Above: Detail of Peruvian geoglyph at Nazca.
Below: Egyptian hieroglyphs.

Photo-Glyph: Introduction to Graphic Geometry

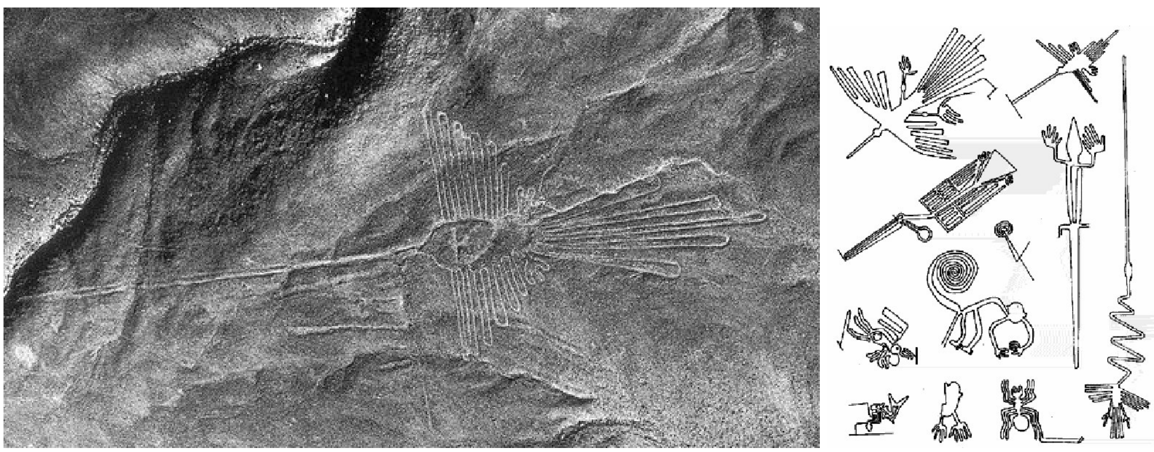
Tools and Materials:
Photograph cut from magazine or printed from an on-line source, photo-copied sheets, tracing paper, drafting bow compass, drafting triangle, circle template, pencil, removable tape.

This tutorial provides instruction in the geometric methods used to engineer images by abstracting them into compass and straightedge constructions. These are methods that designers through the ages have incorporated into the design of symbols, typefaces, corporate logos and other graphic images.

What is a glyph?

A glyph is a graphic symbol that is a highly abstracted emblem of a recognizable entity. Typically a glyph is a form of imagery -- usually familiar plants, animals, land features and tools -- simplified enough to use as writing or as signage. Most word processing programs include collections of such symbols: Webdings and Wingdings are examples of collections that include glyphic images. The term glyph usually appears in combination with prefixes such as in the term *hiero*glyph. In this case the prefix "hiero" suggests that the glyphs are systematically organized, that is, they possess grammatical relationships necessary for written language. Another example is the *petro*glyph, images scratched into or painted on rocks.

The Nazcan earth drawings discussed in Chapter 7 are examples of *geo*glyphs. They are clearly abstracted, some to the point that viewers from outside the Nazcan culture need prompts in order to convey what it is a drawing represents. The ancient Nazcans themselves would have been familiar enough with their own symbolic conventions to recognize these giant glyphs. Conventionality is also a characteristic of a glyph's role as a symbol.



Geoglyphs from the Colorado Plateau at Nazca, Peru

Stylization and Algorithms

By identifying a style, knowledgeable viewers can associate a selected work of ancient art or design with the culture that produced it. A style is the consistent application of prescribed visual elements and their organization. A style becomes unique to its home culture due to the particular elements, methods of application and organizational system that evolved in that culture's visual history.

A style may be, and frequently is, based on a specific set of geometric elements and a set of rules for their joining into the image. In the case of the Nazcan geoglyphs there are only two elements: circular arcs and straight lines. There are also two rules for joining these elements: 1) all elements must meet end to end while maintaining tangent continuity, and 2) the continuous line thus created must close into a loop.

If this description sounds more like math than art, it is because the two rules for joining are actually algorithms, i.e., instructions that can be expressed in terms of mathematical logic. The meaningful pattern and elegant order of much of the world's art can be generated from such mathematical instructions. Often artists are highly trained in the rules of pattern generation and have a keen practical knowledge of how to apply these. Even highly intuitive artists may actually be applying algorithms of their own device, despite their lack of mathematical schooling.

A set of algorithms that can consistently yield the desired range of results from a given set of elements is a program. In this sense the images of the Nazcan plateau were all produced from the same program. It is the algorithmic properties of programs that permit them to be written for computing machines.

Mogollon (Mimbres) potter yfrom Arizona (left) displays greater simplicity of outline and more angular interior patterning than do images on Nazcan pots (right). The smooth contours of these effigy pots carry over into the stylistic strictures of the Nazcan earth drawings.

Stylization and Abstraction

From a visual design perspective this tutorial is an exercise in abstraction.

Abstraction is an essential process in creating symbols. It is the method by which an image is stripped to its essentials and translated into a form that is more immediately grasped by the viewer. Abstraction entails five processes: 1) simplification, 2) selection, 3) exaggeration 4) translation and 5) stylization.

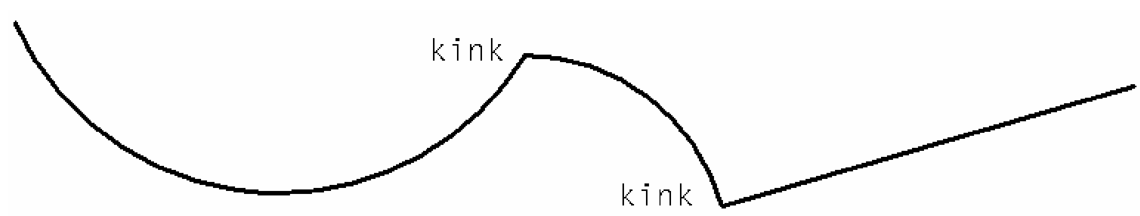
Simplification removes unnecessary detail, while selection retains those elements of the image most essential to its symbolic purpose. Exaggeration gives emphasis to the most significant of the selected elements. Translation denotes the changes in the image necessary for its re-presentation in a chosen medium, e.g., stone, paint, photography, computer graphics, etc. Finally stylization refers the consistent application of a style, as defined above.

