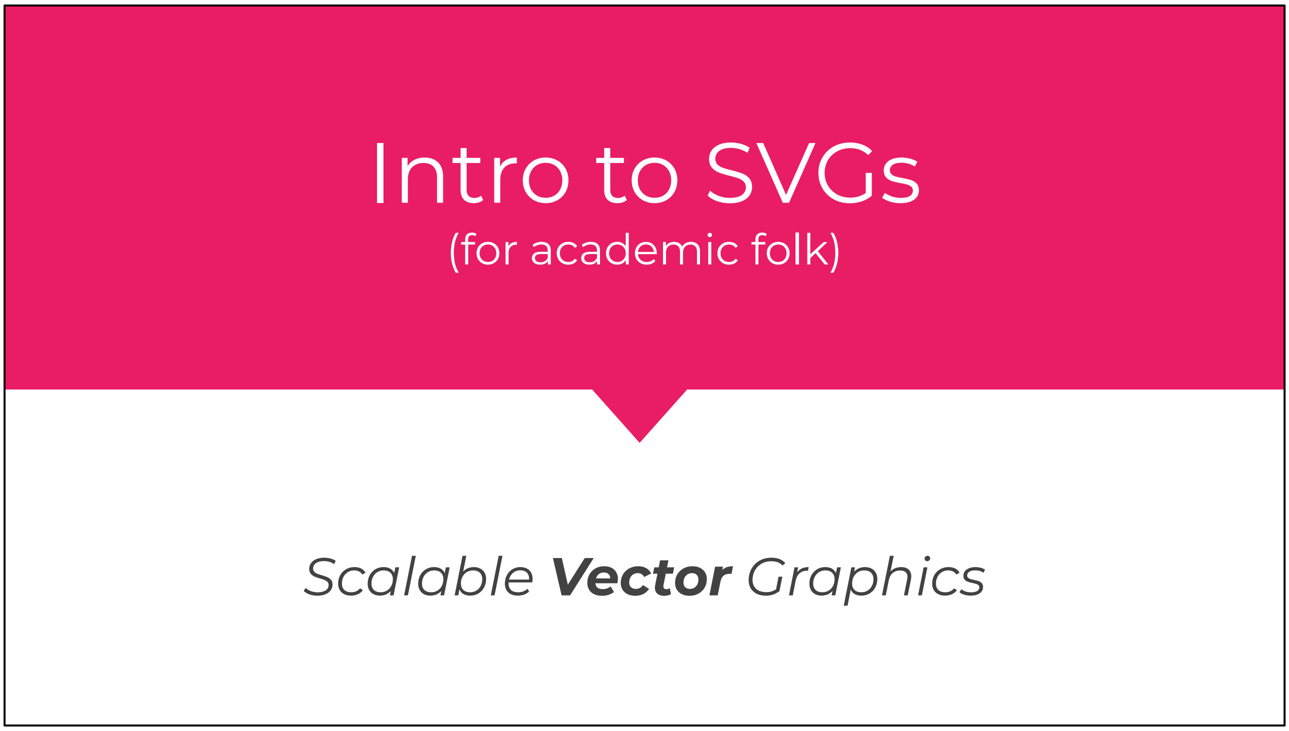


Intro to SVGs

(for academic folk)

*Scalable **Vector** Graphics*

This is a training on SVGs (scalable vector graphics). It is aimed at people in academia and and how they might most commonly use the format.

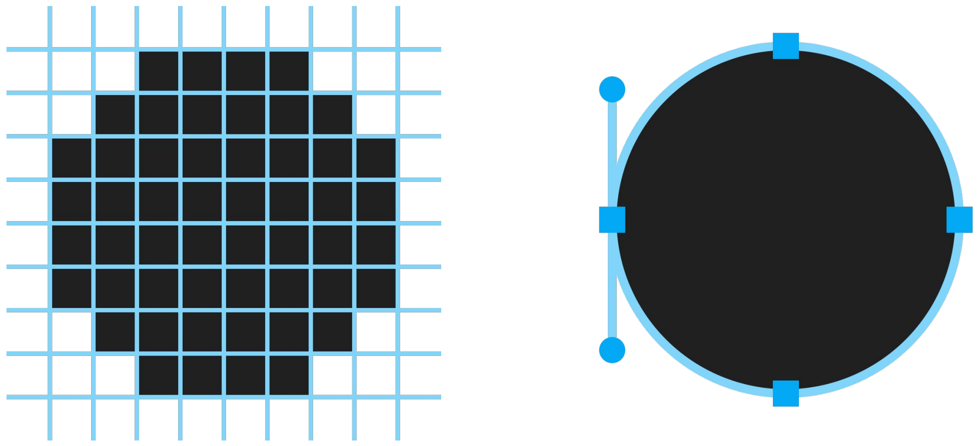
This training should teach you:

- The basic building blocks of the SVG format
- How to make basic SVGs by hand
- How to more confidently edit SVGs made by software or third parties
- When it is appropriate to make an SVG by hand and when it is not
- General familiarity with the format such that you can more effectively Google a particular problem

These slides should also serve as a good basic reference for when you forget a particular method or syntax.

Background

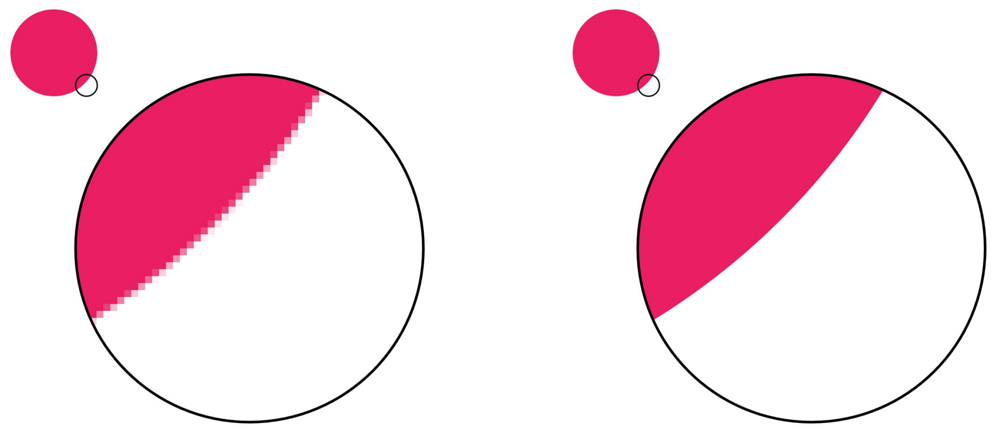
Raster vs Vector



What are vector and raster graphics?

A raster graphic is a grid of pixels.
A vector graphic is a collection primitive shapes.

Raster vs Vector



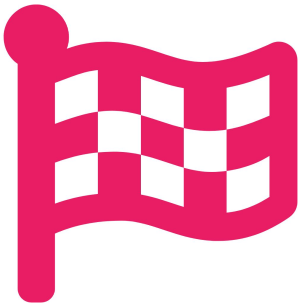
Why do we prefer vector graphics over raster graphics?

A vector graphic can be scaled to any size with perfect clarity and definition. Internally, when a piece of software displays a vector graphic, it "renders" the shapes to a grid of pixels with the same resolution as your monitor, producing a smooth, crisp result. A raster graphic can be scaled to any size too, but requires some sort of upsampling algorithm to interpolate what should go in between the original pixels, which usually produces poor, blurry results.

In addition, vector graphics usually have a smaller file size than raster graphics, because they are defined by a few lines of text that describe shapes, rather than many rows and columns of individual pixels.

What's an example of vector graphics that almost everyone has used? [redacted]

Limitations of Vector Graphics



What are the limitations of vector graphics?

Because vector graphics are drawn with primitive shapes, they are better suited to simpler, less detailed, more "geometric" images that can be drawn using basic shapes. More "photographic" images, such as realistic depictions of people, animals, etc, are usually better captured by raster images.

The <svg> tag

```
<svg
    xmlns="http://www.w3.org/2000/svg"
    viewBox="..."
    width="..."
    height="..."
>
    ...
</svg>
```

How do we start writing an SVG?

In every SVG, there is a top level `<svg>` element that contains all the contents of the image and key attributes about the image. There are only 4 attributes you will likely ever use here: `xmlns`, `viewBox`, `width`, and `height`.

