SPACE

Text abridged and adapted from *Art and Visual Perception* by Rudolph Arnheim (1974)

Dimensions

Geometry tells us that three dimensions suffice to describe the shape of any solid and the locations of objects relative to one another at any given moment. If changes in shape and location are also to be considered, the dimension of time must be added to the three dimensions of space. Psychologically we can say that although we move freely in space and time from the beginning of consciousness, the artist's active comprehension of these dimensions develops step by step, in accordance with the **law of differentiation**.

At the stage of the **first dimension**, spatial conception is limited to a linear track. There is no specification of shape. Disembodied entities, defined only by their relative location, can be conceived in terms of their distance, their relative speeds, and the difference between two directions, coming and going. A mind limited to this elementary conception of space would be primitive indeed. It would apprehend no more than what we can perceive going on behind a narrow slot.

A **two-dimensional conception** brings two great enrichments. First, it offers extension in space and therefore the varieties of size and shape: small things and large things, round and angular and most irregular ones. Second, it adds to mere distance the differences in direction and orientation. Shapes can be distinguished according to the many possible directions they point in, and their placement in relation to one another can be endlessly varied. Motion in the whole range of directions can now be conceived, as can the curves an imaginative skater might execute.

Three-dimensional space, finally, offers complete freedom: shape extending in any perceivable direction, unlimited arrangements of objects, and the total mobility of a bird. Beyond these three spatial dimensions visual imagery cannot reach; the range can be extended only by intellectual construction.

If for our particular purpose we apply these facts to visual representation, we find, first of all, that a purely one-dimensional performance seems not to be realizable for the normal human mind. Even a mere spot of light moving back and forth in the dark, or a single animated dot moving on an empty screen, is perceived as acting in full space and in relation to that space. In the same way, a single line drawn on a piece of paper cannot be seen simply as itself. First of all, it is always related to the two-dimensional extent around it. Depending on the range and also the shape of this empty environment, the appearance of the line changes. Furthermore, there also seems to be no way of seeing the line strictly in a flat plane. Instead, it is seen as lying in front of (or within) an uninterrupted ground. Fig. 1 shows an assortment of dots and lines active in front of empty space.

Fig. 1: Paul Klee: *The Script* (1940).

Our first, surprising discovery, then, is that there is no such thing as a strictly flat, two-dimensional image. We are reminded here of the struggles of the painter Piet Mondrian, who during the last years of his life renounced all references to physical subject matter, even to any shape, except for undifferentiated straight bands (Fig. 2). But there was one remnant of the visual world he could not overcome: the distinction between objects and surrounding empty space. However he tried, this basic trait of physical reality remained.

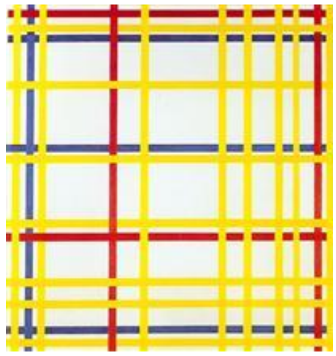
Fig. 2: Piet Mondrian: *New York City I* (1942).

Line and contour

Line presents itself in three basically different ways: as *object line, hatch line,* and *contour line*.

Object line

In the painting by Klee (Fig. 1), the lines are perceived as one-dimensional *objects*, as though they were wrought in iron or made of some other solid material. If they cross one another, they either remain independent objects like sticks piled up for a wood fire or fuse into more complex objects, whose branching resemble the limbs of animals or trees.

Hatch line

The visual combination of lines is controlled by the **law of simplicity**. When the combination produces a simpler figure than the mere sum of separate lines would, it is seen as one integrated whole. One extreme case of such simplicity is obtained by what is called shading: a group of closely packed parallel lines create so simple an overall pattern that they combine to form a coherent surface. The lines cease to be individual objects and act as *hatch lines*. This way of creating surfaces in a linear medium is used in drawing, engraving, and woodcuts. The detail in Fig. 3 of the woodcut *Head of Christ Crowned with Thorns*[1] (Fig. 4) shows how the curvature of parallel hatch lines is used to represent the bending of a surface in depth. Several families of parallels can be made to cross one another in order to show bending in more than one direction, e.g., in a saddle shape.

