LEARNING PROCESSING

A Beginner's Guide to Programming Images, Animation, and Interaction

Daniel Shiffman

MORGAN KAUFMANN

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The Morgan Kaufmann Series in Computer Graphics

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Acknowledgments

In the fall of 2001, I wandered into the Interactive Telecommunications Program in the Tisch School of the Arts at New York University having not written a line of code since some early 80's experiments in BASIC on an Apple II+. There, in a first semester course entitled Introduction to Computational Media, I discovered programming. Without the inspiration and support of ITP, my home since 2001, this book would have never been written.

Red Burns, the department's chair and founder, has supported and encouraged me in my work for the last seven years. Dan O'Sullivan has been my teaching mentor and was the first to suggest that I try a course in *Processing* at ITP, giving me a reason to start putting together programming tutorials. Shawn Van Every sat next to me in the office throughout the majority of the writing of this book, providing helpful suggestions, code, and a great deal of moral support along the way. Tom Igoe's work with physical computing provided inspiration for this book, and he was particularly helpful as a resource while putting together examples on network and serial communication. And it was Clay Shirky who I can thank for one day stopping me in the hall to tell me I should write a book in the first place. Clay also provided a great deal of feedback on early drafts.

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I am also indebted to the energetic and supportive community of *Processing* programmers and artists. I'd probably be out of a job if it weren't for Casey Reas and Benjamin Fry who created *Processing*. I've learned half of what I know simply from reading through the *Processing* source code; the elegant simplicity of the *Processing* language, web site, and IDE has made programming accessible and fun for all of my students. I've received advice, suggestions, and comments from many *Processing* programmers including Tom Carden, Marius Watz, Karsten Schmidt, Robert Hodgin, Ariel Malka, Burak Arikan, and Ira Greenberg. The following teachers were also helpful test driving early versions of the book in their courses: Hector Rodriguez, Keith Lam, Liubo Borissov, Rick Giles, Amit Pitaru, David Maccarella, Jeff Gray, and Toshitaka Amaoka.

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Introduction

What is this book?

This book tells a story. It is a story of liberation, of taking the first steps toward understanding the foundations of computing, writing your own code, and creating your own media without the bonds of existing software tools. This story is not reserved for computer scientists and engineers. This story is for you.

Who is this book for?

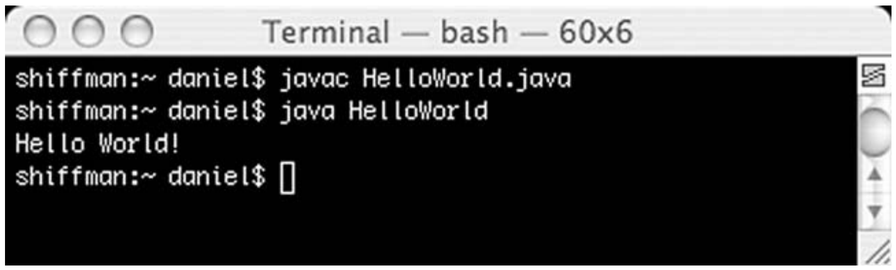
This book is for the beginner. If you have never written a line of code in your life, you are in the right place. No assumptions are made, and the fundamentals of programming are covered slowly, one by one, in the first nine chapters of this book. You do not need any background knowledge besides the basics of operating a computer—turning it on, browsing the web, launching an application, that sort of thing.

Because this book uses *Processing* (more on *Processing* in a moment), it is especially good for someone studying or working in a visual field, such as graphic design, painting, sculpture, architecture, film, video, illustration, web design, and so on. If you are in one of these fields (at least one that involves using a computer), you are probably well versed in a particular software package, possibly more than one, such as Photoshop, Illustrator, AutoCAD, Maya, After Effects, and so on. The point of this book is to release you, at least in part, from the confines of existing tools. What can you make, what can you design if, instead of using someone else's tools, you write your own? If this question interests you, you are in the right place.

If you have some programming experience, but are interested in learning about *Processing*, this book could also be useful. The early chapters will provide you with a quick refresher (and solid foundation) for the more advanced topics found in the second half of the book.

What is *Processing*?

Let's say you are taking Computer Science 101, perhaps taught with the Java programming language. Here is the output of the first example program demonstrated in class:



```
shiffman:~ daniel$ javac HelloWorld.java
shiffman:~ daniel$ java HelloWorld
Hello World!
shiffman:~ daniel$ []
```

Traditionally, programmers are taught the basics via command line output:

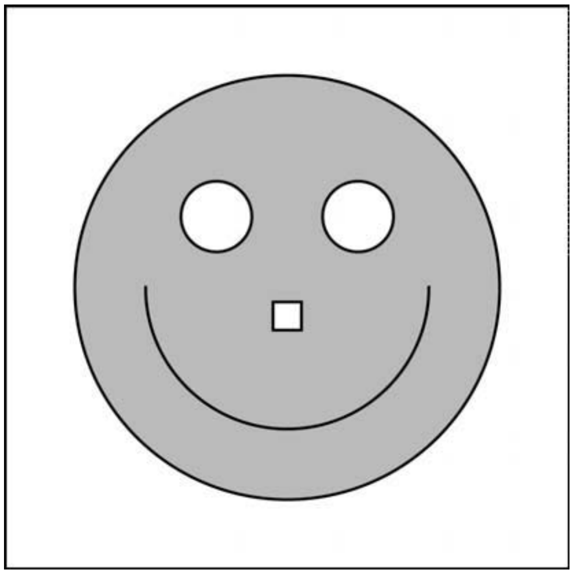
1. TEXT IN → You write your code as text.
2. TEXT OUT → Your code produces text output on the command line.
3. TEXT INTERACTION → The user can enter text on the command line to interact with the program.

The output "Hello, World!" of this example program is an old joke, a programmer's convention where the text output of the first program you learn to write in any given language says "Hello, World!" It first appeared in a 1974 Bell Laboratories memorandum by Brian Kernighan entitled "Programming in C: A Tutorial."

The strength of learning with *Processing* is its emphasis on a more intuitive and visually responsive environment, one that is more conducive to artists and designers learning programming.

1. TEXT IN → You write your code as text.
2. VISUALS OUT → Your code produces visuals in a window.
3. MOUSE INTERACTION → The user can interact with those visuals via the mouse (and more as we will see in this book!).

Processing's "Hello, World!" might look something like this:



Hello, Shapes!

Though quite friendly looking, it is nothing spectacular (both of these first programs leave out #3: interaction), but neither is "Hello, World!" However, the focus, learning through immediate visual feedback, is quite different.

Processing is not the first language to follow this paradigm. In 1967, the Logo programming language was developed by Daniel G. Bobrow, Wally Feurzeig, and Seymour Papert. With Logo, a programmer writes instructions to direct a turtle around the screen, producing shapes and designs. John Maeda's *Design By Numbers* (1999) introduced computation to visual designers and artists with a simple, easy to use syntax.

While both of these languages are wonderful for their simplicity and innovation, their capabilities are limited.

Processing, a direct descendent of *Logo* and *Design by Numbers*, was born in 2001 in the "Aesthetics and Computation" research group at the Massachusetts Institute of Technology Media Lab. It is an open source initiative by Casey Reas and Benjamin Fry, who developed *Processing* as graduate students studying with John Maeda.

> *"Processing is an open source programming language and environment for people who want to program images, animation, and sound. It is used by students, artists, designers, architects, researchers, and hobbyists for learning, prototyping, and production. It is created to teach fundamentals of computer programming within a visual context and to serve as a software sketchbook and professional production tool. Processing is developed by artists and designers as an alternative to proprietary software tools in the same domain."*
> *—www.processing.org*

To sum up, *Processing* is awesome. First of all, it is free. It doesn't cost a dime. Secondly, because *Processing* is built on top of the Java programming language (this is explored further in the last chapter of this book), it is a fully functional language without some of the limitations of *Logo* or *Design by Numbers*. There is very little you can't do with *Processing*. Finally, *Processing* is open source. For the most part, this will not be a crucial detail of the story of this book. Nevertheless, as you move beyond the beginning stages, this philosophical principle will prove invaluable. It is the reason that such an amazing community of developers, teachers, and artists come together to share work, contribute ideas, and expand the features of *Processing*.

A quick surf-through of the *processing.org* Web site reveals this vibrant and creative community. There, code is shared in an open exchange of ideas and artwork among beginners and experts alike. While the site contains a complete reference as well as a plethora of examples to get you started, it does not have a step-by-step tutorial for the true beginner. This book is designed to give you a jump start on joining and contributing to this community by methodically walking you through the fundamentals of programming as well as exploring some advanced topics.

It is important to realize that, although without *Processing* this book might not exist, this book is not a *Processing* book per se. The intention here is to teach you programming. We are choosing to use *Processing* as our learning environment, but the focus is on the core computational concepts, which will carry you forward in your digital life as you explore other languages and environments.

But shouldn't I be Learning __________ ?

You know you want to. Fill in that blank. You heard that the next big thing is that programming language and environment Flibideeflobidee. Sure it sounds made up, but that friend of yours will not stop talking about how awesome it is. How it makes everything soooo easy. How what used to take you a whole day to program can be done in five minutes. And it works on a Mac. And a PC! And a toaster oven! And you can program your pets to speak with it. In Japanese!