Most often stylization involves a translation into geometric components, and there is good reason for this preference for geometry. Humans tend to perceive familiar, previously internalized images very quickly, as opposed to novel images, which require some time to internalize. They also tend to organize their perceptions into simple geometric patterns, which perceptual psychologists call *gestalts*. A simplified and geometric translation of a familiar image, then, makes for a very effective symbol. A well-designed glyph is a good example.

Continuity

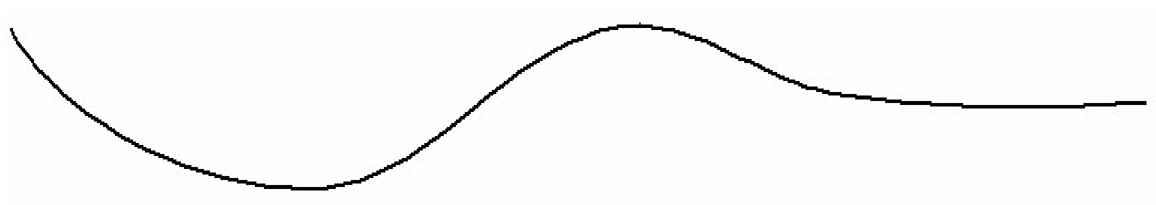
In purely visual terms continuity is the smooth transition or flow between the parts of an image. In geometric terms continuity refers to specific types of transitions between the parts of a complex curve. In geometry continuity falls into three categories: position, tangent and curvature.

Position continuity simply means that the curves touch ends to form a kink, a corner or vertex, before continuing on. The line, in effect, comes to a stop in order to change directions. Continuity exists only because the curve segments are attached end-to-end.



With tangent continuity the curve segments are tangent to one another at their meeting point. The visual effect is truly continuous, as no stoppage is apparent. No kink or vertex appear to interrupt the flow even though the change in the nature of the curve segments may be great, such as the change from a straight stretch of road to a curve in the road.

When a straight stretch of road enters a curve, it snaps instantly from a line with no curvature to an arc with a single radius throughout. While cars may travel smoothly through this change, the change in radius is abrupt: it has no continuity of *curvature*. The curve below, however, constantly and gradually changes radii along its entire length.

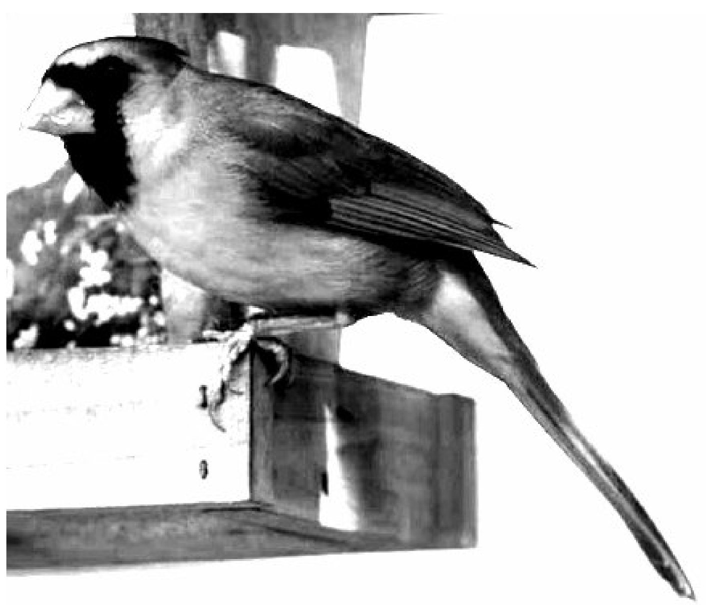


For purposes of visual design tangent and curvature continuity boast individual strengths. Tangent continuity permits the viewer to simultaneously comprehend the individual segments of a complex curve and their continuity. For realistic portrayal of natural curves of living creatures, or the curves of physics and engineering, curvature continuity holds the upper hand. In the case of the Nazcan earth drawings, the artist/engineers stylized the curvature continuity of living form into the tangent continuity permitted by their constructive methods.

Part I. Set Up

1. Select a photograph of an animal to be the subject of the glyph. Enlarge (or diminish) this photograph using a photocopying machine set to a percentage of change that will scale the desired portion of the image to fit it onto an 8-1/2 x 11 sheet with about 3/4 inch margins. Some experimentation may be necessary to arrive at the right percentage. If the initial photocopy is too small, despite copying at the highest permissible percentage, then make a second copy -- a copy of the copy -- to enlarge the image still further.

The original image (below) changes into a larger, cropped, higher contrast image (right) during the process of photocopying.



In this case photocopying initiates the abstraction process. It *simplifies* the image by eliminating color and losing subtle changes in the gray tones to produce a higher contrast black-and-white image. Also, by cropping to the pertinent portion of the photograph, the designer engages in *selection*.

2. Prepare the drawing space.

   Lightly tape the photocopied enlargement to a drawing board (the back of a sketchbook will do). Overlay this with a sheet of tracing paper also taped lightly to the board.

Part II. Constructing Tangent Extensions of Curves

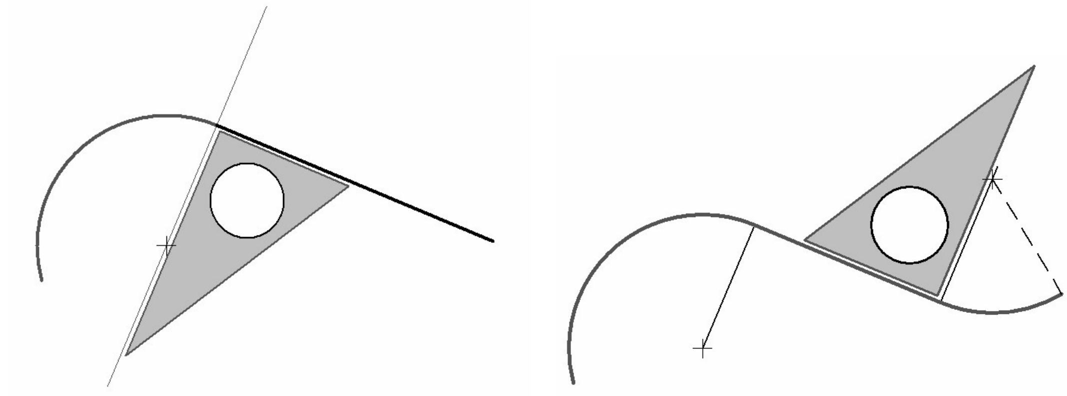
This portion of the tutorial diverges from the photograph for a moment in order to practice some skills necessary to complete the main portion of the tutorial. It follows the construction of a complex curve built from arc and straight line segments, while going through all of the five possible methods for extending lines and arcs with tangent elements.