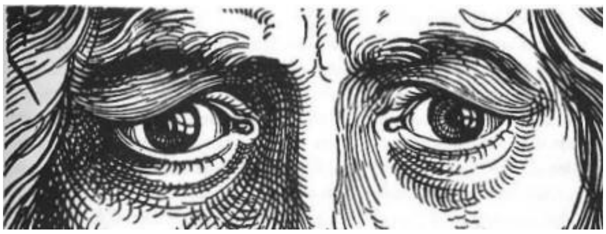
Fig. 3: Detail of *Head of Christ Crowned with Thorns* (c. 1520).


Fig. 4: Sebald Beham (used to be attributed to Albrecht Dürer): *Head of Christ Crowned with Thorns* (c. 1520).

Contour line

Now to the third kind of line —the *contour line*. If we draw a closed loop, e.g. a circle, the result will be variously perceived, but especially in one of the following two ways. The shape may look like a piece of wire, lying on a ground; i.e., we see it as an **object line**. As our Klee example shows, such empty loops will be perceived fairly readily when they are seen in company with other **object lines**. Even under such favorable conditions, however, this view tends to be uncomfortable and hard to hold. This is so because the empty loop requires us to see the

[1] This had been traditionally attributed to Albrecht Dürer, as Arnheim did in the original chapter which is the source of this adaptation, but now it is known to be the work of Sebald Beham in the style of Dürer

surface of the paper as a continuous background, or, to put it differently, to see the spaces on both sides of the line as related to it symmetrically. This works well as long as we are dealing with a straight line, but the symmetry is not supported by the shape of the loop, which creates a distinct difference between the small, closed, surrounded space inside (Fig. 5), and the unbounded, large, surrounding space outside. The total visual experience gains in simplicity when this difference in shape is logically supported by a difference in spatial quality. This is accomplished when the surrounded shape is perceived as a substantial object and its surroundings as empty ground. In the process, the line changes function: from an independent one-dimensional object it is transformed into the *contour* of a two-dimensional object. It becomes a part of a whole.

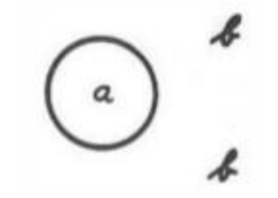

Fig. 5: Surrounded space and surrounding space.

The area surrounded by the loop line gives the impression of greater density than the area outside it, it is more solid-looking; whereas the ground is looser, less limited to a given stable plane. This impression may seem to be nothing but a carry-over from our experience with physical objects, which are seen against the empty space of their surroundings. Experiments suggest, however, that it probably derives from physiological factors underlying the perceptual process itself, quite independently of previous experience.

When the loop line functions as a contour, it is seen as the boundary of a circular or spherical object. If we wish to relate drawings to situations in the physical world we can say that **contour lines** stand for spatial discontinuities, either of depth or direction of slant, or of texture, brightness, or color. Even taken simply by itself, the outline drawing produces such discontinuities —a spatial leap from foreground to background, a difference in the density of the surfaces— to which a painter can add differences of color, brightness, or texture and thus strengthen the action of the line.

A line embracing an area creates a visual object; e.g., a circular line creates a flat disk. We tend to take this perceptual phenomenon for granted until we ask ourselves why the contour induces a flat surface (see the cross section in Fig. 6*a*) instead of any of the myriad other surfaces of which the drawing could serve as a projection, such as *b* or *c*. The straightness of a round table top is only one of the innumerable shapes we could obtain if, instead of the flat top of the round table, we draped a tablecloth over it. Here again the **law of simplicity** is at work. Since the surface comes about by indirection only, perceptual organization takes advantage of the freedom from stimulation and produces the simplest available surface. The straight plane is the simplest surface by which the circle can be filled. With any change of the contour the inner surface changes accordingly, always assuming the simplest available shape.

Fig. 6: Possible cross sections of a circle.

The influence of the contour on the induced inner surface varies with the distance. The larger the enclosed area, the weaker the influence of the **boundary line**, and the effect decreases toward the center with increasing distance from the outline. Also relevant is the size of the area in comparison to other nearby shapes. If one looks at the line drawings of Rembrandt alongside those by Matisse or Picasso, one will notice that the older master obtains solidity by keeping the outlined units relatively small. Rembrandt further reinforces the enclosed surfaces by inner design, such as folds of clothing (Fig. 7). In modern drawings, by contrast, the units are often so large that the contour all but loses its capacity to modulate space.