Here's the thing. That magical language that solves all your problems does not exist. No language is perfect, and *Processing* comes with its fair share of limitations and flaws. *Processing*, however, is an excellent place to start (and stay). This book teaches you the fundamentals of programming so that you can apply them throughout your life, whether you use *Processing*, Java, Actionscript, C, PHP, or some other language.

It is true that for some projects, other languages and environments can be better. But *Processing* is really darn good for a lot of stuff, especially media-related and screen-based work. A common misconception is that *Processing* is just for fiddling around; this is not the case. People (myself included) are out there using *Processing* from day number 1 to day number 365 of their project. It is used for web applications, art projects in museums and galleries, and exhibits and installations in public spaces. Most recently, I used *Processing* to develop a real-time graphics video wall system (*http://www.mostpixelsever.com*) that can display content on a 120 by 12 foot (yes, feet!) video wall in the lobby of InterActive Corps' New York City headquarters.

Not only is *Processing* great for actually doing stuff, but for learning, there really isn't much out there better. It is free and open source. It is simple. It is visual. It is fun. It is object-oriented (we will get to this later.) And it does actually work on Macs, PCs, and Linux machines (no talking dogs though, sorry).

So I would suggest to you that you stop worrying about what it is you should be using and focus on learning the fundamentals with *Processing*. That knowledge will take you above and beyond this book to any language you want to tackle.

Write in this book!

Let's say you are a novelist. Or a screenwriter. Is the only time you spend writing the time spent sitting and typing at a computer? Or (gasp) a typewriter? Most likely, this is not the case. Perhaps ideas swirl in your mind as you lie in bed at night. Or maybe you like to sit on a bench in the park, feed the pigeons, and play out dialogue in your head. And one late night, at the local pub, you find yourself scrawling out a brilliant plot twist on a napkin.

Well, writing software, programming, and creating code is no different. It is really easy to forget this since the work itself is so inherently tied to the computer. But you must find time to let your mind wander, think about logic, and brainstorm ideas away from the chair, the desk, and the computer. Personally, I do all my best programming while jogging.

Sure, the actual typing on the computer part is pretty important. I mean, you will not end up with a life-changing, working application just by laying out by the pool. But thinking you always need to be hunched over the glare of an LCD screen will not be enough.

Writing all over this book is a step in the right direction, ensuring you will practice thinking through code away from the keyboard. I have included many exercises in the book that incorporate a "fill in the blanks" approach. (All of these fill in the blanks exercises have answers on the book's Web site, *http://www.learningprocessing.com,* so you can check your work.) Use these pages! When an idea inspires you, make a note and write it down. Think of the book as a workbook and sketchbook for your computational ideas. (You can of course use your own sketchbook, too.)

I would suggest you spend half your time reading this book away from the computer and the other half, side by side with your machine, experimenting with example code along the way.

How should I read this book?

It is best to read this book in order. Chapter 1, Chapter 2, Chapter 3, and so on. You can get a bit more relaxed about this after the end of Chapter 9 but in the beginning it is pretty important.

The book is designed to teach you programming in a linear fashion. A more advanced text might operate more like a reference where you read bits and pieces here and there, moving back and forth throughout the book. But here, the first half of the book is dedicated to making one example, and building the features of that example one step at a time (more on this in a moment). In addition, the fundamental elements of computer programming are presented in a particular order, one that comes from several years of trial and error with a group of patient and wonderful students in New York University's Interactive Telecommunications Program ("ITP") at the Tisch School of the Arts (*http://itp.nyu.edu*).

The chapters of the book (23 total) are grouped into lessons (10 total). The first nine chapters introduce computer graphics, and cover the fundamental principles behind computer programming. Chapters 10 through 12 take a break from learning new material to examine how larger projects are developed with an incremental approach. Chapters 13 through 23 expand on the basics and offer a selection of more advanced topics ranging from 3D, to incorporating live video, to data visualization.

The "Lessons" are offered as a means of dividing the book into digestible chunks. The end of a lesson marks a spot at which I suggest you take a break from reading and attempt to incorporate that lesson's chapters into a project. Suggestions for these projects are offered (but they are really just that: suggestions).

Is this a textbook?

This book is designed to be used either as a textbook for an introductory level programming course or for self-instruction.

I should mention that the structure of this book comes directly out of the course "Introduction to Computational Media" at ITP. Without the help my fellow teachers of this class (Dan O'Sullivan, Danny Rozin, Chris Kairalla, Shawn Van Every, Nancy Lewis, Mark Napier, and James Tu) and hundreds of students (I wish I could name them all here), I don't think this book would even exist.

To be honest, though, I am including a bit more material than can be taught in a beginner level one semester course. Out of the 23 chapters, I probably cover about 18 of them in detail in my class (but make reference to everything in the book at some point). Nevertheless, whether or not you are reading the book for a course or learning on your own, it is reasonable that you could consume the book in a period of a few months. Sure, you can read it faster than that, but in terms of actually writing code and developing projects that incorporate all the material here, you will need a fairly significant amount of time. As tempting as it is to call this book "Learn to Program with 10 Lessons in 10 Days!" it is just not realistic.

Here is an example of how the material could play out in a 14 week semester course.

Week 1	Lesson 1: Chapters 1–3
Week 2	Lesson 2: Chapters 4–6
Week 3	Lesson 3: Chapters 7–8
Week 4	Lesson 4: Chapter 9
Week 5	Lesson 5: Chapter 10–11
Week 6	Midterm! (Also, continue Lesson 5: Chapter 12)

Week 7	Lesson 6: Chapter 13–14
Week 8	Lesson 7: Chapter 15–16
Week 9	Lesson 8: Chapters 17–19
Week 10	Lesson 9: Chapters 20–21
Week 11	Lesson 10: Chapters 22–23
Week 12	Final Project Workshop
Week 13	Final Project Workshop
Week 14	Final Project Presentations

Will this be on the test?

A book will only take you so far. The real key is practice, practice, practice. Pretend you are 10 years old and taking violin lessons. Your teacher would tell you to practice every day. And that would seem perfectly reasonable to you. Do the exercises in this book. Practice every day if you can.

Sometimes when you are learning, it can be difficult to come up with your own ideas. These exercises are there so that you do not have to. However, if you have an idea for something you want to develop, you should feel free to twist and tweak the exercises to fit with what you are doing.

A lot of the exercises are tiny little drills that can be answered in a few minutes. Some are a bit harder and might require up to an hour. Along the way, however, it is good to stop and work on a project that takes longer, a few hours, a day, or a week. As I just mentioned, this is what the "lesson" structure is for. I suggest that in between each lesson, you take a break from reading and work on making something in *Processing*. A page with project suggestions is provided for each lesson.

All of the answers to all of the exercises can be found on this book's web site. Speaking of which …

Do you have a web site?

The Web site for this book is: *http://www.learningprocessing.com*

There you will find the following things:

- Answers to all exercises in the book.
- Downloadable versions of all code in the book.
- Online versions of the examples (that can be put online) in the book.
- Corrections of any errors in the book.
- Additional tips and tutorials beyond material in the book.
- Questions and comments page.

Since many of the examples in this book use color and are animated, the black and white, static screenshots provided in the pages here will not give you the whole picture. As you are reading, you can refer to the web site to view the examples running in your browser as well as download them to run locally on your computer.

This book's web site is not a substitute for the amazing resource that is the official *Processing* web site: *http://www.processing.org*. There, you will find the *Processing* reference, many more examples, and a lively forum.

Take It One Step at a Time

The Philosophy of Incremental Development

There is one more thing we should discuss before we embark on this journey together. It is an important driving force behind the way I learned to program and will contribute greatly to the style of this book. As coined by a former professor of mine, it is called the "philosophy of incremental development." Or perhaps, more simply, the "one-step-at-a-time approach."

Whether you are a total novice or a coder with years of experience, with any programming project, it is crucial not to fall into the trap of trying to do too much all at once. Your dream might be to create the uber-*Processing* program that, say, uses Perlin noise to procedurally generate textures for 3D vertex shapes that evolve via the artificial intelligence of a neural network that crawls the web mining for today's news stories, displaying the text of these stories onscreen in colors taken from a live video feed of a viewer in front of the screen who can control the interface with live microphone input by singing.

There is nothing wrong with having grand visions, but the most important favor you can do for yourself is to learn how to break those visions into small parts and attack each piece slowly, one at a time. The previous example is a bit silly; nevertheless, if you were to sit down and attempt to program its features all at once, I am pretty sure you would end up using a cold compress to treat your pounding headache.

To demonstrate, let's simplify and say that you aspire to program the game Space Invaders (see: *http://en.wikipedia.org/wiki/Space_Invaders*). While this is not explicitly a game programming book, the skills to accomplish this goal will be found here. Following our newfound philosophy, however, we know we need to develop one step at a time, breaking down the problem of programming Space Invaders into small parts. Here is a quick attempt:

1. Program the spaceship.
2. Program the invaders.
3. Program the scoring system.

Great, we divided our program into three steps! Nevertheless, we are not at all finished. The key is to divide the problem into the *smallest pieces possible*, to the point of absurdity, if necessary. You will learn to scale back into larger chunks when the time comes, but for now, the pieces should be so small that they seem ridiculously oversimplified. After all, if the idea of developing a complex game such as Space Invaders seems overwhelming, this feeling will go away if you leave yourself with a list of steps to follow, each one simple and easy.

