the two doors of an elevator or the lines that represent the mouth and eyes in the outline faces of Figure 5.16. Crack-lines are used sparingly in graphic productions, most likely because it is difficult to make a graphic mark to look like a crack. The reasons for this difficulty will be discussed in chapter 7, where I analyze the problem of how one can draw a hole. A crack line is made up of a line that separates two parts of a surface, or two juxtaposed objects such as the stones that make up a wall or the tiles laid out on the floor. In the last case, the line serves three functions: to border the right object (in the case of Figure 5.17, stones), to border the left object, and to define the fissure, that is, the space between the two stones. An additional, and far from secondary, feature of crack lines is their role in the recognition of expressive components (13). Crack lines are immediately connected with the notion of a fracture, a traumatic modification of an object due to an aggressive external agent. For this reason, lines are more easily interpreted as cracks when they are presented in conjunction with features that evoke

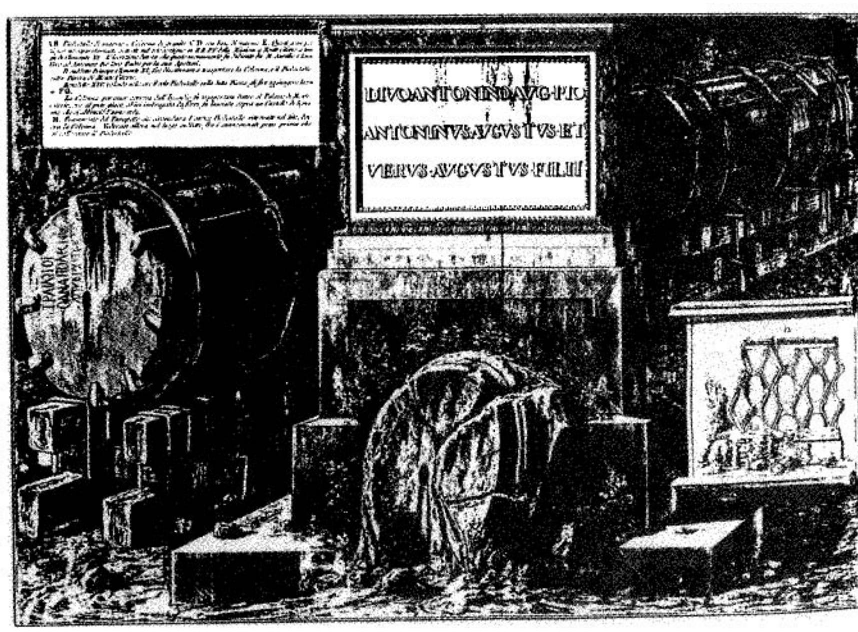
5.15. ***Checking for a leak in the basement. From*** Mind sights, 1990, ***by*** R. ***H. Shepard, New York: Freeman.***

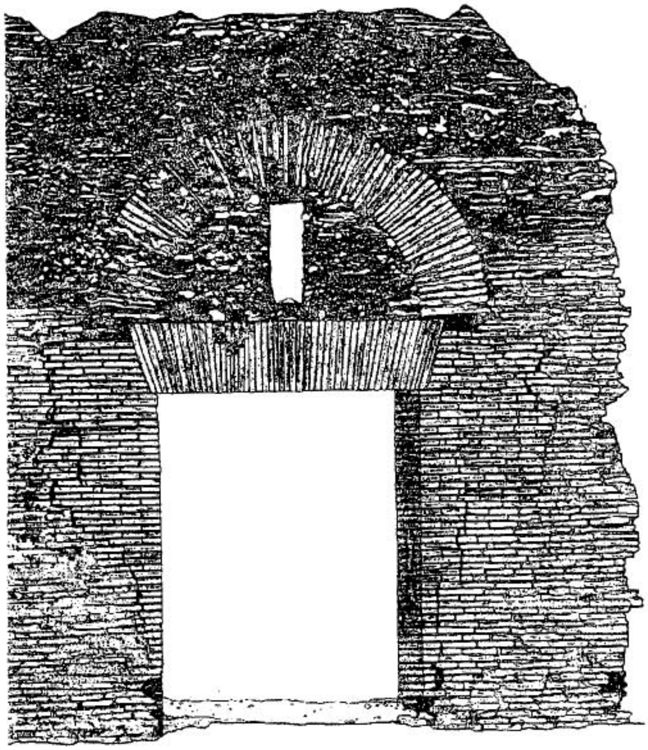


5.16. ***Examples of crack line. From S. Steinberg,*** Dessins **1945–1954, *Paris: Gallimard. Proprieté: Agence Hofman. (Reprinted with permission)***



5.17. The Temple of Cough. ***Etching by Piranesi, from Focillon,*** Piranesi, ***Henri Laurens,*** 1963, ***Paris. (Reprinted with permission)***



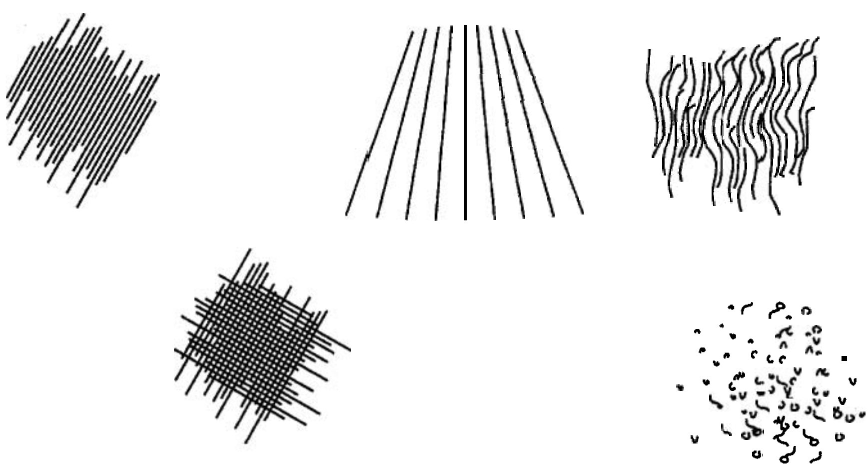


5.18. *Another example of crack line. from Rilievo per il restauro, 1990, by L. Marino, Torino Hoepli.*

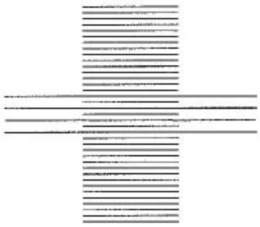
irregularity, causality, an lack of predictability. If you **compare** the drawing of Figure 5.18, you should appreciate that the crack line is more easily seen in the asymmetrical and irregular pattern.

Lines as Texture

When line elements are repeated on the picture plane, either without changes or with regular changes that show a systematic progression (the regularity need not be exact, but it can be simply statistically approximate), then the drawn surface appears to possess texture. Textural elements can take on a number of different forms and properties: They can be lines, dots, dashes, or irregular marks, for example, see Figure 5.19. Given that textural



5.19. *Examples of texture line.*



5.20. The textured area is grouped into a single unit, and the horizontal lines *appear* to pass behind it.

elements are usually rather close to each other, the regions surrounding them are necessarily small geometrically, and in fact nonexistent perceptually. The textured surface appears as a perceptual unit that is "in front," as in Figure 5.20, in which the four longer lines, even if they are not interrupted at the point where they intersect the edge of the column, appear to pass behind the column defined by a texture of horizontal segments (14). By manipulating texture, an artist can show small materials (such as hair, grass, pebbles, leaves, or waves) or differences in the color and the illumination of a surface (lights, shadows, transparencies, or physical color) or even material properties of a surface (such a rigidity, roughness, or hardness).