> ***Definition:*** *In geometry curve is often used as a common term to refer to both arcs and lines. Sometimes the term complex curve is applied to their combination into a more intricate path, but just as often the term curve broadens to cover these combinations as well. Similarly, this tutorial will refer to the complex curve as simply curve and to its component arcs and lines as curve segments.*

3. On a separate sheet of scratch paper draw an arc with the drafting compass, taking care to mark the center point of the arc.

4. Extend the arc by drawing a tangent line from an end point.

   With a side of the drafting triangle, draw a straight line passing through the center and one end of the arc. On this radius line use the square corner of triangle to draw a perpendicular from the end point of the arc. This perpendicular is the linear extension of the arc.

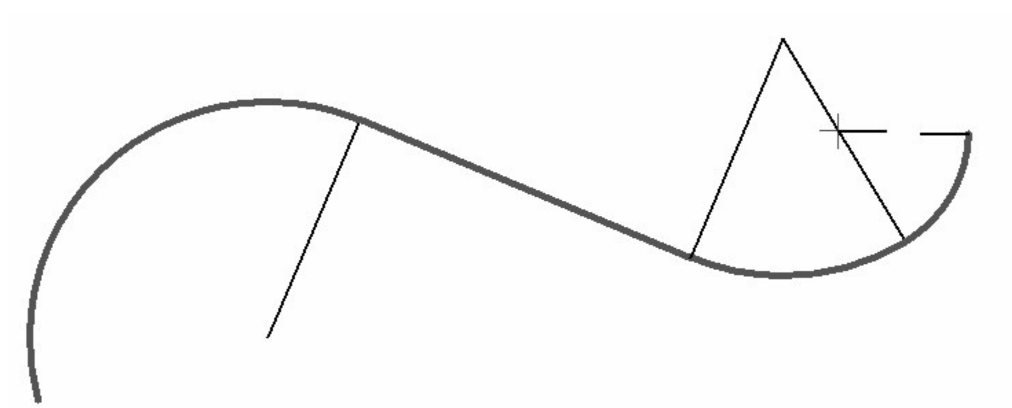


5. Extend the previous line with a tangent arc.

   Using the drafting triangle draw a perpendicular from the open end point of the line. This perpendicular line will be the beginning radius of the arc extension. Mark a point on this radius to serve as the arc center and draw an arc starting from the end of the line being extended.

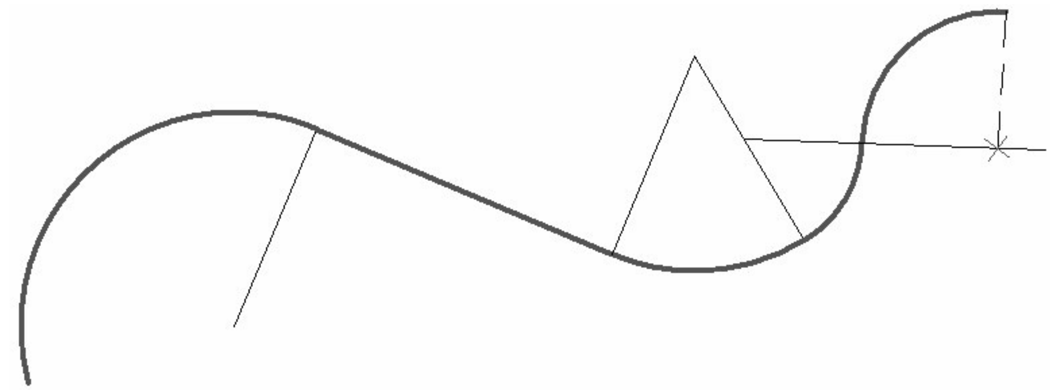
6. Extend the previous arc with an arc of smaller radius.

   Draw a line through the mark at the center of the previous arc and the open end of that arc. This is the ending radius of the previous arc and the starting radius of the extending arc. Mark a point on this radius between the previous arc center and the end of the arc. Using this mark as its center, draw an arc to extend the previous arc.



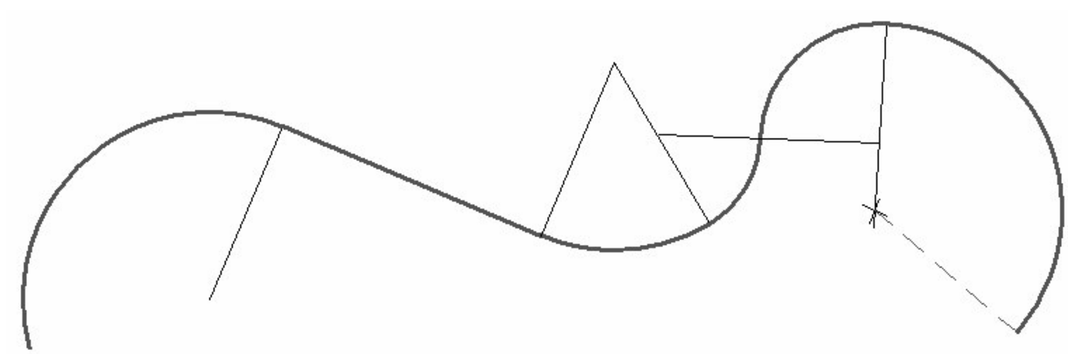
7. Extend the previous arc with an arc of reversed curvature.

   Draw a line through the mark at the center of the previous arc and the open end of that arc. This is the ending radius of the previous arc and the starting radius of the extending arc. Extend this line to the outside of the preceding arc and then mark a point on this extension. Using this mark as its center, draw an arc to extend the previous arc. The extending arc will remain tangent to the arc that it extends, but the direction of the curve will reverse.