With that in mind, let's try a little harder, breaking Step 1 from above down into smaller parts. The idea here is that you would write six programs, the first being the simplest: *display a triangle*. With each step, we add a small improvement: *move the triangle.* As the program gets more and more advanced, eventually we will be finished.

1.1 Draw a triangle onscreen. The triangle will be our spaceship.
1.2 Position the triangle at the bottom of the screen.
1.3 Position the triangle slightly to the right of where it was before.
1.4 Animate the triangle so that it moves from position left to right.
1.5 Animate the triangle from left to right only when the right-arrow key is pressed.
1.6 Animate the triangle right to left when the left-arrow key is pressed.

Of course, this is only a small fraction of all of the steps we need for a full Space Invaders game, but it demonstrates a vital way of thinking. The benefits of this approach are not simply that it makes programming easier (which it does), but that it also makes "debugging" easier.

Debugging[1] refers to the process of finding defects in a computer program and fixing them so that the program behaves properly. You have probably heard about bugs in, say, the Windows operating system: miniscule, arcane errors deep in the code. For us, a bug is a much simpler concept: a mistake. Each time you try to program something, it is very likely that *something* will not work as you expected, if at all. So if you start out trying to program everything all at once, it will be very hard to find these bugs. The one-step-at-a-time methodology, however, allows you to tackle these mistakes one at a time, squishing the bugs.

In addition, incremental development lends itself really well to *object-oriented programming*, a core principle of this book. Objects, which will be introduced in Lesson 3, Chapter 8, will help us to develop projects in modular pieces as well as provide an excellent means for organizing (and sharing) code. Reusability will also be key. For example, if you have programmed a spaceship for Space Invaders and want to start working on asteroids, you can grab the parts you need (i.e., the moving spaceship code), and develop the new pieces around them.

Algorithms

When all is said and done, computer programming is all about writing *algorithms*. An algorithm is a sequential list of instructions that solves a particular problem. And the philosophy of incremental development (which is essentially an algorithm for you, the human being, to follow) is designed to make it easier for you to write an algorithm that implements your idea.

As an exercise, before you get to Chapter 1, try writing an algorithm for something you do on a daily basis, such as brushing your teeth. Make sure the instructions seem comically simple (as in "Move the toothbrush one centimeter to the left").

Imagine that you had to provide instructions on how to accomplish this task to someone entirely unfamiliar with toothbrushes, toothpaste, and teeth. That is how it is to write a program. A computer is nothing more than a machine that is brilliant at following precise instructions, but knows nothing about the world at large. And this is where we begin our journey, our story, our new life as a programmer. We begin with learning how to talk to our friend, the computer.

[1]The term "debugging" comes from the apocryphal story of a moth getting stuck in the relay circuits of one of computer scientist Grace Murray Hopper's computers.

Introductory Exercise: Write instructions for brushing your teeth.

Some suggestions:

- Do you do different things based on conditions? How might you use the words "if" or "otherwise" in your instructions? (For example: if the water is too cold, increase the warm water. Otherwise, increase cold water.)
- Use the word "repeat" in your instructions. For example: Move the brush up and down. Repeat 5 times.

Also, note that we are starting with Step # 0. In programming, we often like to count starting from 0 so it is good for us to get used to this idea right off the bat!

How to brush your teeth by ______________________________

Step 0. ______________________________

Step 1. ______________________________

Step 2. ______________________________

Step 3. ______________________________

Step 4. ______________________________

Step 5. ______________________________

Step 6. ______________________________

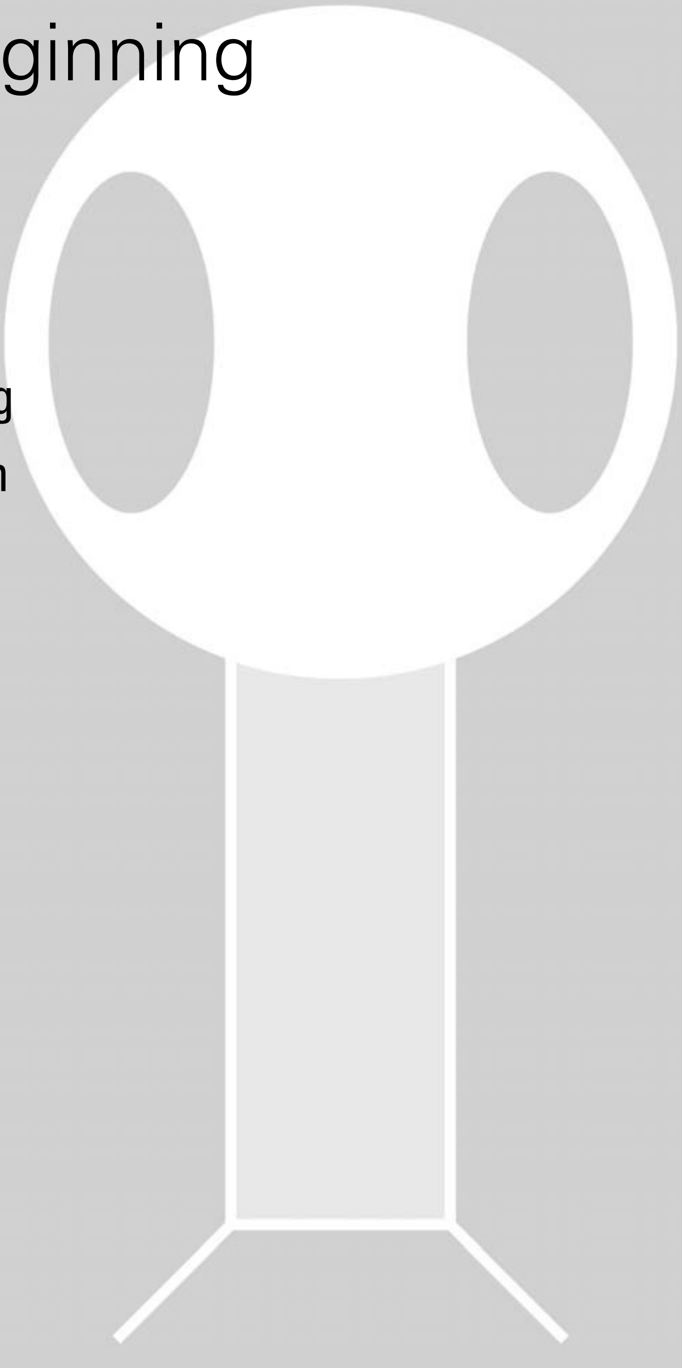
Step 7. ______________________________

Step 8. ______________________________

Step 9. ______________________________

Lesson One

The Beginning



1 Pixels

"A journey of a thousand miles begins with a single step."
—Lao-tzu

In this chapter:
– Specifying pixel coordinates.
– Basic shapes: point, line, rectangle, ellipse.
– Color: grayscale, "RGB."
– Color transparency.

Note that we are not doing any programming yet in this chapter! We are just dipping our feet in the water and getting comfortable with the idea of creating onscreen graphics with text-based commands, that is, "code"!

1.1 Graph Paper

This book will teach you how to program in the context of computational media, and it will use the development environment *Processing* (*http://www.processing.org*) as the basis for all discussion and examples. But before any of this becomes relevant or interesting, we must first channel our eighth grade selves, pull out a piece of graph paper, and draw a line. The shortest distance between two points is a good old fashioned line, and this is where we begin, with two points on that graph paper.

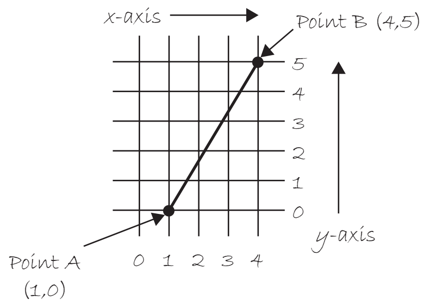


fig. 1.1

Figure 1.1 shows a line between point A (1,0) and point B (4,5). If you wanted to direct a friend of yours to draw that same line, you would give them a shout and say "draw a line from the point one-zero to the point four-five, please." Well, for the moment, imagine your friend was a computer and you wanted to instruct this digital pal to display that same line on its screen. The same command applies (only this time you can skip the pleasantries and you will be required to employ a precise formatting). Here, the instruction will look like this:

```
line(1,0,4,5);
```

Congratulations, you have written your first line of computer code! We will get to the precise formatting of the above later, but for now, even without knowing too much, it should make a fair amount of sense. We are providing a *command* (which we will refer to as a "function") for the machine to follow entitled "line." In addition, we are specifying some *arguments* for how that line should be drawn, from point

A (0,1) to point B (4,5). If you think of that line of code as a sentence, the *function* is a *verb* and the *arguments* are the *objects* of the sentence. The code sentence also ends with a semicolon instead of a period.

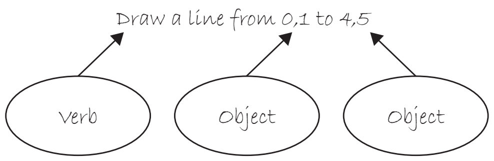


fig. 1.2

The key here is to realize that the computer screen is nothing more than a *fancier* piece of graph paper. Each pixel of the screen is a coordinate—two numbers, an "*x*" (horizontal) and a "*y*" (vertical)—that determine the location of a point in space. And it is our job to specify what shapes and colors should appear at these pixel coordinates.

