

Chapter 18

WORKING WITH VECTOR ART

There are many software applications and file formats for generating and editing vector art. Here we introduce some of these applications, discuss key principles in creating and organizing vector elements of images, and explain the basic illustration tools that are used to create and edit vectors. This will allow you to modify and annotate vector art generated by other programs, begin drawing new images from scratch, and create tracings of photographs.

Vector art mechanics

Like some other topics covered in this book, there are dozens of guides that go into exhaustive detail about using various vector art editors. Because many of these attempt to explain every feature in minute detail, it can be difficult to sift out the parts that are most relevant to scientific illustration. Science curricula, however, rarely include instruction in using graphics programs, and usually skip the topic entirely. To help close this gap we focus here on the aspects of editing vector art that are most directly relevant to the scientific illustration tasks encountered by biologists.

File formats

The primary vector image formats are PDF (Portable Document Format), PS (PostScript), EPS (Encapsulated PostScript), and SVG (Scalable Vector Graphics). AI (used by the program Adobe Illustrator) is also a common format, although proprietary. PDF is the most broadly implemented and frequently used of the vector art file formats, and Adobe Illustrator can also use PDF as one of its native formats. SVG is a completely open standard that is gaining popularity in web design and is supported by a wide variety of programs. In general, PDF and EPS files will address most of your needs. They are both supported across many different software applications, and accepted by most journals.

Generating vector art

After all the discussion in the previous chapter of why you should use vector art wherever possible, you might wonder how to generate it in the first place. There are three common ways to create vector art: (1) export an image, such as a graph or phylogeny, from another program, (2) draw an image from scratch, and (3) trace an existing piece of pixel art.

Exporting images from another program

Vector images can often be exported directly from your analysis programs. Many programs, including MATLAB, can export graphics straight to PDF format, and some can also save to other formats such as SVG and EPS. Even if there is no option to export images directly as vector art, PDF files can be generated from within

 Choose Print to File and select EPS as the format.

almost any Print dialog box by choosing the option Save as PDF. As a last resort, exporting EPS or PostScript files, which are the formats understood by printers, is almost always an option even if PDF is not available on your system. Be aware, though, that just because a file is PDF format does not necessarily mean that the image has the best vector format. Remember that PDF files can store pixel images too, and some export methods, as described below, capture the vector properties of a graph better than others.



In MATLAB, do not use the File ▶ Save As... dialog box to export a figure. Instead, with the desired figure in the foreground, use the command `print('-dpdf', 'myfigure.pdf')`, where `myfigure.pdf` is the name you would like to give your new image file. If you intend to edit the figure in Adobe Illustrator, use the same command, but with `-dill`, in place of `-dpdf`. This gives better results than PDF upon import.¹ Use the PNG format ('`-dpng`') for exporting pixel images. In R, do not use the Save file option that is available in the figure window for your plots. Instead, before making your plot, use the command `pdf("myfigure.pdf")` to open a printer-like output "device." Once you are done with your plot commands and adjustments, close the file with `dev.off()`.



We run almost every figure through a drawing program prior to publication. It is often simpler and more effective to modify image color, line weights, and lettering with a drawing program than within the software that generated the image. Making these changes in an editor can improve clarity and stylistic continuity across figures. Sometimes vector art that is exported from analysis programs will have extraneous invisible elements that complicate editing,² and sometimes entities that appear as a single object are really complex compositions of many different elements. These situations create a bit of extra work, but usually they are relatively straightforward to handle.

¹Some programs and formats will split lines and objects into many separate segments, or even divide text up into individual characters. In MATLAB, certain types of objects (arrows, ovals) are always exported as pixel objects even if you use a vector file format.

²In Illustrator, you can choose View ▶ Outline (⌘ Y) to see the outlines of invisible and obscured elements for easy deletion.

Drawing new images

Vector images are commonly created by drawing them from scratch. This may not sound very easy, but because you can adjust the location and properties of each line and object after creating it, this approach is almost always simpler, and the results look better, than performing the same task in a photo editor. You could be tempted to fire up PowerPoint to draw vector art, and this might be okay for adding some As, Bs, and scale bars to a figure. However, if you limit yourself to this program, you will ultimately have little control over the final look of your image.

There are several subgenres of programs for drawing. If you are trying to create a diagram with 3-D aspects, you can generate images with correct perspective in applications like Blender, Cheetah3D, or the free Google SketchUp, and then export your image as vector format or trace it, as described below (Figure 18.1). For flowcharts, organizational diagrams, and images with many interconnected and repeated elements, programs like OmniGraffle can produce uniform vector diagrams with relative ease.

Tracing photographs

The raw data representing the results of a study may be a pixel image of an organism, a micrograph, or a photo of the experimental set-up. These images typically contain details that are irrelevant to what the picture needs to convey. In these cases, a simplified line drawing can be a more effective communication tool. This is why drawings, not photos, are favored by descriptive morphologists and systematists. The same principle applies to many other situations, such as depicting the setup of an apparatus. To go from a photo to a drawing, tracing the picture using a vector editor is an excellent approach.