8. Extend the previous arc with an arc of larger radius.

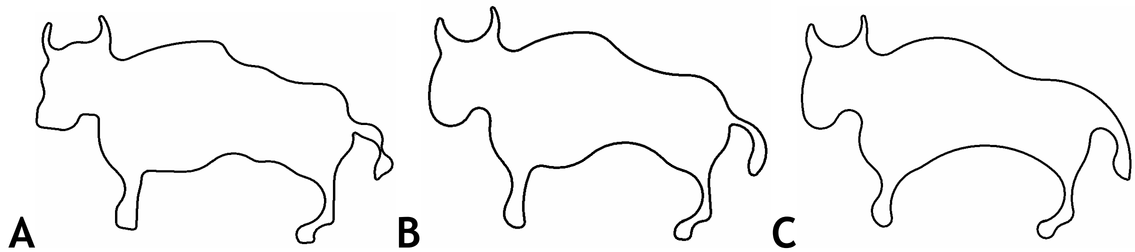
Draw a line through the mark at the center of the previous arc and the open end of that arc. This is the ending radius of the previous arc and the starting radius of the extending arc. Extend this line beyond the center mark and then mark a point on this extension. Using this mark as its center, draw an arc to extend the previous arc. The radius of the extending arc will be larger.



Part III. Constructive Interpretation

The next stage is to *translate* the photocopied image into a smooth sequence of arcs and straight lines. Note that translation is the third principle of abstraction discussed in the introduction. Note, too, that the process of modifying the photograph for use in the drawing space incorporates, of necessity, selection and simplification. The application of the stylistic algorithms that are followed in this interpretation of the sample image into a geometric version constitutes a fourth principle, stylization.

But first some planning is necessary. It is exhaustive and visually ineffective to try to translate every tiny irregularity of the hand drawing into minute arcs. Instead try to streamline the image by smoothing out the image with larger arcs and line segments.



The examples above illustrate the interpretations of a drawing of a bison, ranging from a fairly detailed loop of arc and line extensions to a highly simplified loop. Note that all fulfill the strictures of the Nazcan stylistic program: 1) all extensions are arcs and straight lines, 2) all retain tangent continuity and 3) all comprise a single line closed into a loop. Note, too, that in order to fulfill stricture number 3, the inside lines are gone and the tail is no longer a separate shape attached to the body.

Just as with a free-hand drawing of a buffalo, the sample image for this tutorial is not comprised of straight lines and arcs. In fact, none of the curves that outline the cardinal at a bird feeder image are arcs or straight lines! In addition, there are a number of slight irregularities that can be disposed -- as they must since circular arcs and straight lines possess no such irregularities. Clearly selection and simplification continue as the image undergoes translation and stylization.

This tutorial will expand a bit on the stylistic algorithms of the Nazcan engineers. Note that in the style rules below, the requirement of a single closed loop has eased into one disallowing open ends on curves:

- *All curve segments will be arcs and straight lines.*
- *All curve segments will connect with tangent continuity.*
- *All curves will close or blend tangentially into another curve. No loose ends are permitted.*
- *Hidden lines are permitted.*

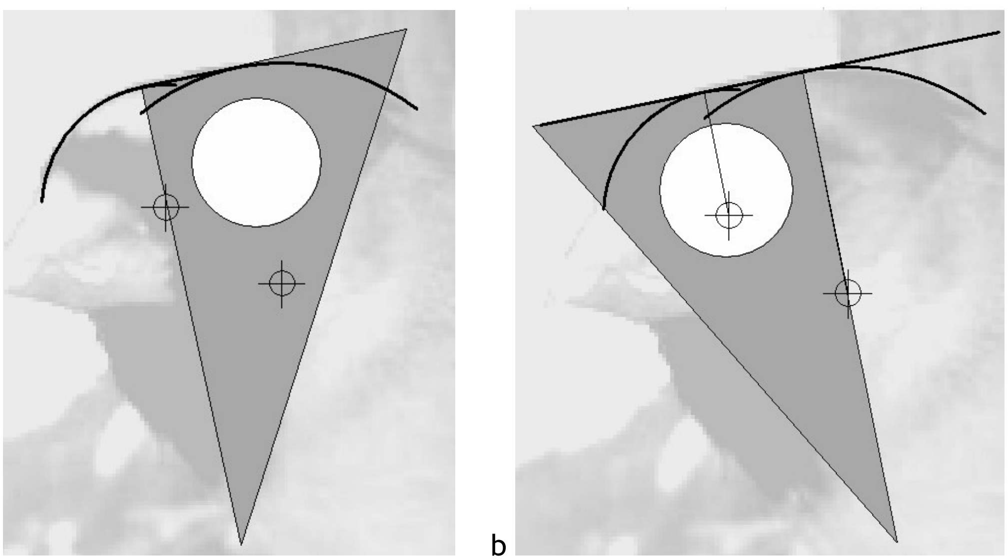
These algorithms will encourage smoothly elegant features and allow the interior detail missing from the bison above. When artists or designers settle on an image style they consciously or unconsciously select stylistic algorithms to achieve the intended results. Such an algorithm is less a restriction and more a strategy to gain elegance.

9. The graphic of the animal will be drawn on the vellum layered over the photocopy using the construction procedures for tangent curves followed in the previous part of this tutorial. The following instructions refer to the cardinal drawing, but the methods given will work for most images.

Begin by drawing an arc that closely matches one of the curved segments of the underlying drawing. This will take some hunting-and-pecking to determine a good center and radius for the arc.

The next series of demo instructions concentrates on the head of the cardinal, and begins with the observation that the line created by the crown of the head and the crest is rounded at both ends and flattened in the middle. This could translate into two arcs with a third broad arc, or perhaps a straight line, between them.