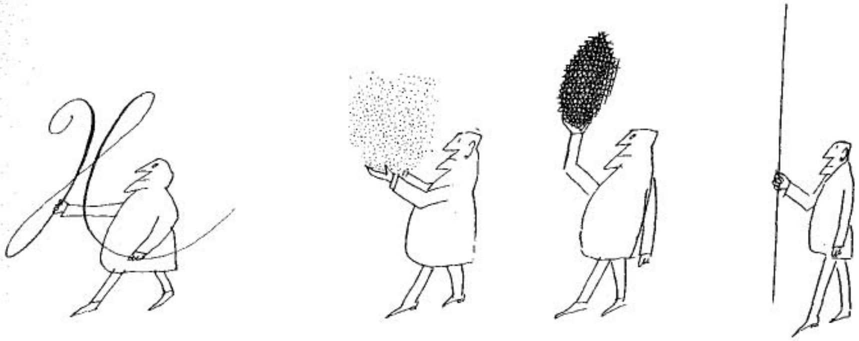
Any skilled engraver knows how to maneuver adroitly between these infinite possibilities, usually succeeding in the production of visual texture that informs about the nature and the properties of a desired surface. The work of Piranesi (Figure 4.2) is an inexhaustible source of evidence for the informative possibilities of textures. By skillful manipulation of texture, one can achieve drawings that tell about subtle qualities such as the hardness, polish, and erosion of stone; the transparency and mobility of water; the waving tree leaves in the wind; the difference between light and shadow in the layout of objects; and the reduction of contrast with distance. This refinement in the use of texture is one of the outcomes of the introduction of perspective: Consideration of perspective is needed to evaluate textural changes on the picture plane to give the sense of surfaces slanting or receding in depth, as well as in the use of aerial perspective, the gradual reduction of contrast as a function of distance. Renaissance theorists gave ample attention to the correct use of texture, which was deemed fundamental to achieving the three goals of visual art: dignity, verisimilitude, and wonder. For instance, one of the most important art theorists of the 16th century, Daniele Barbaro (15), wrote:

> The true accomplishment in art is to draw contours in a delicate and subtle fashion, so that even those things that cannot be seen can be understood. This way of drawing is a sweet escape, a tenderness in the horizon of our field of view. It gives pleasure to the unsophisticated viewer, and it is source of wonder to the viewer aware of the technical difficulties.

Gibson has demonstrated the fundamental role played by textures in the perception of the layout of surfaces. His analysis introduced the concept of stimulus gradient:

> Then, as the image differs progressively from point to point, the perceived surface can differ correspondingly in its distance or depth. There must in other words, be a stimulation gradient... if repetitive order is the stimulus for visual texture, this would constitute a gradient of the impression of continuous distance (16).

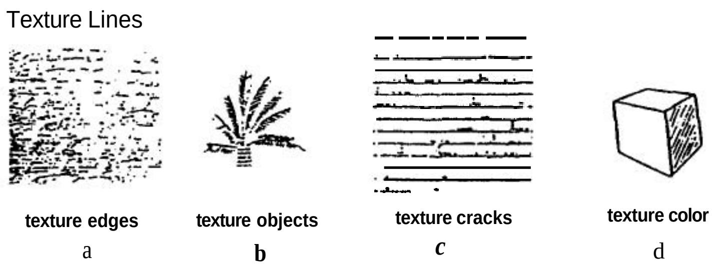
In Figure 5.21, Saul Steinberg, with unmistakable irony, proposed a ceremonious presentation of object lines, edge lines, and texture lines, the three most important kinds of lines presented here. In my opinion, this is an important contribution, even more so because it is constructed without using words. If one examines the examples in Figure 5.22 carefully, it can be noted that some of the structural elements of a texture have the same general properties of the first three classes of lines, transferred onto a smaller scale.



5.21. ***Edge lines, object lines, and texture lines in a drawing by Saul Steinberg (S. Steinberg,*** Dessins ***1945–1954, Gallimard, Paris) © Agence Hofman.***

Starting from this example, it seems possible to make additional distinctions among texture lines. Cutting and Massironi (17) suggested a four-way classification:

1. Texture lines as edges depict small objects nested within a larger object. Examples include depictions of cobblestones in a street (Figure 5.22a), the patterns in tree bark, or waves on a large body of water. Each such edge has a near side and a far side, but in a drawing or painting seldom is there any attempt to draw all cobbles, all bits of bark, or all waves. What is drawn are only a few emblematic strokes. Gombrich (18) called this "the etcetera principle," and it is applicable to texture of all types.
2. Texture lines as objects appear on larger objects. Examples are ripples on a pond (Figure 5.22b), hairs on a head, fur on a pelt, and grass on a lawn. In such cases, each line represents a single small object. Moreover, at a particular local pictorial depth around the stroke, each such texture line appears against a pair of regions of slightly greater depth.
3. Texture lines as cracks may or may not create small objects, but they always make patterns on a larger object. The mortar lines between bricks are created by texture lines and designate small objects within a larger one, but the tessellated cracks in the dried mud of a lake bed (Figure 5.22c) do not inherently create smaller objects; they are simply texture patterns on a large objects. Nonetheless, in each case, what lies unseen inside the crack is at a slightly greater depth.
4. Texture lines as color typically represent shadow or different shades of light (e.g., Figure 5.22d). Thus, they are surrogates for achromatic color. At a normal viewing distance from the picture, dark lines and tightly spaced light regions tend to assimilate and approach a gray. No depth relations are implied, except perhaps as inferred by a light source (19).



5.22. ***Texture lines as edges, objects, cracks, and color. Cutting, J. e Massironi, M. (1998). "Pictures and their special status in perceptual and cognitive inquiry." In J. Hochberg (Ed.),*** Perception and cognition at century's end, ***Academic Press, New York 1998. (Reprinted with permission)***

5.23. Graphic symbols drawn freehand.

The set of lines in Figure 5.23 has been sketched without a ruler. For this reason, all the lines are different from all the others, and it is practically impossible to reproduce them without the aid of some mechanical or photographic device. If one tried to copy them by hand, any careful observer would easily detect differences from the original. In general, the longer the line, the more difficult the reproduction. In Figure 5.23, one can easily determine that each line is different from all the others, even though some of them are the same length and some tend to have approximately the same pattern. Moreover, if we were to look at only one line at a time and were requested to make comparisons based on memory, it would be difficult to make correct judgments (20). Lines, just like any other graphic mark, are defined in a space with three dimensions: length, width, and pattern. The ability to discriminate between length and width is based on psychophysical constraints, whereas the ability to discriminate between patterns is based on processes of perceptual organization and unit formation. Differences in the properties of a graphic mark that depend on the mode of its execution convey information that can be used for graphic communication. If one decided to divide all graphic products according to the manner of their production, one would obtain two sets: the set of graphics with marks drawn using instruments and graphics with marks drawn freehand. One would also note that the elements of each set are homogeneous in terms of their communicative goal and of the kind of information that they can convey. As further illustration of the distinction, try this: Take a ruler and redraw the lines of Figure 5.23; using a ruler, one can obviate to the unavoidable imprecision of freehand sketching to obtain lines that look like those in Figure 5.24. The lines are still varying along the dimensions of length and width, but the variable that 1 have called "pattern" has now become completely irrelevant for discrimination.

Historians of mathematics have not been able to determine exactly when the tools that allow us to draw straight lines were first discovered during the evolution of our culture. Egyptian geometers were allegedly called "rope stretchers" (21). But, evidence suggests that even neolithic humans were interested in spatial relationships of congruence and symmetry. To manipulate such concepts, they must have already learned how to free the abstract concept of a geometric line from the vagaries of freehand drawing.

VIEWPOINT

5.24. Graphic symbols drawn with ruler.

The preceding section was devoted to describing and analyzing the main component of any drawing: the graphic mark. We turn now to investigating the other basic constituent of graphic communication: viewpoint. Two properties of viewpoint are instrumental in defining which information is conveyed by a drawing and how the observer's expectations are set. The first property is the position of the viewpoint relative to the depicted object, which determines the slant of the picture plane relative to the surfaces present in the scene. The second property is the distance of the viewpoint from the object. It is important to clarify at the outset that these two properties are active factors not only for representations that aim at reproducing objects with some degree of verisimilitude, but also for abstract graphic productions.

Viewpoint position. I have defined drawings as sets of graphic marks drawn on two-dimensional surfaces. It will be useful, for the purposes of the present discussion, to think of the drawing surface (say, a sheet of a paper) as having the same properties as one of the structural components of cognitive processes. What I have in mind is Baddeley's (22) notion of a "visual spatial sketch pad" as one of the key components of working memory, or that of a "visual buffer" as proposed by Kosslyn (23). As discussed in the previous chapter, Kosslyn's visual buffer is a cognitive structure that possesses topographic organization, is capable of containing an enormous quantity of implicit spatial information, and can feed some of this information to the visual areas of the brain. The input to the visual buffer is provided by "images produced by low-level vision subsystems or via priming in the pattern activation subsystems," whereas the operations that can performed by the buffer are the "retinotopic representation of perceptual image, topographic representation of mental image, organized into units bottom-up" (24). "The visual buffer contains much more information than can be processed at the same time, and hence an attention window selects one portion for thorough processing" (25). Each time I mention a "plane of representation," I mean both a drawing surface and its cognitive equivalent, which we could picture as a sort of enhanced Alberti's window intersecting light rays as they are reflected by objects, but also capable of performing a first processing of sensory input.