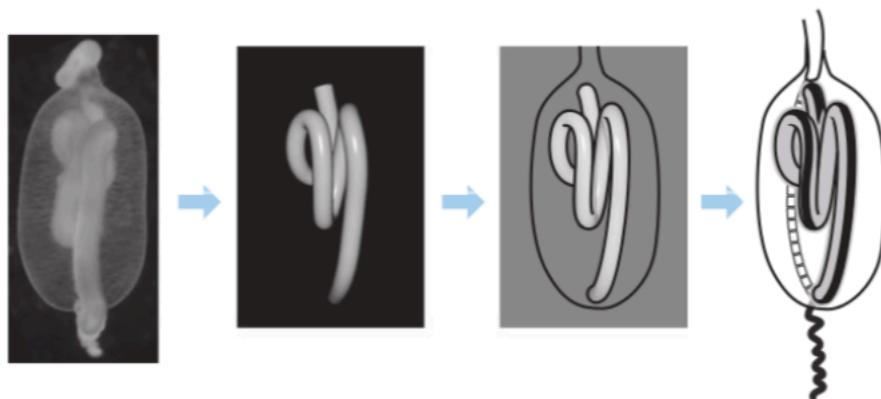


FIGURE 18.1 Stages of creating a 2-D schematic from a photograph of a complex 3-D object With a photograph as the guide, a general 3-D model is created of the tentillum from the siphonophore *Resomia dunnii* and imported into a vector drawing program, where it is made partly transparent and then traced. Using an illustration allows you to highlight important elements that may not show up equally clearly in a photograph.

To start the process, scan or photograph the image, import it into your illustration program, and move it to its own locked layer. Then create drawing layers above the locked image and trace the image using the pen tool, creating Bézier curves as described in the next section. You can hide or delete the layer containing the original image when you are done. It can also be helpful to make the background image invisible or semi-transparent, to quickly check the overall look of your tracing. A drawing tablet is often more convenient to use for tracing and drawing than a mouse or trackpad, especially for bigger projects. You would not want to use a pixel art program such as Photoshop for tracing, as this would result in a simplified pixel image of the original pixel image, rather than a clean vector art representation.

Some programs have an auto-trace feature that can help automate vector tracing, though the results almost always require subsequent adjustment. The Live Trace feature of Adobe Illustrator lets you dynamically control the threshold for identifying which image boundaries should become lines. To create single outlines instead of filled objects, choose Technical Drawing from the Live Trace pop-up menu. Once you have an object you like, you can select Object ▶ Live Trace ▶ Expand to turn the trace into an editable outline.

Anatomy of vector art

Bézier curves

At its core, vector art is composed of anchor points and lines that connect anchor points. These lines are known as **Bézier curves** (pronounced bezz-ee-ay). Vector drawing programs have the standard suite of tools for creating boxes and straight lines, but to get full control over your illustrations, you will need to learn how to manipulate these curves. While they seem confusing at first (and they are hard to describe in words), once you understand them you will find it much easier to draw what you see in your mind.

A Bézier curve is a line that intersects a series of **anchor points**. Anchor points are sort of like pins stuck through a very flexible rod, which represents the line. The line must pass through each anchor point, and its shape is controlled by the

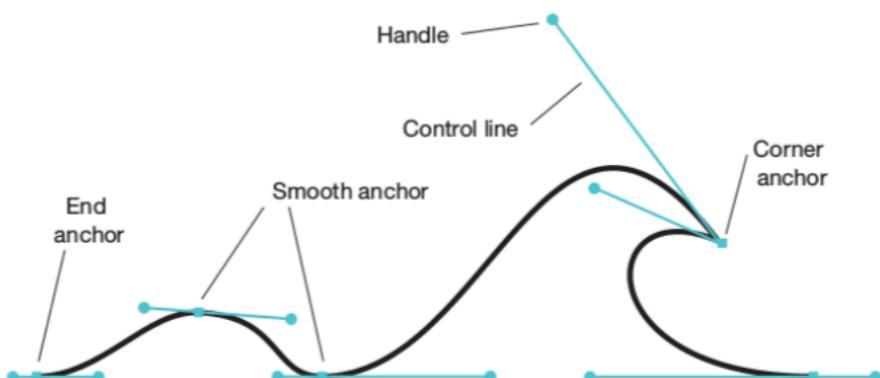


FIGURE 18.2 Bézier curve showing anchor points, handles, and control lines

number and position of the anchor points, as well as by control handles, which can be independently extended, retracted, and rotated about the anchor points (Figure 18.2). These handles control how the curve leaves the anchor point in each direction. Curves always intersect the anchor point tangent to (that is, parallel to) the control line. The length of the control line determines how “attracted” the curve is to that handle, as well as how far the curve extends along the handle in that direction. The handles for a given anchor point can be linked to each other by a straight line which passes through the anchor point (making a smooth intersection), or each control line can intersect at an angle, forming a sharp kink at the anchor point (making it a corner point).

Any two-dimensional shape can be composed of a series of Bézier curves. They therefore provide a general tool for creating and modifying vector elements. A Bézier curve can contain any number of anchor points along its path. It can also be either open, in which case it has two endpoints, or closed, in which case the starting and ending anchor point is the same. The property of being open or closed affects how the curve is filled with color.

Stroke and fill

Each line in a vector art image has several attributes associated with its **stroke** (the line itself) and its **fill** (the space bounded by the line). Both stroke and fill have color attributes, as well as transparency settings. The stroke has settings for width, which is given in points (a point is a standard printing unit that is usually defined as 1/72nd of an inch); whether it is solid or dashed; and the shape of the end cap of the line, which can be rounded or squared off. In addition, strokes can have paintbrush-like attributes, or can exhibit an ornamental pattern made of repeating elements. Fills are usually solid colors, but they can also possess transparency, patterning, or gradients.