Fig. 7: Rembrandt: *Woman with the Arrow* (1661).

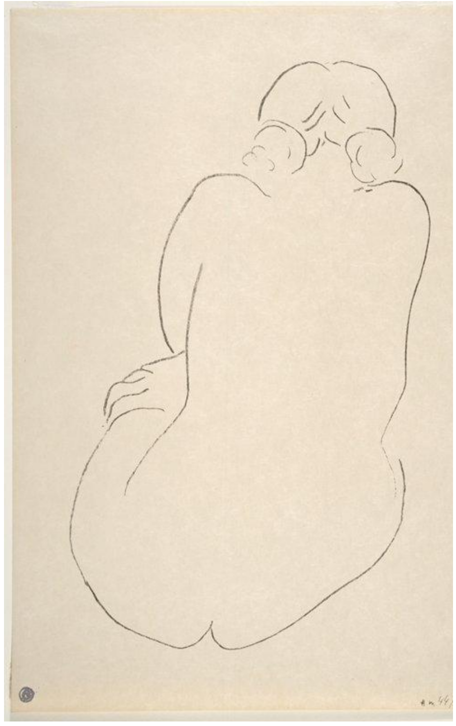

Fig. 8: Henri Matisse: *Seated Nude, Seen from the Behind* (1913).

The borderline character of the Matisse contours is weak (Fig. 8); they have much of the quality of self-contained object lines. The bodies look loose, and tend to reveal that they are nothing but pieces of empty paper surface. The drawing lies like a transparent web of lines on the ground. The three-dimensional effect is reduced to a minimum. Of course, this is done deliberately. Whereas the older artist wished to stress solid volume and clearly discernible depth, the moderns wanted to dematerialize objects and minimize space. The modern drawings are meant as lightweight products, obvious human creations, figments of the imagination, rather than illusions of physical reality. They are meant to stress the surface from which they spring.

To some extent, this is true not only for outline drawings but also for painted surfaces. They, too, are determined largely by the shape of their boundaries. A large, unmodulated stretch of color tends to look loose and empty. In the older paintings this effect is reserved for the representation of empty space, as in the gold ground of Byzantine mosaics or the blue ground of Holbein's portraits or the skies of landscapes; in modern paintings it is often applied to solid objects too.

Figure and ground

As mentioned earlier, there is no such a thing as a truly flat two-dimensional picture. There are many examples, however, in which two-dimensionality prevails in the sense that the image consists of two or more planes or shallow spaces extending parallel to the frontal plane and appearing at different distances from the observer.

Two-dimensionality as a system of frontal planes is represented in its most elementary form by the figure-ground relation. No more than two planes are considered. One of them has to occupy more space than the other and in fact has to be boundless; the directly visible part of the other has to be smaller and confined by a rim. One of them lies in front of the other. One is the figure, the other the ground.

In the figure-ground phenomenon, determining which of the two shapes lies in front is more ambiguous that one might suspect. In the old cosmologies the stars were sometimes seen as pinholes in the curtain of the night sky, through which the observer could have glimpses of a brighter, heavenly world. Another instance of this kind of unclear perception is the red maple leaf of the Canadian flag could be seen as the empty ground between two white angry profiles, Liberal and Conservatives, shouting at each other. Such ambiguous patterns approach a state of "multistability," in which various figure-ground factors balance one another in opposite directions. Some of such factors are mentioned below.

Figure as a surrounded surface

The surrounded surface tends to be seen as figure, the surrounding, unbounded one as ground. If we perceive the stars as sparkling in front of the dark sky, it conforms to this rule. If we see them as pinholes, the sky becomes the figure and the bright heavens assumed to exist beyond become the ground. We note that when the surrounded shapes are seen as ground, both planes involved in the figure-ground situation become boundless.

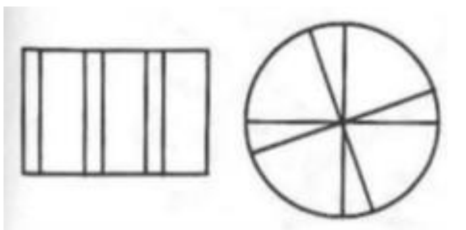

Fig. 9: Figure as a smaller area.