The first example uses a straight line as the transition. It begins by drawing two initial arcs. Be sure to a) mark the center point of each arc and b) to extend the arc past its likely endpoints:

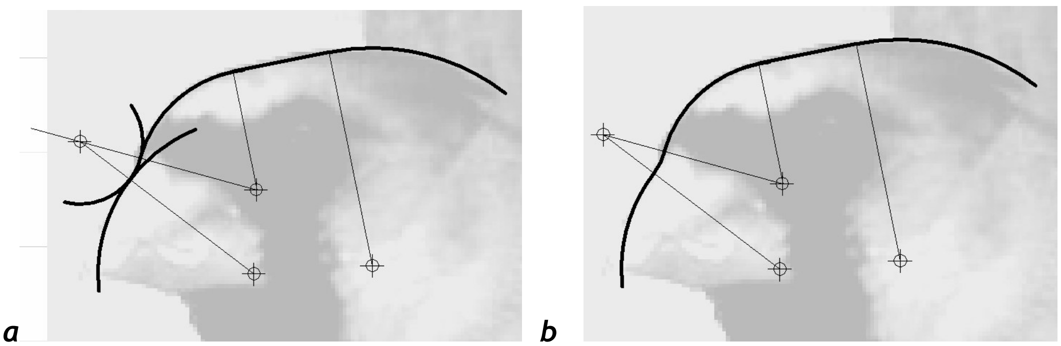

a b

10. To construct a tangent line on the first arc, place the right angle corner of the triangle on the arc line and a leg of the drawing triangle through the arc center. The other leg will be tangent to the arc. Rotate the triangle on the arc center until the tangent leg touches the second arc (see ***a*** below). Lightly rule in this line and the radius line.

11. Flip the triangle and draw the perpendicular from the tangent line to the center of the second arc. This line will be parallel to the radius just drawn in the first arc and its intersection with form the tangent point on the arc. Erase the arc segments between the two parallel radii.

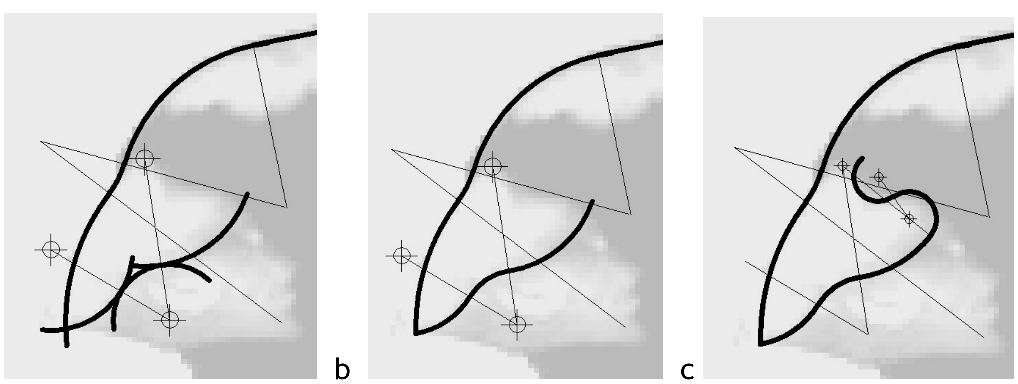
> When drawing with lines designers distinguish among a variety of lines according to the purpose each serves in the drawing. A line that demarcates the outer shape or silhouette of a graphic is termed the *outline*. This is arguably the most important line of the whole image, since it sets the drawn object off from the rest of the image environment and establishes its essential configuration in space. Usually an outline is sufficient to create a recognizable symbol.

12. Three segments of the outline of the cardinal are now complete. Images ***a*** and ***b*** below demonstrate the continuation of the outline to the end of the cardinal's beak. Note that the curve has been extended twice with a succession of two reversing tangent curves. To see how this was done refer to step 5. in Part II of this tutorial.



a ***b***

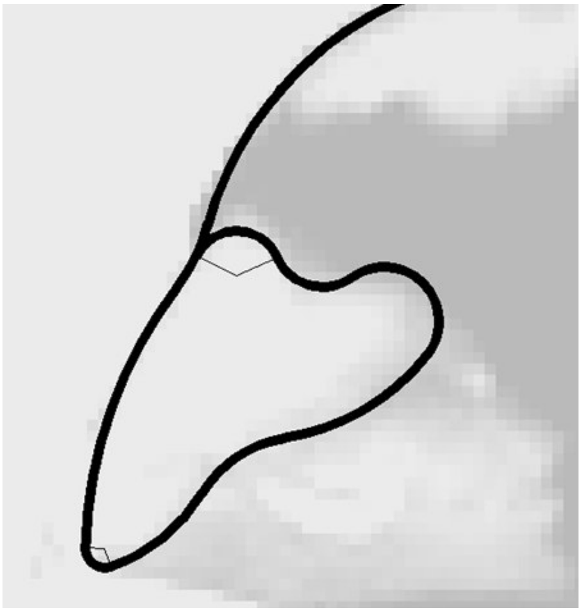
> Another category of lines is *contour lines*. These lines work inside the outlined form to give definitions to the contours of the physical features therein. Contour lines may define muscles, wrinkles, lips or, as is the case below, the details of a bird's beak.



a b c

13. With the outline now at the end of the beak, this demonstration diverges to draw the contour dividing the upper and lower beaks. This example draws the line as a separate curve for the time being. It intersects the outline to form a vertex (not allowed by the rules of style) and leaves an open end (also not allowed).

    Unless the designer is crafting a large image of the head, the arcs of the beak are likely growing too small in radius for the compass. At this point pick up the circles template and use it to trace these smaller arcs. Since the template provides only the curve and no center or radius lines, the designer must estimate the points of tangent continuity. This tutorial will assume that all curves are large enough to construct.



In the drawing to the left both trouble spots have been brought back into line by connecting the contour back to the outline with arcs that are continuous with both the outline curve and the contour curve. The end of the beak, for instance, was a vertex, but a small transitional arc replaces the sharp point with a slightly rounded point. A similar arc swings the open end of the contour back onto the outline with a smooth tangent connection.

