

The Art and Science of Depiction

Denotation system

Fredo Durand

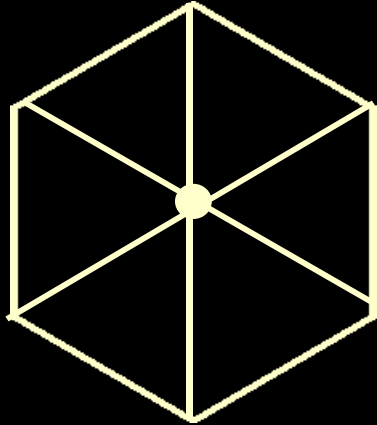
MIT- Lab for Computer Science

Invention of linear perspective

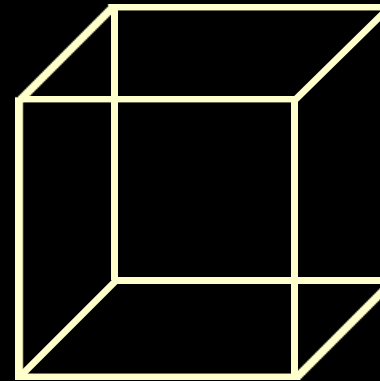
- Why so late?
 - Different goal
 - Different background
 - Advent of measurement
 - Mathematic analytical skills
 - Single viewpoint assumption

Accidental/generic

- From the objective geometric point of view

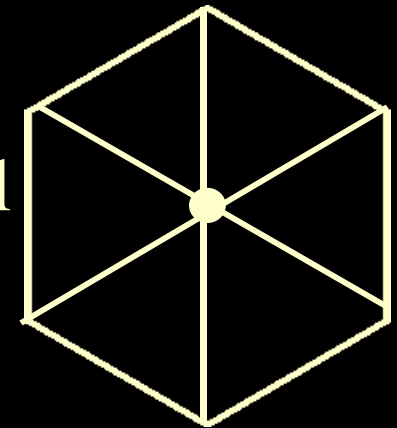


Accidental viewpoint



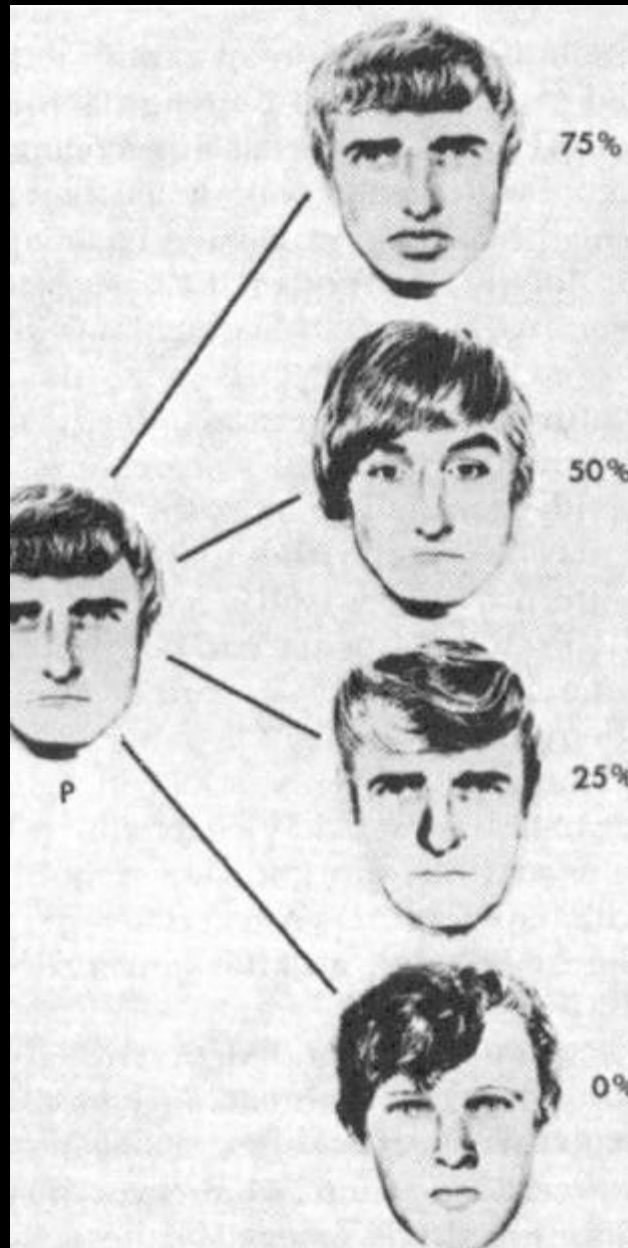
generic viewpoint

- From the subjective analysis point of view
 - Assume viewpoint is generic
 - Thus, the alignment cannot be accidental



Prototypes

- Solso



Denotation system

Maximum size

- Kosslyn
- Imagine a horse in the distance
- Imagine it moves continuously towards you
- When does it “overflows” your visual field?

Maximum size

- Kosslyn
- Imagine a horse in the distance
- Imagine it moves continuously towards you
- When does it “overflows” your visual field?
- 20° for strict overflow
- 40-60 ° for lax overflow

Maximum size

- Kosslyn
- Imagine a horse in the distance
- Imagine it moves continuously towards you
- When does it “overflows” your visual field?
- 20° for strict overflow (equivalent 100mm)
- 40-60 ° for lax overflow (30-50mm)

Denotation system

- Silhouette:
 - 2D (regions)
 - Picasso, *Rite of Spring*
- Line Drawing
 - 1D (lines)
- Optical
 - 0D (points)



Denotation system

- Silhouette:
 - 2D (regions)
- Line Drawing
 - 1D (lines)
 - Picasso,
Portrait of Stravinsky
- Optical
 - 0D (points)



Denotation system

- Silhouette:
 - 2D (regions)
- Line Drawing
 - 1D (lines)
- Optical
 - 0D (points)
 - Picasso, *Paul as Arlequin*



A fourth denotation system

- Sculpture
 - 3D (volume)
Picasso, *Head of a Woman (Fernande)*, 1909
- Silhouette:
 - 2D (regions)
- Line Drawing
 - 1D (lines)
- Optical
 - 0D (points)



Introduction to denotation systems

- Difference between drawing and paintings
- The multiple role of e.g. lines
- What denotes what in the picture?

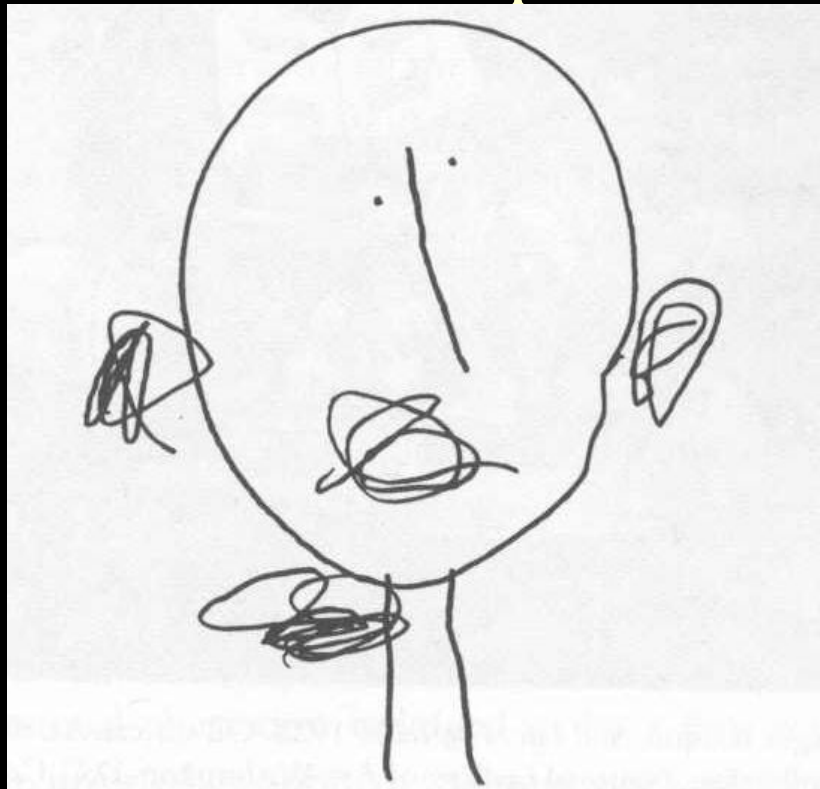


FIG. 1.12. *Drawing of a Man* by a five-year-old boy.

Plan

- Introducing denotation systems
- Line drawing
- A catalogue of primitives

Denotation system

- Scene
- Scene primitive
- Picture primitive
- Marks

Denotation system

- Scene
 - Objects, parts
- Scene primitive
 - Volumes, surfaces, lines and points of the scene.
- Picture primitive
 - Regions, lines and point in the picture
- Marks
 - Physical marks on the canvas

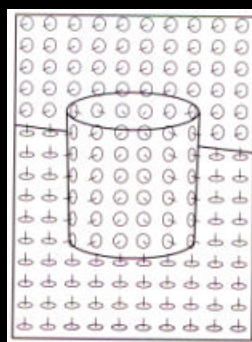
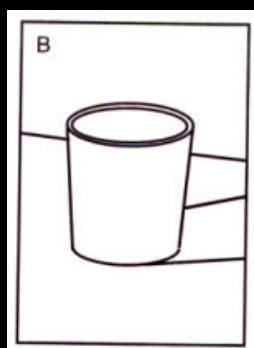
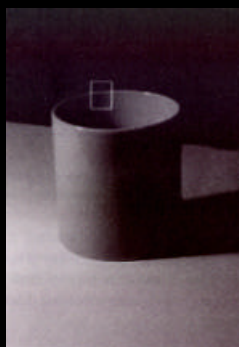
Denotation system

- Scene
- Scene primitive
- Picture primitive
- Marks

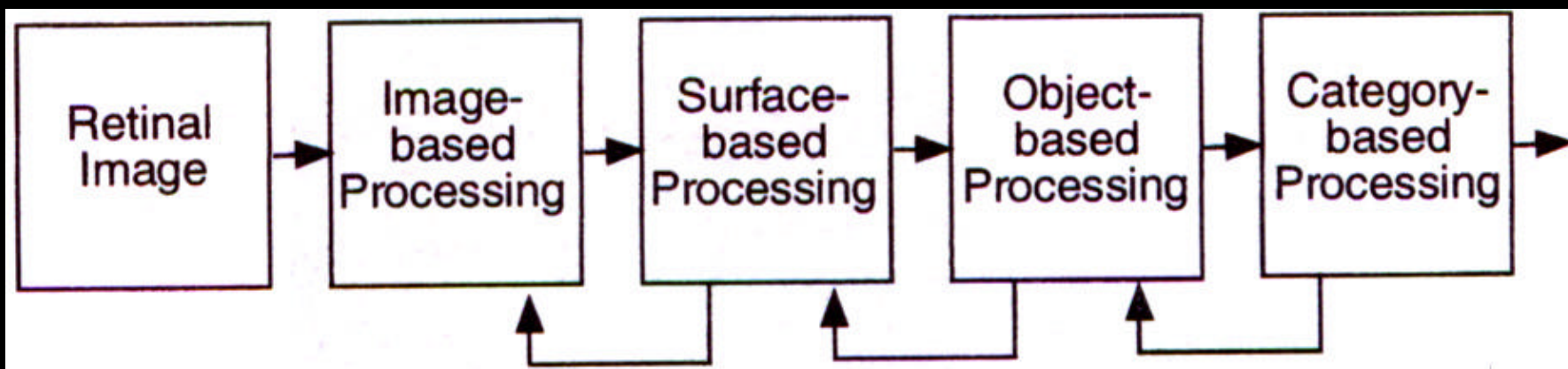
- Dimensions
- Extendedness
- Mapping

Stages of vision

- Bottom-up and top-bottom



Cup



Marks vs. primitive

- The mark is only the physical realization of the primitive
- They can have different dimensionality

Marks vs. primitive

- Mosaic
- Primitives = lines
- Marks = points
(or small regions)



Marks vs. primitive

- Seurat, La Grande Jatte (detail)

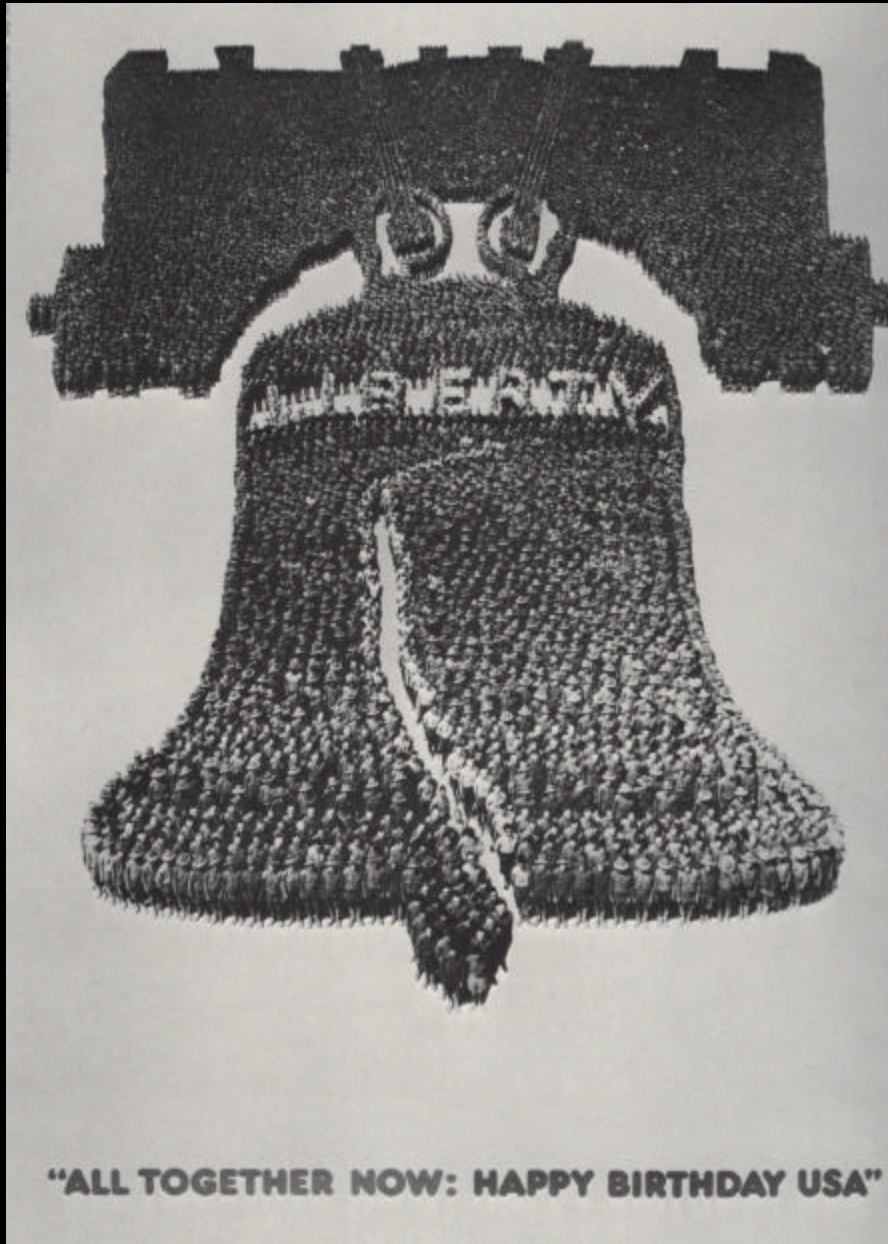


Marks vs. primitive

- Paul Siemsen
Picasso

When the name Picasso falls upon the eye, a portrait of a legend comes to mind. It's the legend in the world of art which surrounds a man who possessed and expressed many of the highest ideals of mankind. The popular legend is of the outward attributes: seclusion and gregariousness; wealth and love; abundance of works and extraordinary versatility in all facets of his field. It has been estimated that Picasso created over fifty thousand works of art. Pablo Ruiz Picasso was born into a family of art, so he naturally had a very early beginning in his creations. His life was long, ninety-one years, but when we do the arithmetic we still find that he averaged throughout his creative years almost two pieces of art per day. Considering the physical size and the conceptual scope of many of his works, these numbers bespeak a remarkable feat. How is it that a man could be so one-pointed and inventive that he would become, as one author describes him, "the most prolific artist of all times?" Picasso's own words may reveal the answer: "Painting is stronger than I am; also, "painting makes me do what I want." Another of the components of the popular legend is that of his departure from tradition. Picasso is known by many as having been instrumental in founding and energizing two new movements in art, cubism and surrealism; and to have inspired other movements including abstract art and pop art. His departure into cubism, which has become perhaps his best known realm, was met at the time with ridicule and contempt. The general attitude of those who saw this new trend was, at best, closer to endurance than to endorsement. A very few had any awareness that in Picasso painting was giving birth to truly significant modes of seeing and expression. These few, and Picasso himself, might have argued that his seemingly radical forms were logical outgrowths or extensions of the traditions of painting thus far, or at least of the spirit of painting. That same unbounded energy of art that had explored so many obvious and subtle ways of seeing was, in this twentieth-century Spaniard, continuing its exploration. The world has indeed marvelled that so much of that energy was concentrated through the eye-hand of this one man. Those who have known Picasso and have written of him begin to reveal the inner, mystical legend when they independently ascribe his superconductivity to his unceasing wonderment—a wonderment born of innocence and openness that had no need to look through the tinted glasses of dogma. Indeed, as his own cubist movement became intellectually structured and dogmatic, he left it behind. He kept himself in the main evolutionary stream of art itself, which adheres to principles of a more general and unaccommodative nature. Picasso was thus free to draw upon the principles he had discovered in several specific modes of painting to achieve an even more comprehensive vision. One needs to be careful not to think that he mixed some of this style and some of that to achieve something new. His art grew from within and manifested itself in the appearance of mixture. He elaborated, "Art is not the application of a canon of beauty, but what the instinct and the brain can conceive independently of that canon. When you love a woman you don't take instruments to measure her body, you love her with your senses." His ability to create independently of the numerous canons of beauty was witnessed by Gertrude Stein, one of his earliest patrons, who said, "He alone among painters did not set himself the problem of expressing truths which all the world can see, but the truth which only he can see." This internal truth must have been operative when Picasso painted his well-known portrait of Gertrude Stein, for without something of an inner vision his reflections on the portrait would seem absolutely baffling. As the story goes, he made Miss Stein sit eighty times for the portrait, and then he wiped out her face and substituted a face with mask-like qualities. There were criticisms which he dismissed with, "Everybody thinks that the portrait is not like her, but never mind, in the end she will look like the portrait." Such a statement might seem impertinent, but it is hard to question his integrity, for his commitment to his work was absolute. Every work was born of desire and in deep concentration. Every work was also born living its own life. A painting or sculpture or lithograph or whatever would begin in impulse, in vague idea, in spirit. Then as art "made him do what he wanted," it would evolve through the brush of its creator. Each stroke and each picture was an end, a breathing universe itself. Picasso seldom signed his works and never dated them. He also customarily refused to explain them. It is perceived that such acts might have put too definitive boundaries on the pieces, limiting the potential that exists to exist within them. A father gives his child his own autonomy, never acknowledging the moment he becomes adult and never saying to him this is the kind of person you are. A parent is the kind of influence you have, because the child may become much more or may be seen to be much more. For similar reasons, one hesitates to write of the legend of Pablo Picasso, for fear of severely limiting its fullness. Yet, even as the legend itself is found within the depths of the viewer's consciousness, so are these words found looking out of a piece of paper.