Figure as a smaller area

The relative smaller areas tend to be seen as figure. In Fig. 9 the figure plane is represented by the narrower bands or sections. This presupposes the **"rule of similarity of location"** ("Shape," Fig. 26 on p. 11), which holds that the more closely located lines are grouped together. Note here that, strictly speaking, these examples fall beyond the range of the figure-ground phenomenon: the ground is not boundless but outlined like the figure, and it lies on a third plane, the surface of the book page.

Reverse situation

If we try to reverse the spatial situation in Fig. 9 by making the larger bands or sectors come forward, we experience a strong resistance and succeed only for brief moments. The two patterns remind us that in a figure-ground situation, all shapes belonging to the ground plane tend to be seen as parts of a continuous backdrop. In the present examples, this backdrop takes the shape of a large rectangle or disk lying in front to the ground plane. In Fig. 10 the situation is reversed. The larger units lie in front because the small squares and sectors are perceived as the visible portions of a strongly coherent horizontal bar or small disk.

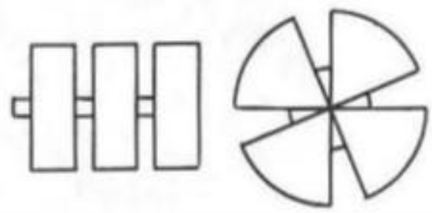

Fig. 10: Figure-ground in reverse size.

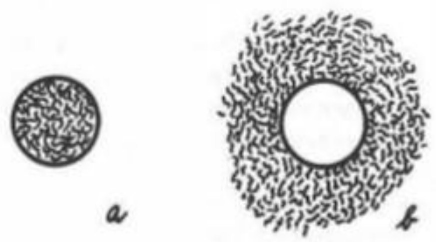

Fig. 11: Textured figure and textured ground.

Figure with more texture

It will be remembered that even in a simple line drawing, the surrounded figure possesses greater density than the looser ground. We may say that the two areas have different textures. Following this, we find that when the density of texture is increased by graphic means, the figure-ground situation created by the contour can be either strengthened (Fig. 11*a*) or reversed (*b*). **Texture**

Fig. 12: Henri Matisse: *Reclining Nude* or *Small Light Woodcut* (1906).

makes for figure. In the Matisse woodcut (Fig. 12) the factors of enclosed shape and texture are in competition with each other. The relatively empty body of the woman looks almost like a hole torn in the tissue of the environment. The artist deliberately dematerializes the body —a specifically modern effect.

Figure at a lower position

If the field consists of two horizontally divided areas (Fig. 13), **the lower one tends to be seen as figure**. This is related to the typical situation in the physical world, where trees and people are often perceived with the sky or the wall, i.e. the ground, in the upper part of the field, and this also corresponds to the observation that the lower part of the picture carries more weight. Note that this holds even when Fig. 13 is turned upside-down and the black part appears at the bottom. And this is the case even though in general, brighter areas seemingly tend to be figure when other factors are kept equal. As far as colors are concerned, we are not surprised to find that a saturated red makes for figure more strongly than a saturated blue; this corresponds to the general tendency of red to advance and of blue to recede.

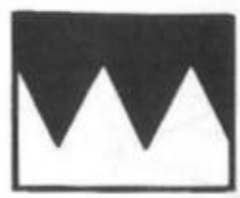

Fig. 13: Figure at a lower position.

Figure with simpler shape (symmetry and convexity)

Simplicity of shape, especially symmetry, predisposes an area to function as figure. The simpler figure will prevail. In the magic banisters of Fig. 14, the contradiction between the right and left sides of each of the drawings makes it impossible to obtain a stable image. But in this fluctuation we rather vividly experience the effect of the various perceptual factors. In *a*, both versions yield symmetrical patterns. For most people the convex columns are more often seen as figure, because convexity tends to win out over concavity. But in *b*, the concave units clearly prevail, because they give the picture more symmetry.