Working with vector art editors

The different programs for drawing and editing vector art have similar workspace layouts and tool selections, but they vary in feature richness, stability, and ease of use. In the world of vector art there is a powerful (and expensive) program that can't be ignored: Adobe Illustrator. If you can afford to purchase Photoshop for your science, you should go the extra step and get Illustrator as well. (Many universities have site licenses and academic discounts.)

As an alternative, the open-source vector art editor Inkscape is gaining traction among graphics artists and web designers. There are a variety of features Inkscape does not yet support, such as CMYK color mode; the OS X version of the program has a very non-OS X user interface; and there aren't as many shortcuts as in Illustrator for speeding up common tasks. Even so, Inkscape is well suited to many of the tasks that it is designed to accomplish, and more than adequate for common graphical tasks. It is a good place to get started if you don't already have access to Illustrator, especially since it works on all platforms and can be downloaded for

free from <http://inkscape.org>. Another free option is sK1; it includes a few technical features that Inkscape lacks, and is available from sk1project.org.

In this chapter, we provide an introduction to both Illustrator and Inkscape. They share many features, although these shared features are often implemented slightly differently. There are many features in both programs that we don't cover here, including some tools that exist in both programs but are only described in detail for one of the programs. This chapter is intended only to give you an initial taste of vector editing and get you headed in the right direction. You are encouraged to look at additional tutorials and resources once you get up and running.

Selecting and manipulating entire objects

The solid arrow  (called the Selection Tool in Illustrator and the Select and transform objects tool in Inkscape) can select, deselect, move, rotate and resize entire objects or groups of objects.³ This arrow is used to adjust how objects are arranged relative to each other, modify their proportions (making them taller or wider), or select one or more objects so that their properties can be changed. Open the file examples/LEDspectra.pdf to try some of the behaviors described next. Don't save your changes (or if you do, use a different file name), so that the files will be useful for future examples.

There are a couple of different ways to use the solid arrow. One is to simply click the object you would like to select. Depending on the structure of the image, the object could be a single line, a simple shape composed of multiple line segments, or a large complex set of objects that are grouped together. If you didn't create the image by hand, it is hard to expect what will be selected with this tool. Vector art exported by some programs is lumped together into a single large object, in which cases the solid arrow isn't useful for editing parts of the image. In that case you could ungroup the objects or use the second arrow described in the next section to select subsets of the group.

You will often want to select several objects, but if you click on one object and then another, the object that was selected first will be deselected. To get around this, hold the `shift` key as you click; this will add subsequent objects to those already selected. Holding the `shift` key while you click an already-selected object will deselect it. You can also select multiple objects by drawing a box around them with the solid arrow; this can be much easier than selecting many smaller objects. You can use these different behaviors of the solid arrow in combination to save time. You may, for instance, want to select most of the items in the region of an image, but not all of them. To do this, draw a box around the entire region with the solid arrow, then hold `shift` and deselect the items you don't want. This is often quicker than selecting the items you do want one-by-one.

Once one or more objects have been selected, the solid arrow can be used to drag them to change their location. It can also be used to resize the entire set of ob-

³If you select an object with this tool but don't get a rectangular frame around it, check that Show Bounding Box is selected in the View menu in Illustrator.

jects by grabbing and moving the corners and sides of the selected area. To maintain proportions, hold **shift** while resizing.

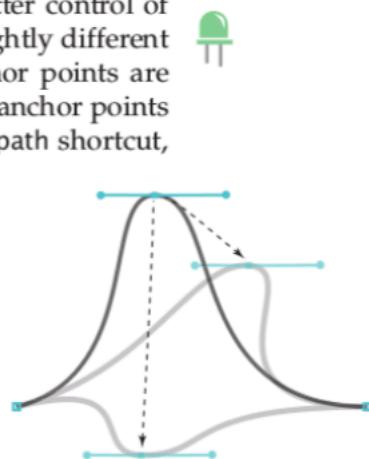
Selecting and manipulating parts of an object

The second type of arrow, the hollow arrow ↗ in Illustrator (the Direct Selection tool) and the elongate triangle in Inkscape (the Edit paths by nodes tool), selects and modifies parts of an object. Most newcomers to vector illustration get confused as to why there are two different types of selection tools and stick with the solid arrow, not realizing that the **second arrow** (as we refer to this tool here) is more convenient for most jobs. In fact, the second arrow is probably the most-used tool for editing vector art.

The second arrow selects individual anchor points and line segments within an object. It shares some features with the solid arrow, but allows better control of individual components of a line or shape. The second arrow has slightly different behaviors for different object types in Inkscape. In Inkscape, anchor points are shown only for some types of shapes. Any shape that doesn't have anchor points in Inkscape can be converted to one that does with the convert to path shortcut, **ctrl** **shift** C.

Try out the second arrow using the *LEDspectra.pdf* file. The curve near the title of the graph has only three anchor points. Select the uppermost point by clicking on it or dragging a box around it with the second arrow. By moving just that point, you can produce a range of curve shapes. Also notice how easy it is to keep a uniform smooth shape of the curve when there are few anchor points, compared with reshaping the other colored curves below.

The second arrow can select or deselect single or multiple anchor points in much the same way as you can select and deselect entire objects with the solid arrow through the use of the **shift** key and by lassoing objects with a box. If all the anchor points in an object are selected using the second arrow, you can move the entire object. If only some of the anchor points in an object are selected, though, moving them will change the shape of the object. This allows you to refine and adjust your artwork. In a typical illustration, you will rough-in the general shapes with the pen tool, creating all the lines and anchor points you will need, and then use the second arrow to carefully lay them out, reshape their handles, and align them.