Marks vs. primitive



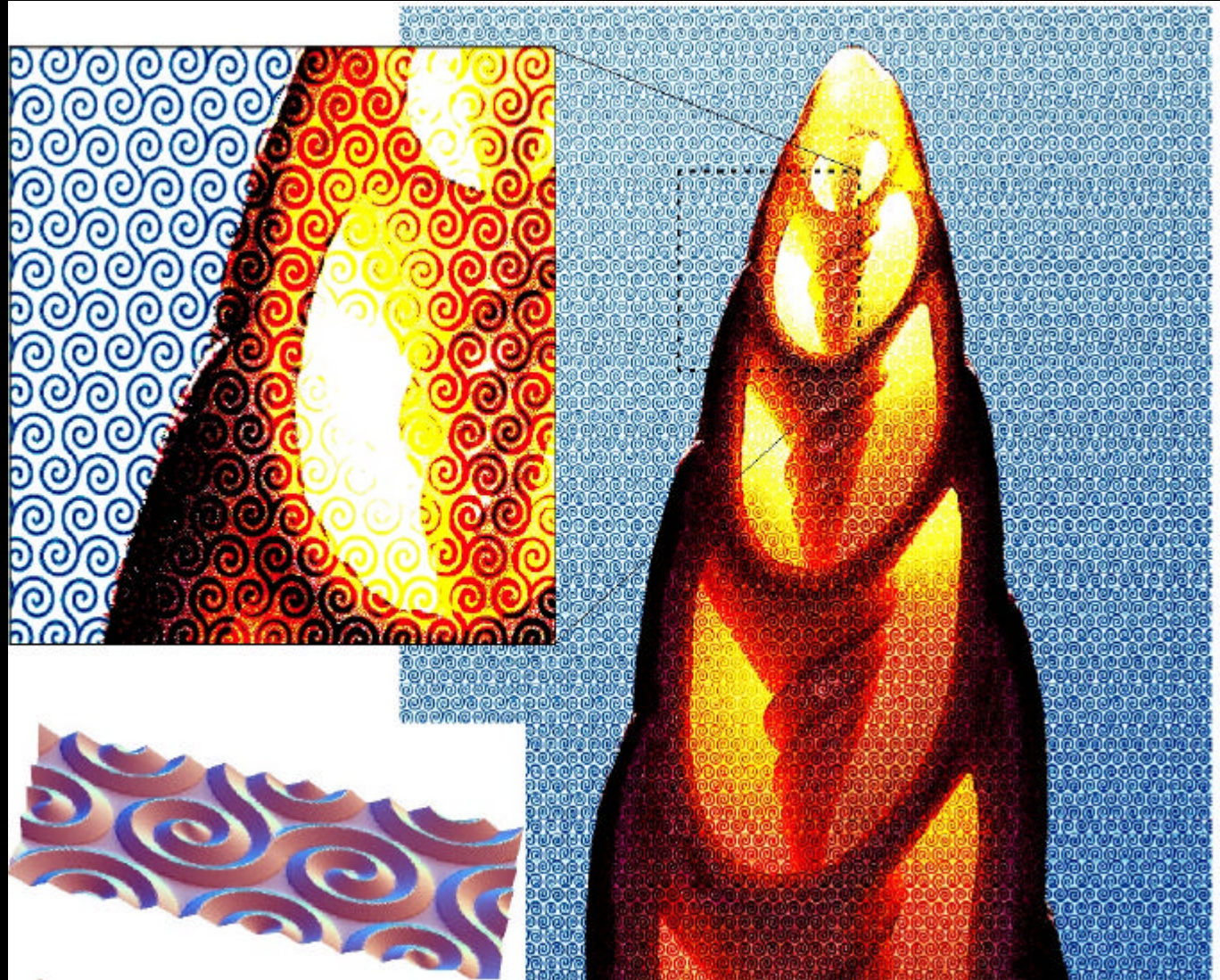
Marks vs. primitive

- Giuseppe Arcimboldo
Summer, 1563



Marks vs. primitive

- Victor Ostromoukhov, Artistic halftoning



Denotation system

Marks vs. primitive

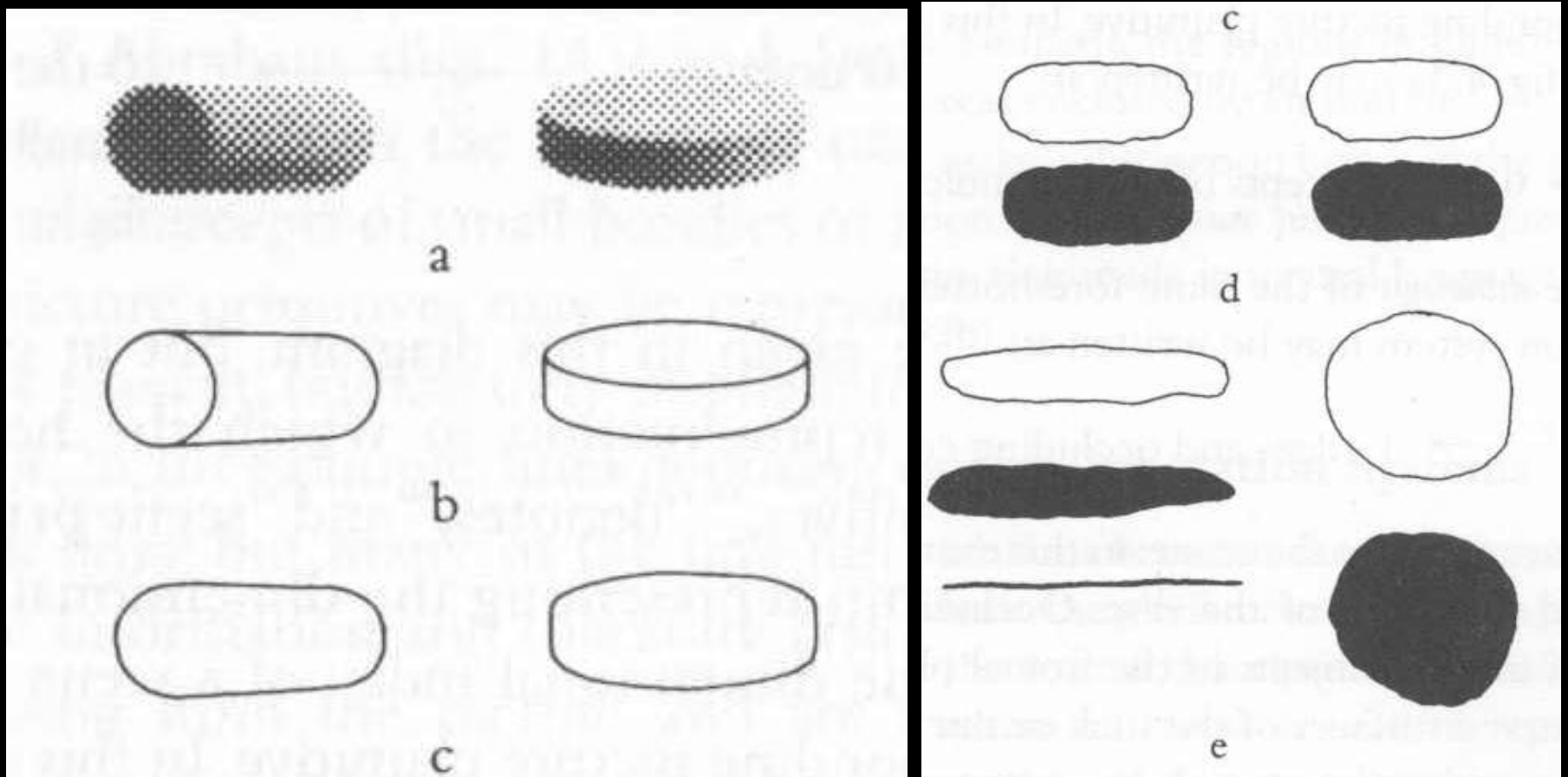
- Chuck Close *Stanley* 1980-81



Denotation system

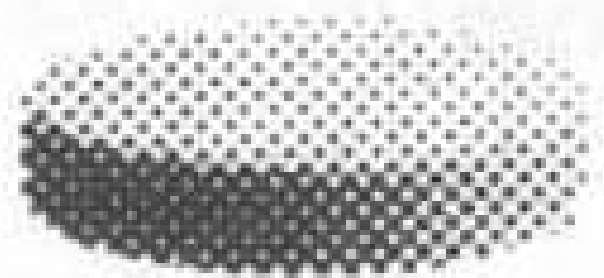
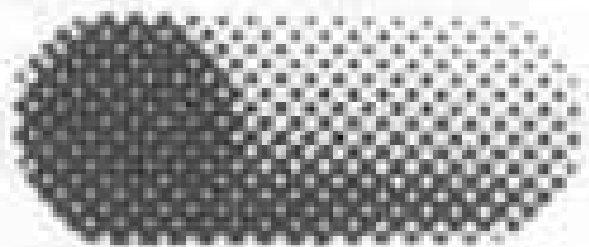
Denotation

- Example of a cylinder and a disc



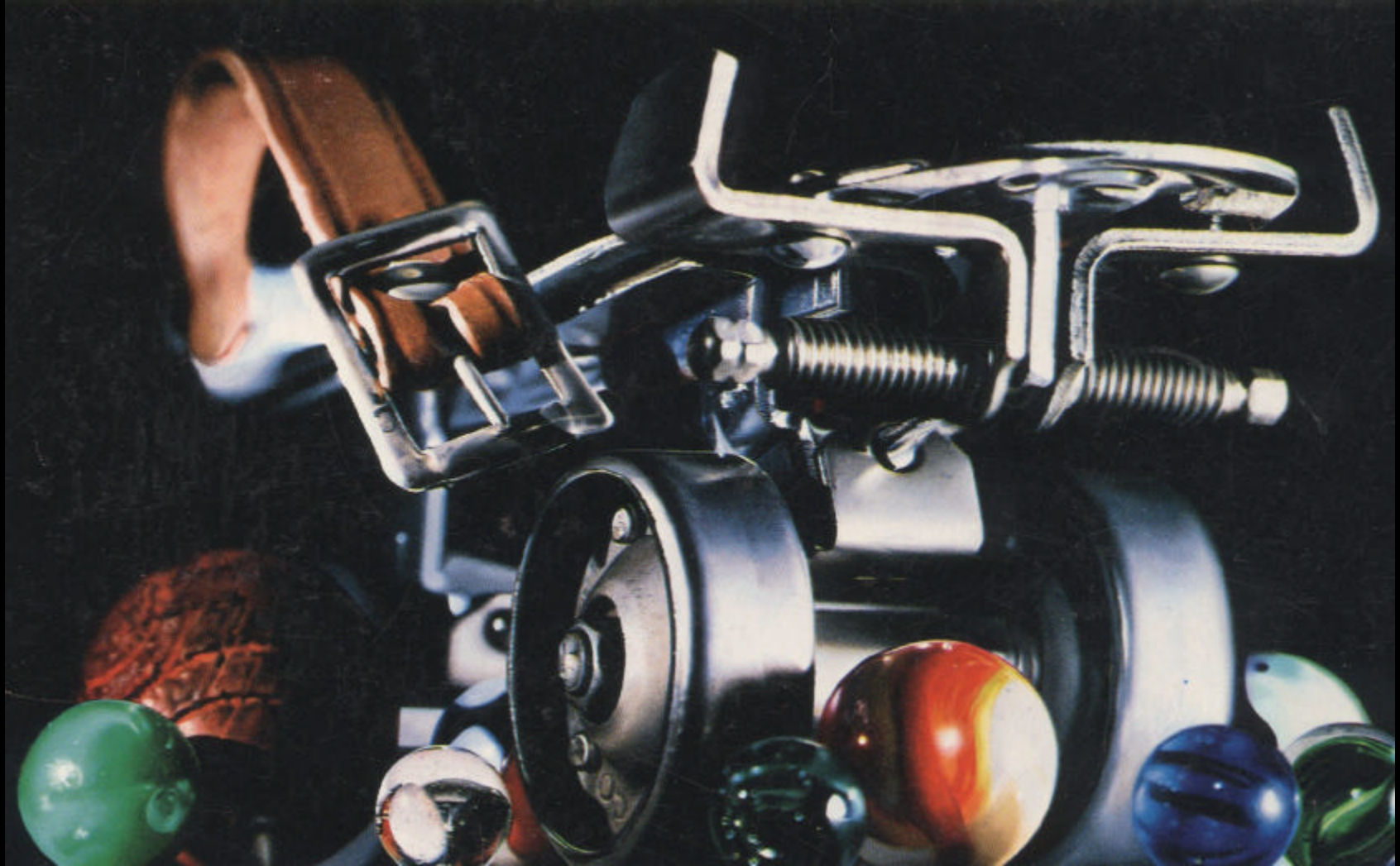
Denotation: optical

- Example of a cylinder and a disc
- Picture point denote scene point
- 0 (dot) \Rightarrow 0 (visible point)



Denotation: optical

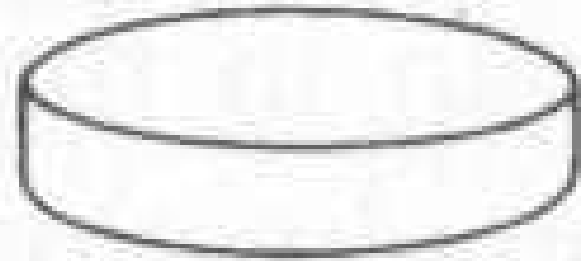
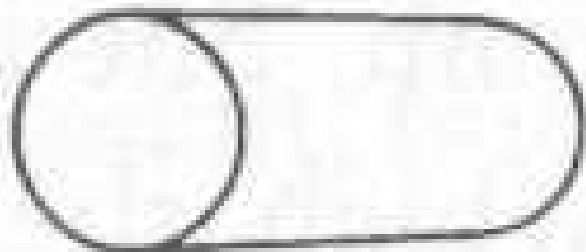
- Charles Bell *Chicago* 1980



Denotation system

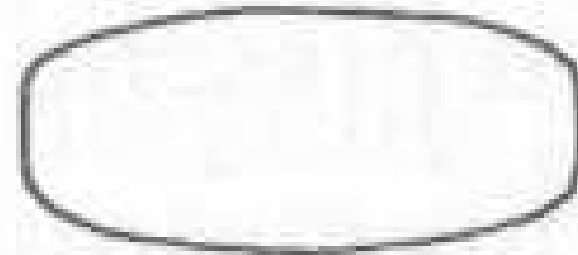
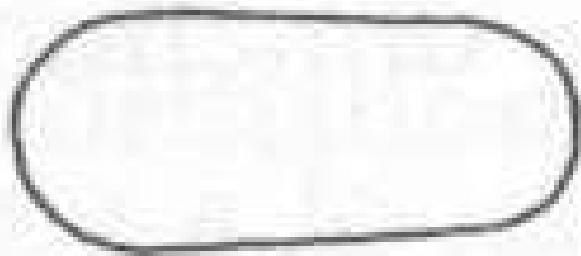
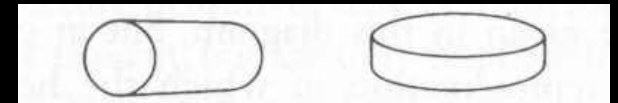
Denotation: line drawing

- Example of a cylinder and a disc
- Picture line denotes scene line
- 1 (line) \Rightarrow 1 (scene occluding contour and edge)



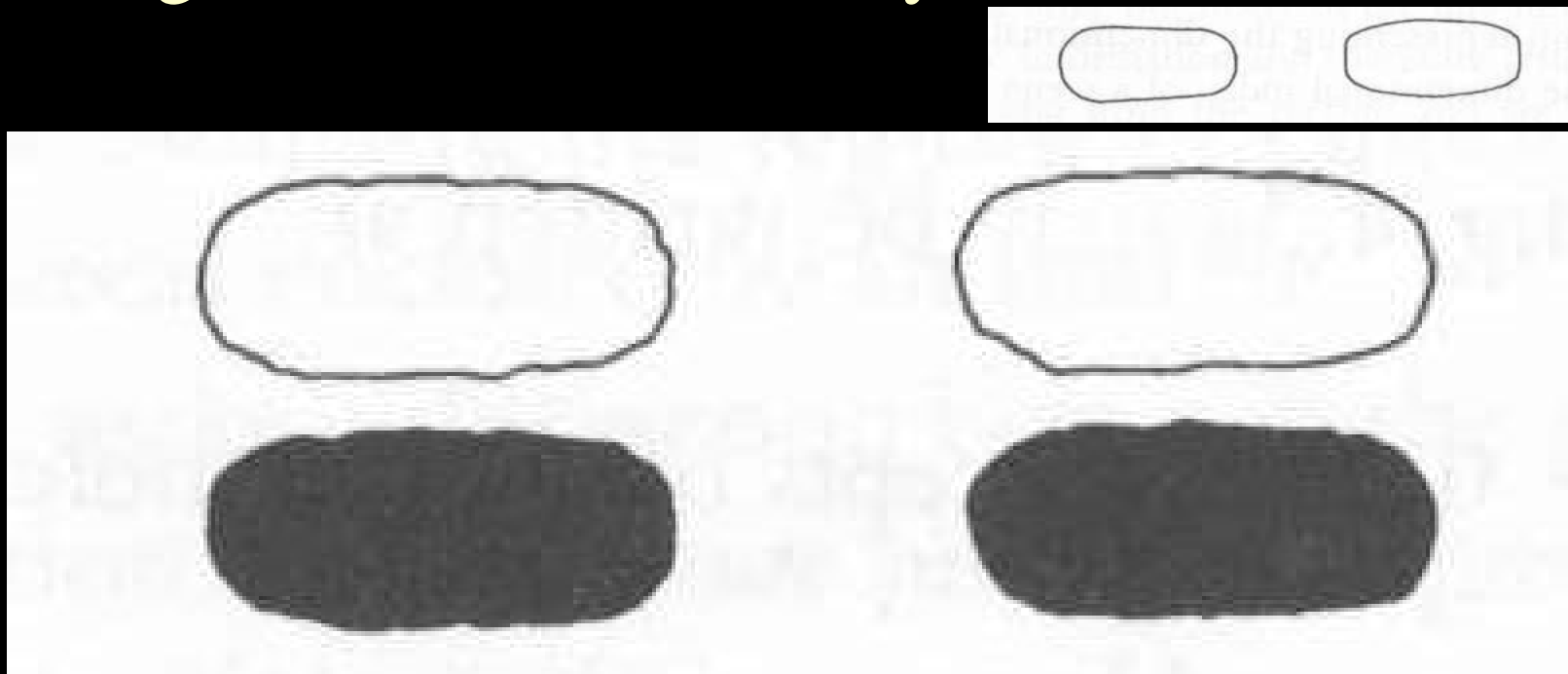
Denotation: outline drawing

- Example of a cylinder and a disc
- Picture line denotes scene line
- 1 (line) \Rightarrow 1 (scene occluding contour)
- No internal edge



Denotation: silhouette

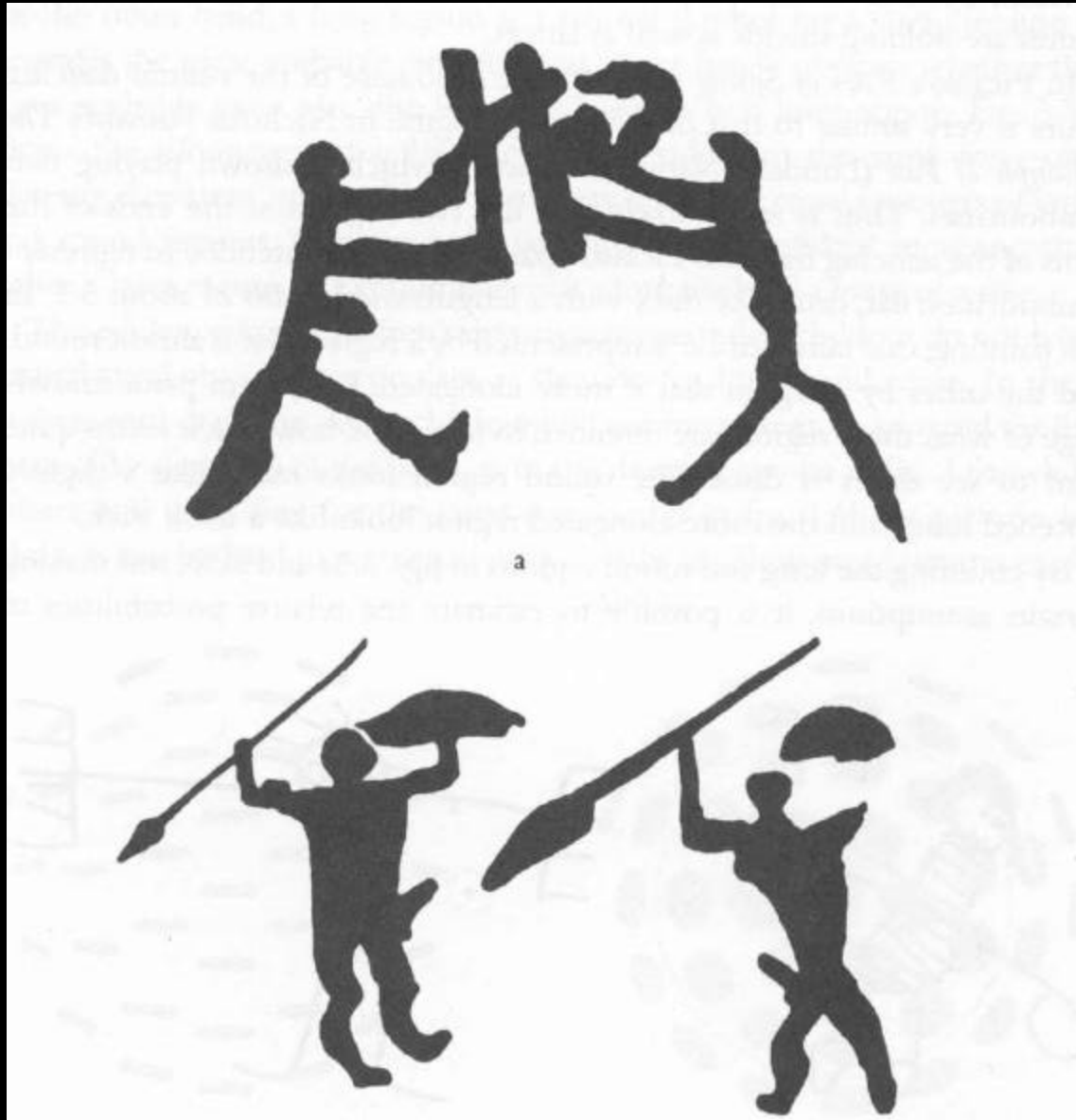
- Example of a cylinder and a disc
- Picture region denotes scene visible region
- 2_{10} (region) \Rightarrow 2_{10} (visible region)
- Edge becomes more fuzzy and less salient