Nevertheless, there is a catch here. The graph paper from eighth grade ("Cartesian coordinate system") placed (0,0) in the center with the *y*-axis pointing up and the *x*-axis pointing to the right (in the positive direction, negative down and to the left). The coordinate system for pixels in a computer window, however, is reversed along the *y*-axis. (0,0) can be found at the top left with the positive direction to the right horizontally and down vertically. See Figure 1.3.

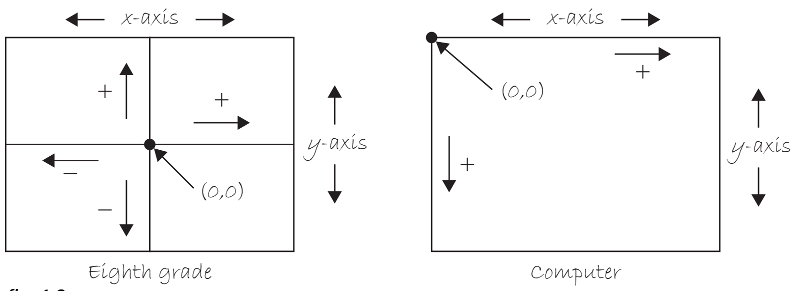


fig. 1.3

Exercise 1-1: Looking at how we wrote the instruction for line "line(1,0,4,5);" how would you guess you would write an instruction to draw a rectangle? A circle? A triangle? Write out the instructions in English and then translate it into "code."

English: ______________________________

Code: ______________________________

English: ______________________________

Code: ______________________________

English: ______________________________

Code: ______________________________

Come back later and see how your guesses matched up with how Processing *actually works.*

1.2 Simple Shapes

The vast majority of the programming examples in this book will be visual in nature. You may ultimately learn to develop interactive games, algorithmic art pieces, animated logo designs, and (insert your own category here) with *Processing*, but at its core, each visual program will involve setting pixels. The simplest way to get started in understanding how this works is to learn to draw primitive shapes. This is not unlike how we learn to draw in elementary school, only here we do so with code instead of crayons.

Let's start with the four primitive shapes shown in Figure 1.4.

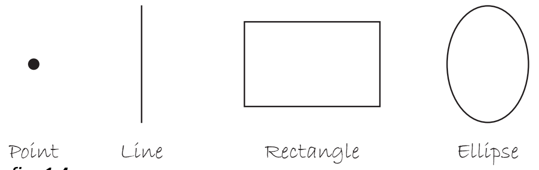


fig. 1.4

For each shape, we will ask ourselves what information is required to specify the location and size (and later color) of that shape and learn how *Processing* expects to receive that information. In each of the diagrams below (Figures 1.5 through 1.11), assume a window with a width of 10 pixels and height of 10 pixels. This isn't particularly realistic since when we really start coding we will most likely work with much larger windows (10 × 10 pixels is barely a few millimeters of screen space). Nevertheless for demonstration purposes, it is nice to work with smaller numbers in order to present the pixels as they might appear on graph paper (for now) to better illustrate the inner workings of each line of code.

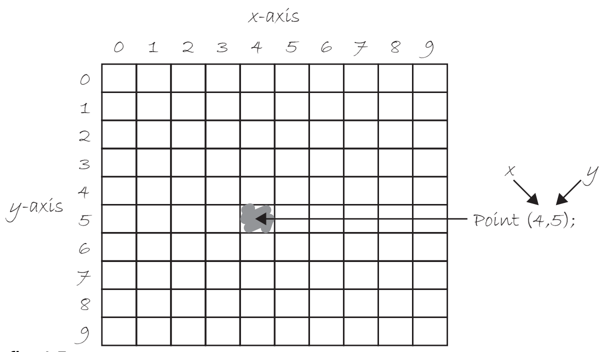


fig. 1.5

A point is the easiest of the shapes and a good place to start. To draw a point, we only need an *x* and *y* coordinate as shown in Figure 1.5. A line isn't terribly difficult either. A line requires two points, as shown in Figure 1.6.

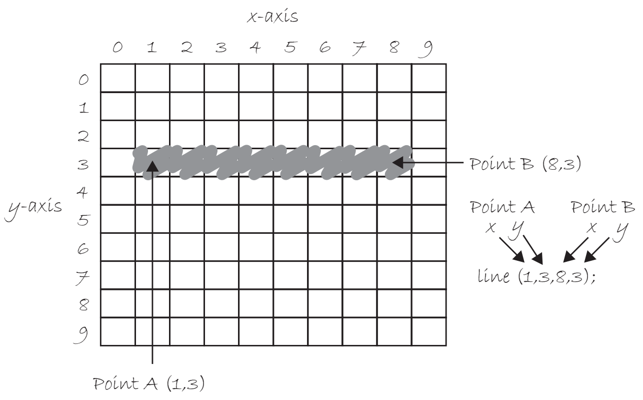


fig. 1.6

Once we arrive at drawing a rectangle, things become a bit more complicated. In *Processing*, a rectangle is specified by the coordinate for the top left corner of the rectangle, as well as its width and height (see Figure 1.7).

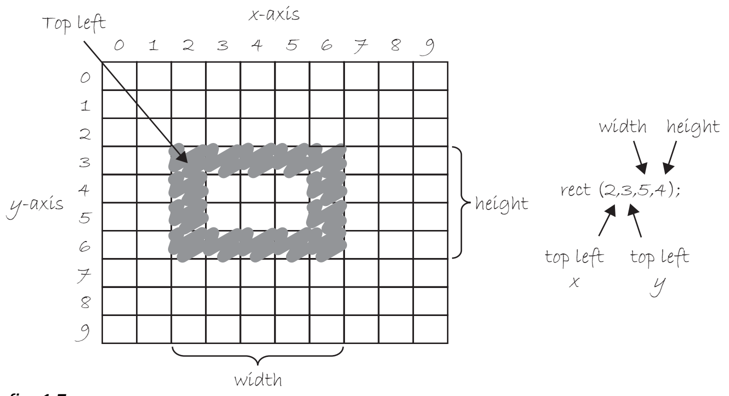


fig. 1.7

However, a second way to draw a rectangle involves specifying the centerpoint, along with width and height as shown in Figure 1.8. If we prefer this method, we first indicate that we want to use the "CENTER" mode before the instruction for the rectangle itself. Note that *Processing* is case-sensitive. Incidentally, the default mode is "CORNER," which is how we began as illustrated in Figure 1.7.

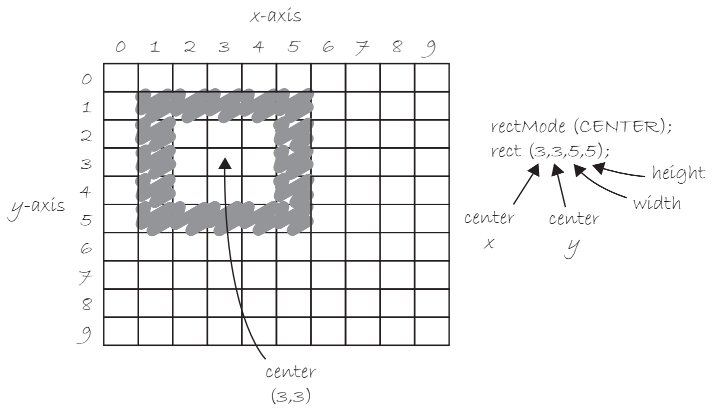


fig. 1.8

Finally, we can also draw a rectangle with two points (the top left corner and the bottom right corner). The mode here is "CORNERS" (see Figure 1.9).

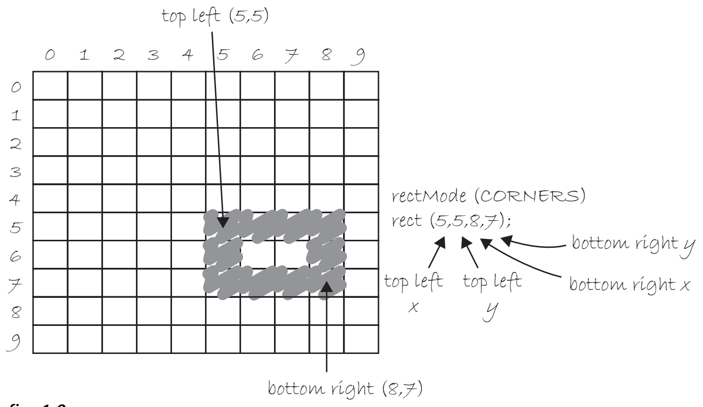


fig. 1.9

Once we have become comfortable with the concept of drawing a rectangle, an ellipse is a snap. In fact, it is identical to ***rect()*** with the difference being that an ellipse is drawn where the bounding box[1] (as shown in Figure 1.11) of the rectangle would be. The default mode for ***ellipse()*** is "CENTER", rather than "CORNER" as with ***rect()***. See Figure 1.10.