In SVGs generated by software, you will often see many other attributes and tags at or near the top-level of the document. Many of these are unnecessary, or only necessary in very specific contexts. Most likely, they are there either to support legacy browsers or versions of the SVG spec, or to provide a specific SVG editing software with supplemental metadata to aid editing. When in doubt, just remove a line and see if it still works.

What is xmlns?

The `xmlns` attribute simply tells the viewing software that the XML document is meant to be parsed as an SVG. It is always required, except in the rare case that you are including an SVG directly (inline) in an HTML document.

How SVGs are written

```
<element attribute="value">
    <child attribute="value">
        ... more content ...
    </child>
    <child attribute="value" />
</element>
<!-- comment -->
```

How are SVGs written?

SVGs are just plain text files that contain text descriptions of what shapes to draw. You can create and edit them in any text editor. You can also use software like Inkscape or Adobe Illustrator to make more complex SVGs, but they are still saved and represented as plain text.

What is the language of these text descriptions?

SVGs are written in a simple markup language called XML that consists of three main concepts:

1) Elements - the individual components or building blocks of your image
2) Element attributes - the properties attached to an element that describes its appearance, behavior, etc.
3) Element hierarchy - the organizational structure of the document, formed by arranging elements in an order or nesting them within one another

Element with children elements inside:
`<element><child>...</child></element>`
Element with attribute:
`<element attribute="value">...</element>`
Self-closing/empty element:
`<element attribute="value" />`

What is SVG

What is SVG?

It's the most popular vector graphic format. It was developed by the W3C, the organization in charge of defining web standards like HTML, CSS, and JavaScript.

Cautionary:

Although it was originally aimed at the web, SVG became so popular that you can now see it in a lot of other contexts too, like Word documents, PDFs, graphs, illustrations, graphic design, printed media, etc. Keep this in mind when using SVG outside of a browser: the context you're using it in might not support all of the advanced features that a browser does, because it has essentially co-opted the technology from another platform.

Basics

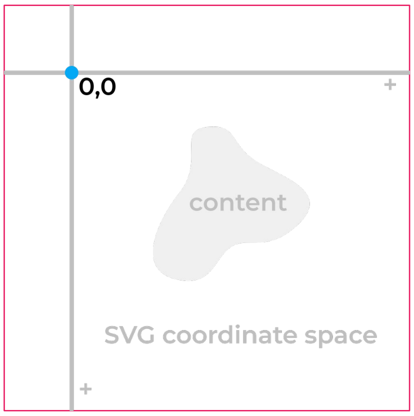
Units

Absolute

1px = 1
1in = 96
1cm = 37.795
1pt = 1.333

Relative

1em = current font size



How do units work in SVG?

An SVG has an abstract coordinate system, measured in arbitrary units called "SVG units" or "user units". It is a consistent, Cartesian coordinate space (positive down and to the right) that eventually gets mapped to some real world space. The dimensions/positions/etc of all elements are given in this coordinate space.

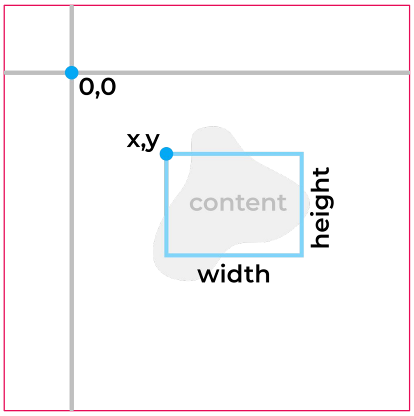
It is possible to specify dimensions/positions/etc in terms of "real world units" like inches, but it is typically not advisable. Real world units will be converted to SVG units based on constants defined in the SVG standard, and the resulting actual size of the element will be affected by the `viewBox`, `width`, and `height` attributes, and may not actually end up as the size you intended.

Bottom line: write SVG without units. It is standard practice, and most SVG editing software seems to generate SVGs in this manner by default. It is also in line with the main purpose of SVGs, which is to create images that are independent of actual size.

https://oreillymedia.github.io/Using_SVG/guide/units.html

viewBox

```
viewBox="x y width height"

viewBox="70 60 100 75"
```



How do we define what is visible in the SVG?

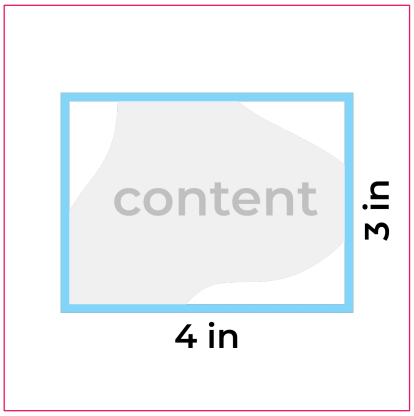
The viewbox is the window into the SVG's coordinate space, and defines the boundaries of the image. You can think of it like a camera or a frame. You specify the x/y coordinates of the upper left corner and the width/height of the viewbox, in SVG units.

Contents of the SVG can extend beyond the viewbox, which you may or may not be able to see depending on the software and the overflow attribute (more on this later).

`viewBox` should always be specified; weird things can happen if it isn't.

Width and height

```
width="..." height="..."

width="4in" height="3in"
```



How do we size our image to real world units when we have to?

The `width` and `height` attributes specify how large the image should appear in its final context. Along with `viewBox`, it essentially defines a mapping from SVG units to real world units.

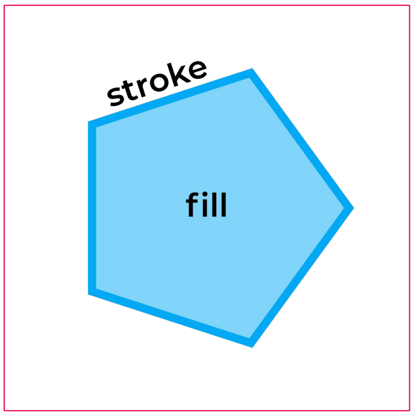
This is the only place in your SVG where you can specify real world units. If no unit is specified, they are interpreted as pixels.

If these attributes are omitted entirely, default behavior will vary from software to software. Browsers will usually scale the image to fit the dimensions of its container. Some software may make them the same as the viewbox width/height in pixels.

In practice, it is usually more useful to not hard-code these attributes into the SVG, and to simply scale the image in situ to the needed size (eg, in CSS for a webpage, or in Inkscape before rendering as a PNG). As such, the minimum/boilerplate code to form a valid SVG is an `<svg>` element with the `xmlns` and `viewBox` attributes.

Stroke and fill

```
fill="..." stroke="..."

fill="skyblue" stroke="blue"
```



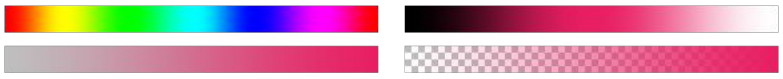
Before getting into drawing basic shapes, it is necessary to understand the `stroke` and `fill` attributes. The stroke is the outline of a shape, and the fill is the area within a shape. Both attributes can be set to a color, or to `none` to be disabled.

By default, SVG shapes have `fill="black"` and `stroke="none"`; even shapes that are intended to be just strokes, like lines. You will likely have to override this frequently.

By default, the stroke is shown in front of the fill. Unfortunately, there isn't a reliable, fully accepted way (for all browsers and software) to switch this order.

Color

	Normal, opaque	With transparency
Named	red	-
Hex	#ff0000	#ff000080
Red, Green, Blue	rgb(255, 0, 0)	rgba(255, 0, 0, 0.5)
Hue, Saturation, Luminance	hsl(0, 0%, 100%)	hsla(0, 0%, 100%, 0.5)



HSL splits colors into hue (red vs green vs purple), saturation (how "much" color there is, black/white vs colorful), and luminance/brightness (dark vs light).

RGB splits colors into red/green/blue "components", between 0 and 255 (256 possible values). Balance the components in different proportions to get different hues. Increase/decrease all of the components to increase/decrease the brightness. All 0's = black, all 255's = white.

Hex is just a more compact way to write RGB. The 0 to 255 range is compressed down to 2 hex digits, each with 16 possible values (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F). The first two digits represent red, the next two green, and the next two blue. Hex colors are the most common way to write colors in web technologies.