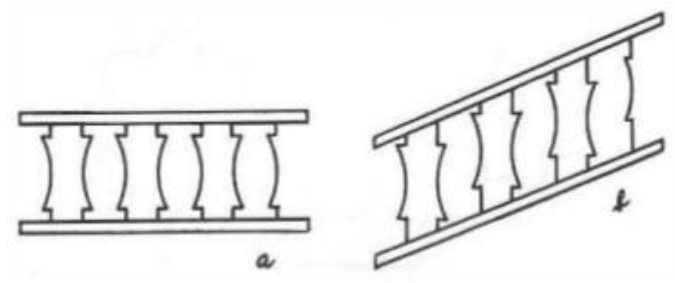

Fig. 14: Symmetrical/asymmetrical and convex/concave banisters columns.

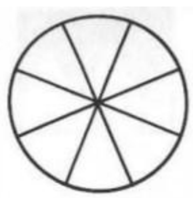

Fig. 15: Maltese crosses and spatial orientation.

Figure axes coinciding with ground axes (spatial orientation)

Simplicity affects not only the shape of a pattern, but also its spatial orientation. The two Maltese crosses in Fig. 15 are identical except for their orientation to the framework of the visual field. Under these conditions **the cross whose main axes coincide with the vertical and horizontal coordinates of the visual field tends to become the figure, whereas the other more often vanishes into the ground**.

Figure with convex shape

Of particular interest for the artist is the fact **that convexity makes for figure, concavity for ground**. Fig. 16*a* tends to look like a hole in the plane, although both *a* and *b* are enclosed areas and are thus more likely to be seen as figure. The phenomenon varies somewhat, depending on which part of the pattern holds the observer's attention. If she looks at the curves, *a* will be more clearly a hole, and *b* a solid patch on top of the ground. The opposite effect is usual when she focuses on the pointed angles between the curves because their narrowness makes for figure character. The examples of Fig. 16 also show strikingly that figure-ground is not just a matter of static spatial location but involves a difference of dynamics. Curves and pointed angles are like wedges pushing forward. Thus the "figure" has the character of active advance. In *a*, the surrounding figure closes in actively on the central hole from all sides; in *b* the central rosette expands vigorously across the ground. Since the ground has no shape, it lacks a dynamics of its own.

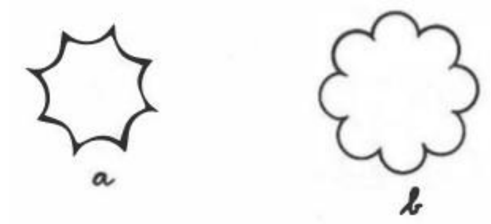

Fig. 16: Concave and convex shapes.

Depth levels

The terms "figure" and "ground" are suitable only as long as we are dealing with an enclosed, homogeneous pattern in an equally homogeneous, endless environment. But conditions are rarely so simple, Even in most of our elementary examples, more than two levels were involved. For example, in Fig. 15 the cross appears on a ground that is not endless but circular, and in turn lies like a disk on top of the surrounding empty plane (which in reality is not boundless because it has a frame). The disk is ground for the cross but figure for the surrounding surface. This is awkward terminology. Also, some of the more interesting organizational factors do not come into play as long as we are dealing with only two planes, one of which must be boundless and therefore shapeless. It seems more adequate to speak of patterns distributed over a number of depth levels, the basic figure-ground pattern being a special case, namely an organization of only two levels.

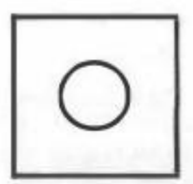

Fig. 17: Depth levels in figure-ground.

If we consult the principles so far described, Fig. 17 should be seen as a disk on top of a square base, which in turn rests on the ground. Instead the figure is perceived more stably, as a square with a circular opening in it. This is seemingly due to a tendency to simplification by economy, which means that the number of depth levels in a given pattern is as small as conditions permit. If the circle produces a disk that lies on top of the square, the result is a three-level distribution, whereas the perforated square makes for a total of only two levels. This leaves us with a smaller number of planes —that is, with a spatially simpler pattern. We conclude that when the perforation (interruption) of the square is weighed against the three-level arrangement, the former represents the simpler solution.

A somewhat more complex example may further illustrate the point. Fig. 18 is a woodcut by Jean Arp. The artist has balanced the perceptual factors

Fig. 18: Jean Arp: *Eleven Configurations* (1945).