Creating Bézier curves with the pen tool

Both Inkscape and Illustrator have a pen tool ↪ for drawing Bézier curves. Unlike the pencil tool, which leaves a trail behind while you hold down the mouse button and drag the cursor, the pen tool defines individual anchor points of the Bézier curves. This means that it takes several clicks of the mouse to draw a single line with the pen tool. Drawing in this way is different than using any physical tool, but it will quickly become second nature. You skim the surface of the new shape, with a glancing click at each inflection point—the places where the curve bends,



kinks, or changes direction. This dragging motion sets the length and angle of the handles for each anchor point, which changes the degree of curvature of the line. While generating a line, clicking without dragging creates a corner point in which two line segments bend sharply where they intersect at the anchor point.

To draw an open shape, press **return** after you have created all the anchor points needed to define your line. To create a closed shape, draw your anchor points and place the last point on top of the first anchor point. The two ends of the line will be fused.

When creating Bézier curves, don't worry if things aren't exactly correct on the first pass—just keep moving along. The beauty of vector graphics is that you can always nudge a point or convert between anchor types until things are just how you want them.

If the object you are making is radially or bilaterally symmetrical, or contains repeating elements, then don't try to draw the whole thing. Draw a fraction of it and then use other transformations to rotate, reflect, duplicate, and join those elements.

Modifying Bézier curves

There is more to Bézier curves than creating anchor points with the pen tool. You will also need to edit the anchor points and control handles of your existing objects.

In Illustrator, the following apply:

- Click on a selected curve with the pen tool to add an anchor point.
- Click on an existing anchor point of a selected path with the pen tool to delete the anchor point.
- Hold the **option** key while the pen tool is selected to get the Convert Anchor Point tool, or **control handle modifier** . This tool is also available in the toolbar if you click and hold on the pen tool icon. Click a smooth anchor point with this tool and release without dragging to turn it into a corner point. Using this tool, you can also create a corner anchor point by grabbing the control handle of a smooth anchor point, which allows you to move it independently of the other control handle on the anchor point. If you click and drag out from a corner anchor point, it will make the curve smooth, adding control handles at the same time. Play with this tool using the curves of the example, or with shapes you have drawn. See Figure 18.3 for examples of different curves.



Windows: use
the **alt** key.

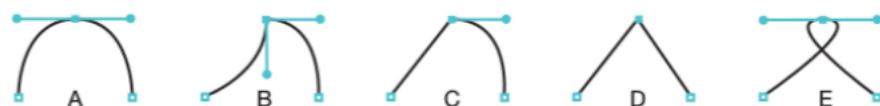


FIGURE 18.3 Bézier curves The three anchor points of these curves are all the same, but their control handles give them very different shapes: (A) smooth anchor; (B) corner point; (C) one handle retracted; (D) both handles retracted; (E) smooth anchor point, but with the control handles rotated 180° relative to (A).

The tools for modifying Bézier curves in Inkscape are associated with the second arrow, rather than with the pen tool as in Illustrator. When you are using Inkscape's second arrow, a toolbar with buttons to add, remove, and otherwise modify anchor points will appear at the top of the screen.

The Join function

Objects may become fragmented into individual line segments, especially when figures are exported from graphing programs or spreadsheets. You may also want to create an object by combining shapes into one. The Join function in Illustrator is one way to achieve this. Select two endpoints on independent curves and then Object ▶ Path ▶ Join (⌘J). If the points are superimposed, they will be welded together into a single anchor point. If the points are far apart, then a straight line will be added between them. The file examples/LEDspectra.pdf includes curves that have been joined in this way, and you can try merging line segments into a single object using that image.

The other way to achieve similar effects is through the Pathfinder tool. The first button in this palette will merge overlapping filled shapes into a single shape that takes the composite outline. Click that button and then click Expand to finish the conversion. This tool is extremely useful and likely overlooked during normal image construction. If your objects are not filled shapes, but are single lines (which don't work well for Pathfinder), you can convert the lines to filled shapes using the Object ▶ Path ▶ Outline Stroke menu. Once the strokes are converted into filled shapes, they can be easily merged.

Stroke and fill

Stroke and fill colors (the outline and inside of an object) are set with the color palette (Figure 18.4). It is located in different places in Illustrator and Inkscape and is used a bit differently.

In Illustrator, you can hide or show the color palette with the menu option Window ▶ Color, or simply click on the two diagonally arranged boxes near the bottom of the tool palette. In this palette you can use any of several color pickers:

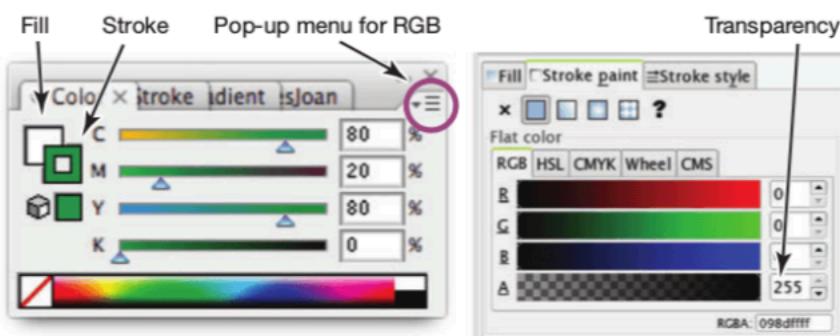


FIGURE 18.4 Color palettes for Illustrator (left) and Inkscape (right)

RGB, CMYK, grayscale, or others (see Figure 18.4). You will probably want to use whatever color picker matches the color space you are using for your source document. Switch between color pickers by using the pop-up menu at the upper right of the palette.