With regard to drawings, the role played by the plane of representation is connected to the contents that one wants to transmit by manipulating the tradeoff between emphasis and exclusion. Each drawing conveys a sense of the slant of the plane of representation relative to the represented scene. You can also think of this slant in terms of its equivalent, which is the slant of the scene relative to the plane.

As I will explain later in this chapter, the slant relative to the plane of representation is an important constraint on how one builds a drawing, be it representational or abstract, and it also constrains how an observer reads the drawing. The relationship between the drawing sheet as a plane of representation and the represented object depends also on the structure of the represented objects. A number of aspects play an important role in this respect. These include:

- the prevalence of planar surfaces in the object (think of a regular solid, such as a cube);
- the main orientation of the object (a tree, for instance)
- the presence of axes of symmetry or other regularities (think of a vase) and
- the presence of sides that convey more information than others (imagine the top view of a butterfly as opposed to its frontal view, or the side view of a horse as opposed to its top view).

The position of the plane of representation relative to the represented object depends logically from the position of the viewpoint, which is defined by the angle formed by the optical axis of the observer with the represented objects. In a nutshell, the optical axis is the height of the optical cone or visual pyramid. Imagine that both your retinae lie on the same plane and that this plane rotates in the direction of your gaze. The optical axis is the line perpendicular to that plane at the midpoint of the segment connecting the centers of the two retinae. The angle formed by the optical axis with the represented objects can take on two classes of values that are important for our discussion. First, the angle between the optical axis and the object can be equal to 90°. Second, the angle can form angles with these structures that are markedly different from 90°.

When the angle is exactly 90°, the corresponding viewpoints are special, in that they preserve in the projection certain metric relationships that are present in the object. For instance, for each point on a planar surface and for a given distance, there is only one viewpoint in such a manner that the optical axis of the observer is perpendicular to that plane, whereas there are infinite viewpoints in such a manner that the optical axis is not perpendicular to that plane. For each point on the corner formed by the junction of two half planes, there are infinite viewpoints if the optical axis forms two right angles with the corner. These viewpoints must belong to a plane orthogonal to the corner itself, however. If an object possesses rotational symmetry around the vertical axis (for instance, in a vase), the relationships between the optical axis and the axis of symmetry of the object will be the same as that with corner. Gibson presented the difference between these two possibilities in the following way (26).

> Consider for a moment the physical environment from which light is reflected that is projected onto the retina. The problem of distance perception has been reduced to the question of how we can see surfaces parallel to the line of sight. These will be called longitudinal surfaces to distinguish them from frontal surfaces, which are perpendicular to the line of sight.... The surfaces of the physical environment and its parts are either longitudinal, frontal, or somewhere between these two extremes.

Viewpoint distance. The distance between the viewpoint and the represented scene is the second fundamental constraint on how drawings convey information. Marr (27) noted that perspective representations are viewer-centered object descriptions, whereas nonperspective representations are object centered. In practice, however, pictures that are either exclusively viewer centered or object centered are quite rare (28). Most pictorial representations occupy an intermediate position between the endpoints of the continuum in Marr's definition. In distinguishing between viewpoint position and viewpoint distance, the classification I propose here is more informative precisely because of these intermediate cases. I hope, therefore, to be able to analyze these images in a more articulated fashion. To get a sense of the relationship between the two ways of classifying images, consider that a completely viewer-centered description, which corresponds to an image that has the viewpoint at a random position relative to the scene and at some finite distance from it, whereas a completely object-centered description exists at a specifically chosen viewpoint position but at an infinite distance. Given that there are two other basic ways of pairing distance and position, the classification proposed here promises to divide images in a more articulated and fruitful way, in accord with the observations of Willats.

As for viewpoint position, there are two classes of distance that are relevant to our definition. The first comprises all the cases in which the viewpoint is at a finite distance from the scene. The second includes all the cases in which the distance from the scene is infinite. Of course, this latter case corresponds to a theoretical possibility, for nobody will ever be able to look at an object from an infinite distance. Nonetheless, the possibility becomes concrete for the artist, who can choose to place the viewpoint at an infinite distance when trying to emphasize certain kinds of information and neglect others. As we will see shortly in the discussion of operational drawings, to represent a scene with a projection having the viewpoint at an infinite distance means to neutralize any perspective clue to three-dimensionality, reducing all objects to the paper surface. Thus, any scene becomes tractable within the domains of descriptive geometry. Conversely, to draw the same scene with a viewpoint at some finite distance means to create the conditions for plausible three dimensionality from the two-dimensional picture. Instead of descriptive geometry, we will be using projective geometry. Depending on how the graphic marks are laid out on the paper, observers will achieve different impressions about the layout of the represented object surfaces, and correspondingly different expectations.

MANIPULATING THE COMPONENTS OF DRAWINGS

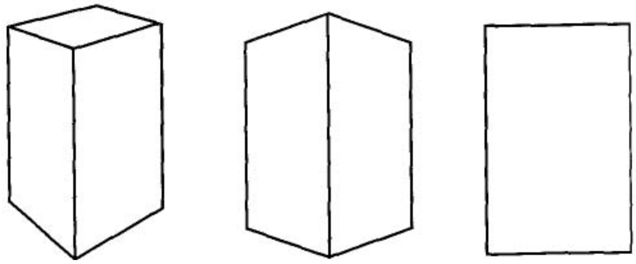
We have now disassembled the simple and economic mechanism that constitutes a drawing. It is now time to discuss how the structural components of a drawing can be manipulated for the purpose of producing a drawing with specific functions. Thus, we will now discuss how these components can be recombined as a function of the information that one strives to transmit and of the communicative goals one is trying to achieve.

Let us start with a brief summary of the components we have isolated. The first, the graphic mark, can take on four different forms: the object line, the edge line, the crack line, and the texture line. Texture lines in turn can take on three different forms, as detailed in the previous sections. In addition, each of these types of graphic marks can be drawn in two different ways: They can be drawn precisely, using appropriate instruments, or they can be drawn freely by hand.

The second component, the position of the viewpoint, can be chosen according to two different criteria. One is purely aesthetic. Choose the viewpoint that yields the most informative, more easily recognizable, and more convincing representation. In some sense, this an empirical issue: One tries several versions and chooses the best. The other criterion is utilitarian. Choose the viewpoint that best guarantees the correct recovery of the information one wishes to convey. Note that here you are not concerned with the most informative viewpoint, but with the viewpoint that best suits the transmission of a specific piece of information. To that aim, the best choice is usually to position the viewpoint at right angles with one of the structural components of the object. This choice is rational and principled; the choice of positioning the viewpoint at an infinite distance from the object always obeys this second criterion. In fact, the choice of this position is so important that it establishes the foundation for a whole branch of geometry, the "descriptive" geometry that provides a complete system for representing part–whole relationships in objects.

The third component, the distance of the viewpoint from the represented object, divides in two major classes: finite distance and infinite distance.