Silhouette vs. outline



Silhouette vs. outline



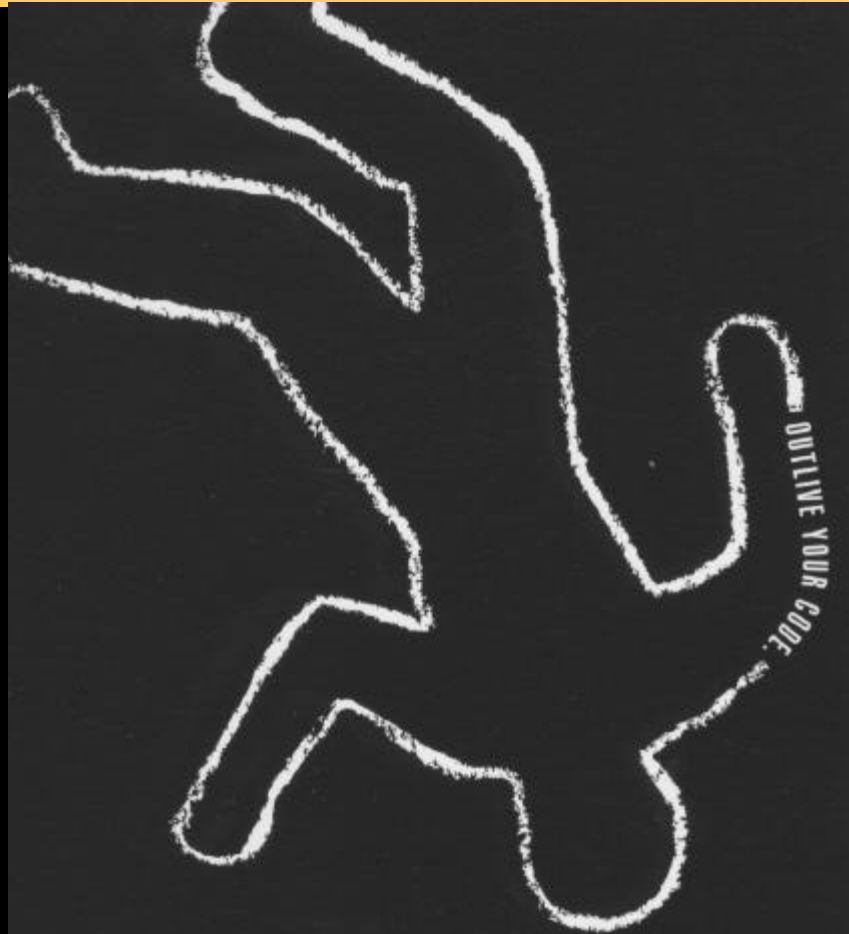
Silhouette vs. outline



Silhouette vs. outline



Silhouette vs. outline

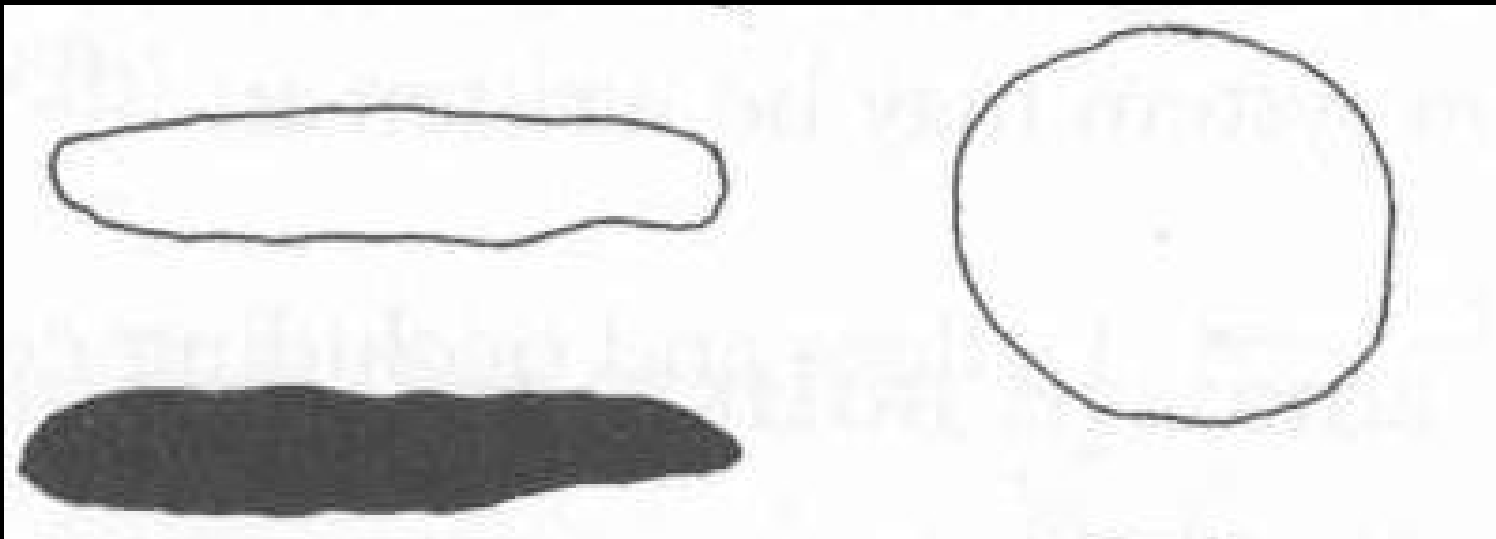


Silhouette vs. outline



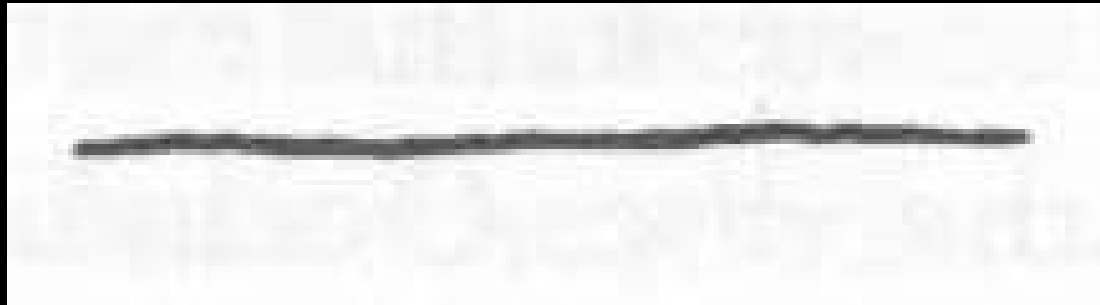
Denotation: volume

- Example of a cylinder and a disc
- Picture region denotes scene volume
- 2_{10} (extended region) $\Rightarrow 3_{100}$ (extended volume)
- 2_{11} (circular region) $\Rightarrow 3_{110}$ (disc)



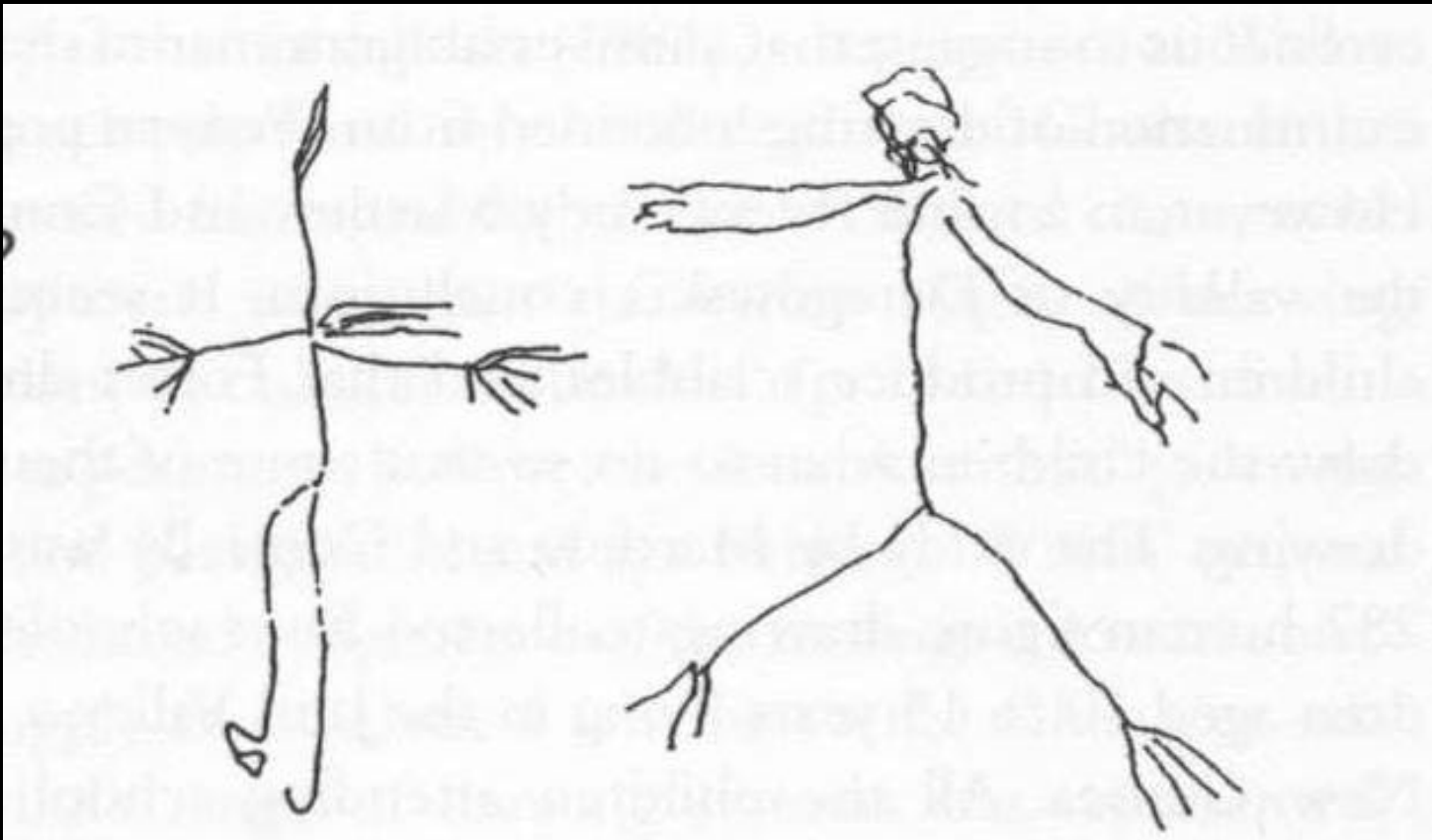
Denotation: volume

- Example of a cylinder and a disc
- Picture region denotes scene volume
- 1 (line) \Rightarrow 3_{100} (extended volume)



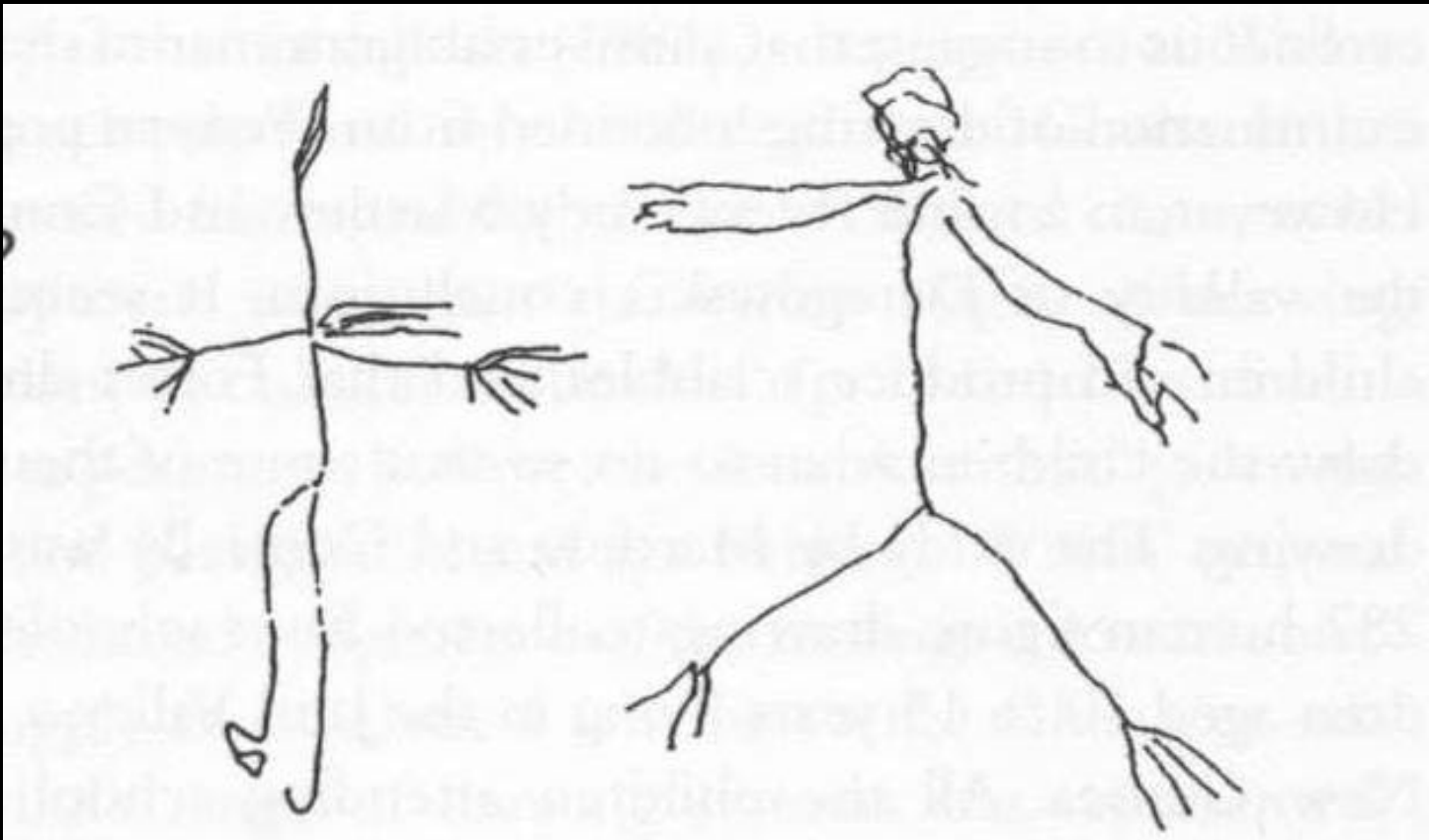
Denotation: volume

- 1 (line) \Rightarrow 3₁₀₀ (extended volume)



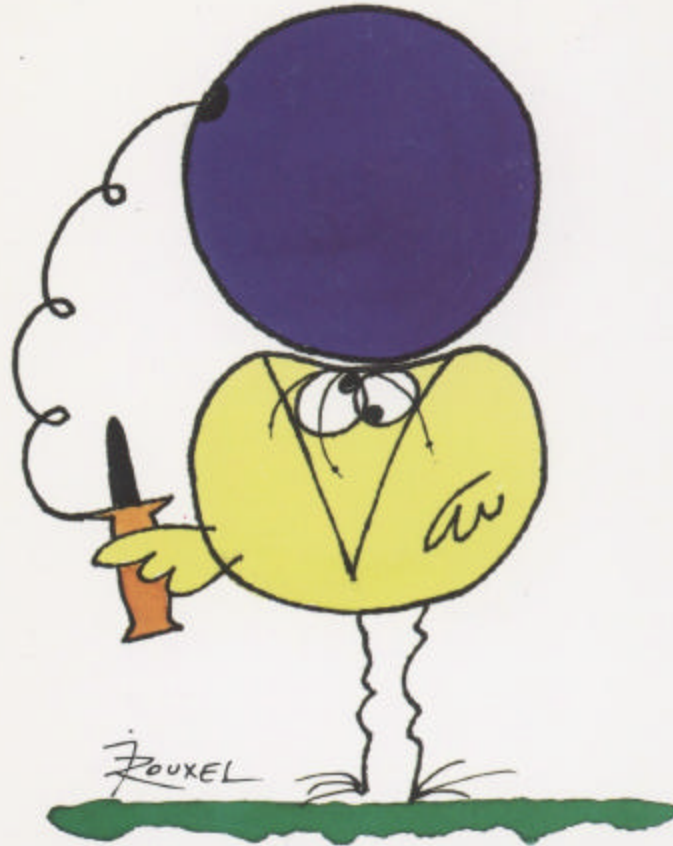
Denotation: volume

- 1 (line) \Rightarrow 3₁₀₀ (extended volume)
- Related to the *structural skeleton*



Denotation: volume

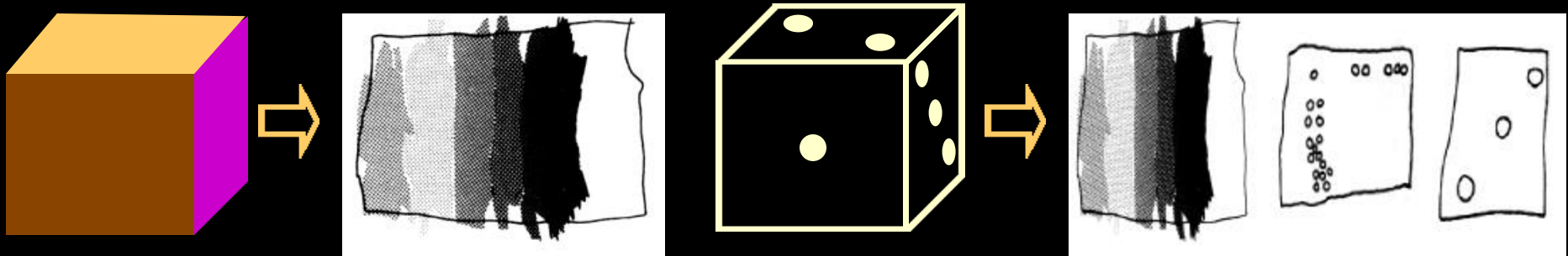
Les devises Shadok



EN ESSAYANT CONTINUUELLEMENT
ON FINIT PAR RÉUSSIR. DONC:
PLUS ÇA RATE, PLUS ON A
DE CHANCES QUE ÇA MARCHE.

3D and 2D attributes

- Show colored or numbered dice to children (6-7)
- The still draw a rectangle
- But different colors or many points
- The rectangle stands for the whole dice
- The notion of 3D object with corners is translated as a 2D object with corners