To set the fill, click on the solid fill box at the upper left of the palette to bring it to the foreground, and then select a color. To change the stroke, bring the box with the little square in it to the foreground. The color of text in most programs is set using the fill option, and there is usually no outline stroke to text. In Illustrator, a separate **stroke palette** (Window ▶ Stroke) controls the width of the line (expressed in points), and this is also where you can create dashed lines and arrowheads. (In versions of Illustrator prior to CS5, arrowheads are generated separately through the Effect ▶ Stylize menu.)

In Inkscape, the color palette can be shown by double-clicking either the fill or stroke color swatch shown at the bottom left of the window. This palette has separate tabs for fill and stroke colors, as well as a third tab for stroke properties, such as line width and control of dashed lines.

If you need more than two or three distinct colors, CMYK and RGB color pickers get cumbersome. They aren't particularly well suited at finding colors that are easy to tell apart but look good together. There is another palette called HSB (hue, saturation, and brightness, or sometimes value) which allows you to directly select the hue of the color from within the RGB space, rather than create it with combinations of other colors. Hue is usually presented in degrees, either as a wheel or a rainbow-colored slider from 0° to 360°. If you want two colors that are as different as possible, you could select any two colors that are 180° degrees apart (such as red and cyan). If you need six colors that are as different as possible, you can pick any six colors that are 60° from each other. You can rotate these colors, while maintaining their distance from each other, to change the composition of the palette for aesthetic purposes or to avoid selecting red and green colors that would be difficult for the color blind to differentiate.

Transparency is also handled differently between Illustrator and Inkscape. In Illustrator it is assigned layer-by-layer or by object using the Transparency palette, while in Inkscape it is also part of the fill and stroke color controls.

Layers

Layers are a critical tool for organizing objects in your images and simplifying your image editing. A layer palette (Figure 18.5) is available in both Illustrator (Window ▶ Layers) and Inkscape (Layer ▶ Layers...). These palettes list the layers in the document, allow you to lock them (with the padlock button to the left of the layer name), control whether they are visible or not (with the eye icon, also to the left of the name), and provide access to a variety of other properties.

A key task for working with layers is to move objects from one layer to another. You can move selected objects between layers in Illustrator by selecting the objects you want to move, then dragging the little colored square to the right of the layer name in the Layers palette so it is next to the name of another layer (the red circle

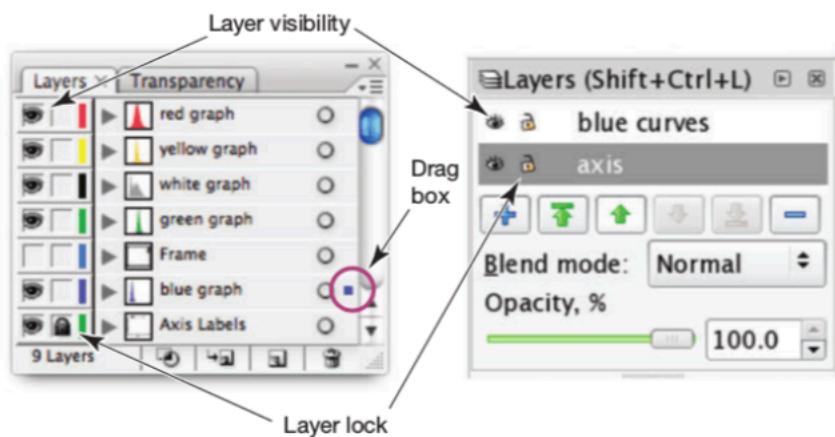


FIGURE 18.5 Layer palettes for Inkscape (left) and Illustrator (right). Layer visibility is toggled by clicking on the eye icons. Layers can be locked so that their objects will not be selected or moved during editing. To move selected objects between layers in Illustrator, drag the colored box at the right of the palette to the layer desired.

in Figure 18.5). In Inkscape, you can move objects between layers using the Move Selection to Layer... options in the Layers menu.

Related to layers is the ability to move objects in front of (above) or behind (below) other objects. This is done with the options in the Object ▶ Arrange options in Illustrator and the Raise and Lower options in the Object menu of Inkscape. Moving things in this way only rearranges them within the layers, so you may have to move the layers themselves to get the desired arrangement.

Illustrator tips

Illustrator has a variety of features and shortcuts that may seem a bit esoteric at first, but that can greatly speed up your work.

Illustrator keyboard shortcuts Illustrator keyboard shortcuts go far beyond the usual cut, copy, paste, and undo tasks: the keyboard lets you move between the various Illustrator tools on the fly, change your view of the document, and modify what the mouse clicks do, all without navigating the menus. Working quickly in Illustrator is a two-handed job, one hand on the mouse and the other positioned on the lower part of the keyboard ready to hit the `space`, Command (`⌘`), `option`, and `shift` keys. Most other keyboard shortcuts are shown in the menus, and they also pop up when you hover over a tool, so you can quickly learn the shortcuts for the ones you use the most.