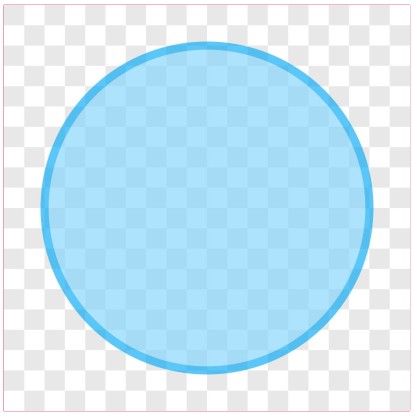
Regular (English) color names, like "red" or "violet", can also be used.

Non-named colors can also accept an additional alpha parameter at the end, which will blend it with whatever content is behind it.

https://www.materialpalette.com/colors
https://htmlcolorcodes.com/color-chart/
http://colormind.io/
http://www.gradients.io/

Opacity

```
opacity="..."
```

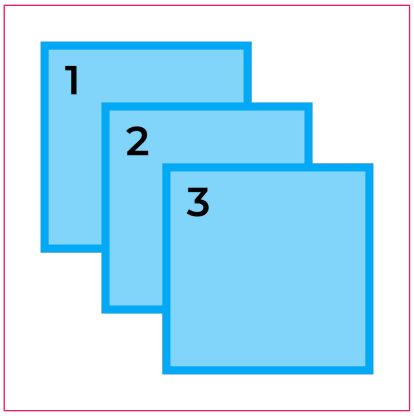


An element's opacity defines how much it will blend in with whatever content is behind it, on a scale of 0 to 1. An opacity of 1 will make an element completely opaque; 0 completely invisible; 0.5 half-way translucent.

There are also `fill-opacity` and `stroke-opacity` attributes to set the transparency of the fill and stroke separately, but they are not broadly supported yet. Use with caution.

Z-order

```
<!-- 1 -->
<rect />
<!-- 2 -->
<rect />
<!-- 3 -->
<rect />
```

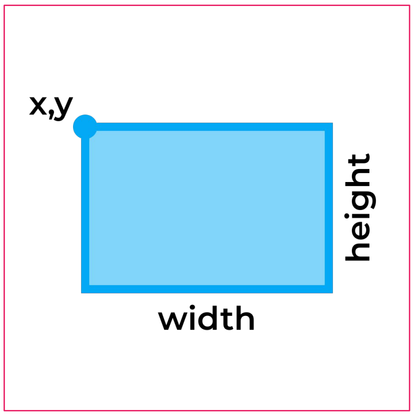


Elements are stacked in the order they appear in your SVG document. Later defined elements are stacked on-top/in-front of earlier defined elements.

Basic Shapes

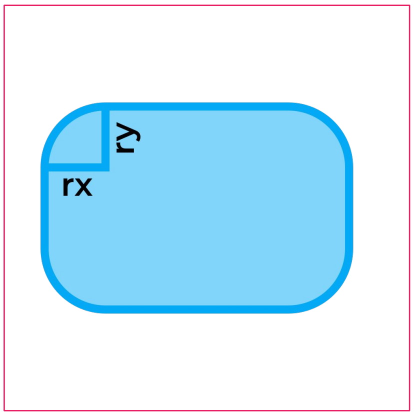
Rectangle

```
<rect
    x="..."
    y="..."
    width="..."
    height="..."
/>
```



Rounded rectangle

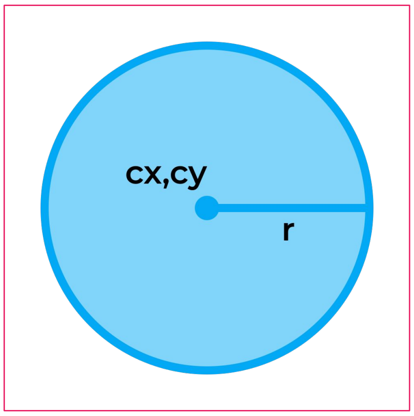
```
rx="..."
ry="..."
```



A rounded rectangle is written in the same way as a regular rectangle, but with the added `rx` and `ry` attributes that specify the corner radius. The `width` and `height` attributes still refer to the full outer width and height of the shape.

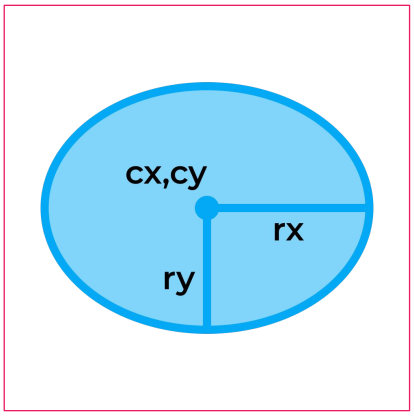
Circle

```
<circle
    cx="..."
    cy="..."
    r="..."
/>
```



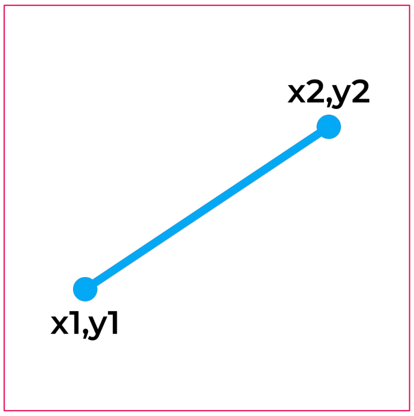
Ellipse

```
<ellipse
    cx="..."
    cy="..."
    ry="..."
    rx="..."
/>
```



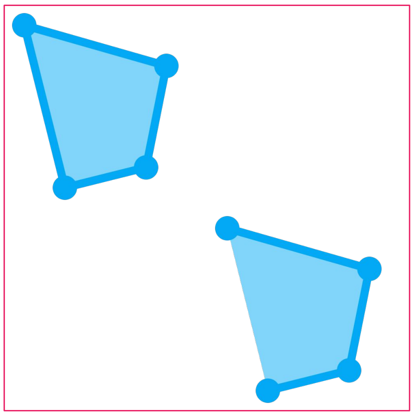
Line

```
<line
    x1="..."
    y1="..."
    x2="..."
    y2="..."
/>
```



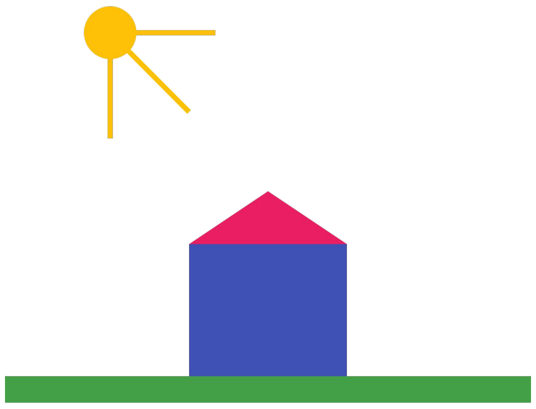
Polygon / polyline

```
<polygon/polyline
    points="... x y x y ..."
/>
```



A `<polygon>` element is intended for closed shapes, where the last point is automatically connected to the first. A `<polyline>` element is intended for multi-segment lines (open shapes), and is not automatically closed. For the `points` attribute, specify a series of x/y coordinates, separated by single space or comma.

Exercise 1

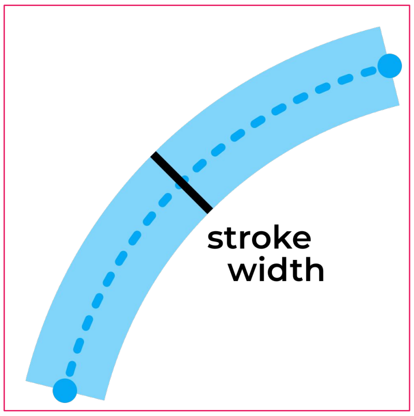


Recreate this SVG on your own using the techniques covered so far. The exact colors, lengths, and dimensions are not important; just try to capture the basic picture.

Strokes

Stroke width

```
stroke-width="..."
```

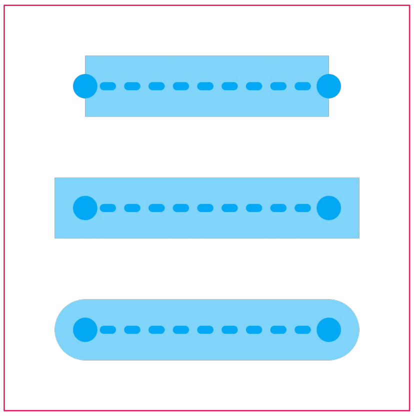


The `stroke-width` attribute specifies the thickness of the stroke around an element. Note that the stroke is always applied "on center" with the outline of the element. Half of the stroke width will be applied on one side of the outline, and the other half on the other side. The outline (center of the stroke) is exactly where you specify it in the geometry of your shapes.