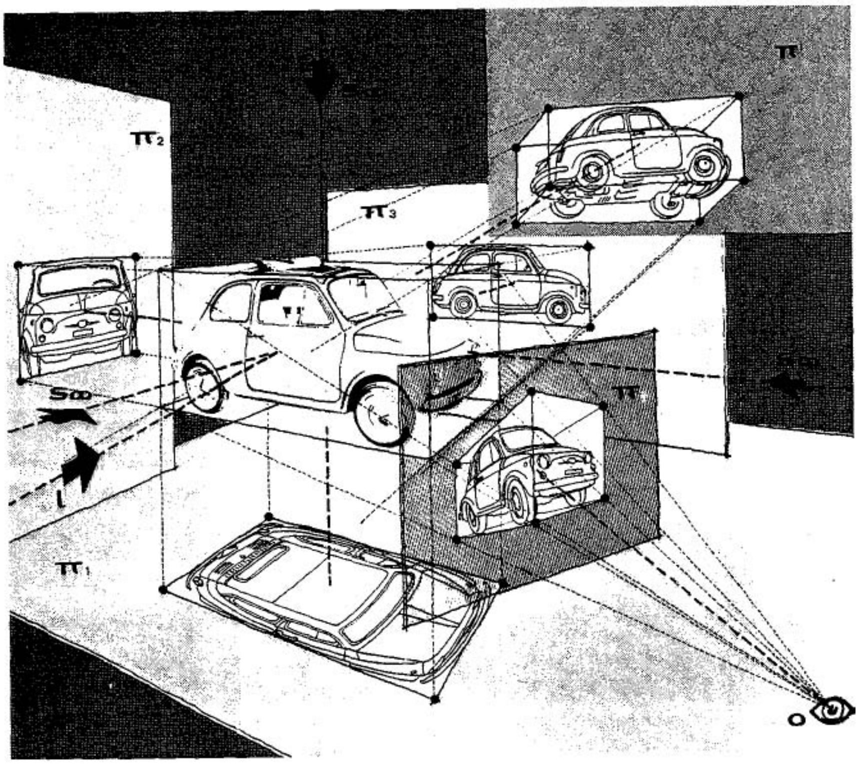
5.25. *Projections of a solid from different viewpoints.*



When the viewpoint is placed at a finite distance, the object obeys the rules of perspective. Therefore, lines parallel to the optical axis converge toward the same point on the horizon (see Figure 5.25b). If instead the viewpoint is at an infinite distance, the depicted object obeys the rules of parallel projections. Therefore, lines parallel to the optical axis remain parallel (see Figure 5.25c). The projections of the Fiat 500 automobile in Figure 5.26 synthesize all that I have said about viewpoint position and distance. The drawings on the *P* and P' planes have random positions and finite distances. Those on the P1, P2, and P3 planes are drawn using a specific viewpoint at an infinite distance.

It is important to keep in mind that the decision on viewpoint position and distance has a much greater cognitive-communicative character than geometric one. The artist must make this decision even if there is no real object to refer to, which is the case when drawing something imaginary and nonexistent or when one is trying to make a graphic model to illustrate logical relationships visually. It also is apparent that the structural components of a drawing are mutually exclusive between classes. A line cannot be object

5.26. *Projection of a Fiat 500 car. From Petrignani, M.,* Disegno e progettazione, *Edizioni Dedalo, Bari 1967. (Reprinted with permission)*



and edge at the same time, and the viewpoint cannot be simultaneously in a random or specific position or at a finite and infinite distance.

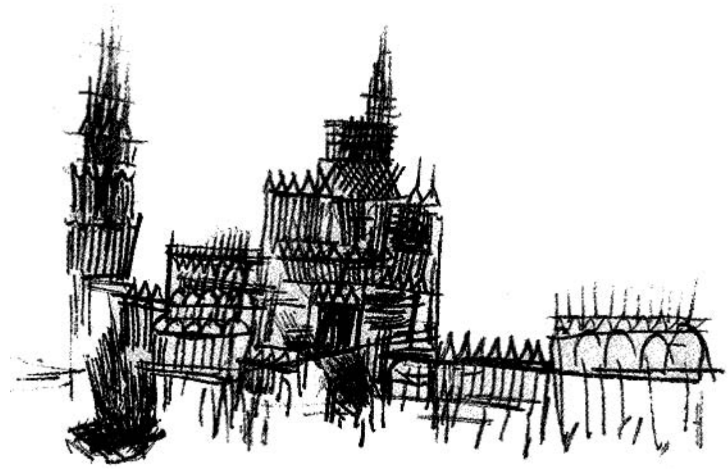
In making a certain choice, the artist puts into the drawing metacontextual information regarding the nature of the graphic product and about the viewing approach required by the observer. Thus, not only are the different components of a drawing selected and combined depending on the contents that one wants to transmit, but also these combinations show up constantly within each class of drawings as a sort of unwritten set of rules. One can then take the whole of graphic production and define subsets of it that have similar communicative functions. The number and kind of these subsets is not fixed. New subsets can emerge with new communicative needs. To verify these conclusions, let's examine three categories of drawings: illustrative, operational, and taxonomic. These three categories are probably the richest in number of graphic productions and are continuously increased by new inventions and contributions. I will draw the distinction between the three classes based on a functional criterion because I consider drawing a tool for communication that can modify its structure when its function changes. In this, drawing is substantially different from language, which maintains the same grammatical structure even if the contents one needs to transmit vary widely.

ILLUSTRATIVE DRAWING

Illustrative drawings are graphics that represent external reality or entities that, even if not experienced by observers in real life, are nonetheless drawn to appear as potentially observable. For the latter reason, illustrative drawings include figures that have symbolic functions. Think about much-exploited themes such as that of the Apocalypse, in which the artist draws monsters that come to Earth to warn mankind about the coming of the great event, and he or she draws them as concrete creatures even if they are nonexistent. Thus, the criterion for placing a drawing into this category is not the ontological status of the subject, but simply the mode of representation of objects, scenes, and characters. Symbolic or allegorical meanings are completely irrelevant. I group graphics from all ages under the rubric of illustrative drawings, from prehistoric cave etchings to today's cyberpunk comics.

Although it is relatively easy to gain a rough understanding of the features of this category of drawings, to define its limits precisely is much more complicated. The domain of illustration lends itself to creative research, and the continuous innovations continually provide new challenges to attempts at classification. We could ask, for instance, to what extent certain drawings of Paul Klee can be considered as having illustrative functions (see Figure 5.27), even if it cannot be denied that they represent recognizable objects. Happily, however, to avoid these "borderline" cases will be easy because the vast materials available for analysis provides more than enough.

If we accept that illustrative drawings are sufficiently homogenous in kind and in the use of their structural components, we can then attempt to outline a set of defining characteristics in terms of these components: line and position and distance of the viewpoint. In illustrative drawings, the use of freehand lines prevails, and these usually take on the form of edge lines and texture lines. Only in some special cases are these lines drawn using instruments, usually when representing artificial environments. Viewpoint



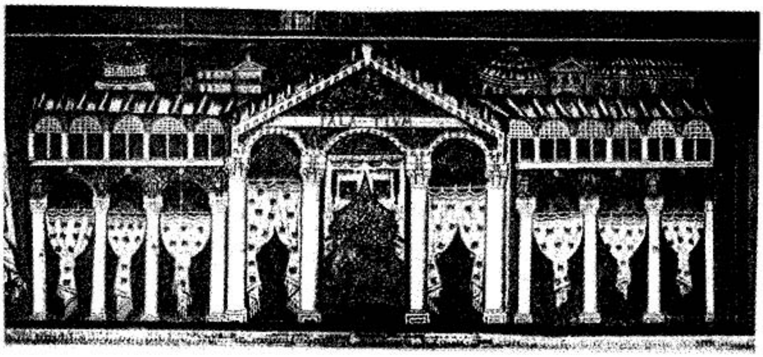
5.27. A special case of drawing with illustrative function: Paul Klee, Dutch Cathedral, *1927. From* Klee drawings, *Dover 1982. (Reprinted with permission)*

positions tend to be chosen by trial and error, and distances tend to be finite. The construction of illustrative drawings has been formalized with discovery of the geometry governing perspective. Before perspective, each object in the scene was shown from a specific viewpoint belonging to that object only. The outcome was an image that was spatially incoherent, as we saw in the portrait of the Antichrist in Figure 4.13, which depicts not a single environment, but a collection of objects each shown from its own viewpoint. With the advent of perspective, all the viewpoints used in earlier representations are collapsed in a single-observer position for the whole scene. The viewpoint of the perspective rendition becomes in this way the framework for the generation of a hierarchy and of a homogenous spatial order. All the elements of the hierarchy become subordinate to this framework. The discovery and the formulation of the geometry of linear perspective represents an exceptional achievement of the visual cultures of the world, so compelling that it became the cornerstone of all Western art from the 15th through the 19th centuries. The widespread use of perspective was accompanied by a flurry of theoretical treatises and of practical handbooks. Even today, after geometry has lost interest in projective geometry, the study of linear perspective continues in the interpretation of its cognitive implications, producing fertile analyses and interpretations (29).