- To temporarily switch from the current tool to the most recently used arrow, hold the Command key (`⌘`). This is particularly helpful when drawing Bézier curves. You can use the pen tool to rough out the line and press `⌘` at any time, to use the hollow arrow to fine tune the anchors and their handles. When you release the `⌘` you will get your pen tool back, all without needing to move your mouse to the side of the screen and click an icon. If you get the solid arrow instead of the hollow arrow when you press `⌘`, select the second arrow in the tool menu and then reselect the pen tool.



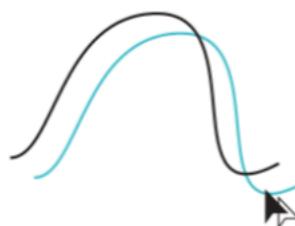
Use `ctrl` in place of `⌘`.



- To duplicate an entire object, select it with the solid arrow key and drag it while holding the `option` key. This saves several keyboard strokes relative to copying and pasting. The `option` key also modifies the behavior of many tools, including rotate and reflect, so that they copy the image as they transform. To repeat the duplication with the same spacing, choose Transform Again (⌘D). This is a quick way to make a uniformly spaced row of objects and is useful for generating grid lines, tick marks, and labels on a graph or map.
- When copying and pasting objects, you may find it frustrating that your copy is displaced an unpredictable amount from its original position. To paste a copy in the exact position that you copied it, use Paste in Front (⌘F) instead of the normal paste command. This is useful for creating overlays or multipanel plots.
- To constrain the current tool to operate only in fixed directions (up, down, left, right, and at 45° angles), press and hold `shift` after pressing the mouse button but before releasing it. This is helpful for laying objects out in precise geometric patterns. Holding `shift` also maintains proportions when resizing. If you press `shift` before pressing the mouse button, the effect will be different, as described in the earlier section about selecting and deselecting multiple objects.
- To drag your entire workspace around in the window, press the `space` and move the page with the hand tool that appears. This can be easier than using the scroll bars to reposition your view.
- There are a variety of keyboard shortcuts for zooming in and out. ⌘= (holding ⌘ and pressing the Equals key) zooms in, while ⌘- zooms out. ⌘ space gives the magnifying glass. Clicking on the image with this tool will re-center and zoom in. Drawing a box with it will zoom in on the boxed region. Add the `option` key to this combination (⌘option space) to get the zoom-out tool. Clicking with this tool re-centers and zooms out.⁴

Illustrator view options There are a couple of view options that are particularly useful. View Outlines (⌘Y) reduces your artwork to a collection of simple wire frames for each object. This can help you understand what objects an image is made of and reveal invisible objects that might be interfering with your selection tools. The Hide Edges (⌘H) view mode doesn't change the properties of the objects themselves, but makes the selection highlighting invisible to keep it from obscuring your artwork. This is particularly helpful for adjusting the stroke of a

⁴One warning: By default in Mac OS X, the Spotlight search tool conflicts with the magnifying glass shortcut. You can change Spotlight's shortcut to `ctrl space` or a similar equivalent in the System Preferences > Spotlight.



selected object, since the selection lines could cover up the very lines you need to see while you make these changes. Remember to unhide the selections (⌘ H again) when you are done adjusting things. It's easy to get confused when you try to select something later and nothing appears to be happening.

Selecting objects with the same properties in Illustrator One of the most useful and overlooked features in Illustrator is the Select ➤ Same series of menu options. Scientific illustrations are often composed of different types of elements, and there may be many of each of these. Common tasks include things like selecting and deleting all tick marks in a graph, or selecting all the tiny line elements that make up the curve for one of many data series in a plot. Manually selecting each of the tens or thousands of elements would be tedious. Instead you can just select one, then use Select ➤ Same ➤ Fill & Stroke to select the entire bunch. You can then change their properties, such as stroke weight or color, en masse. To remove them you could just hit *delete*, or, better yet, create a new layer, drag them all to this layer, and then make the entire layer invisible. You could use the same general strategy to separate the elements of a graph, such as data series, axes, and axis labels, into separate layers. This makes future manipulations simpler since you can lock all layers except the one containing the elements you want to edit.

Creating a keyboard shortcut in Illustrator When you find a command like Select Same Fill and Stroke useful, you can create a keyboard shortcut for the operation, either through the main System Preferences panel, or within Illustrator itself. To do the latter, choose Keyboard Shortcuts... from the very bottom of the Edit menu, and find the corresponding menu command (Figure 18.6). This preset will be saved on your system and will be available to you within future documents.

Inkscape tips

Inkscape also has a variety of time-saving shortcuts and useful unique tools. Being a younger, community-driven program, though, it doesn't yet have as many as those available in Illustrator. A helpful introduction to keyboard

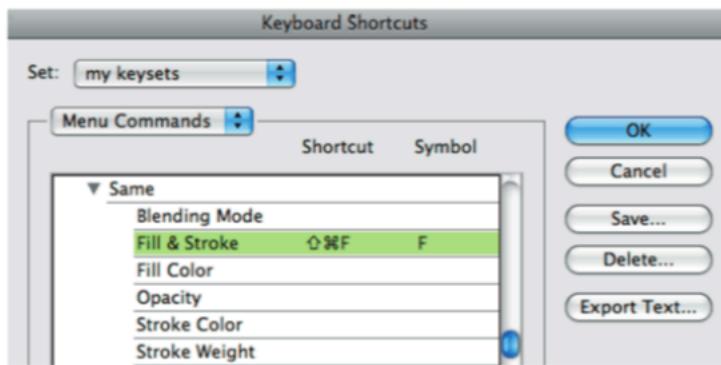


FIGURE 18.6 Creating keyboard shortcuts for Illustrator commands

shortcuts and frequently used methods is available at www.inkscape.org/doc/advanced/tutorial-advanced.html.