Unfortunately, there is no reliable, standard way to set the stroke to be on the inside or the outside of the outline. You will either have to adjust your geometry points to account for the thickness you want, or use a program like Inkscape or Illustrator to help you achieve the desired effect more conveniently.

Stroke line cap

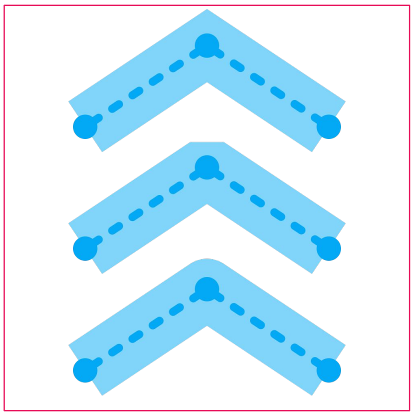
```
stroke-linecap="butt"

stroke-linecap="square"

stroke-linecap="round"
```



The `stroke-linecap` attribute specifies how the strokes of unclosed shapes look at their ends. "Butt" is the default; it specifies that the stroke ends flush with the end of the outline. "Square" specifies that that stroke extends beyond the end of the outline a distance of half the stroke thickness, to create the appearance of a square centered on the end point. "Round" is the same as "square", except the the stroke is rounded to create the appearance of a circle centered on the end point.

Stroke line join

```
stroke-linejoin="miter"

stroke-linejoin="bevel"

stroke-linejoin="round"
```



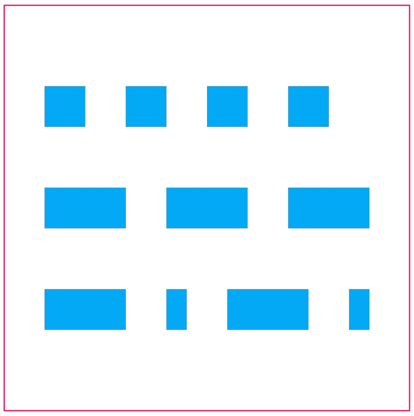
The `stroke-linejoin` attribute specifies how consecutive segments of a stroke are joined. "Miter" is the default; it extends the edges of the stroke until they intersect, and fills the enclosed area. "Bevel" treats the segments as if they were "butt" caps, and fills the resulting gap between them. "Round" treats the segments as if they were "round" caps.

The `stroke-miterlimit` attribute can be used to make a "miter" join by default, but make a "bevel" join where the joint angle is too sharp (to avoid a long point jutting out).

https://www.w3.org/TR/svg-strokes/ Fig. 10

Dashed lines

```
stroke-dasharray="d g d g ..."

stroke-dasharray="10"
stroke-dasharray="20 10"
stroke-dasharray="20 10 5 10"
```

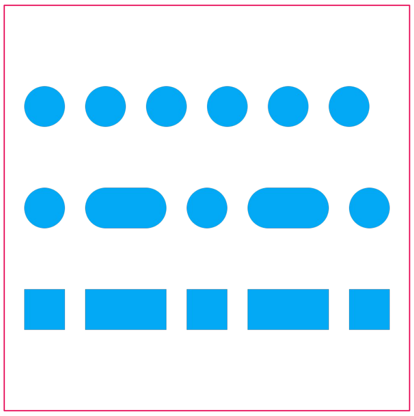


The `stroke-dasharray` attribute allows you to create custom dash patterns for strokes. The attribute is specified as a series of alternating dash and gap lengths, starting with the first dash length.

If you only provide one value, the dash and gap values will be the same. In reality, when an odd number of values is provided, they are repeated once to yield an even number; but this results in unintuitive behavior, and is not recommended for best clarity.

Dotted lines

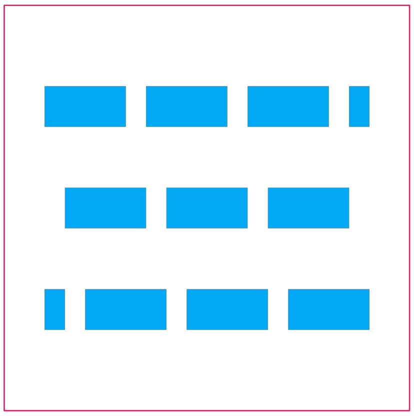
```
stroke-dasharray="0 15"

stroke-dasharray="0 15 10 15"

stroke-dasharray="0 15 10 15"
```



By setting `stroke-linecap` to "round" or "square" and using 0-length dashes, you can create dotted lines.

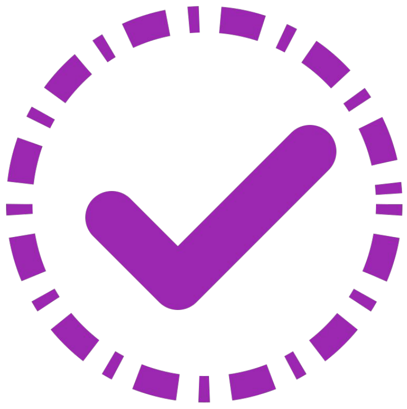
Dash offset

```
stroke-dashoffset="0"

stroke-dashoffset="-5"

stroke-dashoffset="-10"
```



By default, the dash pattern begins at the starting point of the stroke. The `stroke-dashoffset` attribute shifts the dash pattern forward (negative) or backward (positive).

Exercise 2

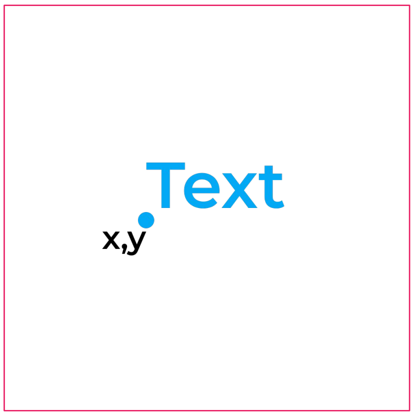


Recreate this SVG on your own using the techniques covered so far. The exact colors, lengths, and dimensions are not important; just try to capture the basic picture.

Text

Text

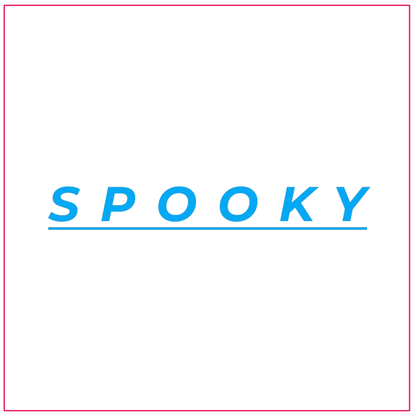
```
<text
    x="..."
    y="..."
>
    Text
</text>
```



Text is one of the most painful things to deal with in SVG. Text will display inconsistently on different platforms and software, especially with regard to alignment. To guarantee they will always look as expected, convert text to raw shapes using SVG software (eg. Inkscape's "Object to path" functionality). For posterity, it is a good idea to either leave in the original `<text>` element commented out, or just make a comment noting the font/size/style you used to generate the text.

Text style

```
font-family="Montserrat"
font-size="16"
font-weight="bold"
font-style="italic"
text-decoration="underline"
letter-spacing="5"
```



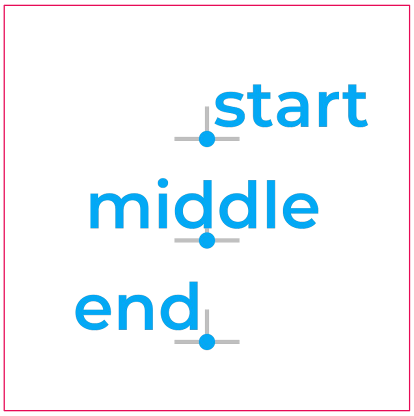
If the specified font family isn't installed, a system default will be used. You can append a comma and "serif", "sans-serif", or "monospace" to the `font-family` attribute to specify a certain type of fallback (usually "Times New Roman", "Arial", and "Courier New", respectively).

The `font-weight` attribute can be set to "normal" (default), "bold", "bolder", "lighter", or a multiple of 100 between 100 and 1000 (400 is normal, 700 is bold).

You may see these attributes specified in different ways, as we will cover later.