OPERATIONAL DRAWING

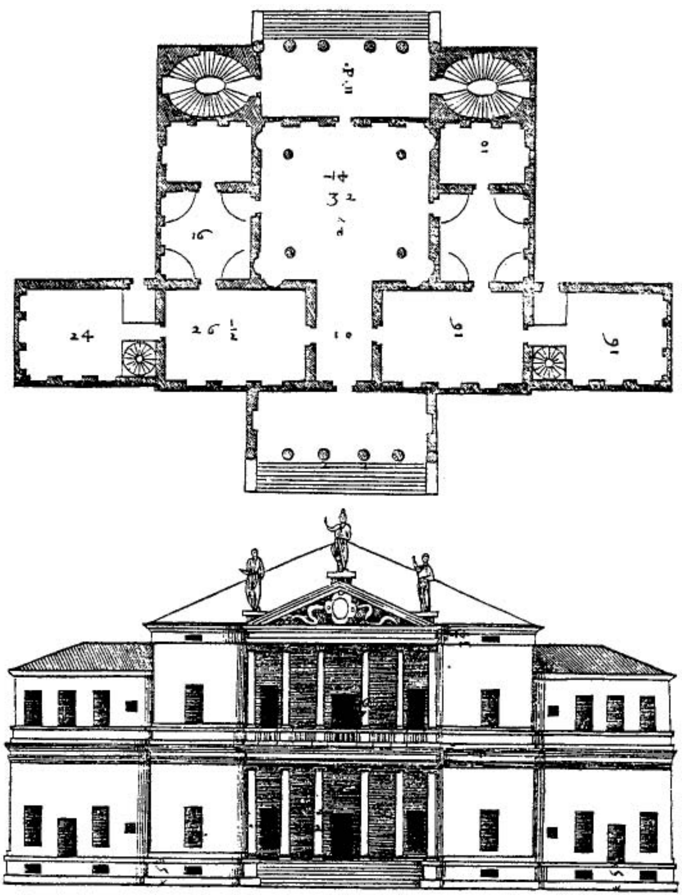
Operational drawings serve the function of preserving and transmitting information useful to performing operations (such as modification, construction, or destruction) on objects or on the environment. To this end, the most important aspects of this category have to do with dimension and relationships between parts. For efficacious operation, a drawing must preserve the dimensions of the represented objects, avoiding distortions, and showing in unambiguous fashion the constructive relations the relate each part to the whole.

The components of operational drawings are the edge line and the object line (usually drawn using instruments), the choice of specific viewpoints, and placing viewpoint positions at an infinite distance from the object. We have seen that the basic components of illustrative drawings are based on the



5.28. *Palace facade, mosaics of Sant'Apollinare Nuovo in Ravenna, 5th and 6th centuries. In Benevolo L.,* Storia della città, *Edizioni Laterza, Bari, 1976. (Reprinted with permission)*

geometry of perspective; the geometric formalization of operational drawings is instead based on the rules of descriptive geometry. Before the seminal work of Monge's *Géometrie Descriptive* (30), it was common to encounter images in which one of the faces of the represented object was frontal–parallel to the projection plane of the image. These images were used mostly to represent fronts of buildings or planimetries. Excellent examples are the Sumerian tables of Figure 5.11, the mosaics of the late Middle Ages of Figure 5.28, and in the projects of the Renaissance architects where the plan and the front of a building tend to be already connected, as in Figure 5.29.



5.29. Palladio, 1508–1580, Villa Cornaro *in Piombino Dese. In Palladio Andrea. I* Quattro Libri dell'Architettura. *Milano: Hoepli,* 1976. *(Reprinted with permission)*

When Andrea Pozzo (1693) presented his perspective machines for scenic productions, he stated explicitly that a realistic and convincing representation must start from the three frontal presentations of a building. Before Monge, artists believed that the only important aspect of the viewpoint was its position, which had to be placed at the center point of the facade. Cultural conditions did not allow the correct interpretation of its indeterminate position in depth as being one of optical infinity. After Monge, the frontal plane is no longer simply the site of projection for a frontal object, it becomes the supporting framework for all the planes one must represent to provide metric and dimensional information about the represented object, as well as information about its spatial relations with other objects.

In this way, after discovering perspective, the Enlightenment produced what we now call orthogonal projections. Perspective provided a system of rules for graphic notation with an illustrative functions. Orthogonal projections, on the other hand, provided a graphic tool for drawing plans and therefore were useful for practical purposes. To achieve this complex and sophisticated simplification, the mechanistic thinkers of 17th century had to cognize that geometry was the heuristic model par excellence, and Pascal and Leibniz had to provide the foundations that rendered the concept of infinity conceptually understandable and mathematically manipulable. Only then could orthogonal projections be understood as presentations of objects as seen from a viewpoint that no observer will ever be able to occupy—a viewpoint at an infinite distance from the scene. In orthogonal projections, space is rigorously conceived as purely Euclidean. Represented objects are dismembered along their orthogonal directions. As a consequence, artists had to give up using pictorial cues of depth to draw the object. Verisimilitude was thus abandoned in favor of an almost abstract treatment of the image. The practical value of the representation supported the new means of production that required plans and design to specify the stages of the project. Some examples of operational drawings were presented in chapter 4 (see, for instance, Figures 4.11 and 4.12), where again the pictures have been drawn while placing the viewpoint in a specific position and at an infinite distance.

Some readers may ask how one determines the position of the viewpoint from looking at an image. After all, it is clear that this position must be in the mind of the artist, but how can one retrieve it from the picture? Does the image uniquely specify a given viewpoint, such that one can readily divide it into parts according to viewpoint properties? These are important questions, and they cannot be readily answered. The problem of tracing a two-dimensional representation back to the three-dimensional original is known as the problem of inverse projection. It is a problem that one finds over and over again in the study of perception and that also has important implications on how one may read a drawing—especially an operational drawing.

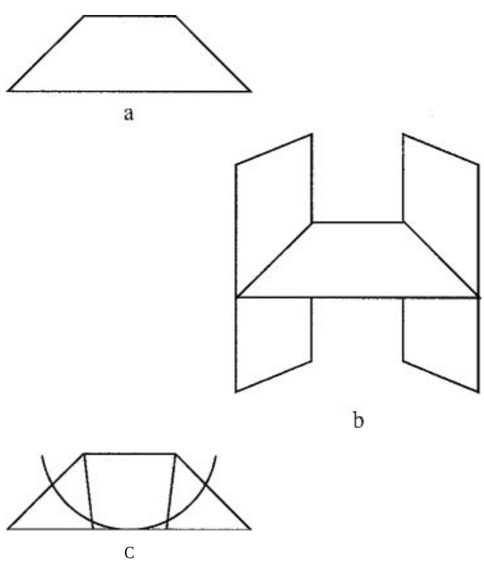
Solving the direct projection problem, that is, going from the distal state to the proximal is a straightforward task. The circumstances are drastically different when the inverse projection problem is assayed: When the occurrent retinal state is known, it is impossible to pick out a unique distal property, object, or event as the source. In contrast to the direct projection problem, going from the occurrent proximal state to the distal state constitutes an poorly posed problem. The difficulty arises from the fact that although a specific distal event or arrangement is compatible with only a single retinal state, a given retinal state is compatible with countless distal states (31).

The problem of direct projection is the problem an artist solves whenever he or she sets out to draw a scene. The problem of inverse projection is instead a challenge for the observer of the image. Now, direct projection has a unique solution, but inverse projection does not, for the two-dimensional drawing of any surface is geometrically a legitimate projection of an infinite number of three-dimensional surfaces differently sized and angled relative to the viewpoint. Remarkably, when looking at a drawing, one does not feel disturbed by this wealth of alternative interpretations for each surface. To the contrary, most drawings do not appear at all ambiguous or uninterpretable. How can that be?

The puzzle of inverse projection is especially salient when thinking about operational drawings, for illustrative drawings tend to be richer in pictorial cues to depth. Presumably, cue redundancy reduces the set of projectively equivalent three-dimensional arrangements, thereby helping the observer solve the inverse projection problem. Surprisingly, there is little evidence in the psychophysical literature on depth perception that this is really the case (32).

What seems clear, on the other hand, is that in operational drawings, cues to depth tend to be avoided, except for interposition. As an expert of perspective and a skillful manipulator of depth cues, Monge was well aware that placing the viewpoint at infinity tends to flatten out the appearance of the projected object. For this reason, to correctly describe the three-dimensional form of an object in an operational drawing, one needs at least three orthographic projections, and often more. And yet, when looking even at a single orthographic projection, such as the one in Figure 4.16, observers do not usually experience uncertainty. They simply decide that the object is seen frontally and easily reach an interpretation of the distal state portrayed in the drawing. Why do observers make this assumption?