Denotation: volume

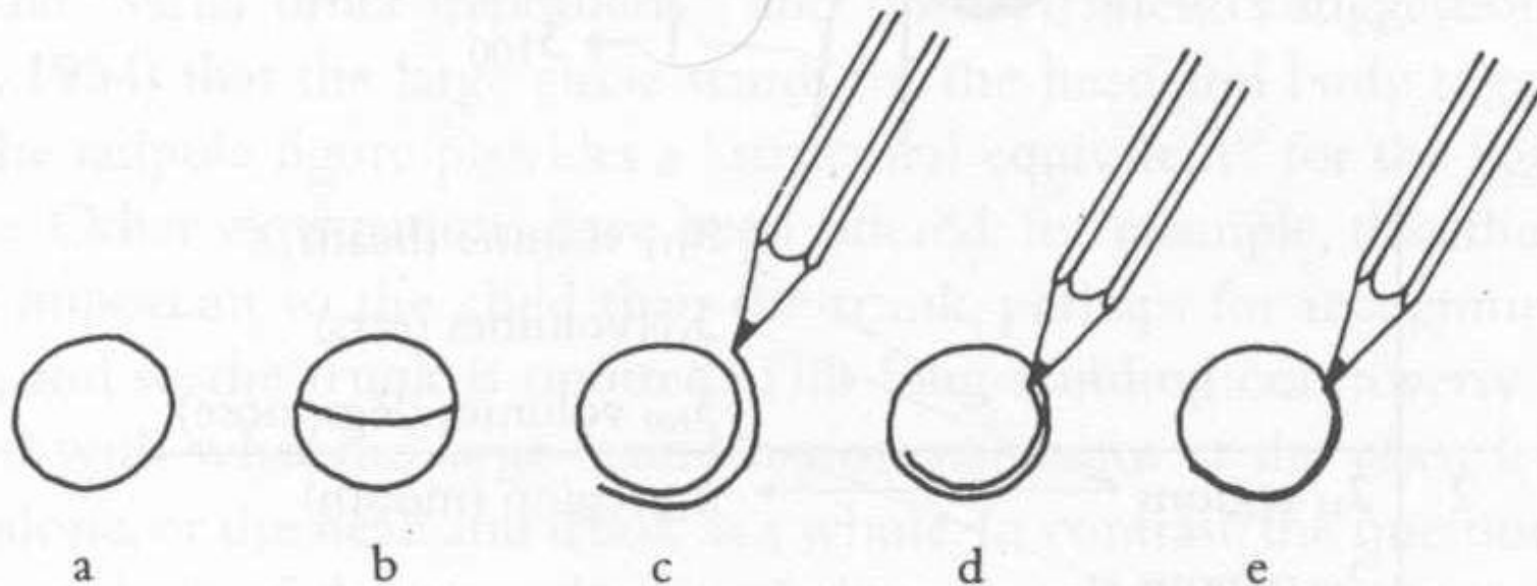
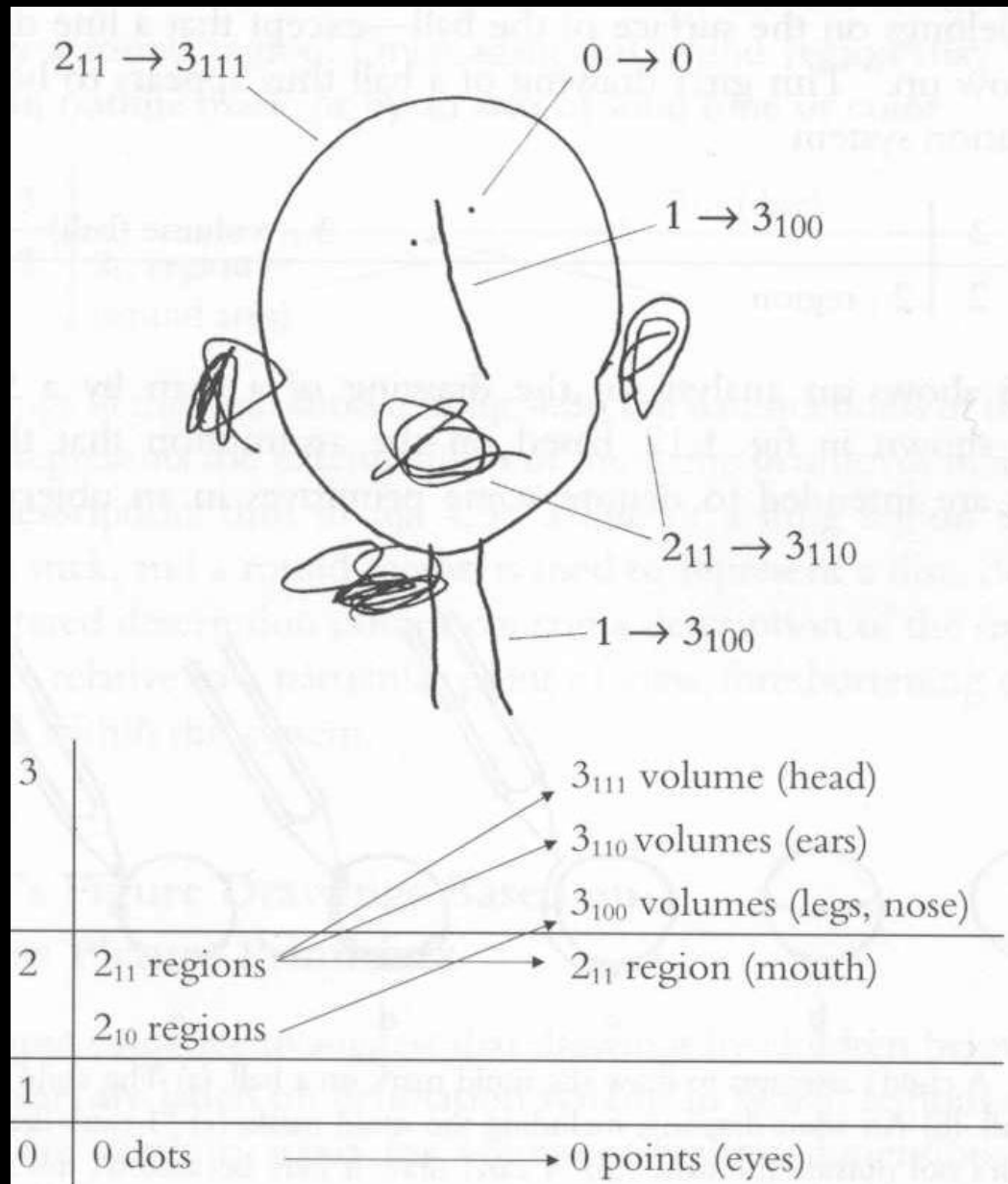
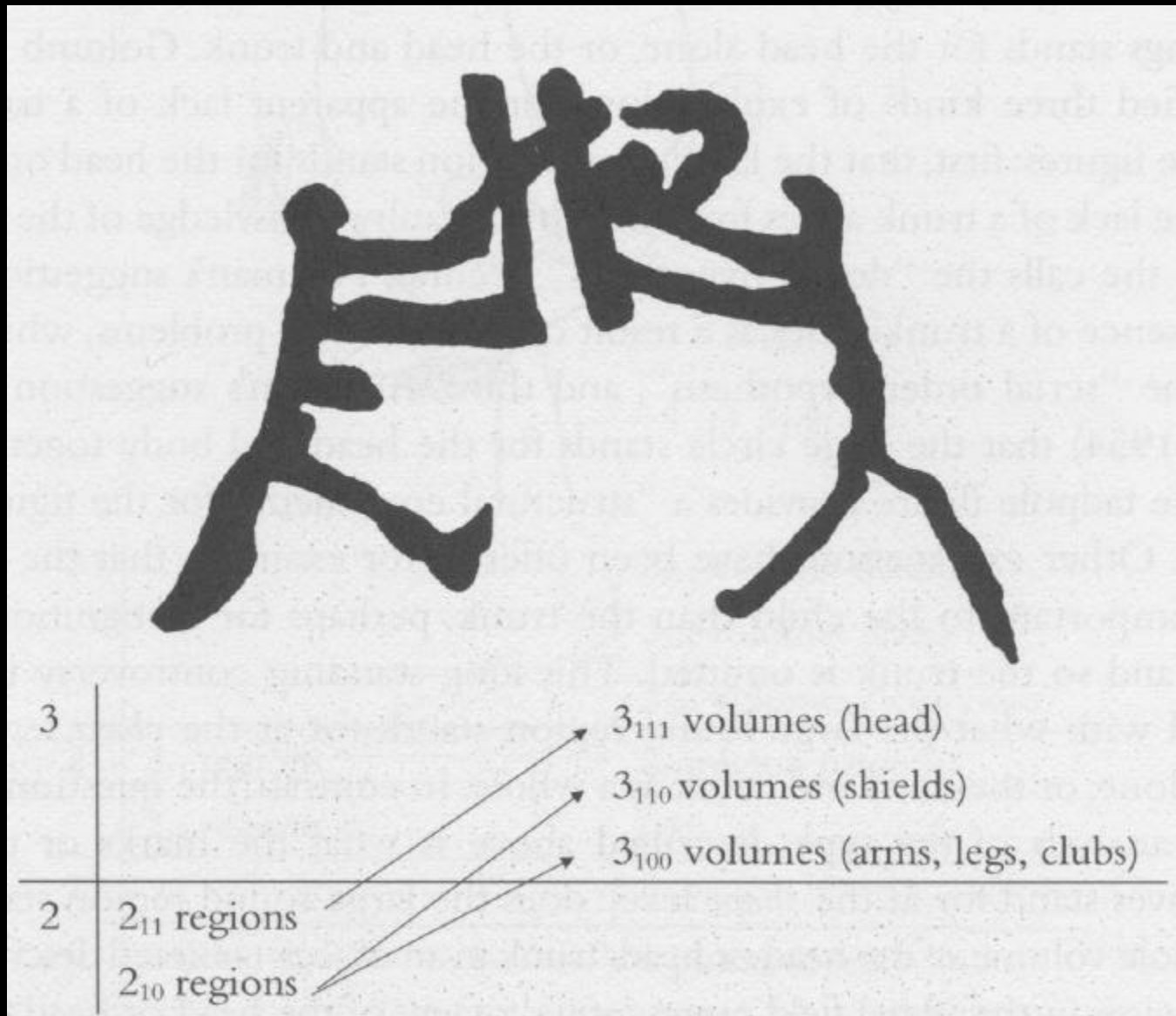


FIG. 4.4. A child's attempts to draw the mold mark on a ball. (a) The child's drawing of the ball. (b) An adult drawing, including the mold mark. (c) "I can't draw it here because it's not outside the ball." (d) "I can't draw it here because it's not inside the ball." (e) "And I can't draw it here because it won't show up. So I can't do it." From Willats (1985), courtesy of Cambridge University Press.

Denotation analysis

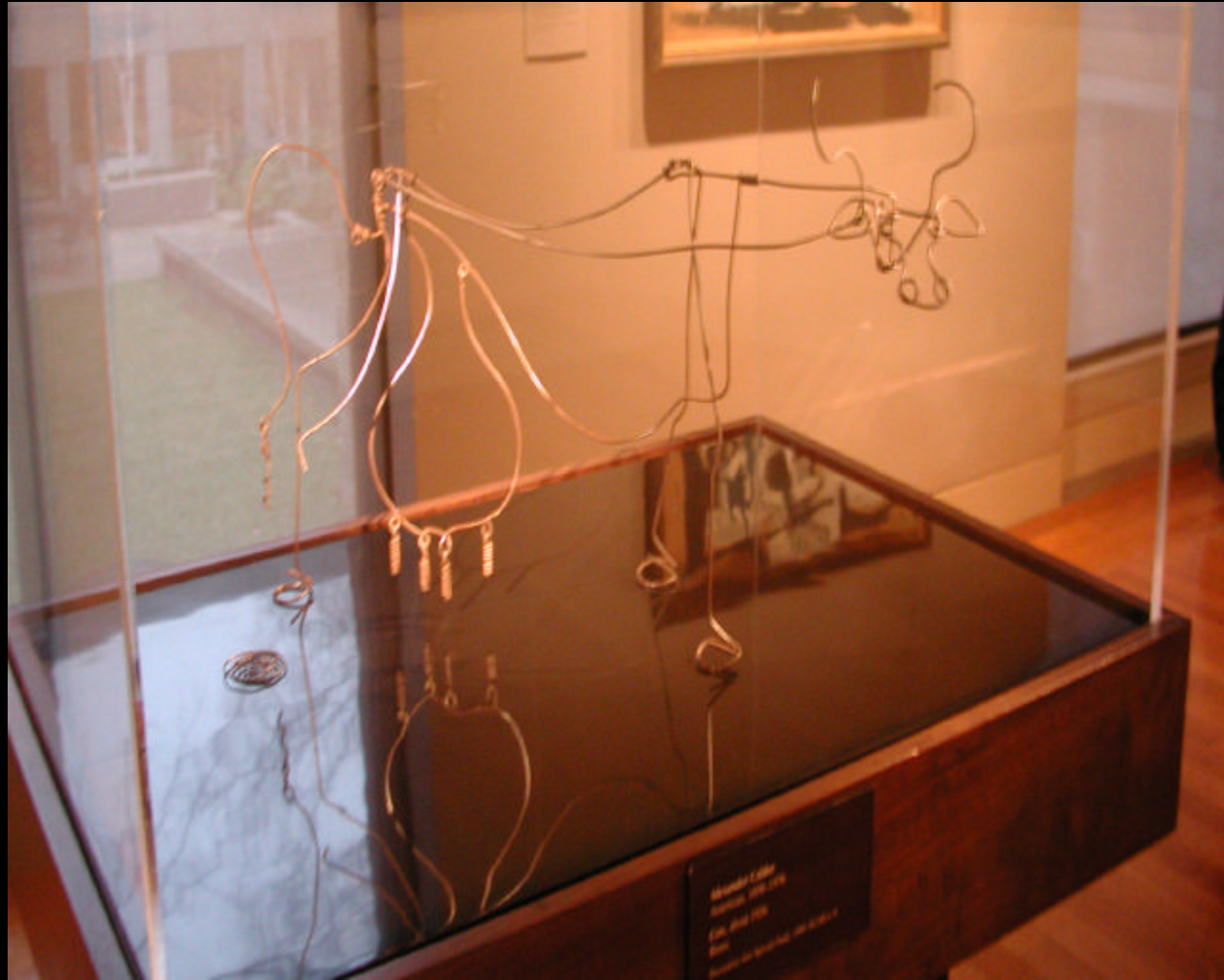


Denotation analysis



Denotation: special case

- Alexander Calder, *Cow*, 1926



Denotation system

Lineal/pictorial

- Heinrich Wölfflin, 1916
- Renaissance vs. Baroque
- The line and drawing vs. the brush stroke

Lineal/pictorial

- E.g. Michelangelo vs. Rembrandt



Plan

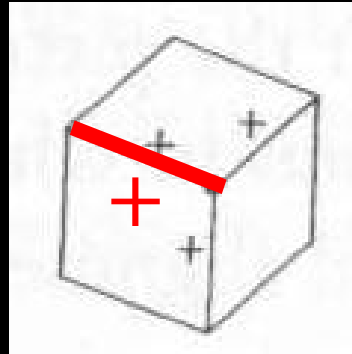
- Introducing denotation systems
- Line drawing
- A catalogue of primitives

Line drawing polyhedral objects

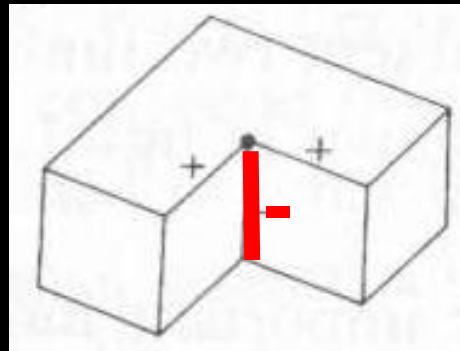
- [Clowes 71, Huffman 71, Waltz 75]
- Computer vision
- Analyze line drawing
- Label regions, analyze occlusions
- Classify edges and vertices of the line drawing

Labeling edges

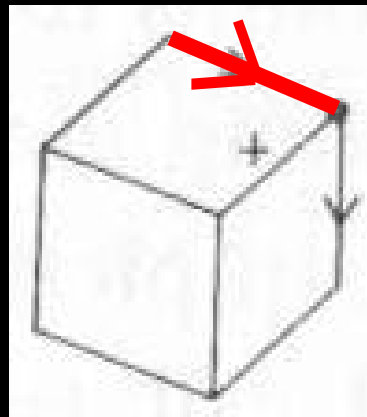
- Convex +



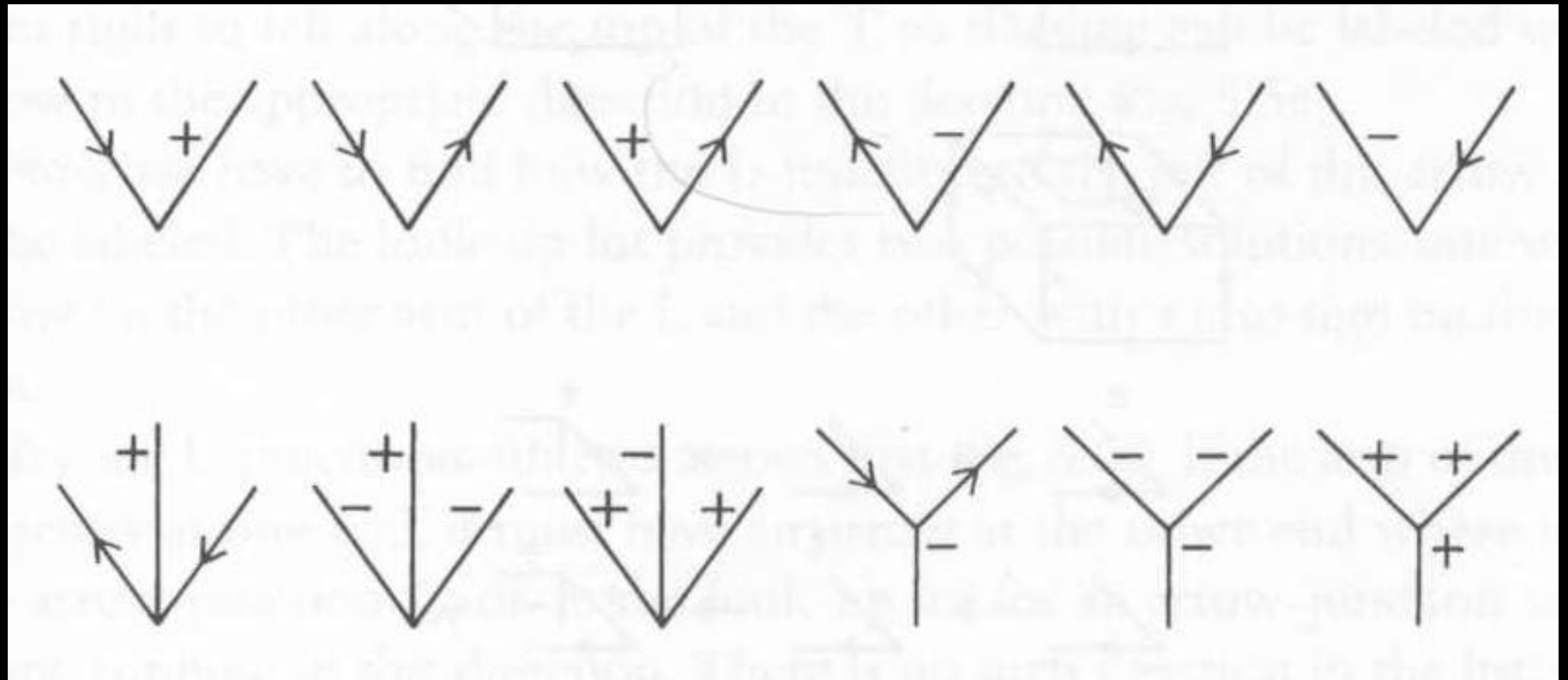
- Concave -



- Occluding ->
(object on the right)



Labeling corners



Labeling corners

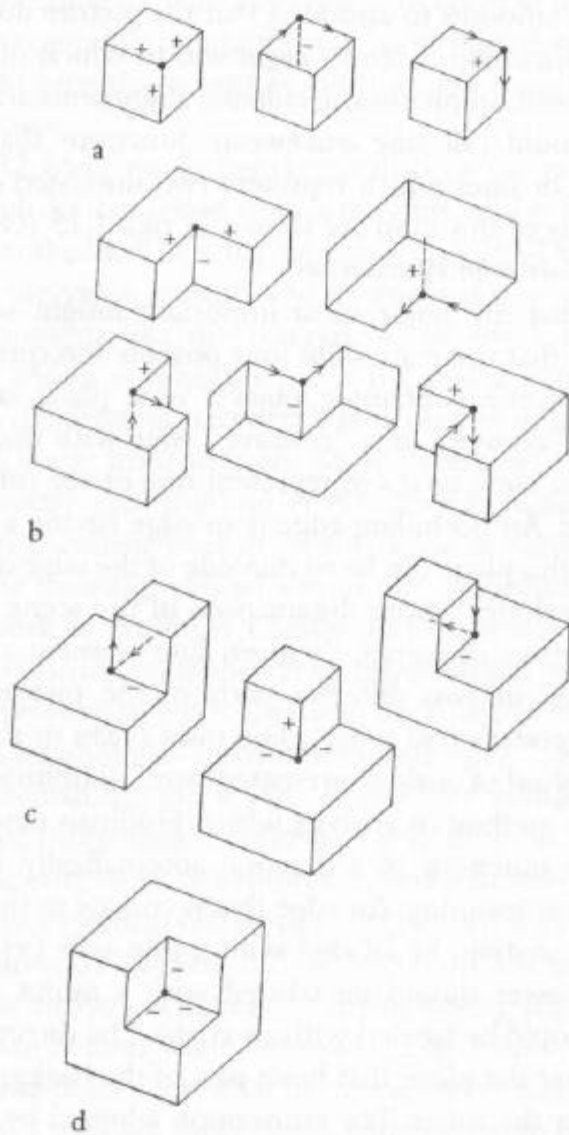
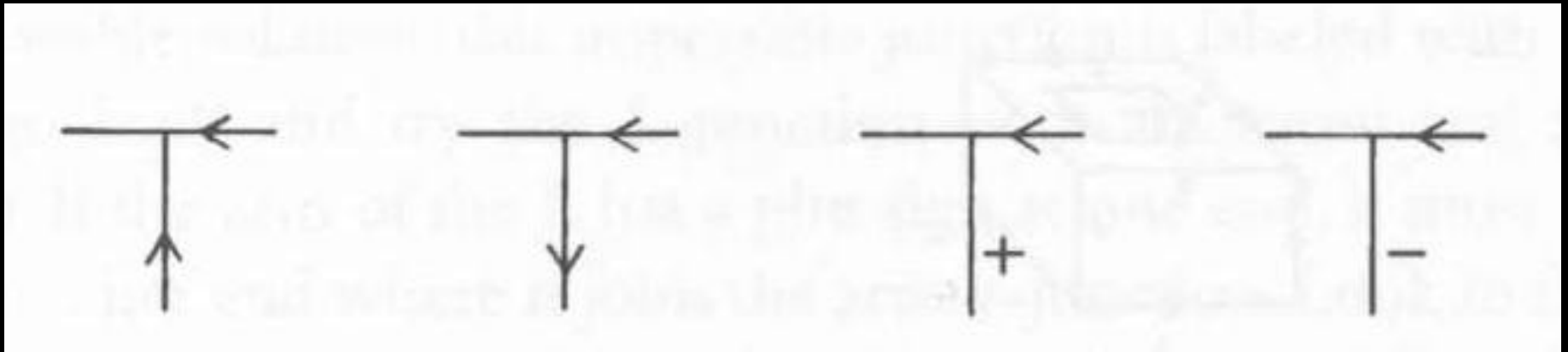


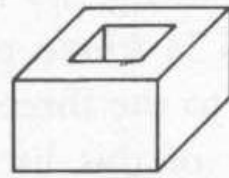
FIG. 5.3. Complete listing of possible pictures of corners in drawings of rectangular objects. From Huffman (1971), courtesy of Edinburgh University Press.