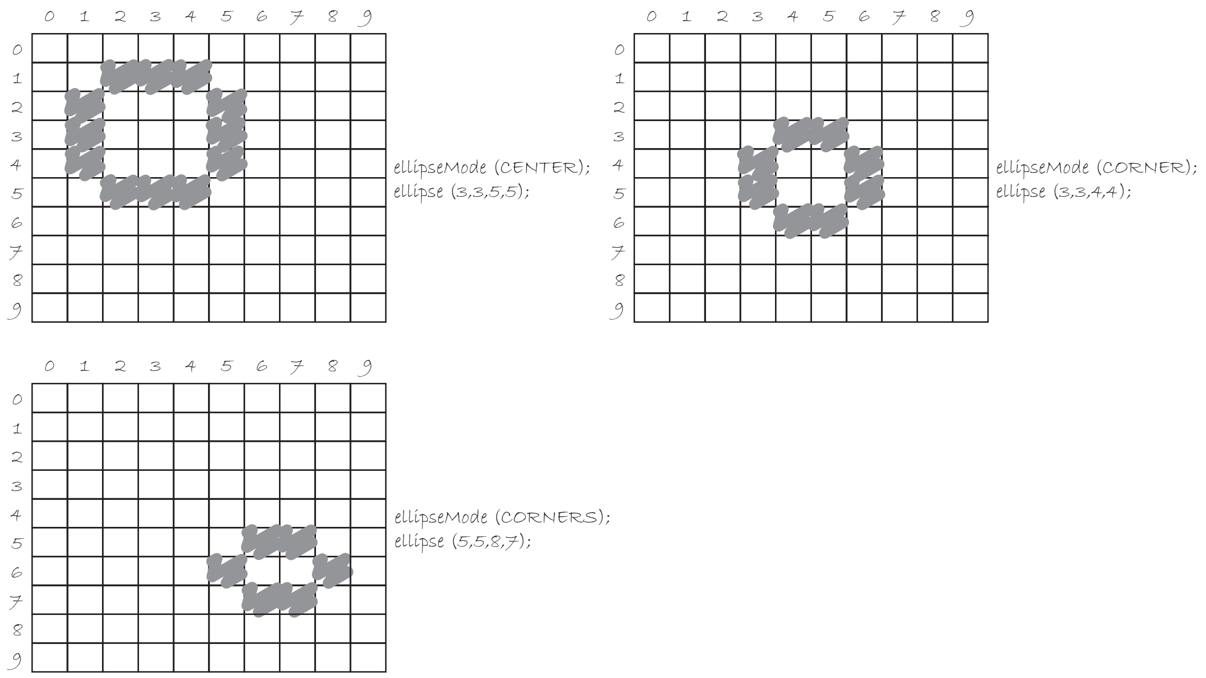


fig. 1.10

It is important to acknowledge that in Figure 1.10, the ellipses do not look particularly circular. *Processing* has a built-in methodology for selecting which pixels should be used to create a circular shape. Zoomed in like this, we get a bunch of squares in a circle-like pattern, but zoomed out on a computer screen, we get a nice round ellipse. Later, we will see that *Processing* gives us the power to develop our own

[1]A bounding box of a shape in computer graphics is the smallest rectangle that includes all the pixels of that shape. For example, the bounding box of a circle is shown in Figure 1.11.

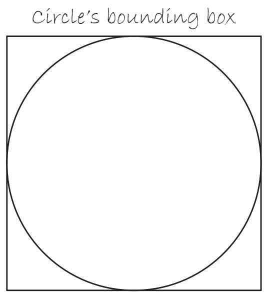


fig. 1.11

algorithms for coloring in individual pixels (in fact, we can already imagine how we might do this using "point" over and over again), but for now, we are content with allowing the "ellipse" statement to do the hard work.

Certainly, point, line, ellipse, and rectangle are not the only shapes available in the *Processing* library of functions. In Chapter 2, we will see how the *Processing* reference provides us with a full list of available drawing functions along with documentation of the required arguments, sample syntax, and imagery. For now, as an exercise, you might try to imagine what arguments are required for some other shapes (Figure 1.12):

triangle()
arc()
quad()
curve()

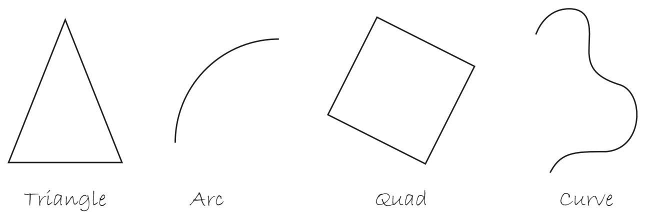
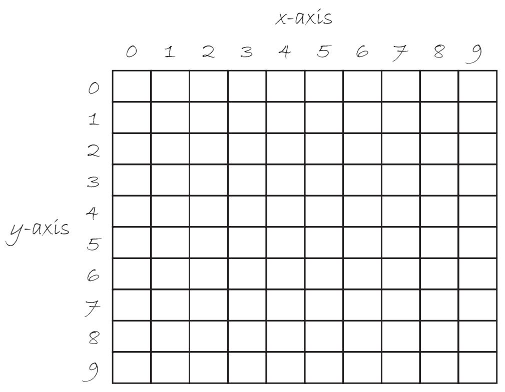


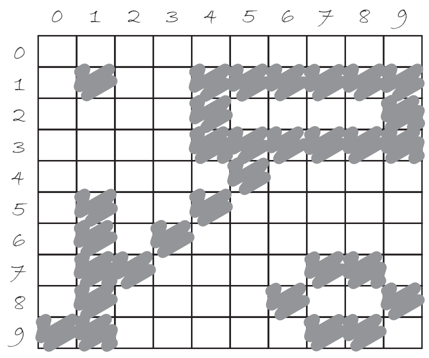
fig. 1.12

Exercise 1-2: Using the blank graph below, draw the primitive shapes specified by the code.

```
line(0,0,9,6);
point(0,2);
point(0,4);
rectMode(CORNER);
rect(5,0,4,3);
ellipseMode(CENTER);
ellipse(3,7,4,4);
```



Exercise 1-3: Reverse engineer a list of primitive shape drawing instructions for the diagram below.



Note: There is more than one correct answer!

1.3 Grayscale Color

As we learned in Section 1.2, the primary building block for placing shapes onscreen is a pixel coordinate. You politely instructed the computer to draw a shape at a specific location with a specific size. Nevertheless, a fundamental element was missing—color.

In the digital world, precision is required. Saying "Hey, can you make that circle bluish-green?" will not do. Therefore, color is defined with a range of numbers. Let's start with the simplest case: *black and white* or *grayscale*. In grayscale terms, we have the following: 0 means black, 255 means white. In between, every other number—50, 87, 162, 209, and so on—is a shade of gray ranging from black to white. See Figure 1.13.

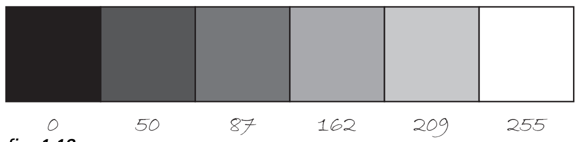


fig. 1.13

Does 0–255 seem arbitary to you?

Color for a given shape needs to be stored in the computer's memory. This memory is just a long sequence of 0's and 1's (a whole bunch of on or off switches.) Each one of these switches is a *bit*, eight of them together is a *byte*. Imagine if we had eight bits (one byte) in sequence—how many ways can we configure these switches? The answer is (and doing a little research into binary numbers will prove this point) 256 possibilities, or a range of numbers between 0 and 255. We will use eight bit color for our grayscale range and 24 bit for full color (eight bits for each of the red, green, and blue color components; see Section 1.4).

Understanding how this range works, we can now move to setting specific grayscale colors for the shapes we drew in Section 1.2. In *Processing*, every shape has a ***stroke()*** or a ***fill()*** or both. The ***stroke()*** is the outline of the shape, and the ***fill()*** is the interior of that shape. Lines and points can only have ***stroke()***, for obvious reasons.

If we forget to specify a color, *Processing* will use black (0) for the ***stroke()*** and white (255) for the ***fill()*** by default. Note that we are now using more realistic numbers for the pixel locations, assuming a larger window of size 200 × 200 pixels. See Figure 1.14.

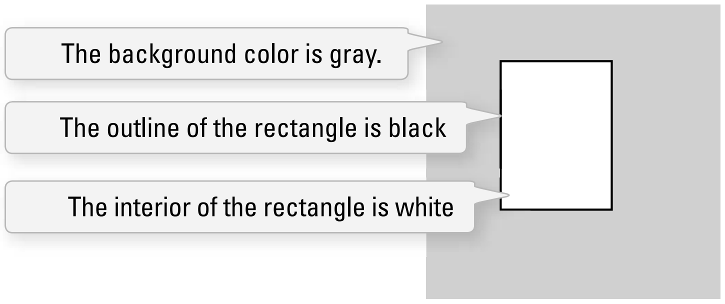

The background color is gray.
The outline of the rectangle is black
The interior of the rectangle is white

fig. 1.14

```
rect(50,40,75,100);
```

By adding the ***stroke()*** and ***fill()*** functions *before* the shape is drawn, we can set the color. It is much like instructing your friend to use a specific pen to draw on the graph paper. You would have to tell your friend *before* he or she starting drawing, not after.

There is also the function ***background()***, which sets a background color for the window where shapes will be rendered.

Example 1-1: Stroke and fill

```
background(255);
stroke(0);
fill(150);
rect(50,50,75,100);
```

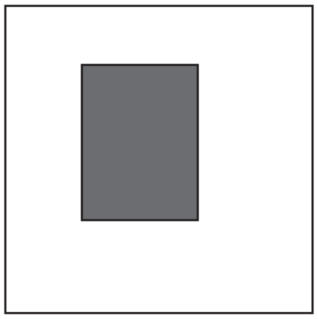


fig. 1.15

stroke() or ***fill()*** can be eliminated with the ***noStroke()*** or ***noFill()*** functions. Our instinct might be to say "***stroke(0)***" for no outline, however, it is important to remember that 0 is not "nothing", but rather denotes the color black. Also, remember not to eliminate both—with ***noStroke()*** and ***noFill()***, nothing will appear!