To this date, there is no clear consensus on the answer to this question. Based on my personal, empirical observation, it seems that only sufficiently simple configurations are experienced as projectively ambiguous. This is the case of the trapezoid of Figure 5.30a, which is readily interpreted



5.30. A trapezoid (a) can be interpreted as a rectangle slanted in depth (b) or as frontal–parallel trapezoid (c).

both as a frontal trapezoid and as a slanted rectangle. When the configuration becomes more complex, the degree of experienced uncertainty is reduced. If, for instance, the additional lines introduce more cues to depth, as in Figure 5.30b, then the impression of a slanted rectangle becomes more compelling. If the additional lines do not introduce cues to depth, as in Figure 5.30c, then the frontal trapezoid is preferred. In terms of the problem of inverse projection, this seems to suggest that a frontal view is assumed when the frontal view is consistent with the simplest of all the projectively equivalent shapes, for instance, squares and rectangles among the set of quadrilaterals or the circle among conic sections. Thus, to show an object from a viewpoint that is frontal–parallel to one of its surfaces, one should choose a view with the simplest surface in front. This rule of thumb is consistent with the notion that perceptual activity always proceeds from the complex to the simple, never from the simple to the complex. A trapezoid can be seen as a slanted rectangle, but a slanted rectangle will never be seen as a trapezoid (33).

In conclusion, I think that there are two reasons why drawings do not appear ambiguous even if they are ambiguous in terms of the inverse projection problem. The first reason is that a drawing may contain redundant cues to depth. If these cues mutually constrain the interpretation of the drawing in a coherent fashion, then the set of potential interpretations is reduced and, in many cases, completely disambiguated. The second reason is that we have a bias toward simpler interpretations. If a surface is shown frontally and the projection shows a simple geometric figure, then the simple interpretation is preferred, and all the more complex alternatives are not considered. Figure 4.16 shows two examples of operational drawings containing a large number of simple geometric figures (circles, rectangles, partly occluded squares). The impression that the view is frontal–parallel is very compelling, leaving no room for perceptual ambiguity. One readily interprets the view as faithfully depicting the distal arrangement of the mechanical components, which is the goal of an operational drawing.

TAXONOMIC DRAWING

Taxonomic drawings are drawn with the explicit aim of preserving and transmitting visual information to be used for classification. They must render explicit features that support a systematic ordering of entities into distinct sets and on the basis of fixed criteria. If these criteria are morphological or inherent to directly observable features, then the graphic tool is not only apt, but also necessary to communicate criteria and methods for classification. The natural sciences in particular have used taxonomic drawings in a systematic fashion. In this usage, the scientists have created a vast investigation and description of the components of the natural world.

As with illustrative drawings, taxonomic drawings are a consequence of the introduction and diffusion of perspective. In the taxonomic variety, however, one finds no rigid geometric formalization. Instead of a geometric framework, there are procedures that are functional to the aim of the drawing and are generally followed even if they are rarely spelled out. To understand the genesis of these procedures, it is useful to recall that perspective was the medium that enabled Renaissance artists to connect the forms of objects in a coherent and uninterrupted continuum. Before perspective, objects were isolated, separate entities. After perspective, they become parts of a visual discourse, a fluent narrative without empty spaces. In this sense, rendering three-dimensionality was not only a new way of representing things on a two-dimensional sheet, but also a new way of looking at things. During the Middle Ages, symbolic meanings had often emphasized deformation to the detriment of form (34).

In the Renaissance, the symbolism gave way to rules for ordering forms in a well-defined spatial hierarchy. When symbols lost their importance, empirical observation could become more precise and more exploratory. The representation of observables, the object of perceptual experience, acquired greater reliability and a higher degree of reality relative to what was described or assumed in the classical texts. The new capacity to connect observables became ordered representation, with the connection between objects made apparent by the appropriate rendering of spatial depth. If artists were earlier attracted by vast compositions, now they directed their attention to each single object, realizing that each possessed an intrinsic form, independent of the descriptions, images, associations, and symbolism that were previously attached to them to the point of hiding their form.

Thus, to understand and represent the space of landscape, to see and show light and color in their proper spatial relationships, were conceptual leaps similar in kind to those that pushed scientists to dissect human bodies and then to draw accurate representations of their constituent parts. Anatomy was rightly the first domain where observable variables demonstrated how a systematic and orderly representation of nature could be attained. The interest for natural systems developed, spreading from anatomy to botany and zoology (see Figures 5.31 and 5.32).

Foucault argued for the primary role of botany in the epistemology of the 17th and 18th century:

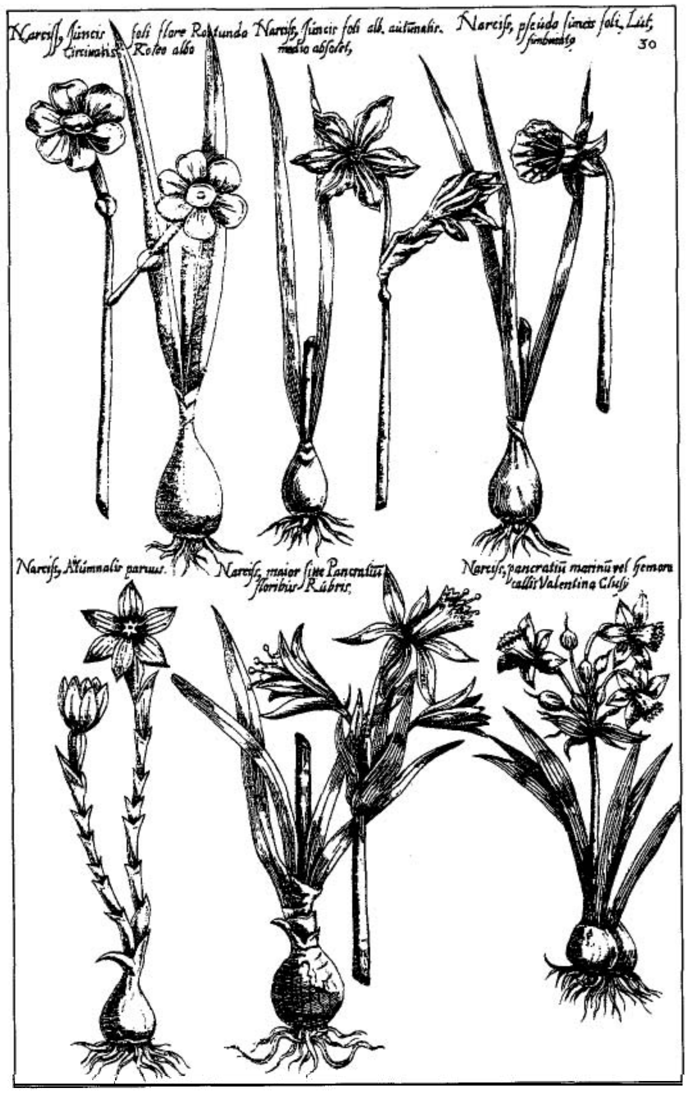
> The fundamental arrangement of the visible and the expressible no longer passed through the thickness of the body. Hence the epistemological precedence enjoyed by botany: the area common to words and things constituted a much more accommodating, a much less "black" grid for plants than for animals; in so far as there are a great many constituent organs visible in a plant than are not so in animals, taxonomic knowledge based upon immediately perceptible variables was richer and more coherent in the botanical order than in the zoological. (35)

Such a novel interest required a new tool that would fit its communicative goals. Given that botany relies on visual analysis, the graphic tool was a natural candidate. The method for representing objects in nature was shaped by a tacit but widespread consensus along paths that were stable and largely shared by intellectuals (see Figure 5.31) and that are still used for similar goals with little variation (see Figure 5.33).