Labeling junctions

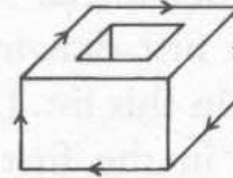
- The arrow is always in the same direction (because of occlusion)



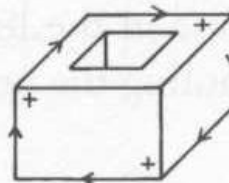
Labeling



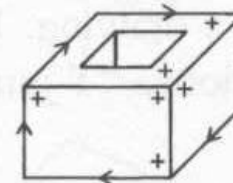
a



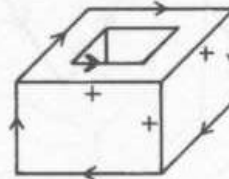
b



c



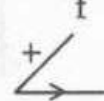
d



e

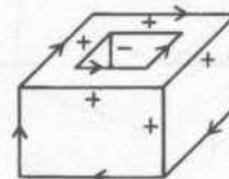


no



yes

g



h

Ambiguous/impossible

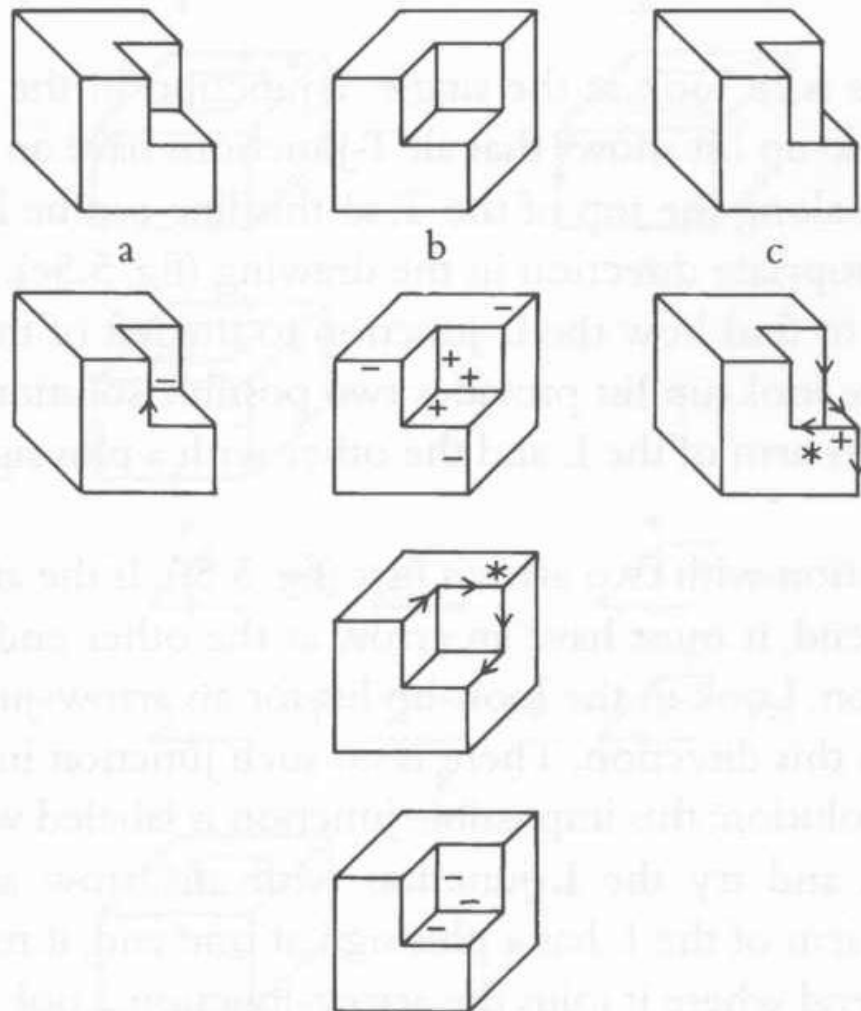
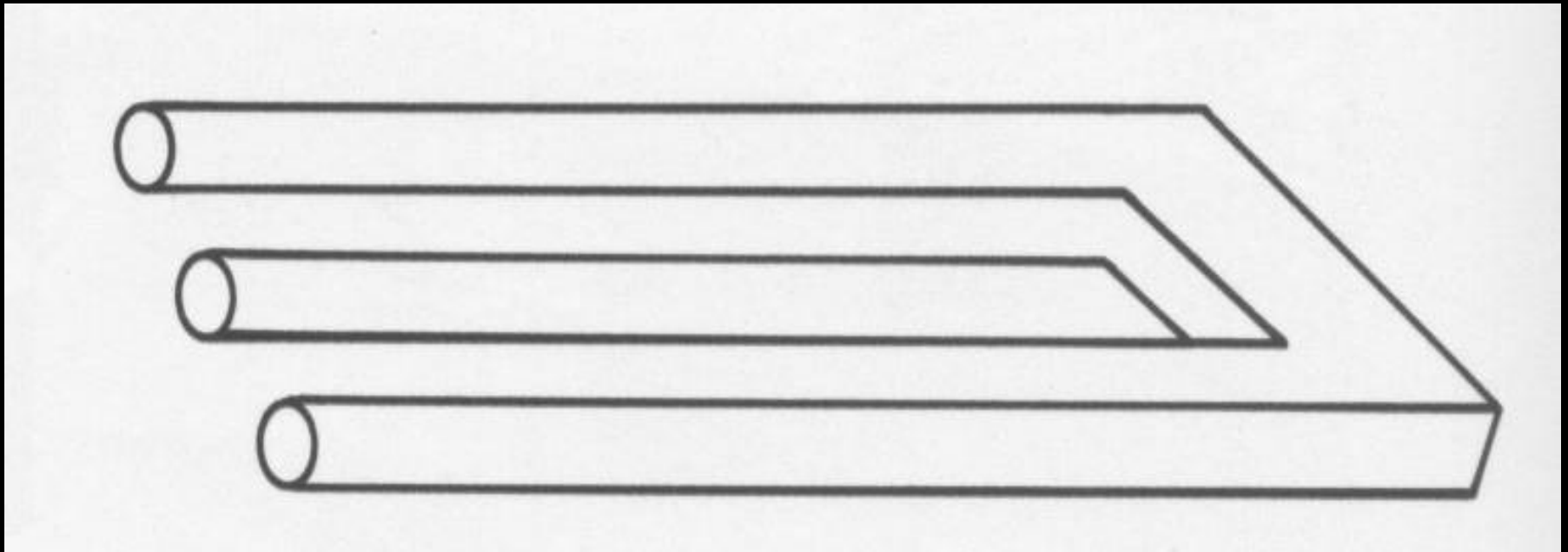
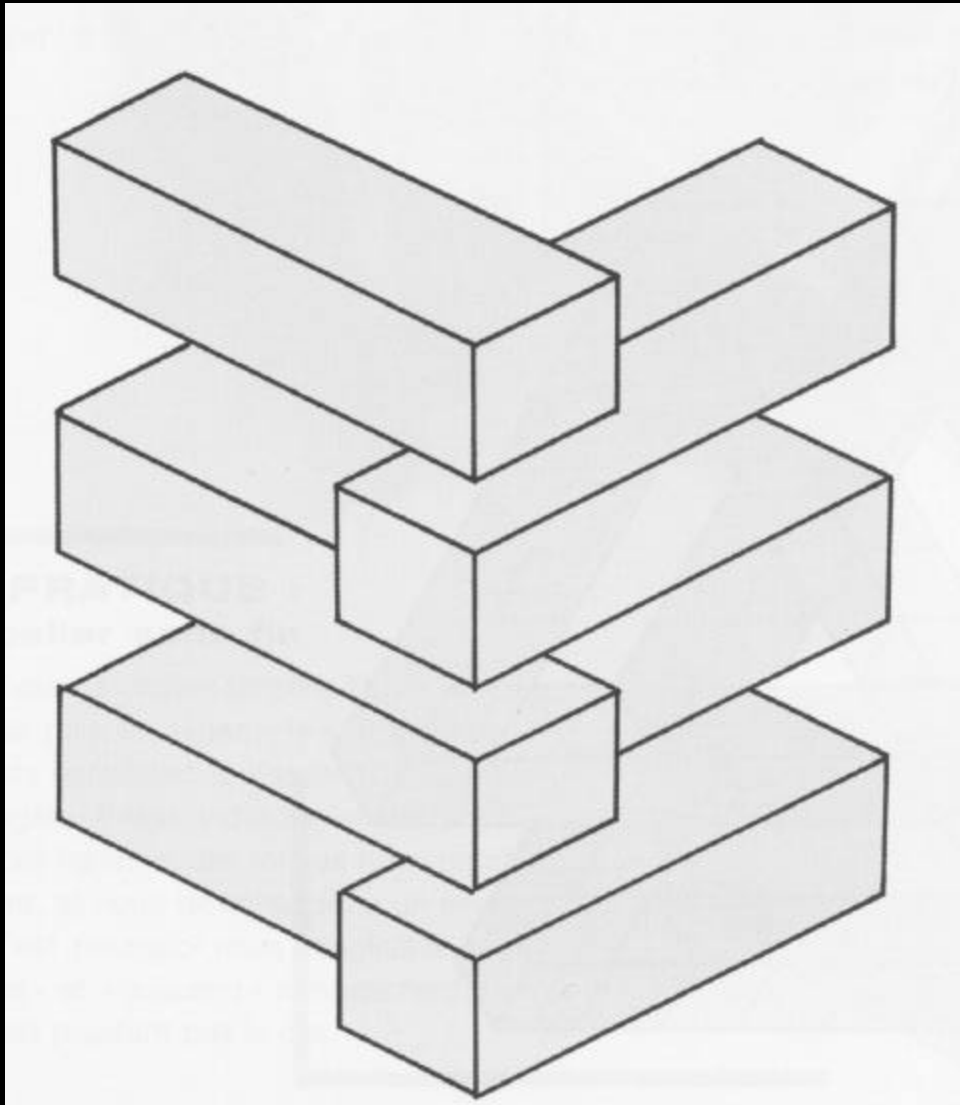


FIG. 5.6. Labelings for (a) unambiguous, (b) ambiguous, and (c) impossible drawings of rectangular objects. The “impossible” labeling is marked with an asterisk.

Ambiguous/impossible



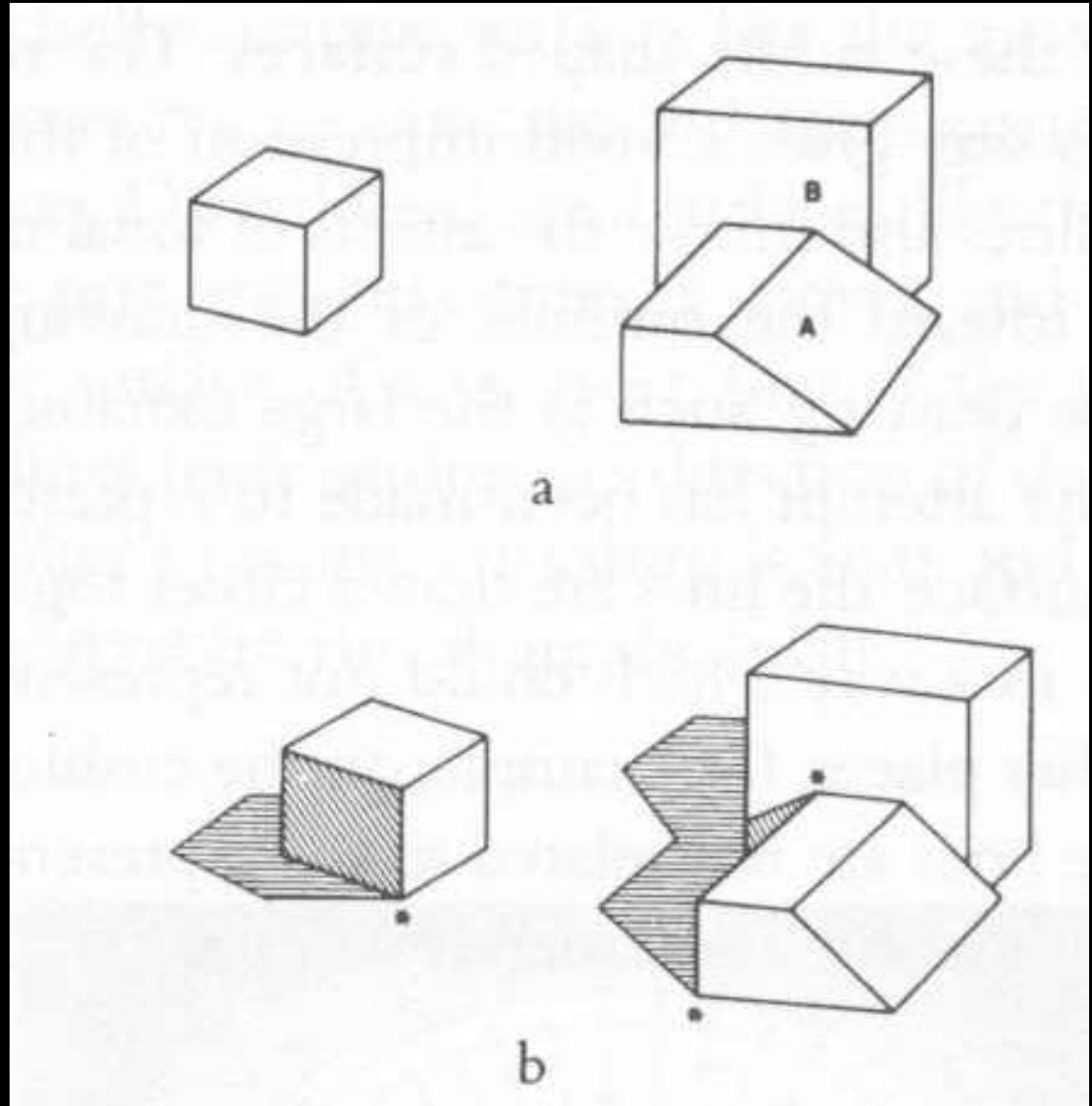
Ambiguous/impossible



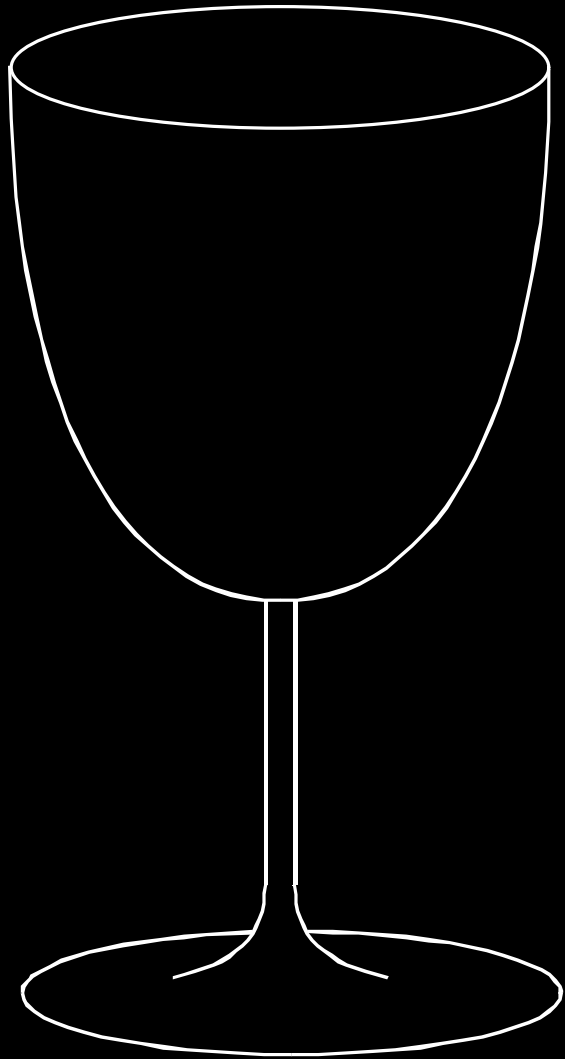
Denotation system

Extension to shadowed scenes

- Waltz 1975

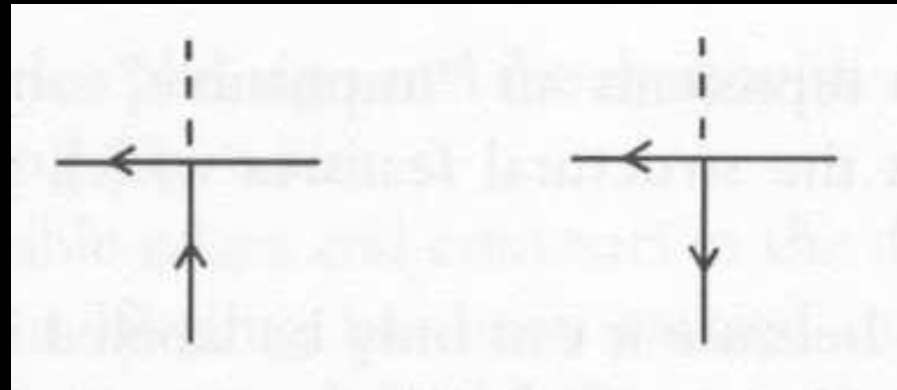


Line drawing of smooth objects

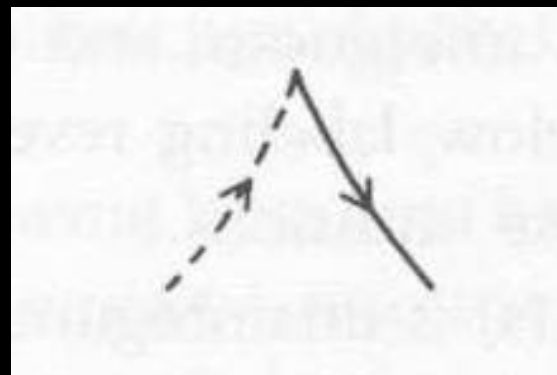


Line drawing of smooth objects

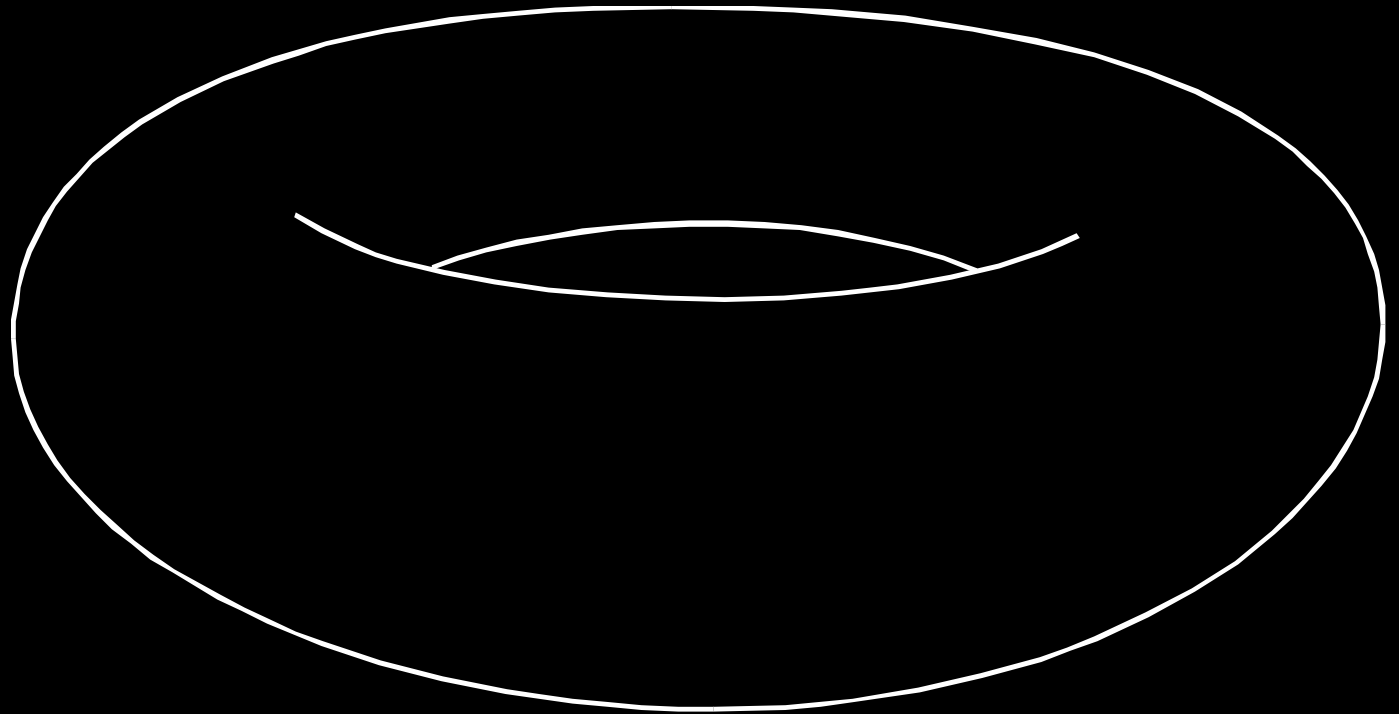
- Only one kind of edge
 - occluding contour
- Two types of vertices
 - T-junction
(a.k.a. T-vertex)



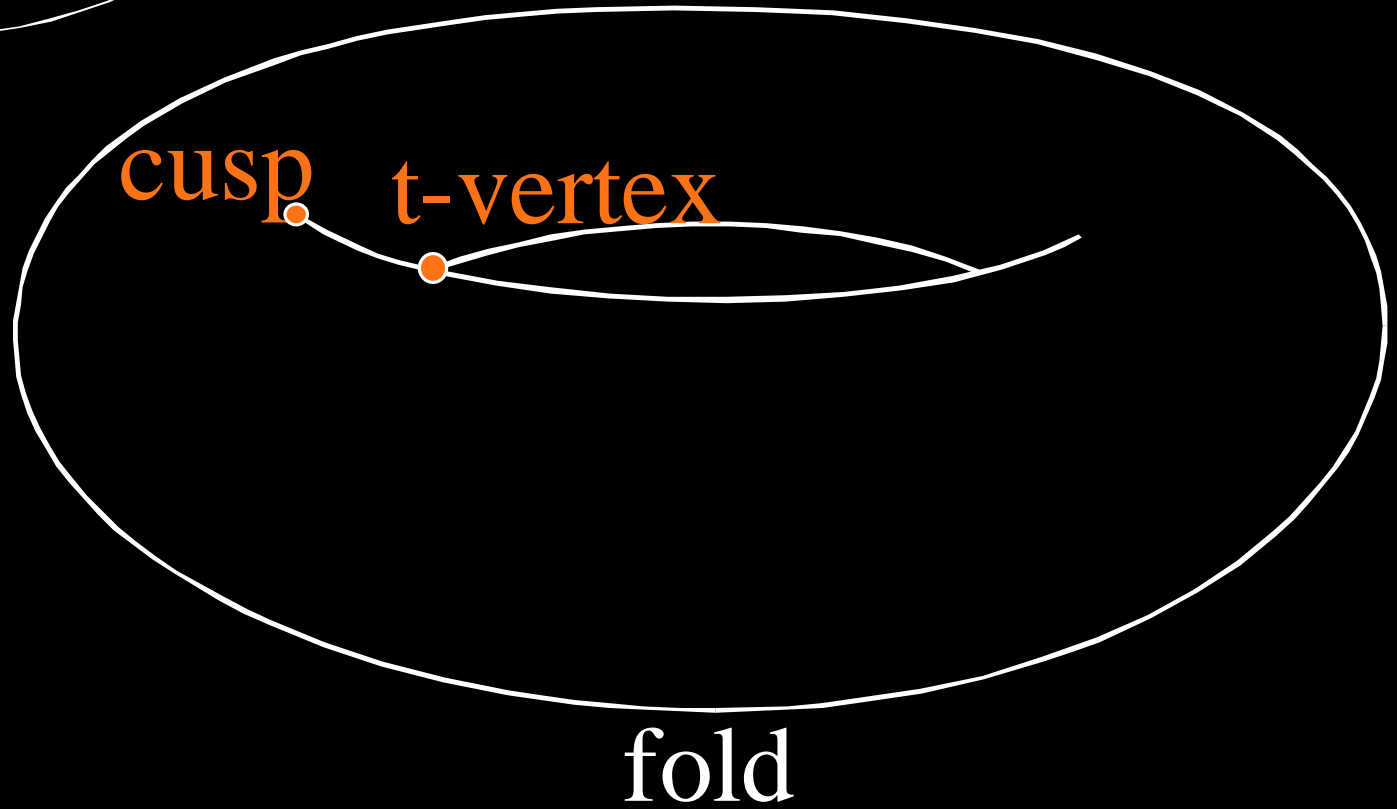
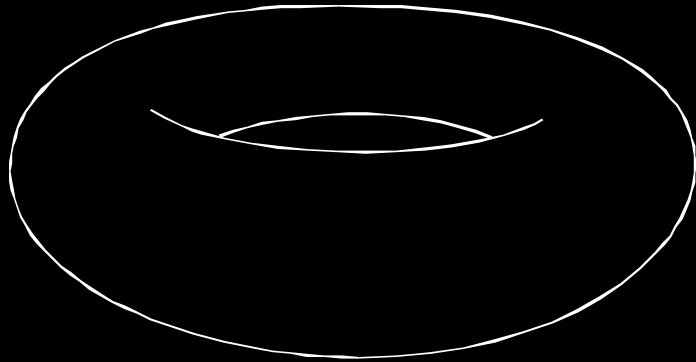
- End-junction
(a.k.a. cusp)