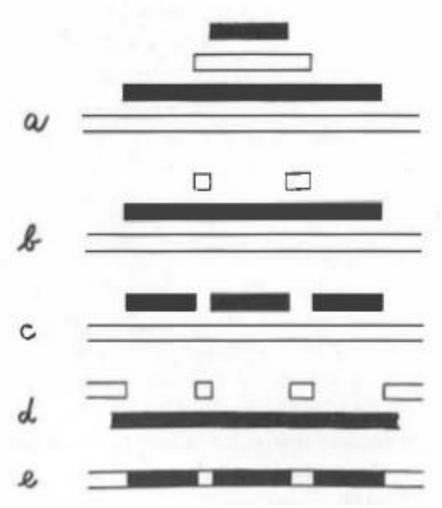

Fig. 19: Depth levels in Arp's *Eleven Configurations* (1945).

against one another in such a way that several spatial conceptions are equally possible. We may see a four-plane arrangement (Fig. 19*a*); a pyramid, consisting of a small black patch on top, a larger white one underneath, this resting in turn on a black patch, and the whole lying on an endless white ground. Fig. 19*b* illustrates a three-plane solution, in which a white ring lies on a black patch. Two two-plane solutions are given in *c* and *d*: a large black ring with a black patch in the center lies on a white ground; or everything white lies in front, and a black background is seen through the cutouts.

The **principle of economy** would of course favor a one-plane solution as the simplest (*e*); but this would involve a series of interruptions, which is avoided by a three-dimensional conception. The only solution that has the advantage of avoiding all interruptions is the pyramid (*a*), which is also favored by the **rule of enclosedness**. The pyramid, however, requires the largest number of planes. If brightness makes for figure character, *d* will be favored; this version is also enhanced by the two narrow bridges in the white ring. Finally, similarity of brightness tends to group all whites as against all blacks in two separate planes (*c* and *d*).

Application to painting

There are, then, definite rules according to which perceptual factors determine the depth location of frontally oriented planes in pictorial space. Artists apply these rules intuitively or consciously to make depth relations visible. In looking at photographs or representational paintings, the viewer is helped somewhat by what she knows about physical space from her own experience. She knows that a large human figure is meant to be closer by than a small house. The artist, however, cannot rely much on mere knowledge. If she wants a figure to stand out against the background, she must use the direct visual effect of perceptual factors such as the ones we have just discussed. She may also choose to reverse the way these same factors are usually employed to obtain a paradoxical effect, as exemplified in the work by Matisse (Fig. 12).

Frames and windows

The function of picture frames is also related to the psychology of figure and ground. The frame as we know it today developed during the Renaissance from the façade-like construction of lintels and pilasters that surrounded the altarpieces. As pictorial space emancipated itself from the wall and created deep vistas, a clear visual distinction became necessary between the physical space of the room and the world of the picture. This world came to be conceived as boundless —not only in depth, but also laterally—so that the edges of the picture designated the end of the composition, but not the end of represented space. The frame was thought of as a window, through which the observer peeped into an outer world, confined by the opening of the peephole but unbounded in itself. In our present discussion, this means that the frame was used as figure, with the picture space supplying an underlying borderless ground. This trend was brought to a climax in the nineteenth century, when (for example, in the work of Degas, Fig. 20) the frame was made to cut across human bodies and objects much more ostentatiously than ever before. This emphasized the accidental character of the boundary and therefore the figure character of the frame.

At the same time, however, painters began to reduce the depth of pictorial space and to stress flatness. Instead of representing a pictorial world, quite detached from the physical space of canvas and viewer, they began to think of the picture as an elaboration of the surface of the canvas. Pictorial space was no longer boundless but tended to end at the edges of the composition. This meant that the boundary line between frame and canvas was no longer the inner contour of the frame, but the outer contour of the picture. The picture was no longer ground behind the frame, but figure. Under these conditions the figure character of the traditional heavy frame and the spatial interval between the window in front and the pictorial world in back became unsuitable. The frame adapted itself to its new function by either narrowing to a thin strip, a mere contour, or even slanting backward ("reverse section") and thus establishing the picture as a bounded surface —a "figure," lying well in front of the wall.