This type of transitional curve, called a fillet (pronounced fill-**it**), is the subject of the next part of this tutorial

Part IV. Constructing Fillets

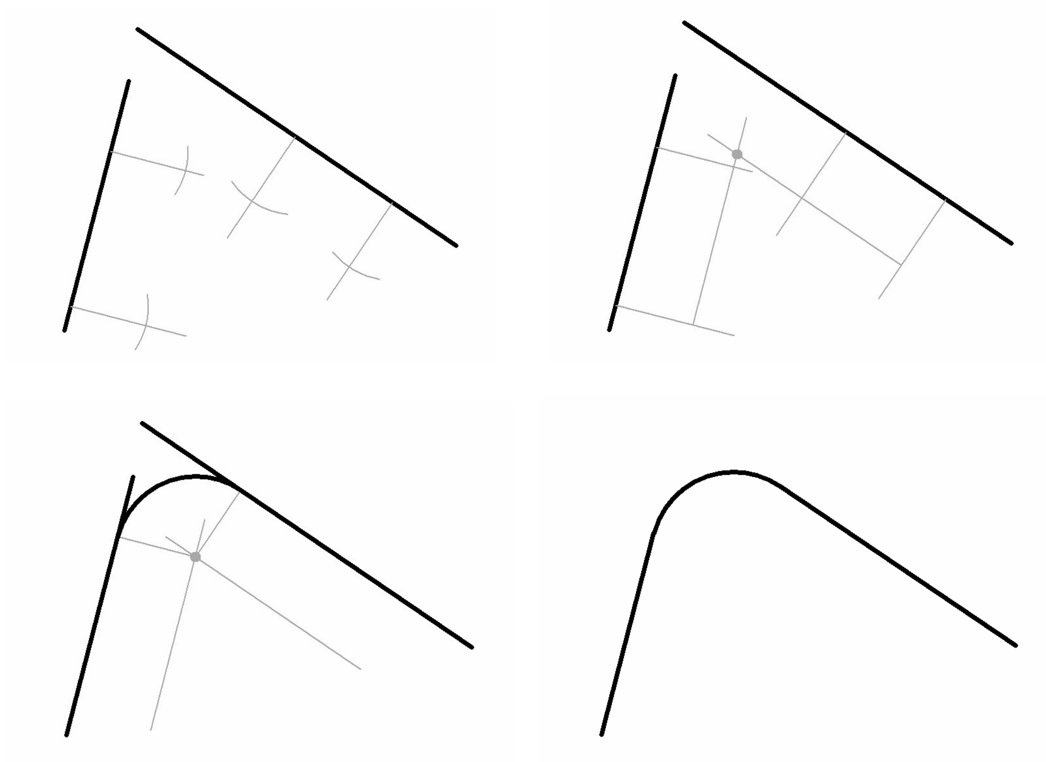
A fillet connects the ends of two curves with an arc, which is tangent to both curves. The term comes from machining and mechanical drawing, where it is a common method for rounding off corners in practical design applications.

Below are three methods for constructing fillets: 1) filleting two lines, 2) filleting two arcs and 3) filleting an arc to a line. All entail the same principle, which is to determine a single point equidistant from both curves. Since the distance from a point to a curve is measured on a line perpendicular to a curve (in the case of a circular arc this is a radius line), then any arc whose radius is equal to the common distance from both curves will meet these curves tangentially.

14. Filleting two lines.

    a) From each of the given lines construct a parallel line of the same distance from their respective given lines.

        i) Using the triangle draw perpendicular lines from two points on each line.
        ii) With the drafting compass set to the desired distance, strike arcs from the base of each perpendicular to intersect the perpendicular. These intersections will be equidistant from their respective given lines.
        iii) Draw lines to pass through each pair of equidistant points to achieve the parallel.

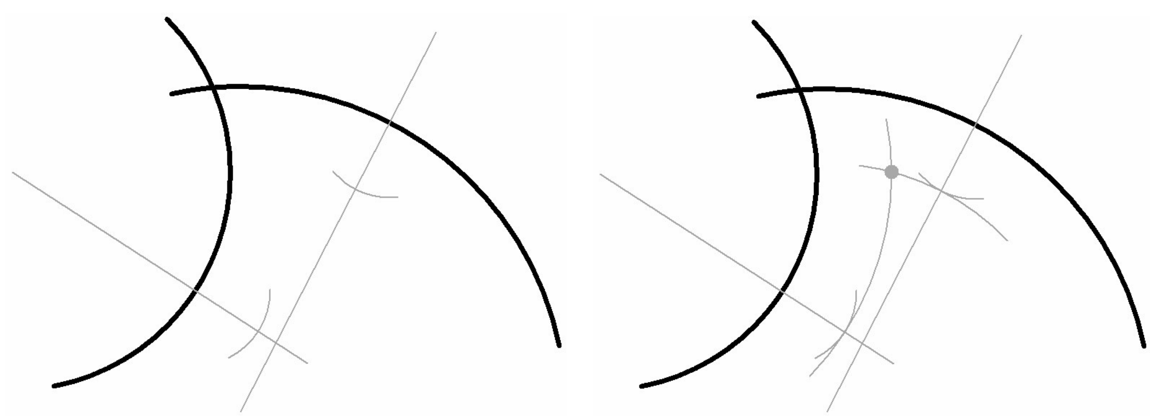


b) The intersection of the two parallels will be the center of the filleting arc. The beginning and ending radii of this arc will be perpendicular lines drawn from the center point to the two given lines. Draw these using the triangle.

15. <u>Filleting two arcs.</u>

a) Draw arcs concentric to both given arcs. Each concentric arc should be equidistant from their respective given arcs.

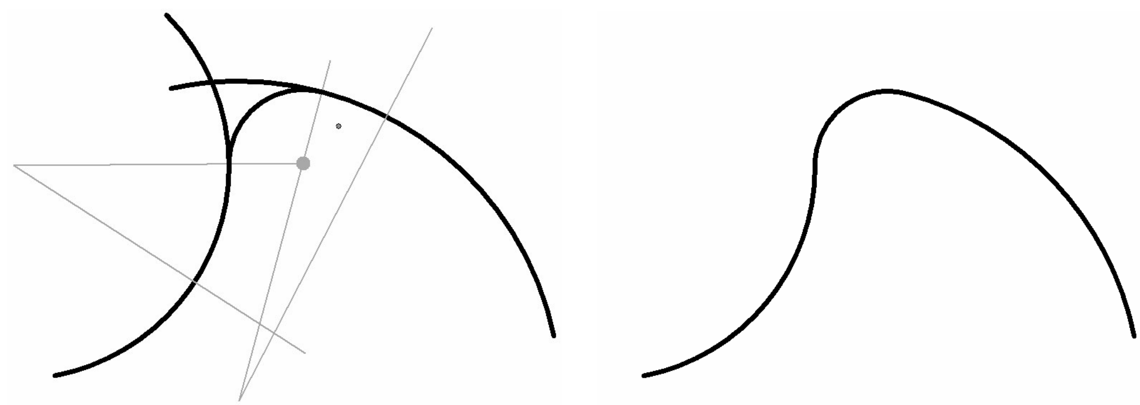
i) Draw lines from the center of each arc to intersect the arc and to extend as the radius of the concentric arc.



ii) Set the compass to the offset distance of the concentric arcs and mark this distance and the direction of concentricity from the intersection of the radial lines with the given arcs.

iii) Draw the concentric arcs to intersect one another.