Example 1-2: *noFill ( )*

```
background(255);
stroke(0);
noFill();
ellipse(60,60,100,100);
```

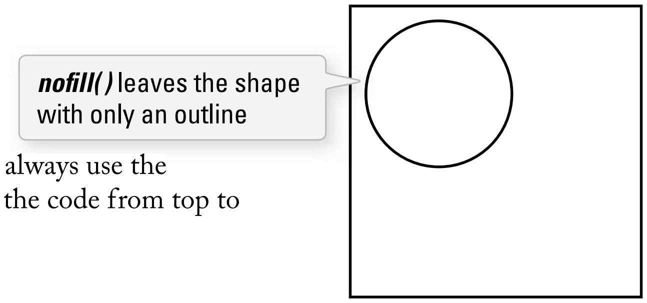
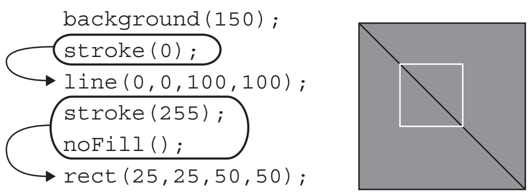


fig. 1.16

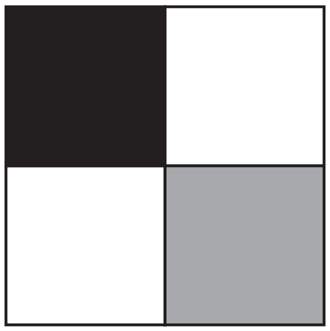
If we draw two shapes at one time, *Processing* will always use the most recently specified ***stroke()*** and ***fill()***, reading the code from top to bottom. See Figure 1.17.



```
background(150);
stroke(0);
line(0,0,100,100);
stroke(255);
noFill();
rect(25,25,50,50);
```

fig. 1.17

Exercise 1-4: Try to guess what the instructions would be for the following screenshot.



____

____

____

____

____

____

____

____

1.4 RGB Color

A nostalgic look back at graph paper helped us learn the fundamentals for pixel locations and size. Now that it is time to study the basics of digital color, we search for another childhood memory to get us started. Remember finger painting? By mixing three "primary" colors, any color could be generated. Swirling all colors together resulted in a muddy brown. The more paint you added, the darker it got.

Digital colors are also constructed by mixing three primary colors, but it works differently from paint. First, the primaries are different: red, green, and blue (i.e., "RGB" color). And with color on the screen, you are mixing light, not paint, so the mixing rules are different as well.

• Red	+	green			=	yellow
• Red	+	blue			=	purple
• Green	+	blue			=	cyan (blue-green)
• Red	+	green	+	blue	=	white
• No colors					=	black

This assumes that the colors are all as bright as possible, but of course, you have a range of color available, so some red plus some green plus some blue equals gray, and a bit of red plus a bit of blue equals dark purple.

While this may take some getting used to, the more you program and experiment with RGB color, the more it will become instinctive, much like swirling colors with your fingers. And of course you can't say "Mix some red with a bit of blue," you have to provide an exact amount. As with grayscale, the individual color elements are expressed as ranges from 0 (none of that color) to 255 (as much as possible), and they are listed in the order R, G, and B. You will get the hang of RGB color mixing through experimentation, but next we will cover some code using some common colors.

Note that this book will only show you black and white versions of each *Processing* sketch, but everything is documented online in full color at *http://www.learningprocessing.com* with RGB color diagrams found specifically at: *http://learningprocessing.com/color*.

Example 1-3: RGB color

```
background(255);
noStroke();

fill(255,0,0);
ellipse(20,20,16,16);

fill(127,0,0);
ellipse(40,20,16,16);

fill(255,200,200);
ellipse(60,20,16,16);
```

Bright red

Dark red

Pink (pale red).

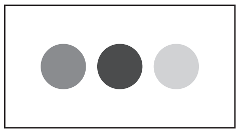


fig. 1.18

Processing also has a color selector to aid in choosing colors. Access this via TOOLS (from the menu bar) → COLOR SELECTOR. See Figure 1.19.

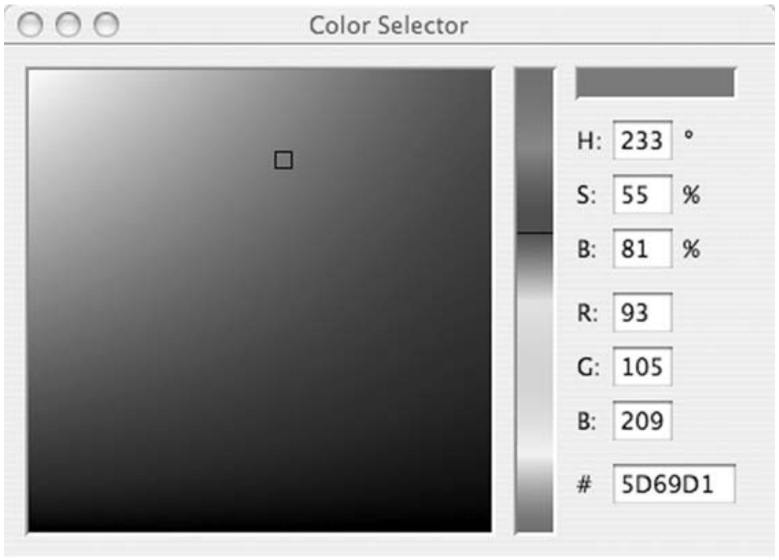


fig. 1.19

Exercise 1-5: Complete the following program. Guess what RGB values to use (you will be able to check your results in Processing *after reading the next chapter). You could also use the color selector, shown in Figure 1.19.*

```
fill(________,________,________);     Bright blue
ellipse(20,40,16,16);

fill(________,________,________);     Dark purple
ellipse(40,40,16,16);

fill(________,________,________);     Yellow
ellipse(60,40,16,16);
```

Exercise 1-6: What color will each of the following lines of code generate?

```
fill(0,100,0);          ______________________________
fill(100);              ______________________________
stroke(0,0,200);        ______________________________
stroke(225);            ______________________________
stroke(255,255,0);      ______________________________
stroke(0,255,255);      ______________________________
stroke(200,50,50);      ______________________________
```

1.5 Color Transparency

In addition to the red, green, and blue components of each color, there is an additional optional fourth component, referred to as the color's "alpha." Alpha means transparency and is particularly useful when you want to draw elements that appear partially see-through on top of one another. The alpha values for an image are sometimes referred to collectively as the "alpha channel" of an image.

It is important to realize that pixels are not literally transparent, this is simply a convenient illusion that is accomplished by blending colors. Behind the scenes, *Processing* takes the color numbers and adds a percentage of one to a percentage of another, creating the optical perception of blending. (If you are interested in programming "rose-colored" glasses, this is where you would begin.)

Alpha values also range from 0 to 255, with 0 being completely transparent (i.e., 0% opaque) and 255 completely opaque (i.e., 100% opaque). Example 1-4 shows a code example that is displayed in Figure 1.20.

Example 1-4: Alpha transparency

```
background(0);
noStroke();

fill(0,0,255);          // No fourth argument means 100% opacity.
rect(0,0,100,200);

fill(255,0,0,255);      // 255 means 100% opacity.
rect(0,0,200,40);

fill(255,0,0,191);      // 75% opacity
rect(0,50,200,40);

fill(255,0,0,127);      // 50% opacity
rect(0,100,200,40);

fill(255,0,0,63);       // 25% opacity
rect(0,150,200,40);
```

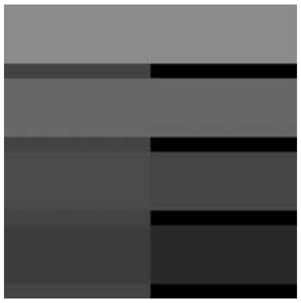


fig. 1.20

1.6 Custom Color Ranges

RGB color with ranges of 0 to 255 is not the only way you can handle color in *Processing*. Behind the scenes in the computer's memory, color is *always* talked about as a series of 24 bits (or 32 in the case of colors with an alpha). However, *Processing* will let us think about color any way we like, and translate our values into numbers the computer understands. For example, you might prefer to think of color as ranging from 0 to 100 (like a percentage). You can do this by specifying a custom ***colorMode()***.

```
colorMode(RGB,100);
```

With ***colorMode( )*** you can set your own color range.

The above function says: "OK, we want to think about color in terms of red, green, and blue. The range of RGB values will be from 0 to 100."

Although it is rarely convenient to do so, you can also have different ranges for each color component:

```
colorMode(RGB,100,500,10,255);
```

Now we are saying "Red values go from 0 to 100, green from 0 to 500, blue from 0 to 10, and alpha from 0 to 255."

Finally, while you will likely only need RGB color for all of your programming needs, you can also specify colors in the HSB (hue, saturation, and brightness) mode. Without getting into too much detail, HSB color works as follows:

- **Hue**—The color type, ranges from 0 to 360 by default (think of 360° on a color "wheel").
- **Saturation**—The vibrancy of the color, 0 to 100 by default.
- **Brightness**—The, well, brightness of the color, 0 to 100 by default.