Text horizontal align

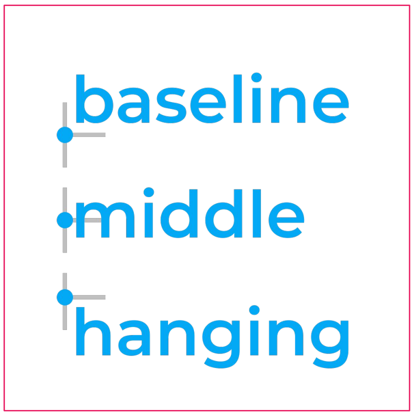
```
text-anchor="start"

text-anchor="middle"

text-anchor="end"
```



Default is "start".

Text vertical align

```
dominant-baseline="baseline"

dominant-baseline="middle"

dominant-baseline="hanging"
```

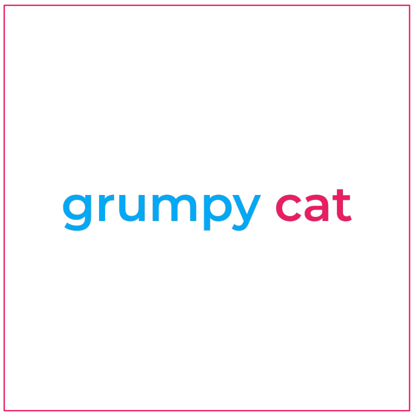


Default is "baseline".

Don't confuse this with the `alignment-baseline` attribute, which is similar but not quite the same.

<tspan>

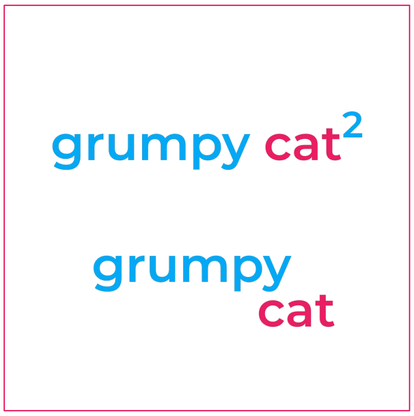
```
<text>
    grumpy
    <tspan fill="#e91e63">
        cat
    </tspan>
</text>
```



`<tspan>` elements can be placed inside `<text>` elements to style individual words/strings without breaking the normal flow of text.

<tspan> offset

```
baseline-shift="super"
baseline-shift="sub"

dx="..."
dy="..."
```



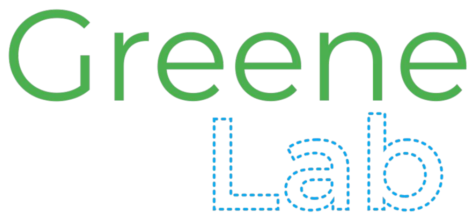
`<tspan>` elements can be positioned normally with `x` and `y`, but can also be positioned relative to the preceding text using the `dx` and `dy` attributes. Note that using these attributes offsets all of the following text as well as the element it is applied to. You can think of it as moving the typing cursor; once you move it, it will stay there, and new text will be added at that position.

The `baseline-shift` attribute can be used to quickly create a superscript or subscript without affecting the text after it.

Remember, "em" can be used as a font size unit to specify a size relative to the current font size. For example, you may want to set `font-size="0.75em"` on a superscript element to make it 75% the size of the normal text.

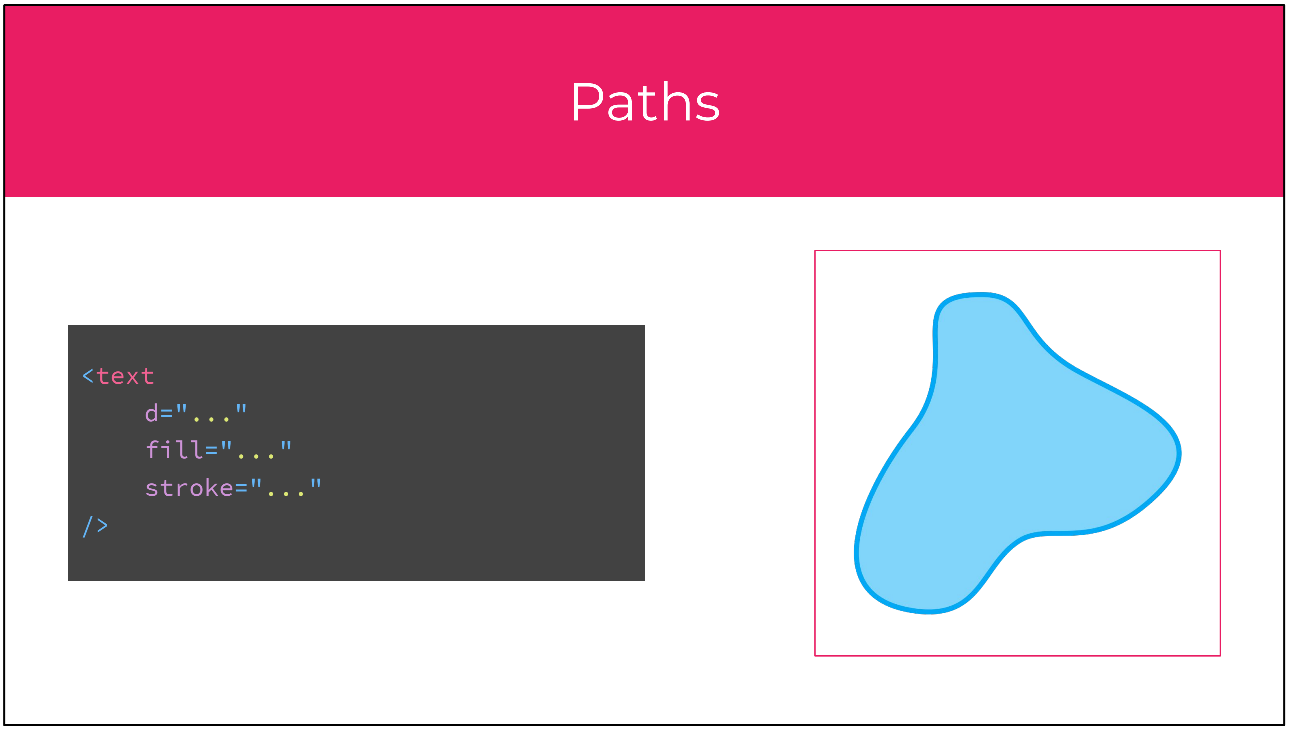
Unfortunately, there is no reliable way to auto-wrap text in SVG. You will have to manually break text at the desired places and position lines beneath one another.

Exercise 3



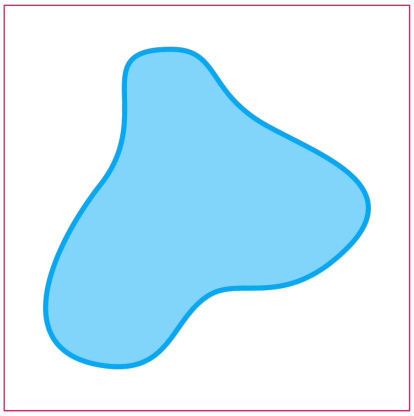
Recreate this SVG on your own using the techniques covered so far. The exact colors, lengths, and dimensions are not important; just try to capture the basic picture.

Paths



Paths

```
<text
    d="..."
    fill="..."
    stroke="..."
/>
```



`<path>` elements can be used to create arbitrary shapes that behave like any of the standard shapes. The geometry of a path is specified in its `d` (description) attribute.

Path d syntax

```
M 50 50 L 100 100 C 75 100, 50 75, 50 50


M 50,50 L 100,100 C 75,100 50,75 50,50


M 50 50
L 100 100
C 75 100 50 75 50 50
```

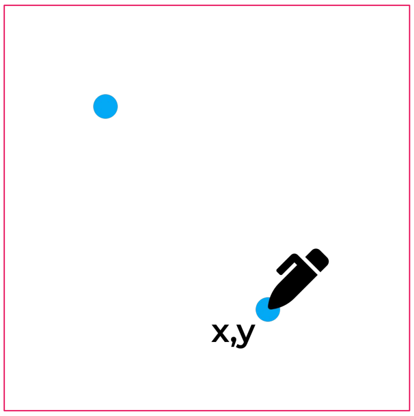
The `d` attribute takes a sequence of draw commands. You can think of these commands as moving a paint brush around a canvas. Each command is a single letter, and can be followed by numerical values to specify where and how to draw the command.