In the second half of the 16th century, the Italian naturalist Ulisse Aldovrandi (1522–1605) wrote convincingly about the new attitude:

> If it occurs to the painter to depict a plant according to different stages of growth, such as when it sprouts and emerges the soil, or when it bears flowers and fruit, being at the perfect age ready to reproduce itself by means of its own seed, he must see it in a similar state and imitate it, so as not to make a mistake. And what I say about the whole plant, one must also consider for all its parts, considered together, which make the plant complete, such

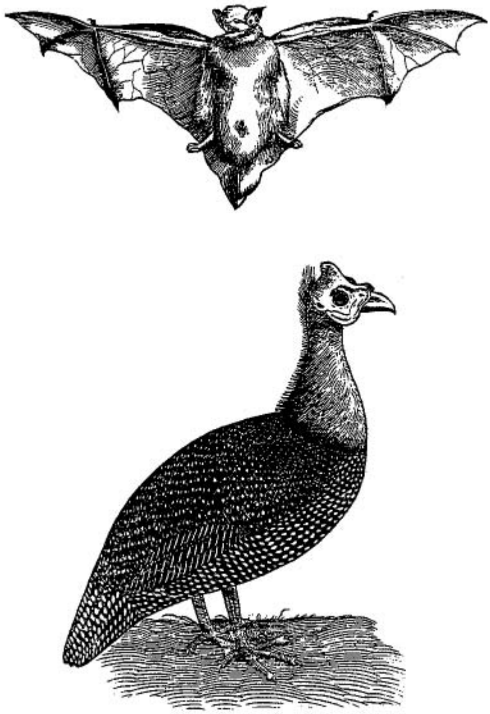
5.31. Sweerts, Narcissus and Other Plants, in Florilegium, 1612. Note. from *E. F. Bleiler* (Ed.), Early Floral Engravings, 1976, New *York:* Dover. (Reprinted with permission)



> as the root, the leaves, the stem and flowers and seeds, fruits, and other similar proportional parts, even occasionally considering their excrements, such as gums and resins. **(36)**

Foucault recognized the impact of Aldrovandi's contribution and described it as a turning point in the history of knowledge:

> Until the time of Aldrovandi, history was the inextricable and completely unitary fabric of all that was visible of things and of the signs that had been discovered or lodged in them: to write the history of a plant or an animal was as much a matter of describing its elements or organs as of describing the resemblances that could be found in it, the virtues that it was thought to possess, the legends and stories with which it had been involved, its place in heraldry, the medicaments that were concocted from its substance, the foods it provided, what the ancients recorded of it, and what travellers might have said of it. The history of a living being was that being itself, within the whole semantic network that connected it to the world. The division, so evident



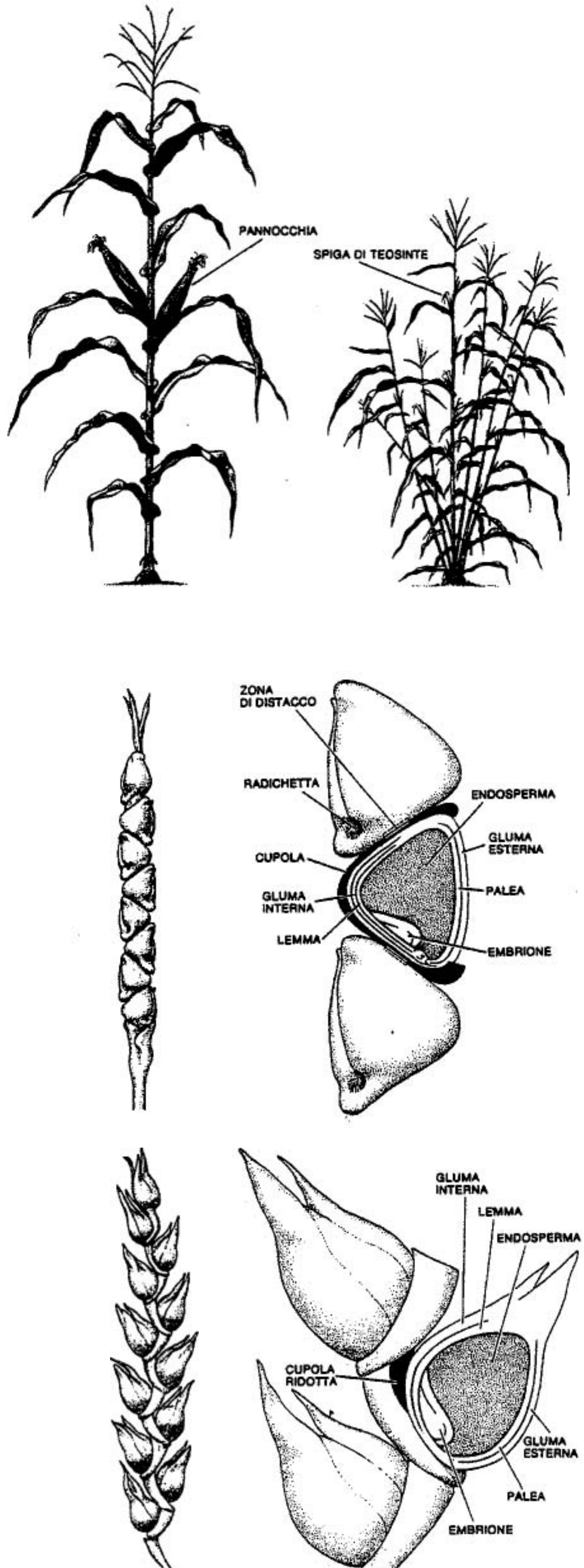
5.32. ***Gesner,*** Bat and common guinea-fowl, 1560. Note. From Curious Woodcuts of Fanciful and Real Beasts, Dover 1971. (Reprinted with permission)

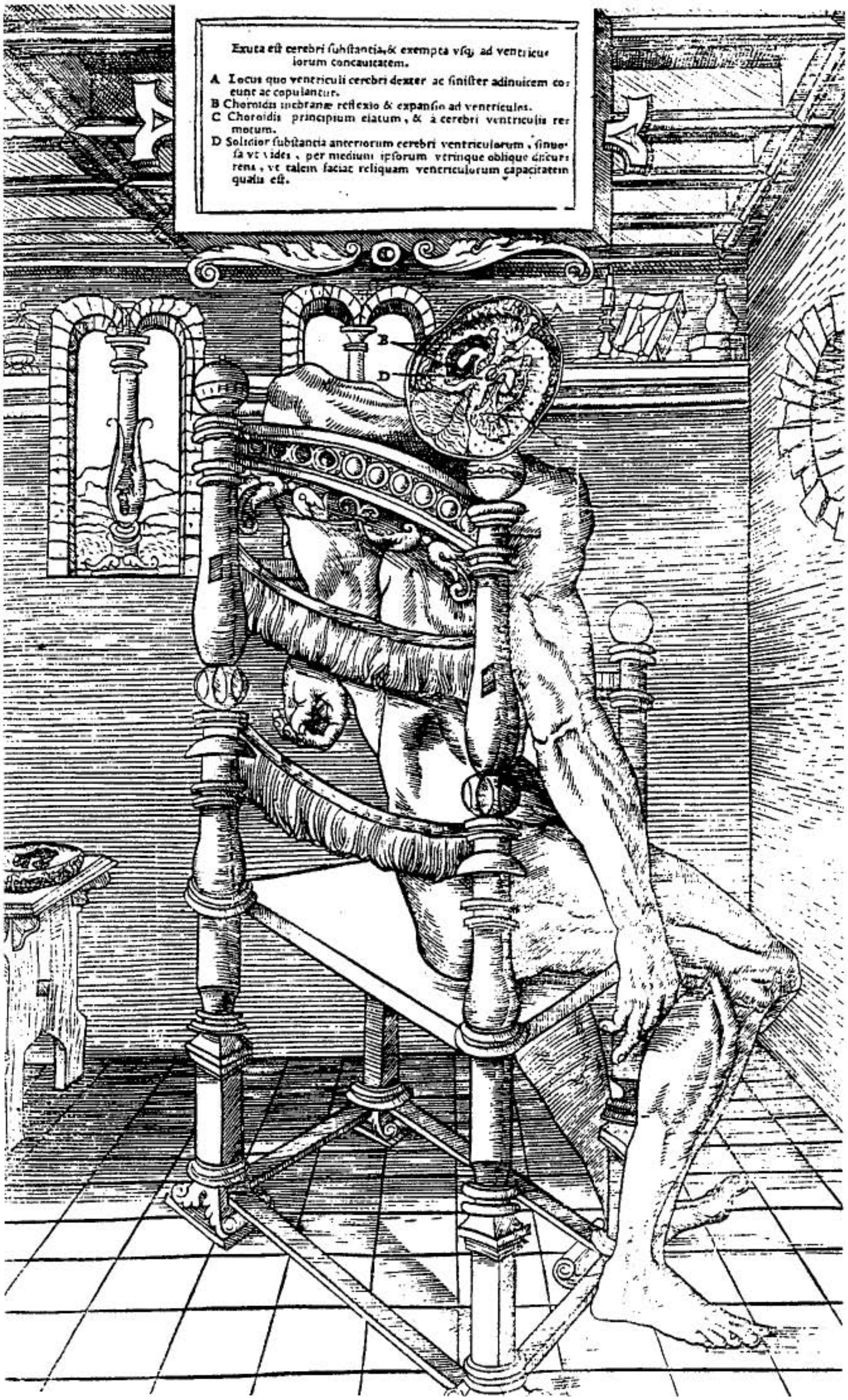
> to us, between what we see, what others have observed and handed down, and what others imagine or naïvely believe, the great tripartite division, apparently so simple and so immediate, into Observation, Document, and Fable, did not exist. (37)