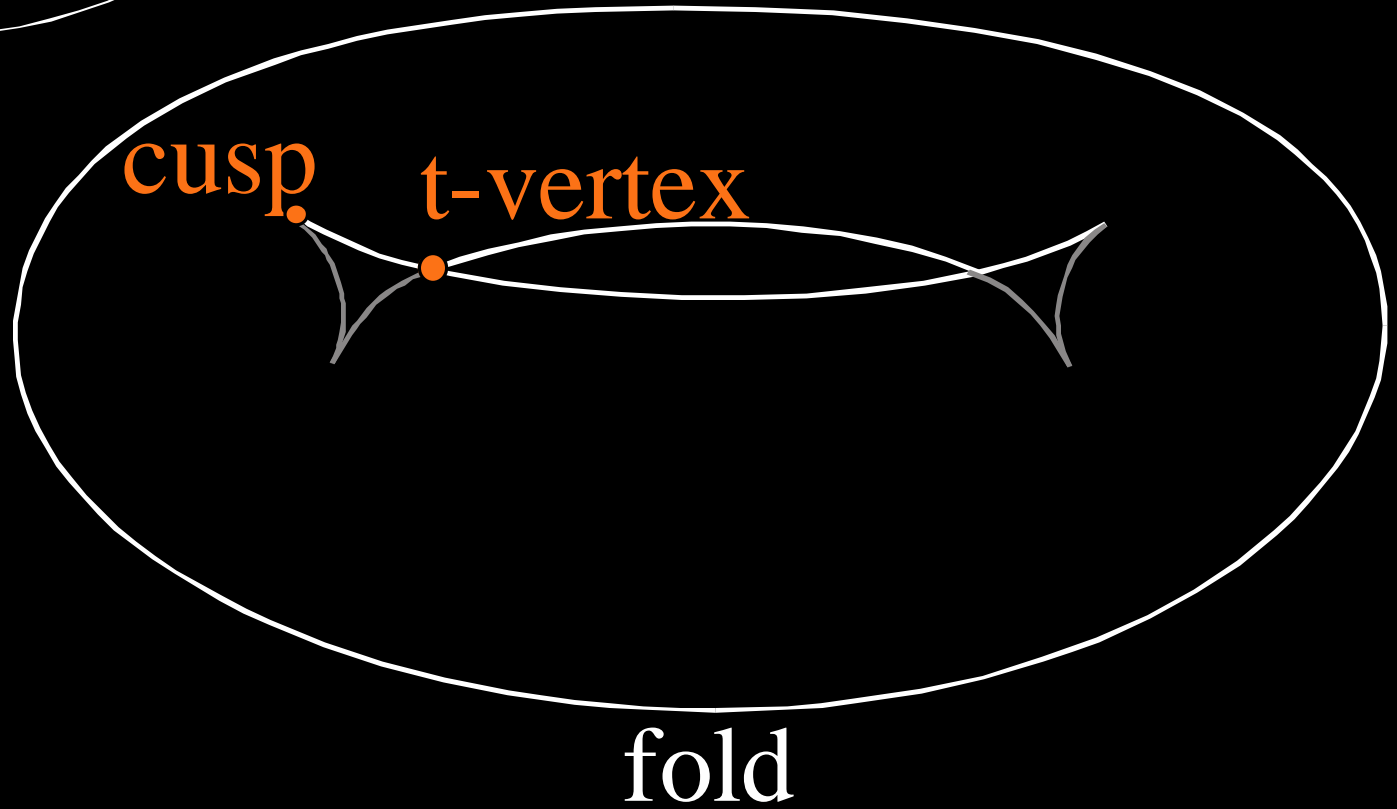
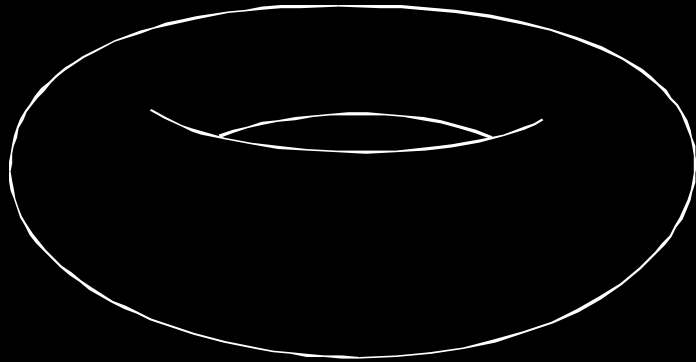
Line drawing of a torus



Line drawing of a torus



Line drawing of a torus



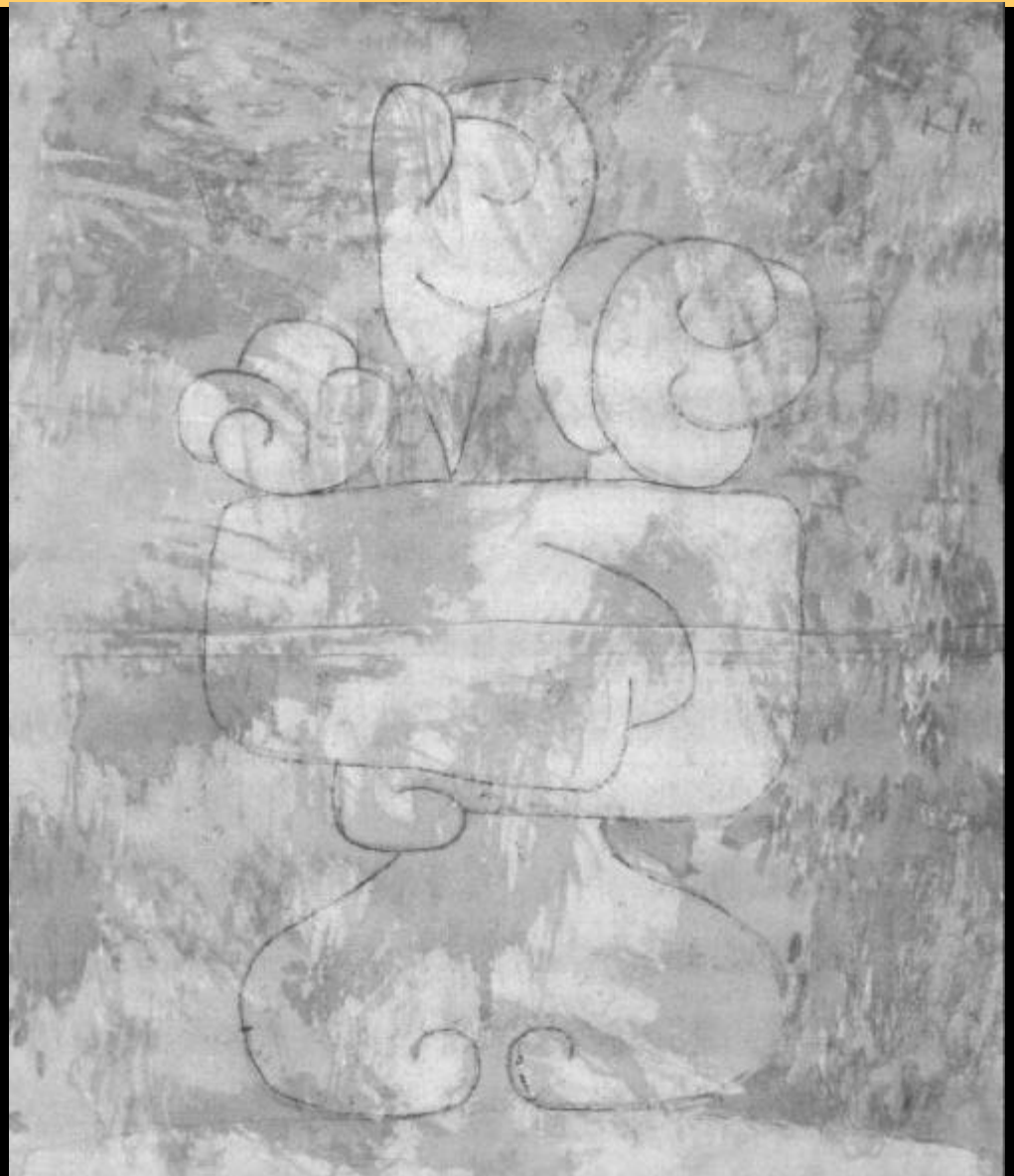
Drawing of smooth objects

- Walt Disney *sketch for Mickey's Parrot* 1938



Drawing of imaginary smooth object

- Paul Klee
- “As the figure grows little by little before our eyes an association of ideas may easily tempt us into objective interpretation. For with a bit of imagination every complex structure lends itself to a comparison with familiar forms in nature”



Ambiguous/impossible

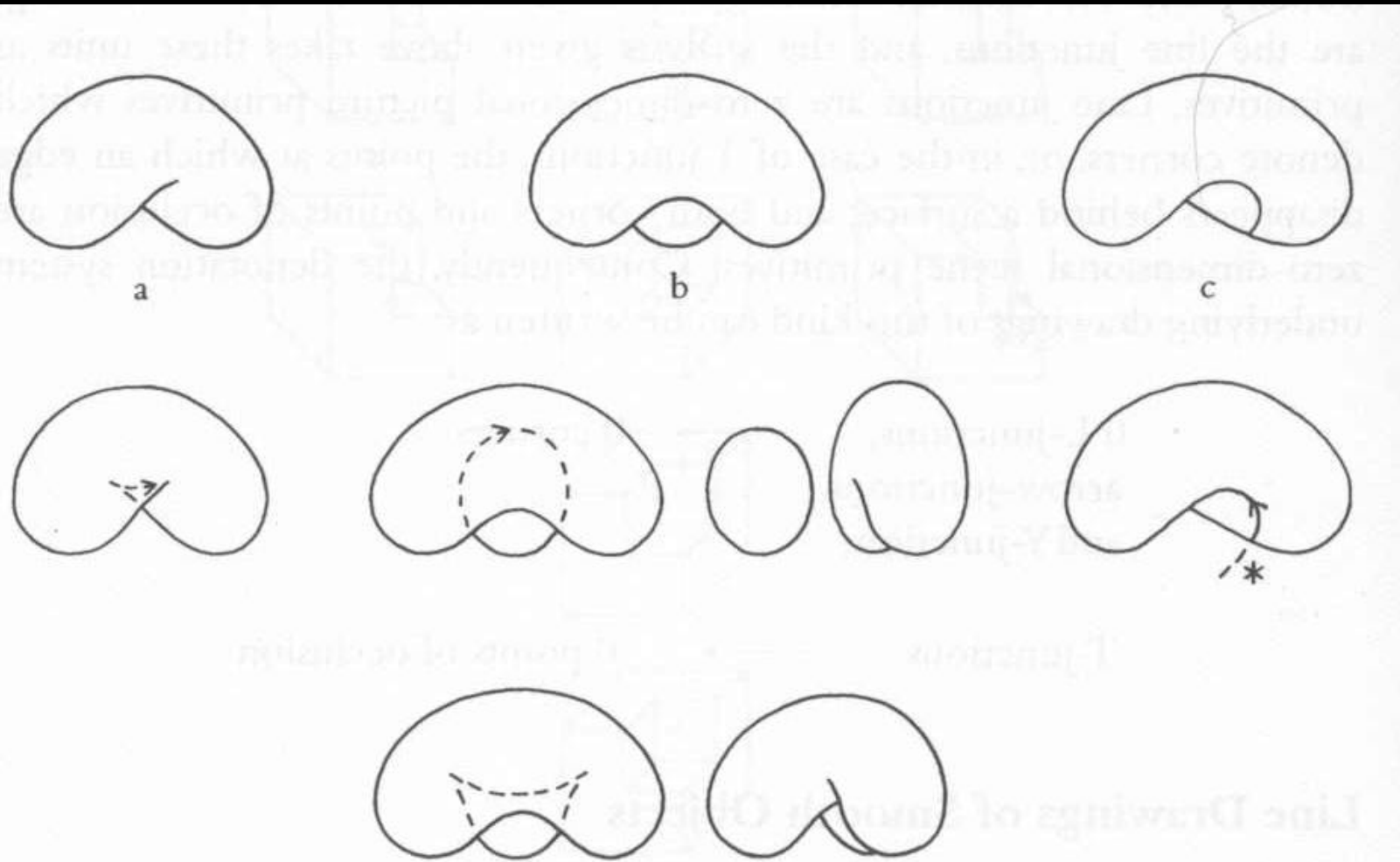
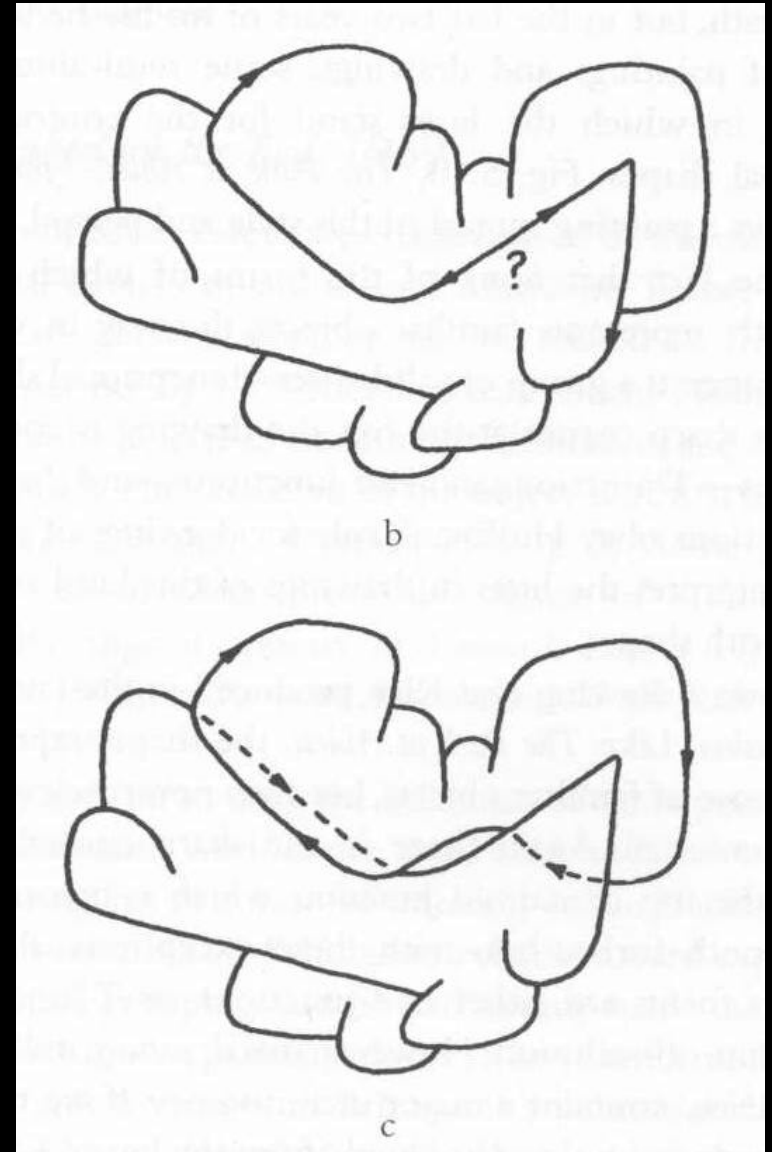
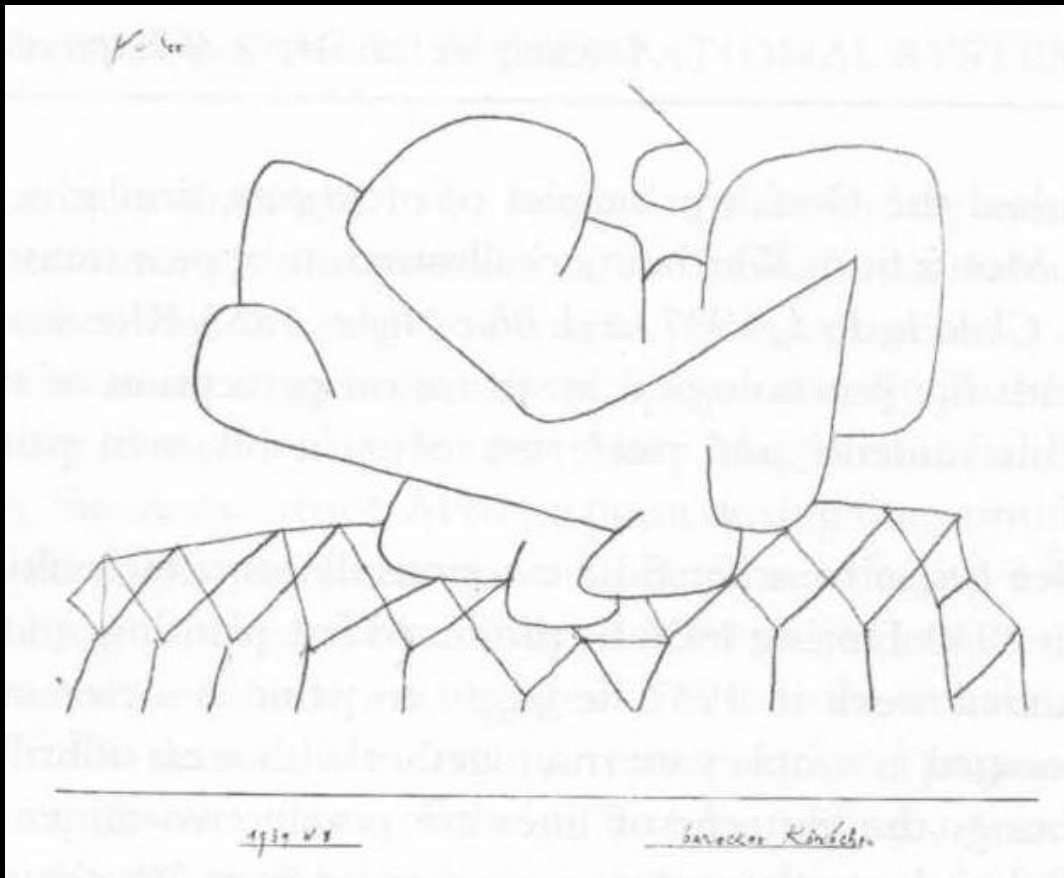


FIG. 5.8. Labelings for (a) unambiguous, (b) ambiguous, and (c) impossible drawings of smooth objects. The “impossible” labeling is marked with an asterisk.