Exercise 1-7: Design a creature using simple shapes and colors. Draw the creature by hand using only points, lines, rectangles, and ellipses. Then attempt to write the code for the creature, using the Processing *commands covered in this chapter:* ***point(), lines(), rect(), ellipse(), stroke()****, and* ***fill()****. In the next chapter, you will have a chance to test your results by running your code in* Processing.

Example 1-5 shows my version of Zoog, with the outputs shown in Figure 1.21.

Example 1-5: Zoog

```
ellipseMode(CENTER);
rectMode(CENTER);
stroke(0);
fill(150);
rect(100,100,20,100);
fill(255);
ellipse(100,70,60,60);
fill(0);
ellipse(81,70,16,32);
ellipse(119,70,16,32);
stroke(0);
line(90,150,80,160);
line(110,150,120,160);
```

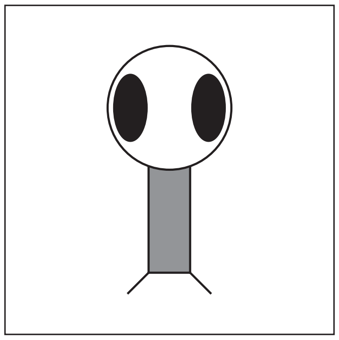


fig. 1.21

The sample answer is my *Processing*-born being, named Zoog. Over the course of the first nine chapters of this book, we will follow the course of Zoog's childhood. The fundamentals of programming will be demonstrated as Zoog grows up. We will first learn to display Zoog, then to make an interactive Zoog and animated Zoog, and finally to duplicate Zoog in a world of many Zoogs.

I suggest you design your own "thing" (note that there is no need to limit yourself to a humanoid or creature-like form; any programmatic pattern will do) and recreate all of the examples throughout the first nine chapters with your own design. Most likely, this will require you to only change a small portion (the shape rendering part) of each example. This process, however, should help solidify your understanding of the basic elements required for computer programs—Variables, Conditionals, Loops, Functions, Objects, and Arrays—and prepare you for when Zoog matures, leaves the nest, and ventures off into the more advanced topics from Chapter 10 on in this book.

2 Processing

"Computers in the future may weigh no more than 1.5 tons."
—Popular Mechanics, 1949

"Take me to your leader."
—Zoog, 2008

In this chapter:
– Downloading and installing *Processing*.
– Menu options.
– A *Processing* "sketchbook."
– Writing code.
– Errors.
– The *Processing* reference.
– The "Play" button.
– Your first sketch.
– Publishing your sketch to the web.

2.1 *Processing* to the Rescue

Now that we conquered the world of primitive shapes and RGB color, we are ready to implement this knowledge in a real world programming scenario. Happily for us, the environment we are going to use is *Processing*, free and open source software developed by Ben Fry and Casey Reas at the MIT Media Lab in 2001. (See this book's introduction for more about *Processing*'s history.)

Processing's core library of functions for drawing graphics to the screen will provide for immediate visual feedback and clues as to what the code is doing. And since its programming language employs all the same principles, structures, and concepts of other languages (specifically Java), everything you learn with *Processing* is *real* programming. It is not some pretend language to help you get started; it has all the fundamentals and core concepts that all languages have.

After reading this book and learning to program, you might continue to use *Processing* in your academic or professional life as a prototyping or production tool. You might also take the knowledge acquired here and apply it to learning other languages and authoring environments. You may, in fact, discover that programming is not your cup of tea; nonetheless, learning the basics will help you become a better-informed technology citizen as you work on collaborative projects with other designers and programmers.

It may seem like overkill to emphasize the *why* with respect to *Processing*. After all, the focus of this book is primarily on learning the fundamentals of computer programming in the context of computer graphics and design. It is, however, important to take some time to ponder the reasons behind selecting a programming language for a book, a class, a homework assignment, a web application, a software suite, and so forth. After all, now that you are going to start calling yourself a computer programmer at cocktail parties, this question will come up over and over again. I need programming in order to accomplish project *X*, what language and environment should I use?

I say, without a shadow of doubt, that for you, the beginner, the answer is *Processing*. Its simplicity is ideal for a beginner. At the end of this chapter, you will be up and running with your first computational design and ready to learn the fundamental concepts of programming. But simplicity is not where *Processing* ends. A trip through the *Processing* online exhibition (*http://processing.org/exhibition/*) will uncover a wide variety of beautiful and innovative projects developed entirely with *Processing*. By the end of this book, you will have all the tools and knowledge you need to take your ideas and turn them into real world software projects like those found in the exhibition. *Processing* is great both for learning and for producing, there are very few other environments and languages you can say that about.

2.2 How do I get *Processing?*

For the most part, this book will assume that you have a basic working knowledge of how to operate your personal computer. The good news, of course, is that *Processing* is available for free download. Head to *http://www.processing.org/* and visit the download page. If you are a Windows user, you will see two options: "Windows (standard)" and "Windows (expert)." Since you are reading this book, it is quite likely you are a beginner, in which case you will want the standard version. The expert version is for those who have already installed Java themselves. For Mac OS X, there is only one download option. There is also a Linux version available. Operating systems and programs change, of course, so if this paragraph is obsolete or out of date, visit the download page on the site for information regarding what you need.

The *Processing* software will arrive as a compressed file. Choose a nice directory to store the application (usually "c:\Program Files\" on Windows and in "Applications" on Mac), extract the files there, locate the "Processing" executable, and run it.

Exercise 2-1: Download and install Processing.

2.3 The *Processing* Application

The *Processing* development environment is a simplified environment for writing computer code, and is just about as straightforward to use as simple text editing software (such as TextEdit or Notepad) combined with a media player. Each sketch (*Processing* programs are referred to as "sketches") has a filename, a place where you can type code, and some buttons for saving, opening, and running sketches. See Figure 2.1.

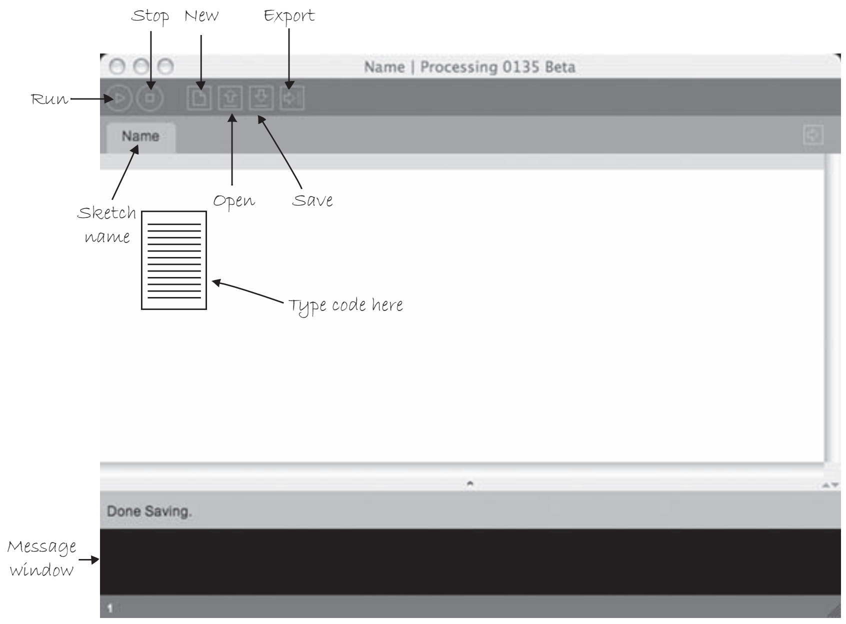


fig. 2.1

To make sure everything is working, it is a good idea to try running one of the *Processing* examples. Go to FILE → EXAMPLES → (pick an example, suggested: Topics → Drawing → ContinuousLines) as shown in Figure 2.2.

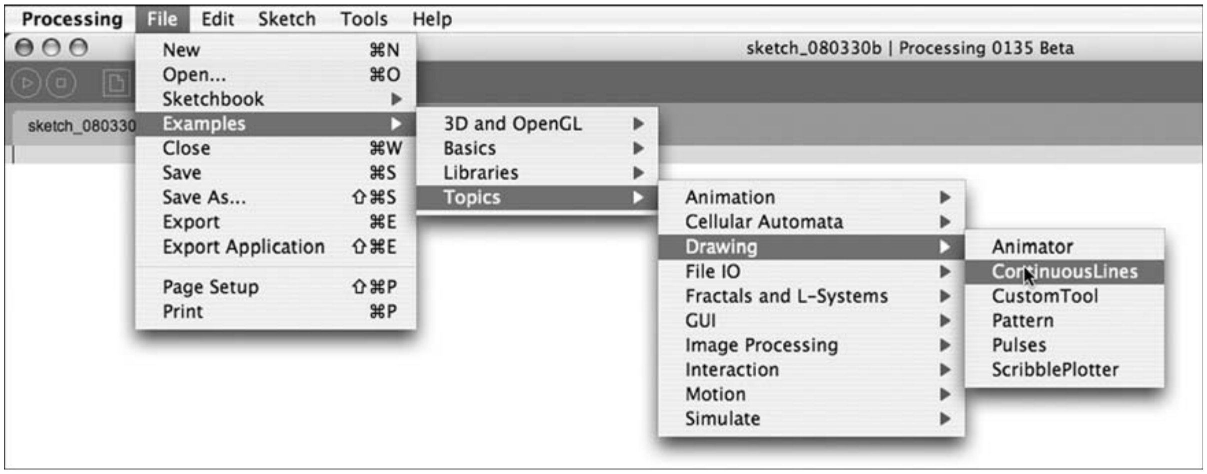


fig. 2.2

Once you have opened the example, click the "run" button as indicated in Figure 2.3. If a new window pops open running the example, you are all set! If this does not occur, visit the online FAQ "Processing won't start!" for possible solutions. The page can be found at this direct link: *http://www.processing.org/faq/bugs.html#wontstart*.