Taxonomic images use the components of drawings in their own special way. All four varieties of graphic lines can appear: line objects, edge lines, crack lines, and texture lines. Lines tend to be drawn freehand. The use of freehand drawing and the frequent appearance of textures give a similar effect to that of illustrative images. On further consideration, however, one realizes that taxonomic drawings are fundamentally different from illustrative ones. The difference depends on the simultaneous use of many different viewpoints, all placed at finite distances. The choice of viewpoints aims at clarifying the salient aspects of the different parts of the represented object. If the object is a plant, for instance, the stalk, leaf, flower, and root will each be presented in such a way as to illustrate their most salient characteristics. Another defining feature of taxonomic drawings is the abolition of backgrounds. Objects are drawn against the white of the paper to make sure that no other visual structure disturbs the understanding of their forms and to make them look as if they were laid out on a surface with their relief directed toward the observer. As we have seen before, perspective representations of layout tend instead to recede in depth relative to the drawing plane. In this sense, taxonomic images can be conceived as going beyond the methods of perspective drawing.

Presumably, to give up the powerful tools of perspective must have been a diffiult direction to take, even if taxonomic drawings lend themselves naturally to such choices. In Figure 5.34, an anatomic drawing of the human brain, the larger portion of the image is wasted to show a room and a

5.33. ***Permanence of the criteria for executing a taxonomic drawing. From The ancestry of corn, by J. W. Beadle, in Scientific American, January 1980. (Reprinted with permission)***





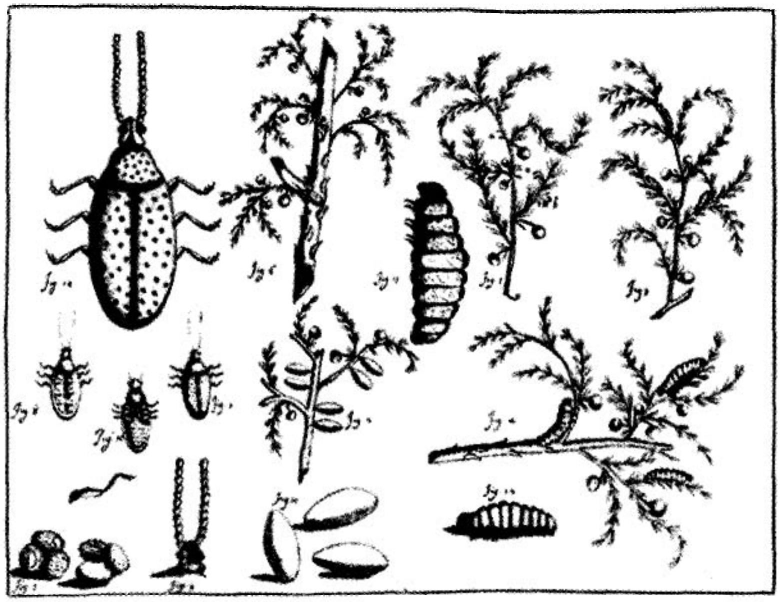
5.34. The larger part of the image is occupied by the surrounding scene, but the center of interest is limited to the human brain. Note. From De Dissetione Partium corporis humani, 1545 by C. Etienne, Paris. (In Brion ed. Quattro Secoli di Surrealismo, Milano Libri, 1973).

dissected cadaver on a chair. Even in the famous drawings of Vesalio (see Figure 4.6), which are entirely devoted to anatomic detail, one finds some hint of the supporting terrain and background of the figures.

In the botanical images of the following century, however, artists had completely given up representing backgrounds and started taking liberties with projections relative to the chosen viewpoint for the sake of illustrating plant structure in detail. The images in Figure 5.31 indeed look as if they had been copied from a live specimen. After careful observation, however, one realizes that the images portray prototypical specimens, not actual specimens. The visual attributes that are critical for morphological ordering and classification have been emphasized and sharpened, to the detriment of individual variation. Again, Foucault made this point most forcefully:

> To observe, then, is to be content with seeing—a few things systematically. With seeing what, in the rather confused wealth of representation, can be analyzed, recognized, and thus given a name that everyone will be able to understand: "All obscure similitudes," said Linnaeus, "are introduced only to the shame of art." Displayed in themselves, emptied of all the resemblances, cleansed even of their colours, visual representations will now at last be able to provide natural history with what constitutes its proper object, with precisely what it will convey in the well-made language it intends to construct. This object is the extension of which all natural beings are constituted—an extension that may be affected by four variables. And by four variables only: the form of the elements, the quantity of those elements, the manner in which they are distributed in space in relation to those elements, and the relative magnitude of each element. (38)

In botanical representations, minor, unavoidable, individual deviations from the norm found in single specimens are excluded from the picture. Here, the depicted specimen stands for the whole species; it is used to highlight the species' characteristics. It is not a coincidence that even today, in most cases, drawings and not photographs are still used for taxonomic purposes. A photographer necessarily reproduces the appearance of an existing individual, with it is potentially misleading specific characteristics. A drawing does have this limitation, and so the species can be described in an elegant and convincing fashion. In the domain of taxonomic drawing, one notes different adaptations in modality, forced on the technique by the different contents of the representation. Consider, for instance, zoology drawings, such as those used in entomology. In drawings aimed at illustrating zoological classifications, a global representation of the animal is usually accompanied by a series of sequential, supplementary views. In the global representation, the animal is presented in its most typical appearance, using the viewpoint that makes the drawing maximally expressive. Note that this viewpoint is not necessarily the one we take when seeing the animal. The additional sequence serves the purpose of illustrating different features, or different ways the animal can appear. This technique is especially useful in the case of insects, which undergo a number of metamorphoses during their lifetimes, with corresponding visual features presented for different stages of life (see Figure 5.35). Even when presenting the same stage of the life of an individual, a series of sequential presentations still affords the display of different appearances of the species, usually according to axes of symmetry or to notable features present on some parts of the animal. Incidentally, one may note that the technique exploiting different viewpoint for presenting the same object is closely related to a certain kind of Baroque experimentalism. Natural history textbooks contain a plethora of drawings and graphic materials. This immense graphic production rarely has any aesthetic pretension, but it is nonetheless created with careful, systematic attention to detail, patience, and skill in the use of visual means. One can appreciate the uniformity of the technique, which



5.35. *Vico,* The Development Cycle of Cantarella degli Asparagi. In *Penso,* G. *(1973).* La Conquista del Mondo Invisibile, *Milano: Feltrinelli.*

is based on unwritten but seldom-violated rules. Foucault defined drawing as the medium that allows nature to be conveyed by language. The effects of the enormous work of illustrators in the natural sciences goes beyond Foucault's suggestion, however, generating a corpus of visual materials that constitutes an integrated system of signs. Verbal or written discourse often would be incomprehensible if it were not accompanied by an orderly and functional set of drawings. The images in the drawings provide evidence for the discourse. Some content is conveyed well through language, but some is conveyed well only through vision. Messaris suggested the following line of division between these two kinds of content:

> What distinguishes images . . . from language and from other modes of communication is the fact that images reproduce many of the informational cues that people make use of in their perception of physical and social reality. Our ability to infer what is represented in an image is based largely on this property, rather than on familiarity with arbitrary conventions. (39)
>
> However, in my view, a more balanced summary of the study's findings would yield the conclusion that, although the particular physical environment of one's culture may make one more or less sensitive to certain visual cues, a base-level set of common perceptual processes is the shared property of all people. (40)

Taxonomic images can function as substitutes for objects of discourse because the visual features that define objects and differentiate between them can be presented simultaneously from different viewpoints. In this way, the drawings become prototypical examples that can define a class. To this end, the representation must be planned explicitly. A plant, at a first impression, can appear to be simply a copy of a real plant. But then one notices that flowers are drawn both in bloom and before blooming, both from the side and frontally; leaves, stems, and roots are all presented from different viewpoints. The representation is not just of an individual from a species; it is a representation of the defining characteristics of the species.