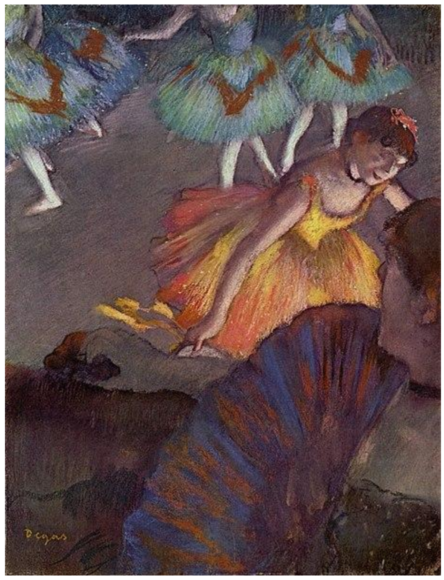

Fig. 20: Edgar Degas: Ballet, Seen from a Box (1885).

Why do we see depth?

As we proceed from the limited figure-ground relation between two planes to the stacking of frontal visual objects more generally, we realize that we are dealing with a special case of subdivision. In the organization of plane figures, it was found that subdivision occurs when a combination of self-contained parts results in a structurally simpler pattern than the undivided whole. This rule holds true not only for the second dimension but also for the third. Areas physically located in the same picture plane split apart in depth and assume a figure-ground configuration because simplicity increases when the one-sidedness of the contour is uncontested and when the ground can be seen as continuing beneath the figure without interruption.

In Fig. 21, *a* looks like a circle fitted into a square although the pattern could be the projection of two figures, one located at some distance from the other. The pattern clings to the second dimension because it is strongly unified: the centers of circle and square coincide, and the diameter of the circle is equal to the side of the square. The situation is quite different in *b* and *d*, where the two components are much more independent of each other. In fact, they tend to detach themselves from each other in depth because this divorce frees them from the stressful combination that exists in the flat projection. The tendency is weaker in *c*, where the projective structure has some simplicity: the center of the circle lies on one of the corners of the square and thus produces symmetry around a diagonal of the square. In *e* the divorce has become complete: both shapes display their simplicity without interference from the other. With the diminution of tension, the urge to separate in depth is no longer observable. If anything, the relative location in depth of square and circle is now undefined.

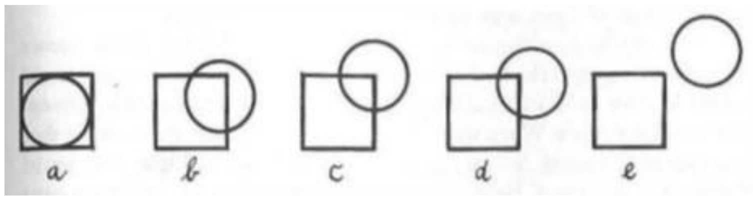

Fig. 21: Patterns of depth.

As long as the eye looks at these figures, their location within the frontal plane is unchangeable; it is controlled by the stimulus pattern on the retina. This pattern does not, however, prescribe location in the depth dimension. As a projection it may represent figures or parts of figures at any apparent distance from the eye. The third dimension is therefore an "avenue of freedom," which allows for changes in the interest of simplification of structure. If detachment increases simplicity, the segregation in depth can be accomplished without any modification of the projective pattern.

We are now ready for an answer to the questions *Why do we see depth?* The answer may seem strange. As long as we look at the physical world, the three-dimensionality of vision seems to offer no problem —until we recall that the optical input for all our visual experience consists in the two-dimensional projection on the retina.

The usefulness of three-dimensional perception is obvious for humans and animals that need to find their way around in the physical world. However, *how does depth perception come about?* The answer is particularly relevant for the artist who is concerned with visual representation on a flat plane; because in her case all physically derived cues show that the eyes are faced with a surface. Therefore, the experience of depth must be provided by the picture itself.

The artist realizes that she cannot simply rely on what the viewer knows about the physical world. Such knowledge must always be restated with visual means in order to be artistically effective, and it is easily undercut by perceptual counterevidence. When we look at a map of the United States we see that a corner of Wyoming lies on top of a corner of Utah, and that a corner of Colorado lies on top of Nebraska. No knowledge that this is not so prevents us from seeing what we see. Which are the visual factors that promote depth?

The basic principle of depth perception derives from the **law of simplicity** and indicates that *a pattern will appear three-dimensional when it can be seen as the projection of a three-dimensional situation that is structurally simpler than the two-dimensional one*. In Fig. 21 we watched this principle in action.