Many of the same general shortcuts are available in Inkscape as in Illustrator, but they are often controlled with slightly different keyboard commands. For instance, you can constrain the geometry of a tool to help draw objects at precise angles by holding the **ctrl** key once you start using the tool. This has the same effect as holding the **shift** key after you start using a tool in Illustrator.

A typical workflow

You can try your new skills out with the example graph (`examples/ScatterandBoxPlot.pdf`) shown in Figure 18.7.

This graph combines plots from several analyses—something which is difficult to do with most graphing programs. It is relatively easy to make the plots separately and then combine them in a drawing program as long as you keep the data together with their associated axes at all times. To create such an image from your own graphs, export them as PDFs, import them, and place each plot on its own layer. Choose one to be the reference, then resize the axes of the secondary graphs so they match exactly with it. Then you can move the unused axes labels to their own layer and make it invisible.



With a graph like the example, you might want to see how it looks with slightly larger or smaller data points. In Illustrator, the PDF file will preserve the layer information, since PDF is a native format. Lock the other layers and select all the dots. To make the results of your experimentation more clearly visible, you can hide edges (either through the menu with **View > Hide Edges**, or with the keyboard shortcut **⌘ H**). In Inkscape, to get to this same point you can select the groups of

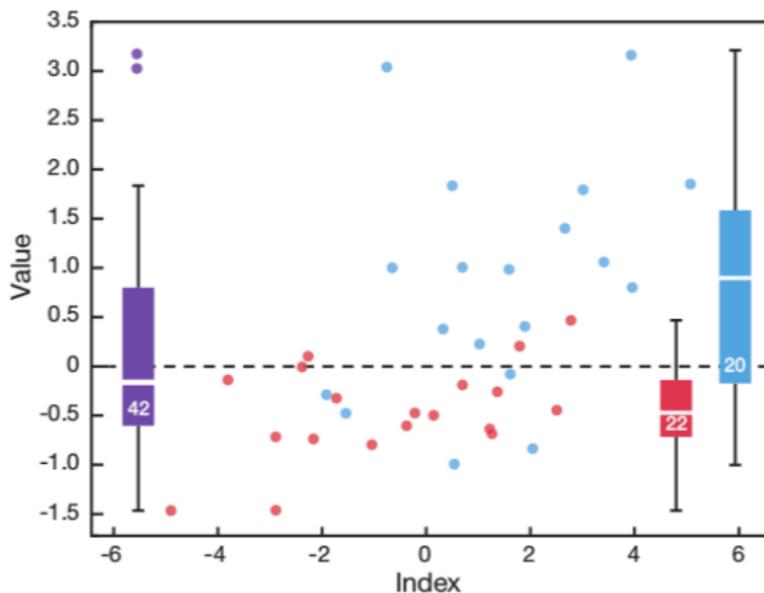
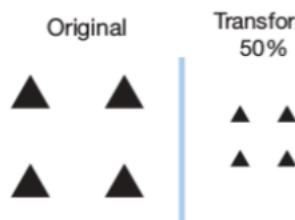


FIGURE 18.7 A graph image created by merging plots generated by different programs

Transform
50%Transform Each
50%**FIGURE 18.8** A comparison of Transform and Transform Each

points and move them together to a new layer. Then ungroup them all so that they appear as individual points, and lock the background layer (the layer that doesn't have the data points any longer).

In Illustrator, now choose Object ▶ Transform ▶ Transform Each. In Inkscape, choose Object ▶ Transform and check the Apply to Each Object Separately box. Instead of transforming the whole view as one, this option changes each element individually. This command only works as expected if the objects selected are not part of a larger group. Select with the solid arrow and choose Object ▶ Ungroup before trying to transform items individually. (You can maintain the ability to select a group of objects together if you move them all to their own layer.) You can see the difference between scaling using Transform and Transform Each in Figure 18.8.

Within the Transform Each dialog, try scaling the dots up to 150% or 200% of their original size, both horizontally and vertically. Undo that change ($\text{⌘ } Z$), and then, try 75%. There are also some overlapping points in the plot. To make these more distinct from each other, you can change the fill color so it is partially transparent. Test this when the dots are larger and overlapping to see the effect better.

At times you might need to rescale the graph non-proportionally to fit into a page layout, or to merge with another image. This operation maintains the quantitative nature of the data, but distorts the symbols in the process, making your circles into ovals. To recover proportionality, you can use Transform Each with the inverse of the scaling ratio—for example, if you shrank the *x*-axis to 75% of its original size but left the *y*-axis at 100%, then transform each symbol horizontally by 133.3% ($=1/.75$) to regain the original proportions.

When working with quantitative data in an illustration program you have to be very aware that the transformations you make are uniform and consistent. You can rescale the *x*- and *y*-axes independently, but any associated or overlaid graphs have to be resized to exactly match.

Creating regularly arranged objects

A common task in scientific illustration is to generate a set of consistent, regularly spaced, regularly aligned objects. These could be tick marks on a graph, a panel of photographs, or an illustration of a replicated experimental design. Creating regularly spaced objects is very easy using the Align and Distribute commands. A palette with tools for automatically aligning and distributing objects is available in both Illustrator (Window ▶ Align; Figure 18.9) and Inkscape

(Object ▶ Align and Distribute...). Here we only describe how to use the Illustrator tools in detail, but the Inkscape tools are similar.