The syntax of these commands is similar to that of the `points` attribute for polygons and polylines. Values can be separated by a single space or single comma. Letters next to numerical values do not need to be separated at all, because they can be differentiated by the parser just by their type (whereas "10,10" can't be condensed to "1010" without looking like one thousand and ten). Line breaks are also permitted.

As such, there are many different ways to format the same path string. However, for best clarity, separate commands by line, and separate command values by space

Move to

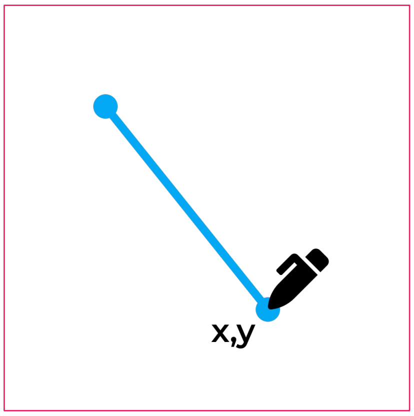
```
M x y
```



The "M" command moves the brush to the specified point without drawing anything between.

Line to

```
L x y

H x
V y
```

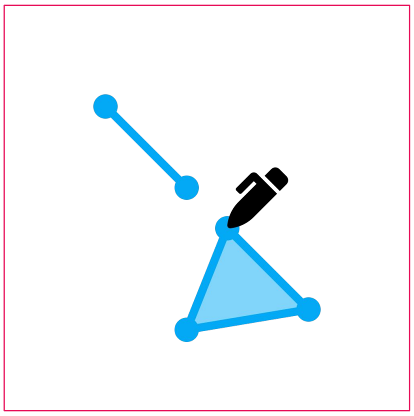


The "L" command draws a straight line from the previous point to the specified point.

The "H" and "V" commands draw horizontal and vertical lines, respectively, from the previous point to the specified x or y coordinate.

Close

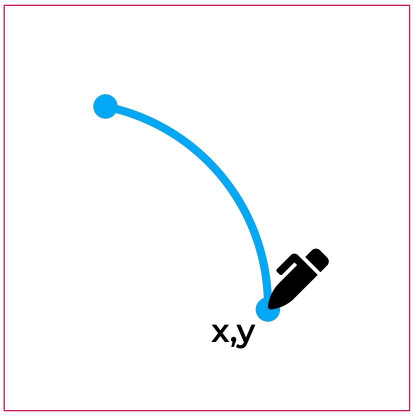
```
M 25 25
L 45 45
M 55 55
L 75 75
L 45 80
Z
```



The "Z" command closes the current path, or sub-path (since the painting brush can be moved, creating separate filled shapes within the same path).

Arc to

```
A rx ry angle large cw x y

A 50 50 0 0 1 65 75
```



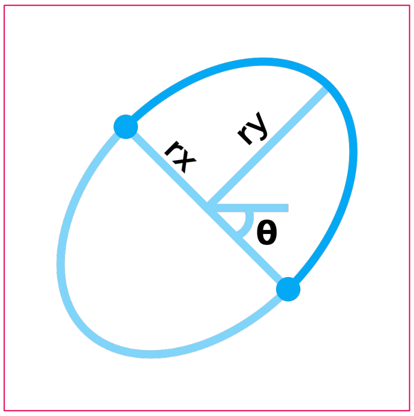
The "A" command draws an elliptical arc from the current point to the specified point.

You might expect that arcs would work by specifying the center point and start and end angles. Instead, it works from point to point, and you choose 1 of the 4 possible arcs between them. This unfortunately means that if the start/end angles you want to draw aren't multiples of 90 degrees, you'll have to do some trigonometry to calculate coordinates, and you'll end up with a lot of not-nice, floating point numbers.

https://developer.mozilla.org/en-US/docs/Web/SVG/Tutorial/Paths
https://codepen.io/lingtalfi/pen/yaLWJG

Arc to - radius and rotation

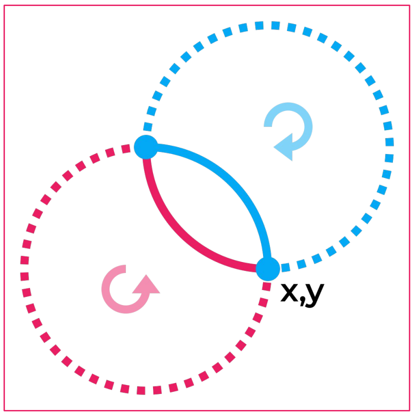
```
A rx ry angle large cw x y
```



The "rx" and "ry" inputs specify the x and y radii of the ellipse that forms the arc. The angle input specifies the rotation of the ellipse that forms the arc; clockwise, in degrees.

Arc to - flags

```
A rx ry angle large cw x y
```



Given a radius, there are 4 possible arcs that can be drawn between two points. The "large" and "cw" (often called the "large arc" and "sweep" flags) inputs allow you to specify which of the 4 possible arcs should be used. These inputs should be set to 0 (for false) or 1 (for true).

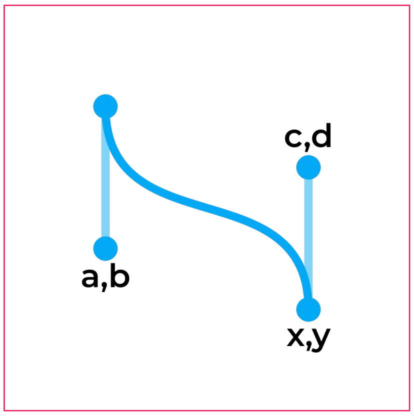
When "large" is set to 1, the outer/larger arc is used (shown as dotted lines above). When "large" is set to 0, the inner/smaller arc is used (shown as solid lines above).

When "cw" is set to 1, the arc that represents a clockwise rotation around the center is used (shown as blue above). When "cw" is set to 0, the arc that represents a counter-clockwise rotation around the center is used (shown as red above). Imagine driving a car along the arc from start point to end point. If you have turn right the whole time, the "cw" flag is 1. If you have to turn left the whole time, the "cw" flag is 0.

If the radii you've specified aren't large enough to create an arc to the specified point, they are increased until they are.

Curve to

```
C a b c d x y
```

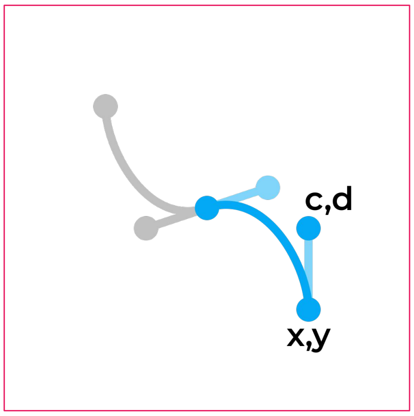


The "C" command draws a bezier curve with two control (handle) points from the current point to the specified point. If you've ever tried to draw a curve in a program like Inkscape or Illustrator, you are probably familiar with the "handles" on each point. The best way to understand how control points behave and form curves is to just play with them in one of these softwares.

Tip: If you want to connect two curved segments smoothly without any visible joint, make sure that the slopes/angles of the two connecting control point tangent lines are the same.

Curve to - shorthand

```
S c d x y
```



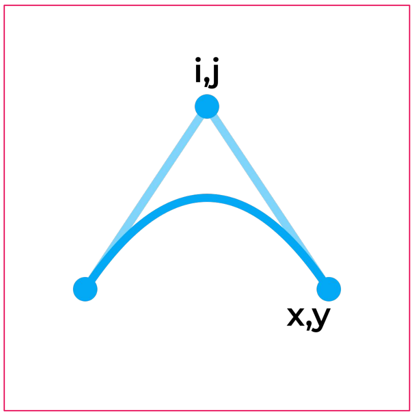
The "S" command is a quicker way to draw a series of bezier curves in succession. The command essentially does the same thing as the "C" command, except that the "a b" control point is assumed to be a reflection of the "c d" control point of the previous curve.

This command should only be used right after a "Q" command or another "S" command.

This is how curve pen tools in programs like Inkscape and Illustrator typically work, where you click and drag to define the first control point of the next curve and the second control point of the previous curve at the same time.