Ambiguous/impossible

- Klee
Little Baroque Basket 1939



Ambiguous/impossible

- Pratt Institute
Gresh Mc Ginn

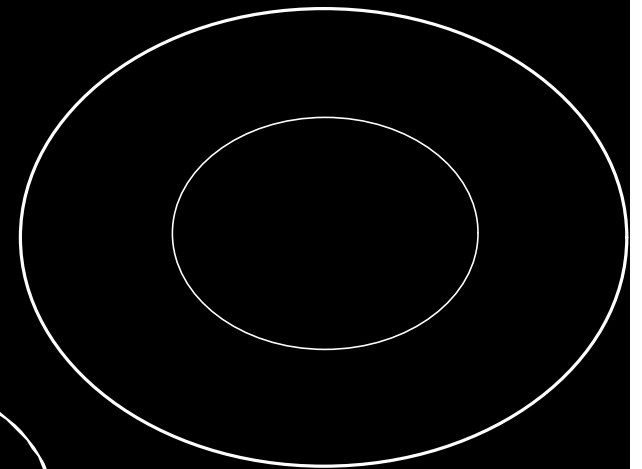
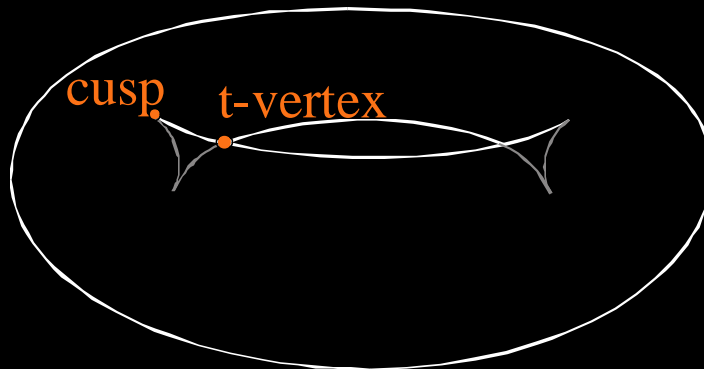
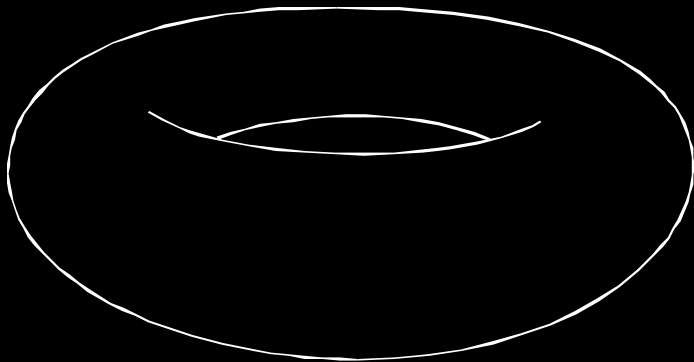


Ambiguous/impossible

- Pratt Institute
Gresh Mc Ginn

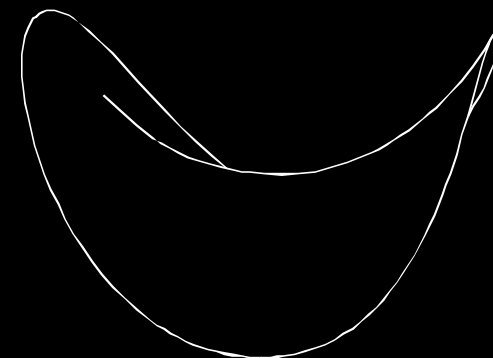
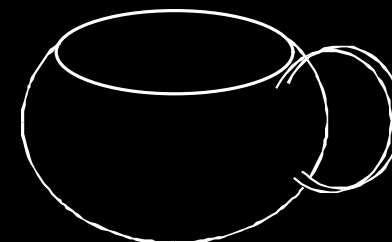
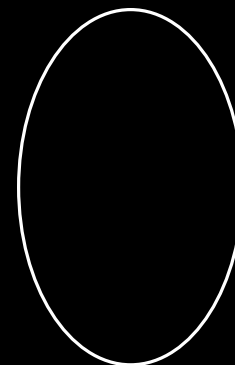
Just for fun

- Theory of singularity
- Evolution of the drawing when the viewpoint moves
- Structure changes at *visual events*



Convex/concave/saddle

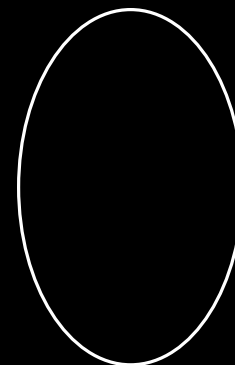
- Convex: positive curvature
 - Egg
- Concave: negative curvature
 - Interior of cup
- Saddle: mix of positive and negative curvature
 - Saddle (surprising, isn't it?)



Convex/concave/saddle

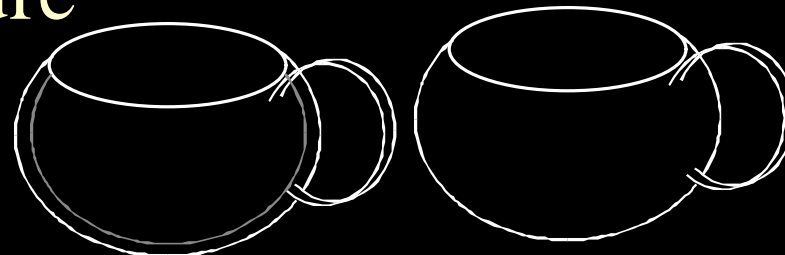
- Convex: positive curvature

- Egg
- Convex contour



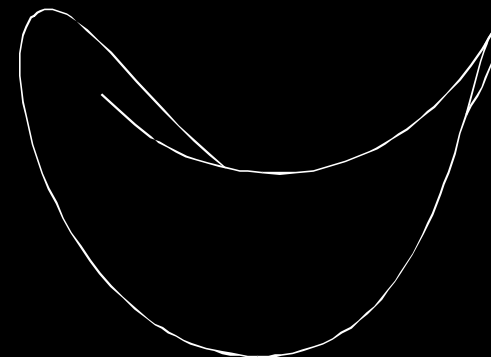
- Concave: negative curvature

- Interior of cup
- Hidden contour



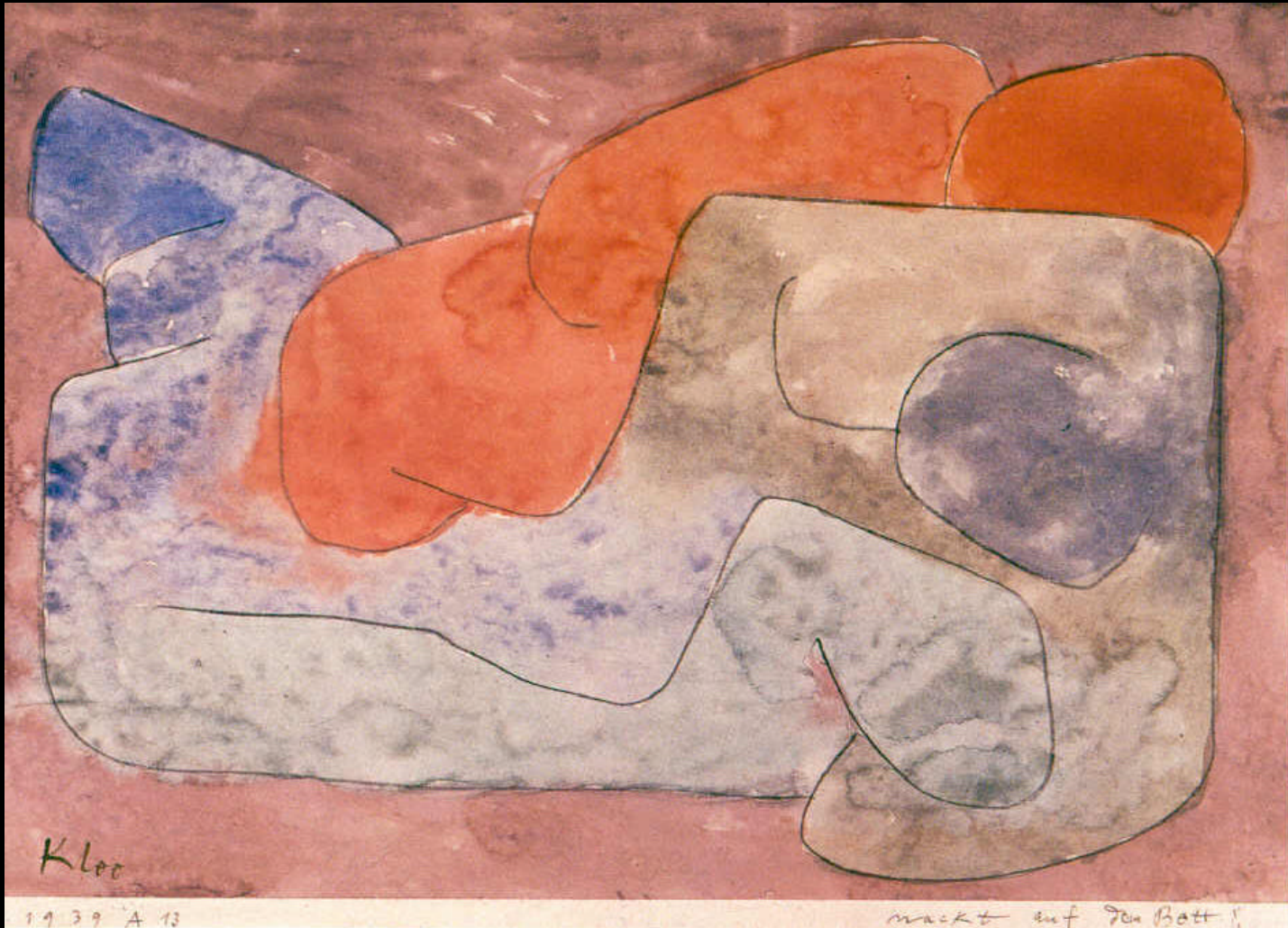
- Saddle: mix of positive and negative curvature

- Saddle (surprising, isn't it?)
- Concave contour

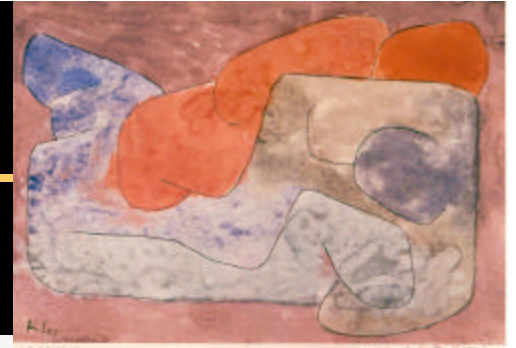


Drawing of smooth objects

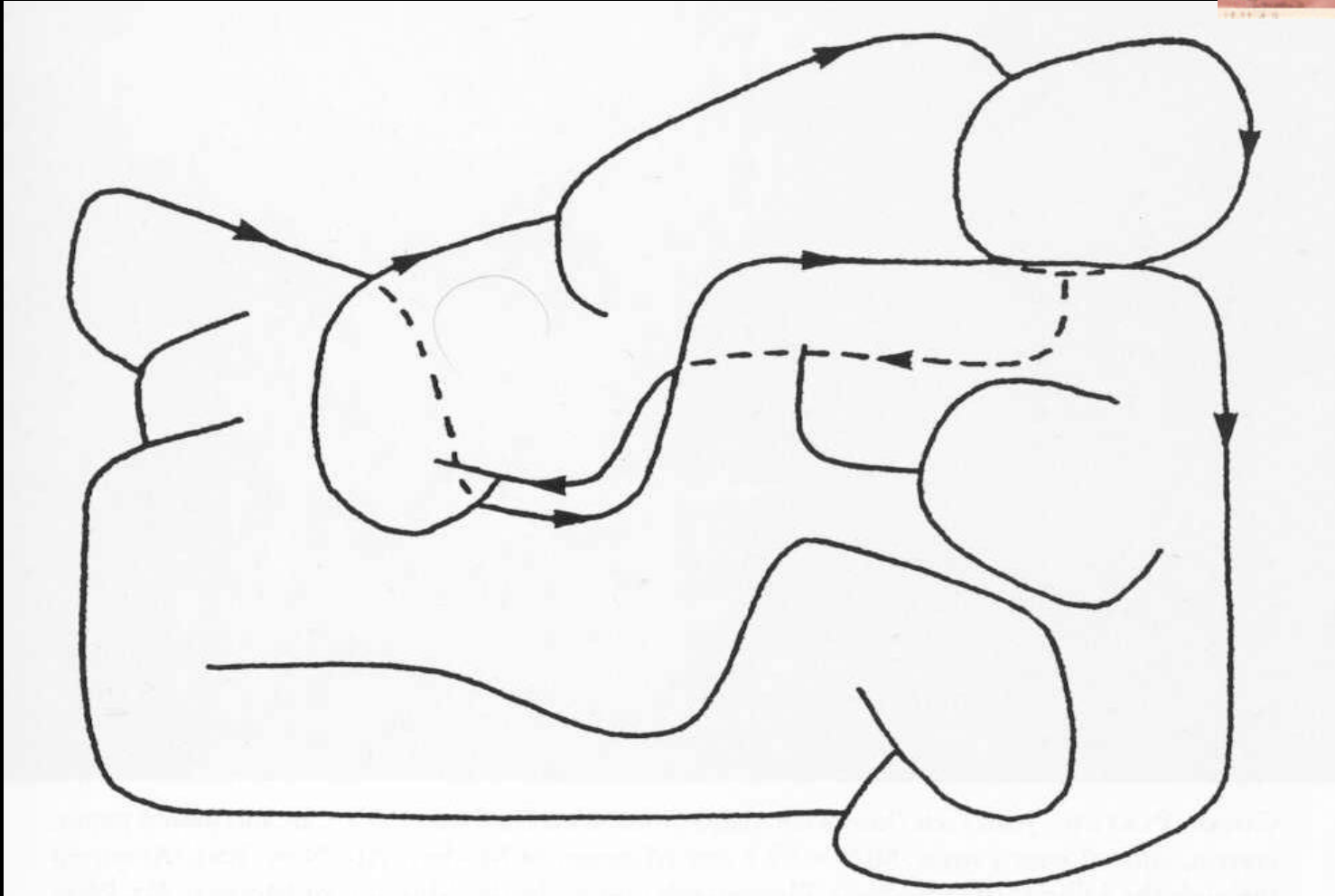
- Klee, *Naked on the Bed*, 1939



Drawing of smooth objects



- Klee, *Naked on the Bed*, 1939



Drawing of smooth objects

- Picasso,
Portrait of Stravinsky



Drawing of smooth objects

- Katsuka Shunsho,
Japanese, 1782



A second look

- Cup
- Table



Plan

- Introducing denotation systems
- Line drawing
- A catalogue of primitives

Picture primitive

- Points
- Lines
- Regions

Scene primitive

- View independent vs. view dependent
- 3D
- 2D
- 1D
- 0D

3D and 2D scene primitives

- 3D
 - Volume
 - Extendedness (sphere, disc, lump)
- 2D
 - Surface

1D scene primitives

- View independent
 - Very thin objects (string, etc.)
 - Edge
 - Reflectance edge
 - Shadow edge
 - Transparency edge
 - Surface contours
- View dependent
 - Occluding contour
 - Silhouette

1D scene primitives

- View independent
 - Very thin objects (string, etc.)
 - Edge
 - Reflectance edge
 - Shadow edge
 - Transparency edge
 - Surface contours
- View dependent
 - Occluding contour
 - Silhouette



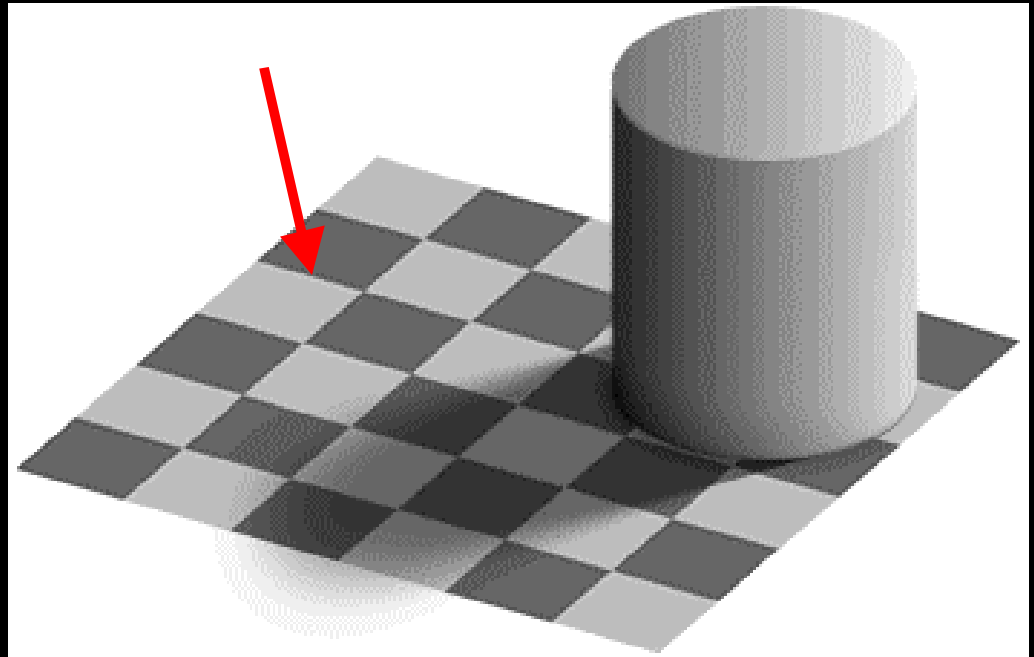
1D scene primitives

- View independent
 - Very thin objects (string, etc.)
 - Edge
 - Reflectance edge
 - Shadow edge
 - Transparency edge
 - Surface contours
- View dependent
 - Occluding contour
 - Silhouette



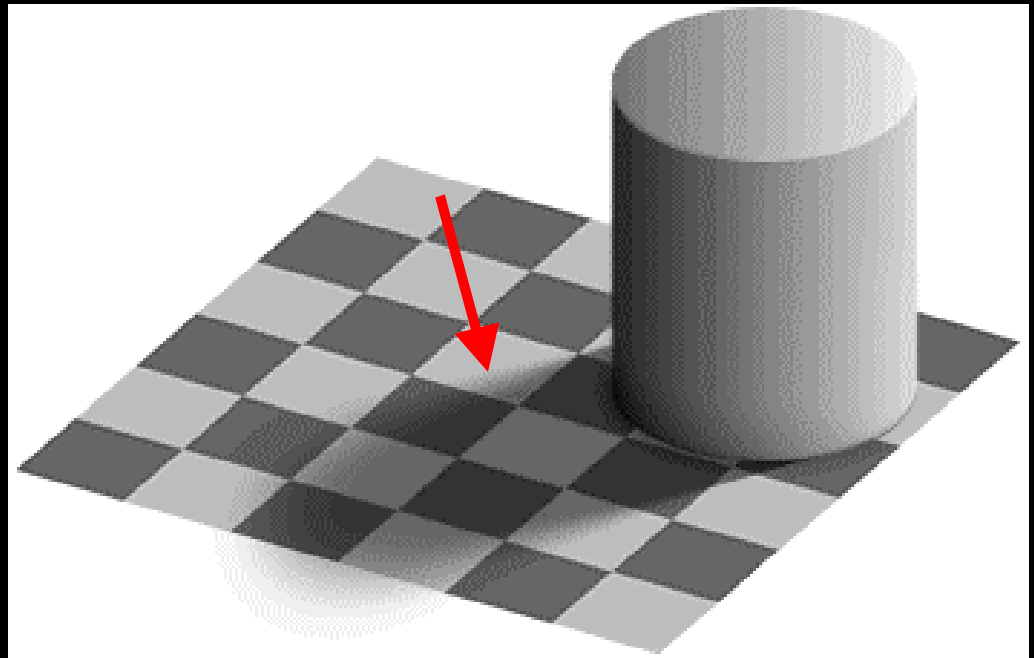
1D scene primitives

- View independent
 - Very thin objects (string, etc.)
 - Edge
 - Reflectance edge
 - Shadow edge
 - Transparency edge
 - Surface contours
- View dependent
 - Occluding contour
 - Silhouette



1D scene primitives

- View independent
 - Very thin objects (string, etc.)
 - Edge
 - Reflectance edge
 - **Shadow edge**
 - Transparency edge
 - Surface contours
- View dependent
 - Occluding contour
 - Silhouette



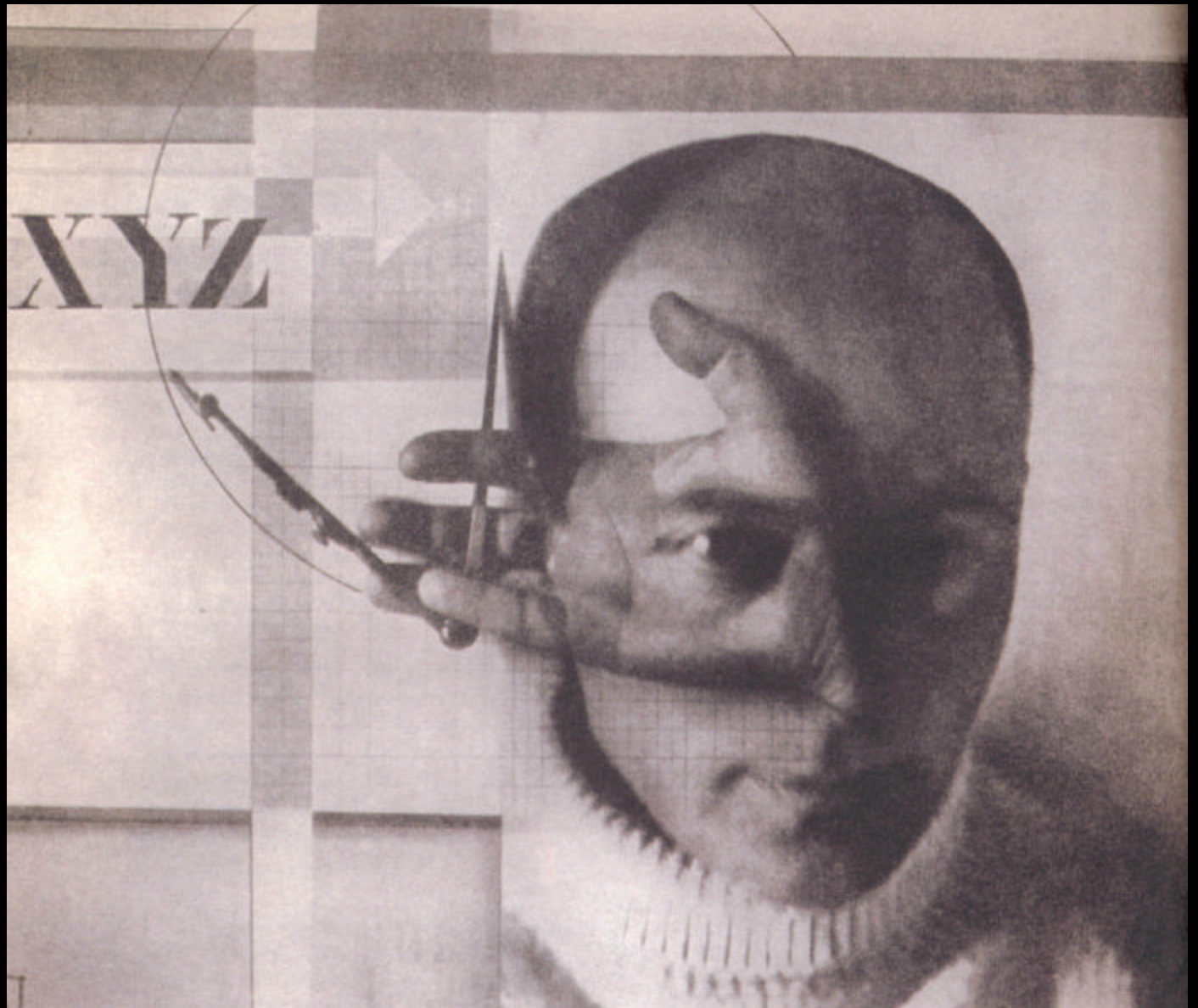
1D scene primitives

- View independent
 - Very thin objects (string, etc.)
 - Edge
 - Reflectance edge
 - Shadow edge
 - Transparency edge
 - Surface contours
- View dependent
 - Occluding contour
 - Silhouette