In this example, you will make a vertical grid marking every 50 nm along the x-axis for the graph of LED spectra. On a new layer in Illustrator in the LEDspectra.pdf document, draw a vertical straight line with the pen or line tool. Give this line the stroke color and size that you want for the grid (you can try gray, dashed, etc., from the stroke and color palettes). Then click and hold the line with either arrow, and press and hold [option] (clone) and [shift] (constrain) simultaneously. If you hold the [shift] key before you click on the line, it may cause it to be added to any existing selection. Drag the line horizontally to approximate the spot where the next grid line should fall. Repeat this step to create as many lines as you need, without worrying about their exact positions. (You could also use the Transform Again shortcut, ⌘ D, to generate additional copies after you make the first copy.) Now move the rightmost and leftmost gridlines precisely where they should go (lined up with the 400 and 800 nm tick marks), select all the lines, and click the Distribute Objects Horizontally button on the Align palette (see Figure 18.9). The lines will jump into evenly spaced positions between the two end lines. There are also buttons to distribute objects vertically, and you can control whether the spacing is relative to the center of objects or one of their edges.

In addition to uniformly distributing objects, as you might suspect, the Align tools can also automatically align objects so that they are flush. If entire objects are selected (either using the solid arrow, or with all anchor points selected using the second arrow), then the Align Top button will move the objects so their top edges are flush. If the second (hollow) arrow is used to select only some anchor points within each object, then the alignment tool will just move those anchors into line.

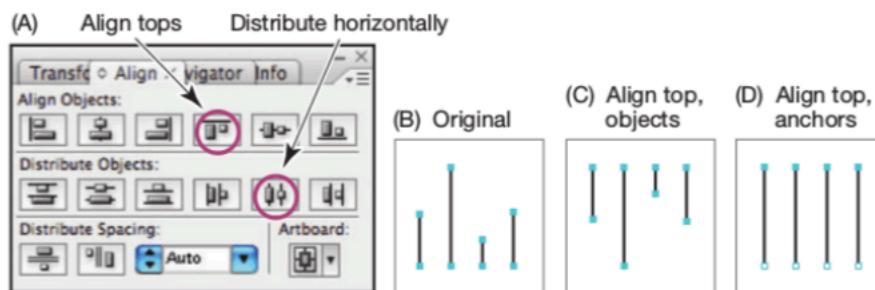


FIGURE 18.9 Alignment tools and examples The Illustrator Align palette (A) and examples of the effects of aligning objects vertically. If the original lines (B) are selected with the solid arrow and aligned vertically, each object is moved so that its upper end is flush with the top of the object that had the highest point (C). If the second arrow is used to select just the upper anchor point of each line and the same alignment is used, the length of each line changes when the anchor points are made flush (D).

This can be used to resize lines and shapes so that they have the same length or width.

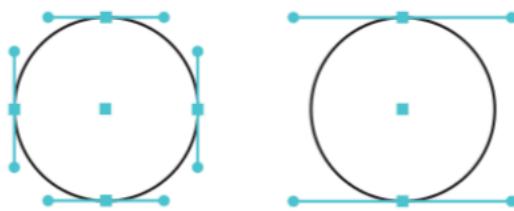
Best practices for composing vector objects

A few common problems often crop up with the drawing and presenting of vector art. These can be distracting and reduce the clarity, editability, and professionalism of the final piece. Developing good practices from the start will save time in the long run.

You should use the minimum number of points necessary to define a curve. If you have too many extra points, the curve will tend to look irregular and will be more difficult to modify since excess adjustments will be required. The number of anchor points required to define a shape is often much less than one might imagine at first. For example, a circle can be defined with just two anchor points, although four are created by most circle tools to provide additional points of control.



If you are drawing several straight lines and intend them to be parallel or at fixed angles, use guide tools (such as Align or **shift** to constrain) as described above to ensure that they are correctly arranged. You can also use a built-in underlying grid as a guide for arranging your objects by turning on Snap to Grid in the View menu.



Lines that terminate on other lines should intersect exactly, with the endpoint of one line lying along the other line so that there is no space and no overextension beyond the point of intersection. Corners require special attention and overlapping endpoints should be typically joined into a single path.

There are of course many valid stylistic reasons for breaking these rules, but that is different from not taking these issues into consideration in the first place. One irony of computer illustration tools is that while they make precise drawing accessible to untrained illustrators, the very regularity of the tools and precision of the final product are unforgiving of even very small errors. This means that would-be illustrators must pay careful attention to detail, particularly with regular geometric illustrations.

SUMMARY

You have learned that:

- There are many software environments and file formats for handling vector art
- Vector art can be generated by exporting from analysis programs, by making new drawings, and by tracing other images
- Bézier curves are a simple and powerful way to build up complex shapes

- Minimizing the number of anchor points used to define shapes makes them more regular and simpler to work with
- Layers are a critical tool for organizing image elements, as well as for locking them and changing their visibility
- A small number of tools and shortcuts within Illustrator and Inkscape will serve many of your drawing needs

Moving forward

- Open a PDF file in a vector editing program, and see what elements are grouped together, how to select similar images, and what it would take to modify the color scheme.
- Experiment with transparency in some of the graphical elements to see how this might be used to convey more information.
- Explore some of the Adobe Illustrator tutorials available for free online, for example at <http://lynda.com>. (Free tutorials are underlined in their directories. Others require a subscription.)