Quadratic to

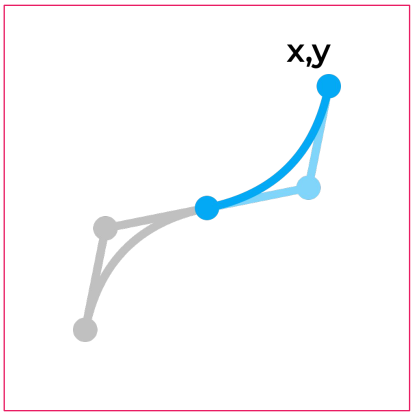
```
Q i j x y
```



The "Q" command is a simplified version of the "C" command, where both control points are assumed to be at the same point.

Quadratic to - shorthand

```
T x y
```

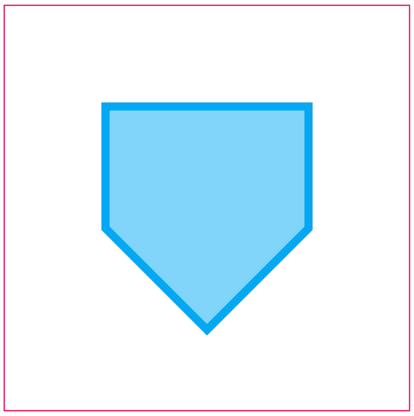


The "T" command is a quicker way to draw a series of quadratic curves in succession. The command essentially does the same thing as the "Q" command, except that the "i j" control point is assumed to be a reflection of the "i j" control point of the previous curve.

This command should only be used right after a "Q" command or another "T" command.

Relative coordinates

```
M 25 25
h 50
v 30
l -25 25
l -25 -25
z
```

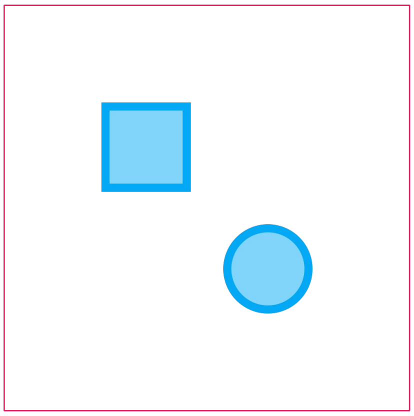


Note that all of the previous commands were shown as capital letters. If you provide a lowercase command letter, coordinates you give it are assumed to be relative to the previous coordinate, instead of relative to the origin of the image.

This can be very useful when you know the difference between each point better than its absolute position in the overall image.

Quirks

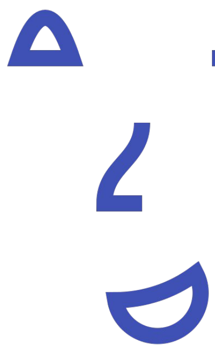
```
M 25 25                 M 65 55
l 20 0                  A 10 10 0 0 1 65 75
  0 20                  A 10 10 0 0 1
  65 55                 z
  -20 0
z
```



If you provide more inputs than are needed for a command, the extra inputs overflow into a new command of the same type. For example, if you write a "line to" command, and keep providing pairs of coordinates without a new command letter, it will simply be parsed as multiple consecutive line commands.

If you are trying to draw a circle in a path, you unfortunately cannot draw it with only one arc command; you must split it up into multiple. It's usually the clearest and simplest to just draw two semi-circles.

Exercise 4

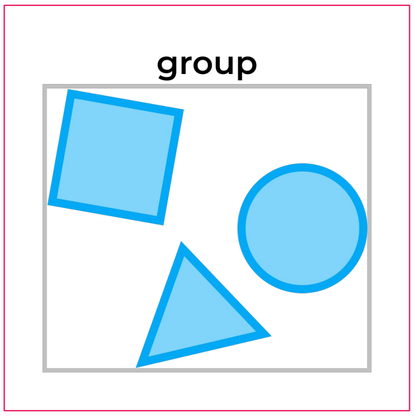


Recreate this SVG on your own using the techniques covered so far. The exact colors, lengths, and dimensions are not important; just try to capture the basic picture.

Groups & Transforms

Groups

```
<g fill="skyblue" stroke="blue">
    <rect />
    <polygon />
    <circle />
</g>
```



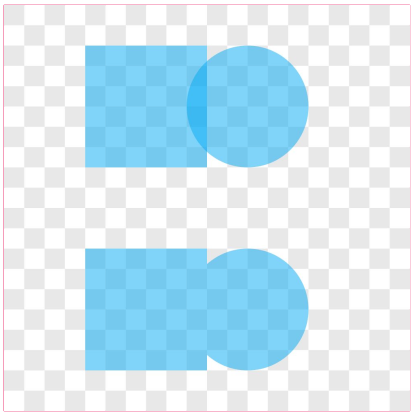
A group is an element that can be used to group together other elements. Once grouped, the elements can be operated on as a whole, just like in any software that has grouping. Groups can be nested within each other, allowing a complex hierarchy of visual components.

Style attributes like fill and stroke can be set once, on the group element, and be automatically inherited by all of the children elements. Transformations can be applied to a group to affect all of the children as if they were a single cohesive element.

SVG editing software usually uses groups as a way to make layers that can be toggled on/off.

Group opacity

```
<rect opacity="0.5" />
<circle opacity="0.5" />

<g opacity="0.5">
    <rect /><circle />
</g>
```

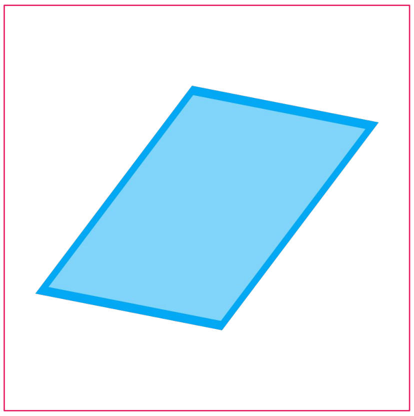


When the opacity attribute is applied to a group, all of its children are drawn as normal before the opacity is applied. If you draw several overlapping shapes with solid/opaque fills and put them in a group with an opacity, they will become translucent together as a cohesive shape, rather than being individually translucent.

This is a useful trick when the shape you need is drawn much more easily with basic shapes than with a multi-part `<path>` element, and you need it to be transparent.

Transform

```
<element transform="..." />

"last() third() second() first()"
```

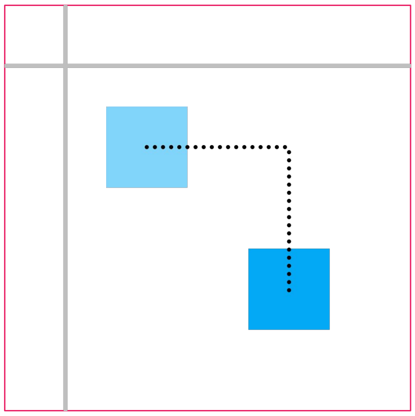


The `transform` attribute can be applied to an element to translate, scale, rotate, or skew it. The transformations are applied at (or near) the end of the rendering process, meaning that they will transform the element "as is". That is, any stroke, fill pattern, child shapes, etc will be warped.

The attribute takes a series of functions that are applied right to left. Multiple functions of the same type can be specified, and in any order. Arguments can be separated by space or comma.

Transform - translate

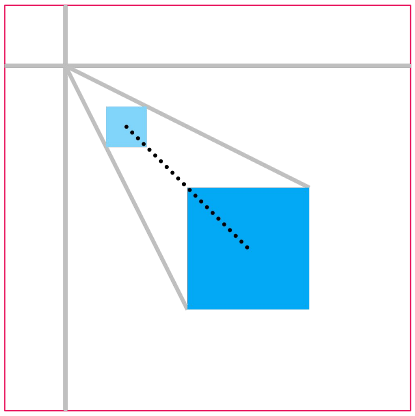
```
translate(dx,dy)
```



The "translate" function takes an x and y distance (specified the same way as any other unit) to move the object.

Transform - scale

```
scale(sx,sy)
```

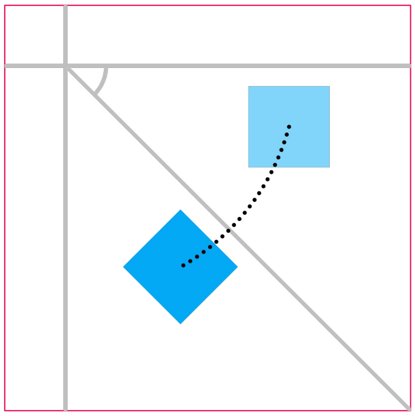


The "scale" function takes an x and y factor to scale the object by, where 1 is original size, 0.5 is half size, 2 is double size, etc.