Transparency

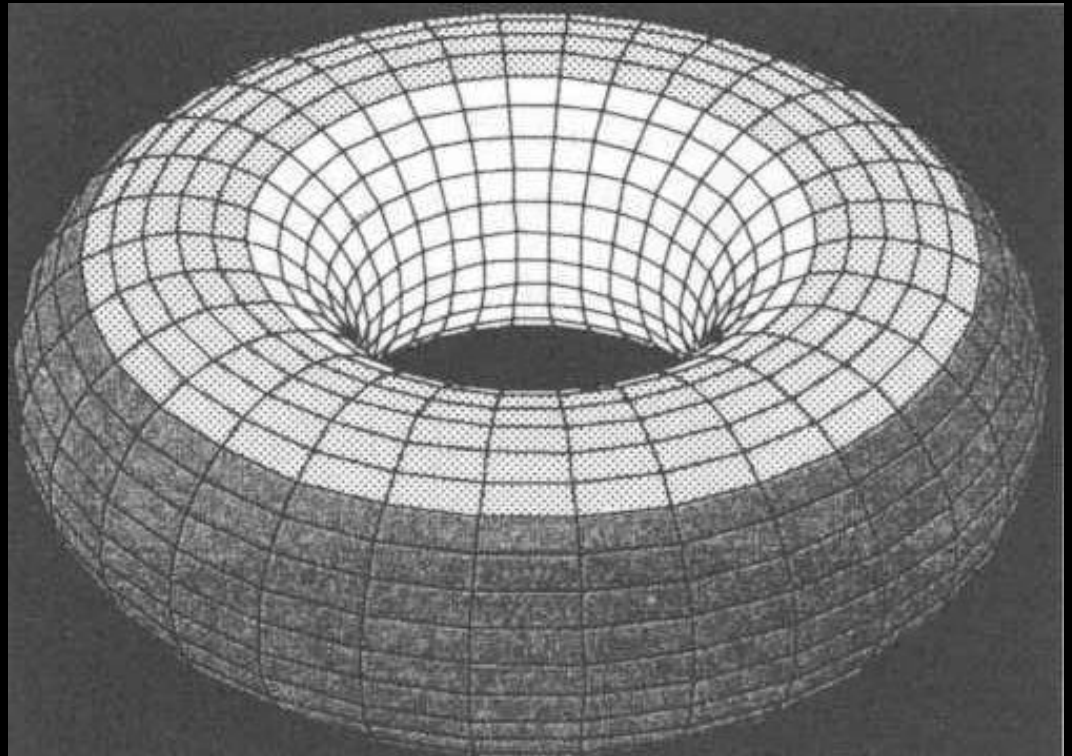
- Lissitzky



Denotation system

1D scene primitives

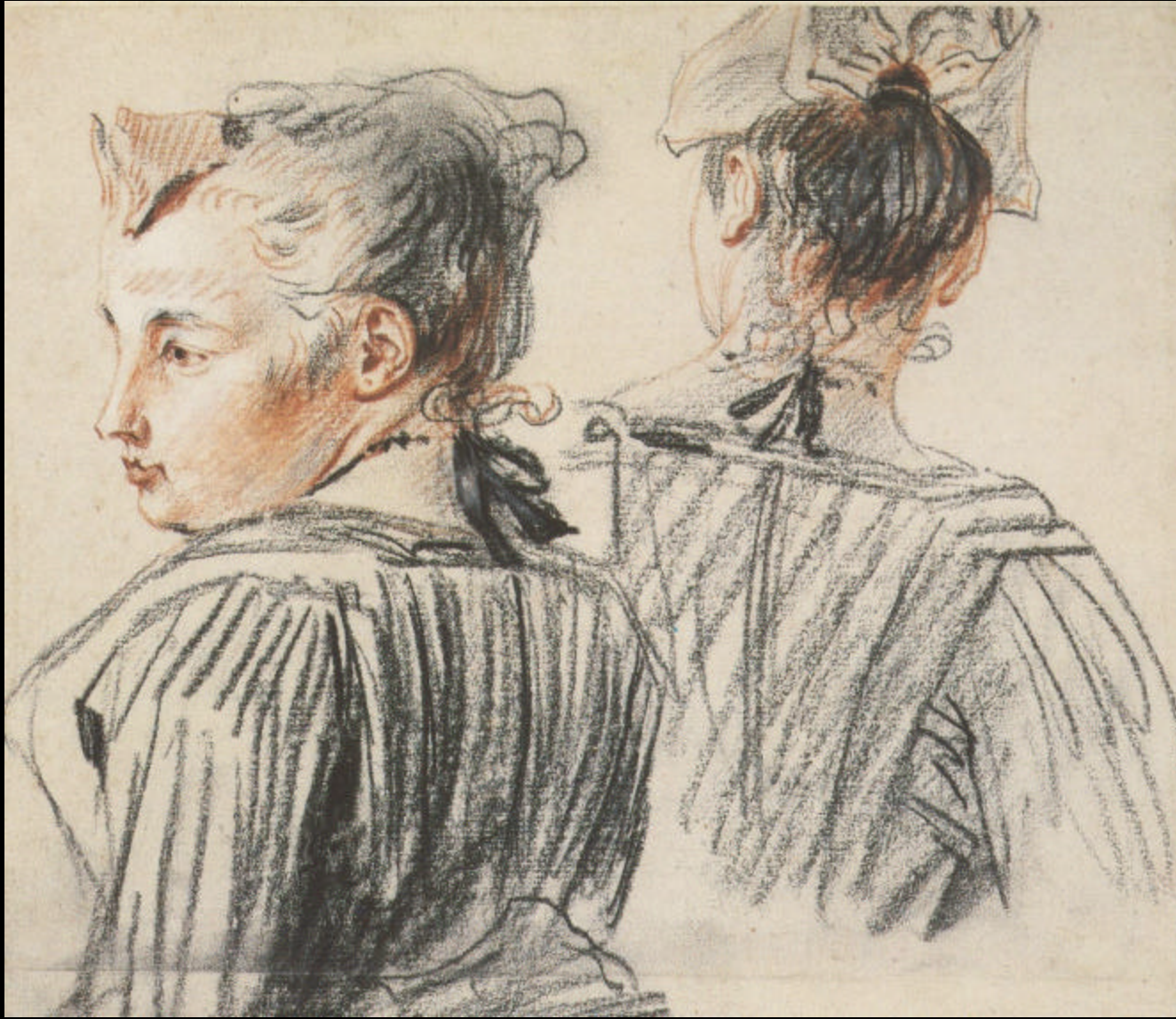
- View independent
 - Very thin objects (string, etc.)
 - Edge
 - Reflectance edge
 - Shadow edge
 - Transparency edge
 - **Surface contours**
- View dependent
 - Occluding contour
 - Silhouette



Surface contours



Surface contours



Denotation system

Surface contours



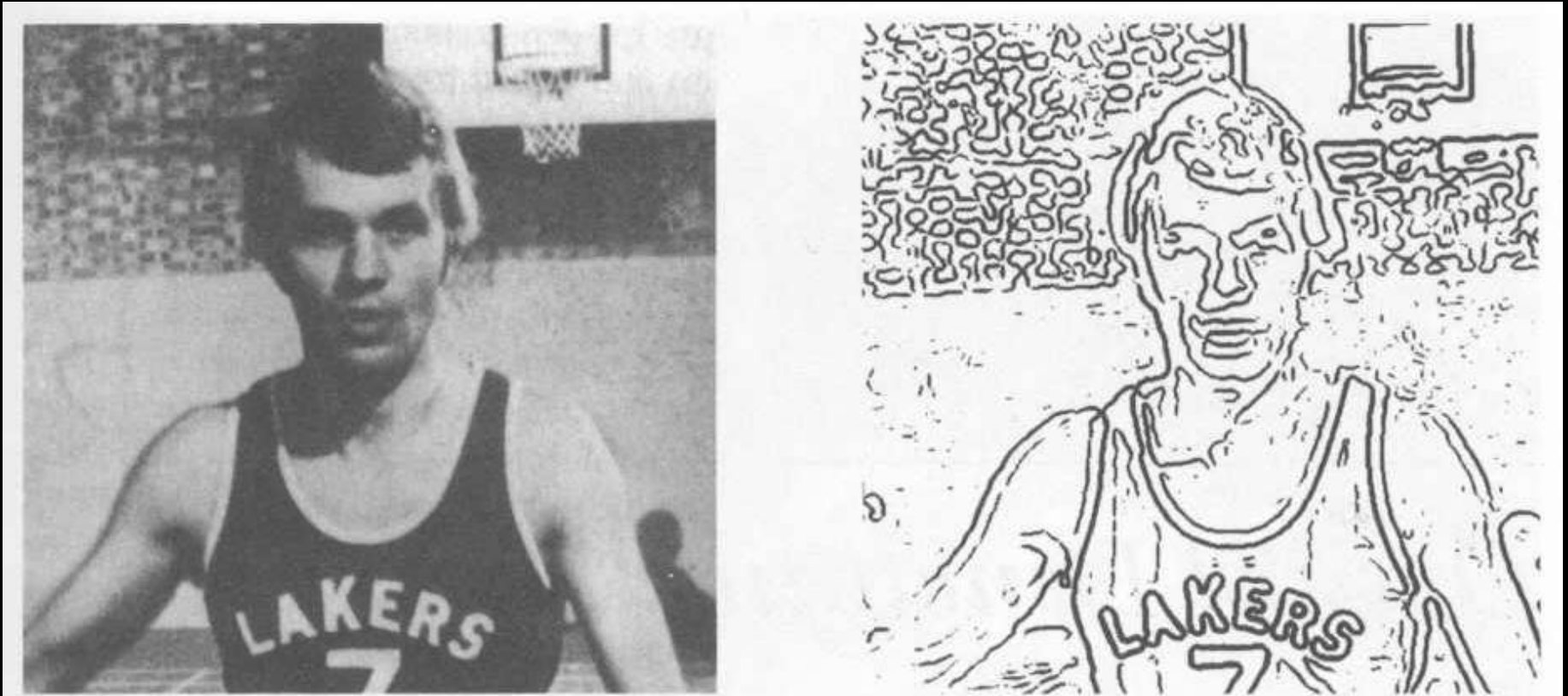
Denotation system

1D scene primitives

- View independent
 - Very thin objects (string, etc.)
 - Edge
 - Reflectance edge
 - Shadow edge
 - Transparency edge
 - Surface contours
- View dependent
 - Occluding contour
 - Silhouette



Edge detection



Denotation system

Edge detection

- Contour film



Edge detection

- Matisse, *Loulou*



Edge detection

- Matisse, *Loulou*



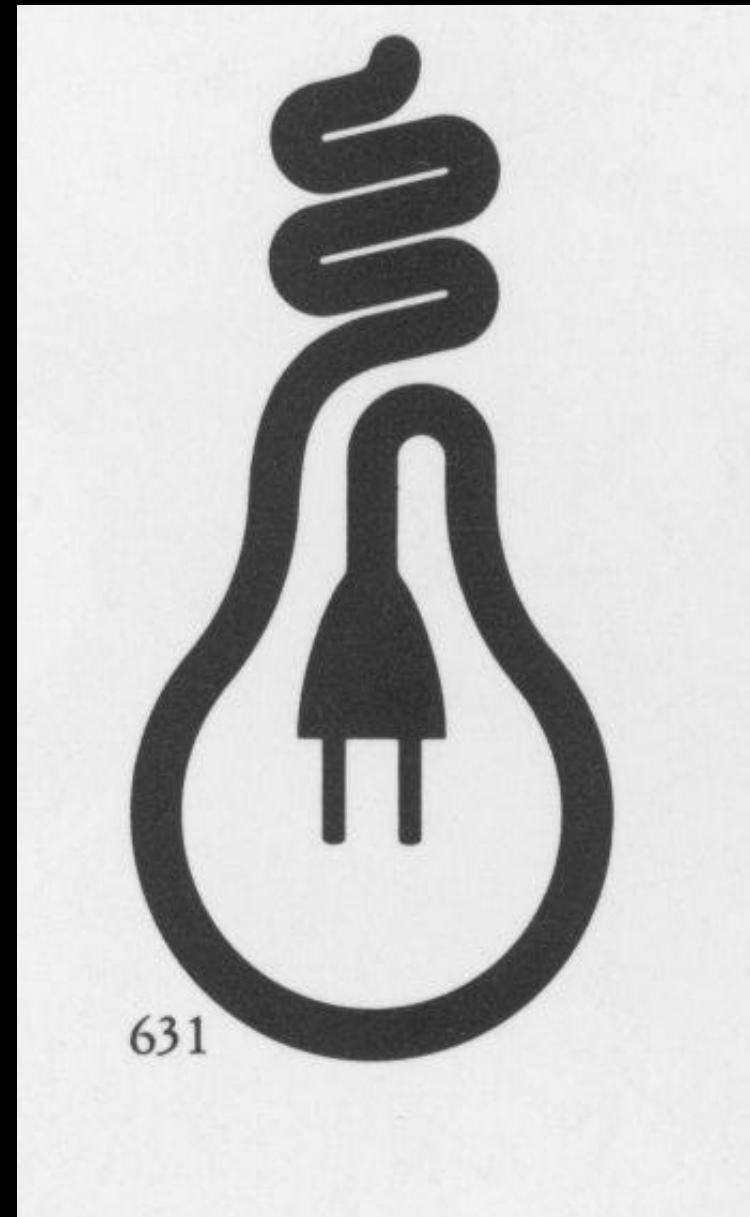
Denotation system

Disappears rather quickly, doesn't it.

0D scene primitives

- Generic visible point
- View independent
 - Corner
 - X-junction for shadow
- View dependent
 - T-junction
 - Cusp
 - X-junction for transparency

A complex example



A complex example

- Tom Purvis 1935



A complex example

- E Mc Knight
Kauffer 1947



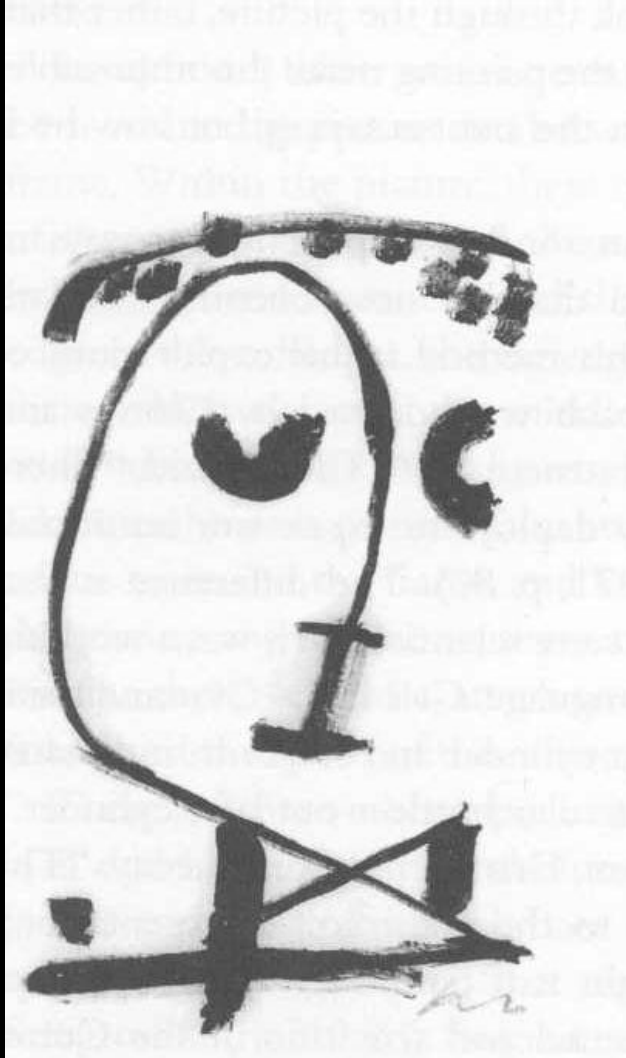
A complex example

- Ingres



A complex example

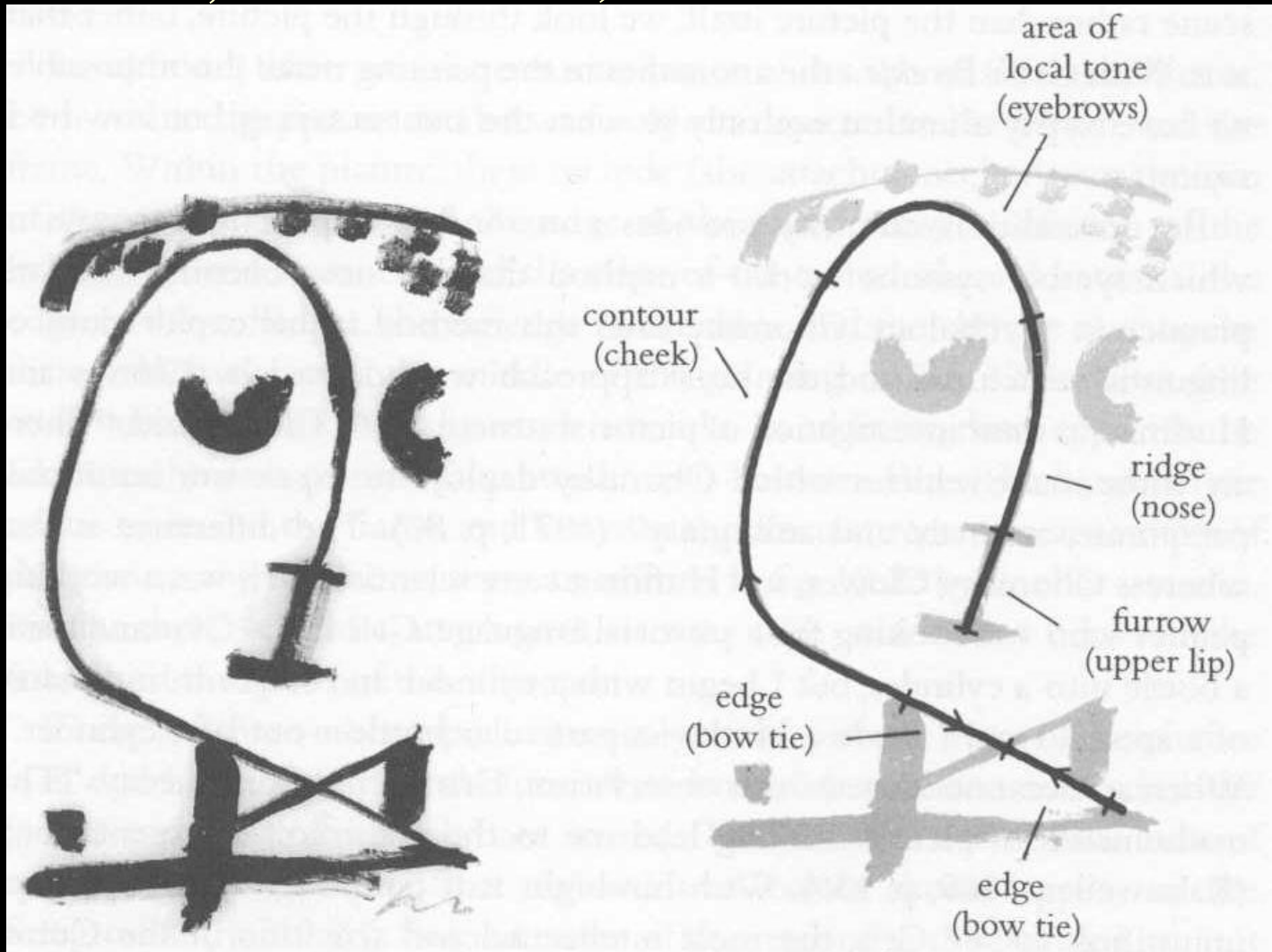
- Klee, *Oh But Oh!*, 1937



Denotation system

A complex example

- Klee, *Oh But Oh!*, 1937



Backlighting

- Line drawing...



Complex system

- Henry Wolf
Nude



Drawing

- Dürer,
Head of a Man



Drawing

- Raphael



Drawing

- Georges Seurat *Sous la Lampe* 1882-83



Denotation system

Simplification

- Picasso *The Bull* 1945