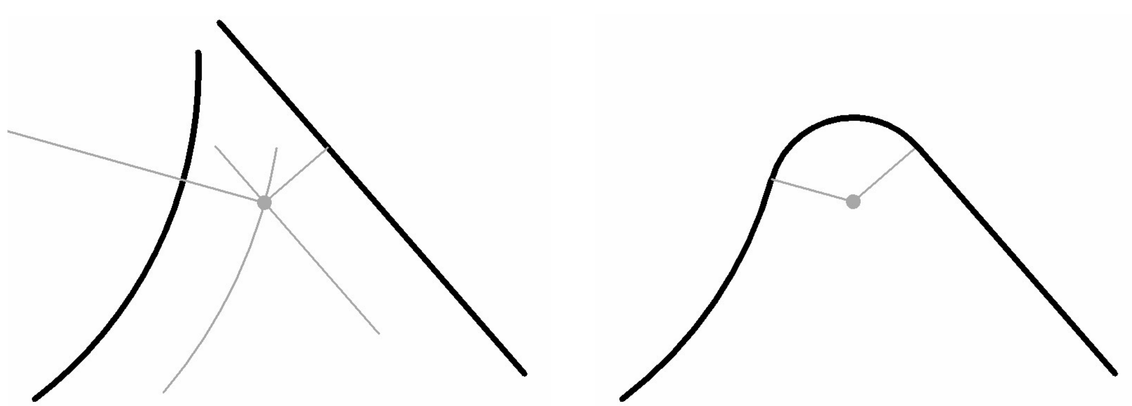
b) This point of intersection will be the center of the fillet. Determine the beginning and ending radii of the fillet by drawing lines from this point to the centers of the given arcs.



16. <u>Filleting an arc and a line.</u>

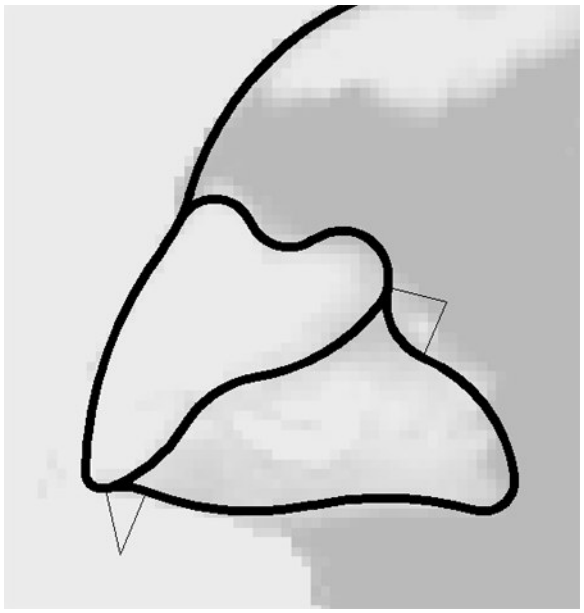
a) Draw a line parallel to the given line as instructed in Part V,1 above. Draw an arc concentric to the given arc as instructed in Part V,2 above. Make sure the concentric and parallel lines are the same distance from their respective givens.

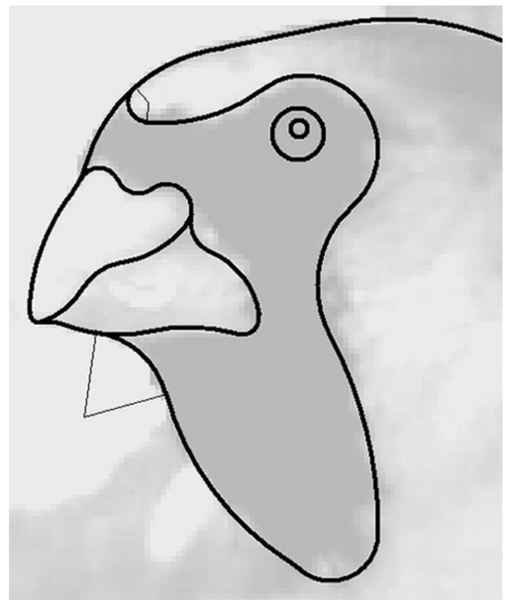
b) The center of the fillet is the intersection of the concentric arc and the parallel line. Determine the radius to the given line as instructed in Part V,1 above and to the given arc instructed in Part V,2 above.



Part V. Constructive Interpretation, *continued*

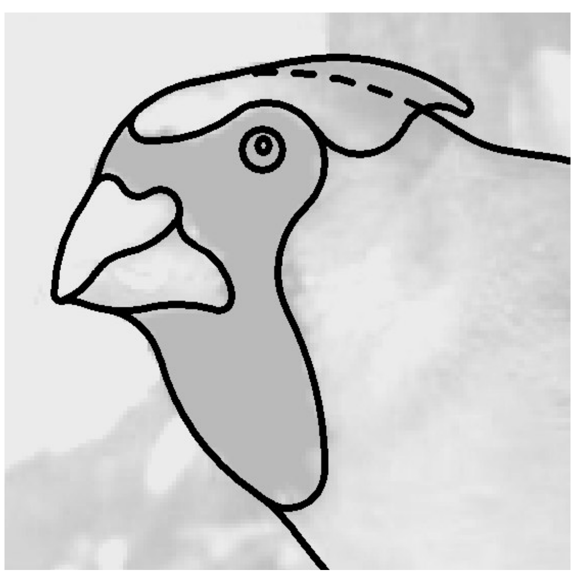
17. The following illustrations continue the process of drawing contours, and then attaching these either to the outline or to a previously drawn contour line.