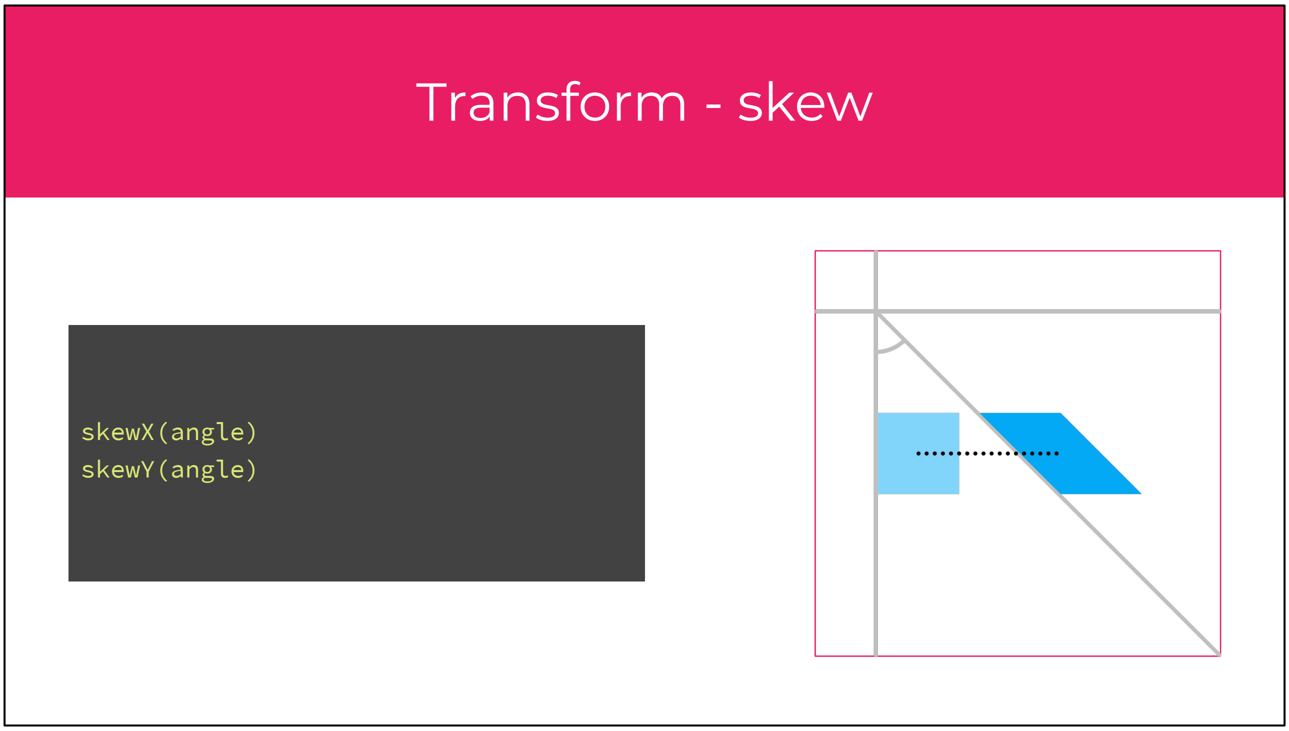
If the y factor is not provided, it is assumed to be the same as the provided x factor; ie, a aspect-ratio-preserving scale.

Transform - rotate

```
rotate(angle,x,y)
```



The "rotate" function takes an angle to rotate the object by (clockwise, from positive x axis). The function also takes an optional x and y rotation pivot point, which is assumed to be the origin if not provided.

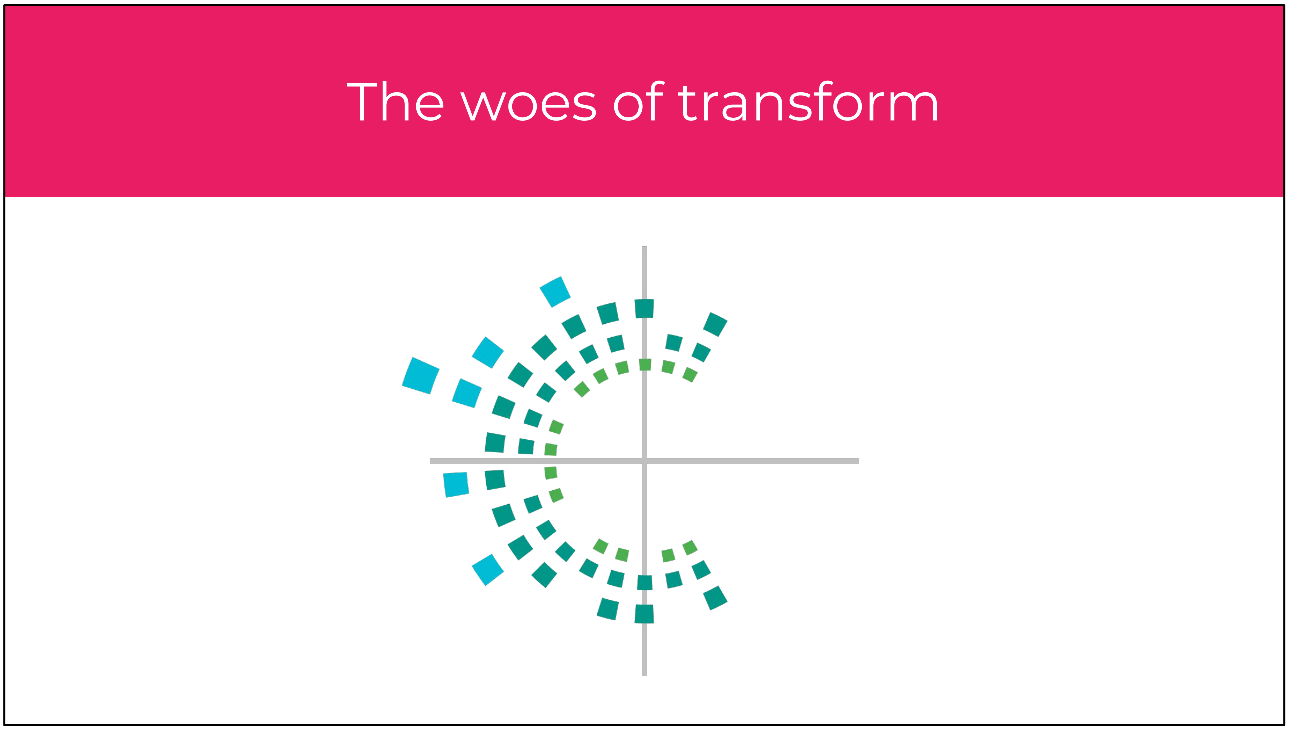


Transform - skew

```
skewX(angle)
skewY(angle)
```

The "skewX" and "skewY" functions take an angle to horizontally and vertically (respectively) skew the image by. Skewing can be thought of slicing the image (horizontally with skewX or vertically with skewY) and splaying those slices out like a deck of cards.

The x skew can be visualized as rotating the vertical axis (counter-clockwise) by an angle, and the y skew as rotating the horizontal axis (clockwise).



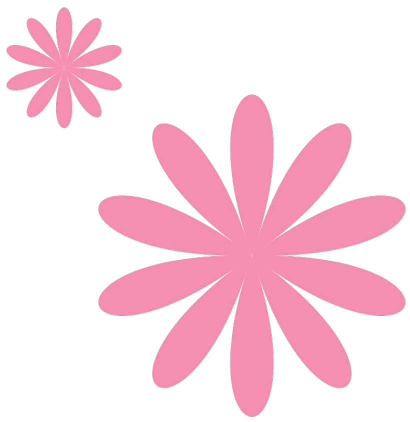
The woes of transform

Transform operations are done relative to the origin of the image. If you wish to transform an element around its center, you unfortunately must go through a tedious process: first translate the object such that its center is at 0,0, apply your rotation/scale/skew, then translate it back to its original position.

There is an attribute `transform-origin` that can change which absolute point the element is transformed around, but unfortunately it is not reliable on all devices and softwares. Also, it only allows you to set the transform origin relative to the viewbox (eg, center of the view), not around the center of a particular element as is often desired.

As such, sometimes it's a good idea to simply draw shapes around the origin from the start, then translate them to the desired location after using a transform on the shape or on a parent group. This also often makes the coordinates more symmetric, making them easier to read and change later.

Exercise 5



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