The first drawing above has the lower beak attaching to the upper beak, and the second drawing features the cardinal's mask attaching to its beak and to its forehead.

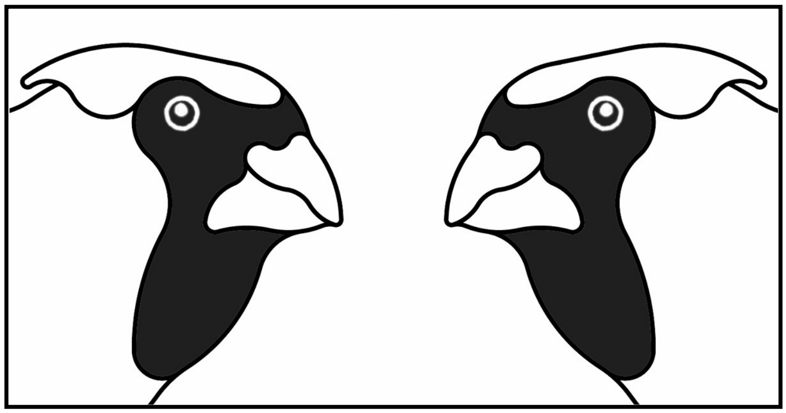
The drawing below then adds the cardinal's crest and continues the outline into its body.



This drawing also features the final rule of style for this demo: the inclusion of *hidden lines*.

Hidden lines are unseen but important. They come into play where the object depicted is overlapped by another object and the portion they describe is hidden from view. They are drawn to ascertain continuity in the back object, but later erased. In practice hidden lines are drawn very lightly to ease erasure. Technical drawings often draw these as dashed lines.

18. The use of tangent blending of curves worked well for the beak of the cardinal, since in reality the beak is structurally integrated with the bird's head. On the other hand the cardinal's crest, while blending smoothly into his forehead, overlaps the nape of his neck. Hidden line can contribute to this effect, while maintaining good visual continuity between the neck and the head. In the above drawing the hidden line meets the neck at a tangent and the top of the head at a tangent.

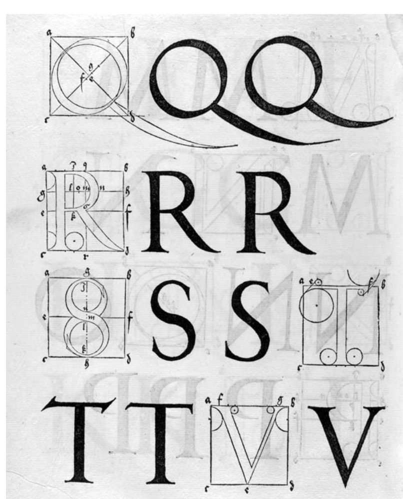


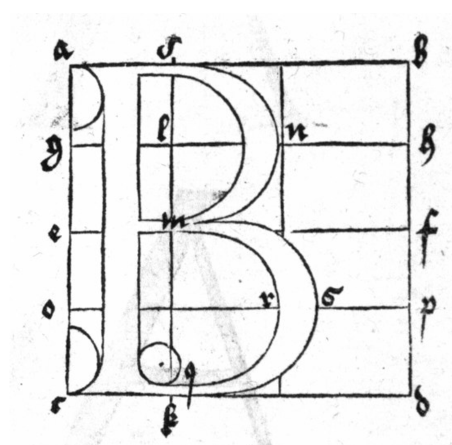
19. At this point the head alone is sufficient to represent the cardinal. This can be seen in the image above. Moreover, the construction of the head reveals almost all of the procedures and rules of style covered by this tutorial. The remainder of the building of the image of the cardinal will proceed more quickly.

Appendix. Construction in Type Design

Throughout history printers and engravers designed and laid out letters using extensions of arcs and lines. Examples of two famous methods are illustrated.

Albrecht Durer*, *1525

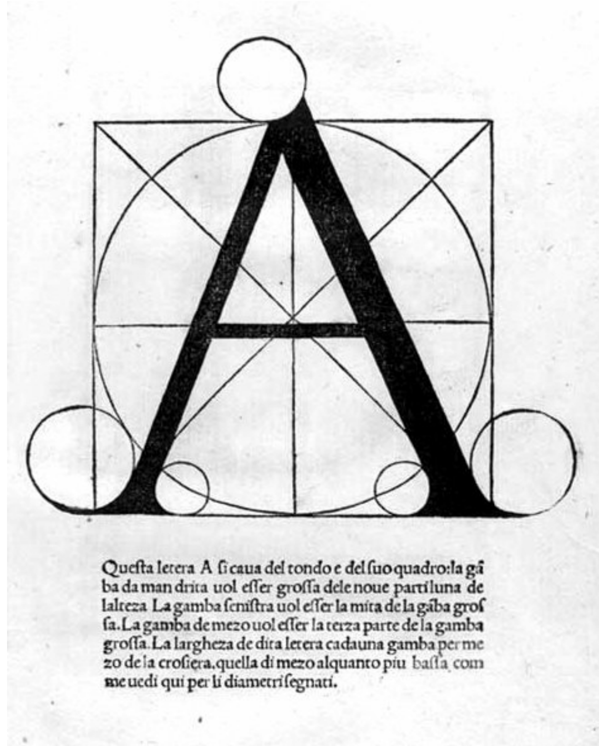




Albrecht Durer, a fine artist and commercial printer of the 16th century, published his method as part of a 1525 text on geometry for artists. He established proportion by the regular divisions of the square and crafted the letters from compass arcs and ruled lines.

Italian geometer, Luca Pacioli, published a similar text sixteen years earlier, which was the inspiration for Durer's later and more pragmatic text. Both artist/ geometers offered typefaces akin to Roman lettering, which featured serifs that curve to a point. This augmented the legibility of letters engraved on stone by emphasizing the ends and corners of the letter. It turns out to do the same for small type on the page and today the family of Roman typefaces remains the most preferred for body type.

The design of traditional typefaces called for continuity where necessary and clear precise endings where necessary



Luca Pacioli, 1509