Exercise 2-2: Open a sketch from the Processing *examples and run it.*

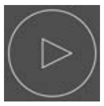


fig. 2.3

Processing programs can also be viewed full-screen (known as "present mode" in *Processing*). This is available through the menu option: Sketch → Present (or by shift-clicking the run button). Present will not resize your screen resolution. If you want the sketch to cover your entire screen, you must use your screen dimensions in ***size()***.

2.4 The Sketchbook

Processing programs are informally referred to as *sketches*, in the spirit of quick graphics prototyping, and we will employ this term throughout the course of this book. The folder where you store your sketches is called your "sketchbook." Technically speaking, when you run a sketch in *processing*, it runs as a local application on your computer. As we will see both in this Chapter and in Chapter 18, *Processing* also allows you to export your sketches as web applets (mini-programs that run embedded in a browser) or as platform-specific stand-alone applications (that could, for example, be made available for download).

Once you have confirmed that the *Processing* examples work, you are ready to start creating your own sketches. Clicking the "new" button will generate a blank new sketch named by date. It is a good idea to "Save as" and create your own sketch name. (Note: *Processing* does not allow spaces or hyphens, and your sketch name cannot start with a number.)

When you first ran *Processing*, a default "Processing" directory was created to store all sketches in the "My Documents" folder on Windows and in "Documents" on OS X. Although you can select any directory on your hard drive, this folder is the default. It is a pretty good folder to use, but it can be changed by opening the *Processing* preferences (which are available under the FILE menu).

Each *Processing* sketch consists of a folder (with the same name as your sketch) and a file with the extension "pde." If your *Processing* sketch is named *MyFirstProgram*, then you will have a folder named *MyFirstProgram* with a file *MyFirstProgram.pde* inside. The "pde" file is a plain text file that contains the source code. (Later we will see that *Processing* sketches can have multiple pde's, but for now one will do.) Some sketches will also contain a folder called "data" where media elements used in the program, such as image files, sound clips, and so on, are stored.

Exercise 2-3: Type some instructions from Chapter 1 into a blank sketch. Note how certain words are colored. Run the sketch. Does it do what you thought it would?

2.5 Coding in *Processing*

It is finally time to start writing some code, using the elements discussed in Chapter 1. Let's go over some basic syntax rules. There are three kinds of statements we can write:

- Function calls
- Assignment operations
- Control structures

For now, every line of code will be a function call. See Figure 2.4. We will explore the other two categories in future chapters. Functions have a name, followed by a set of arguments enclosed in parentheses. Recalling Chapter 1, we used functions to describe how to draw shapes (we just called them "commands" or "instructions"). Thinking of a function call as a natural language sentence, the function name is the verb ("draw") and the arguments are the objects ("point 0,0") of the sentence. Each function call must always end with a semicolon. See Figure 2.5.

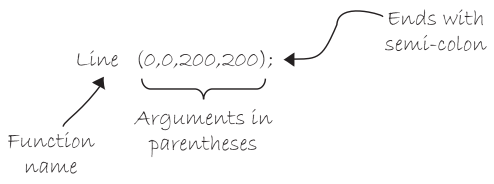


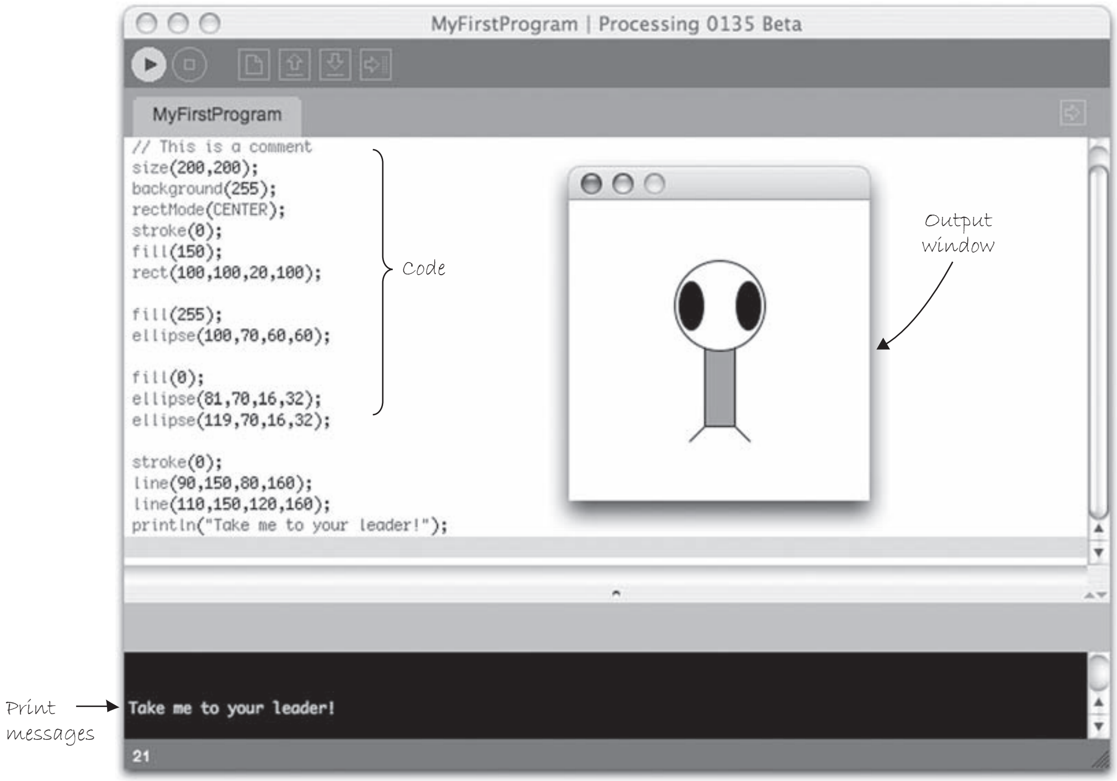
fig. 2.4

We have learned several functions already, including ***background(), stroke(), fill(), noFill (), noStroke(), point(), line(), rect(), ellipse(), rectMode(),*** and ***ellipseMode()***. *Processing* will execute a sequence of functions one by one and finish by displaying the drawn result in a window. We forgot to learn one very important function in Chapter 1, however—***size()***. ***size()*** specifies the dimensions of the window you want to create and takes two arguments, width and height. The ***size()*** function should always be first.

```
size(320,240);
```

Opens a window of width 320 and height 240.

Let's write a first example (see Figure 2.5).



```
// This is a comment
size(200,200);
background(255);
rectMode(CENTER);
stroke(0);
fill(150);
rect(100,100,20,100);

fill(255);
ellipse(100,70,60,60);

fill(0);
ellipse(81,70,16,32);
ellipse(119,70,16,32);

stroke(0);
line(90,150,80,160);
line(110,150,120,160);
println("Take me to your leader!");
```

```
Take me to your leader!
```

fig. 2.5

There are a few additional items to note.

- The *Processing* text editor will color *known* words (sometimes referred to as "reserved" words or "keywords"). These words, for example, are the drawing functions available in the *Processing* library, "built-in" variables (we will look closely at the concept of *variables* in Chapter 3) and constants, as well as certain words that are inherited from the Java programming language.
- Sometimes, it is useful to display text information in the *Processing* message window (located at the bottom). This is accomplished using the ***println()*** function. ***println()*** takes one argument, a *String* of characters enclosed in quotes (more about *Strings* in Chapter 14). When the program runs, *Processing* displays that *String* in the message window (as in Figure 2.5) and in this case the *String* is "Take me to your leader!" This ability to print to the message window comes in handy when attempting to *debug* the values of variables (see Chapter 12, Debugging).
- The number in the bottom left corner indicates what line number in the code is selected.
- You can write "comments" in your code. Comments are lines of text that *Processing* ignores when the program runs. You should use them as reminders of what the code means, a bug you intend to fix, or a to do list of items to be inserted, and so on. Comments on a single line are created with two forward slashes, //. Comments over multiple lines are marked by /* followed by the comments and ending with */.

```
// This is a comment on one line

/* This is a comment that
spans several lines
of code */
```

A quick word about comments. You should get in the habit right now of writing comments in your code. Even though our sketches will be very simple and short at first, you should put comments in for everything. Code is very hard to read and understand without comments. You do not need to have a comment for every line of code, but the more you include, the easier a time you will have revising and reusing your code later. Comments also force you to understand how code works as you are programming. If you do not know what you are doing, how can you write a comment about it?

Comments will not always be included in the text here. This is because I find that, unlike in an actual program, code comments are hard to read in a book. Instead, this book will often use code "hints" for additional insight and explanations. If you look at the book's examples on the web site, though, comments will always be included. So, I can't emphasize it enough, write comments!

```
//A comment about this code
line(0,0,100,100);
```

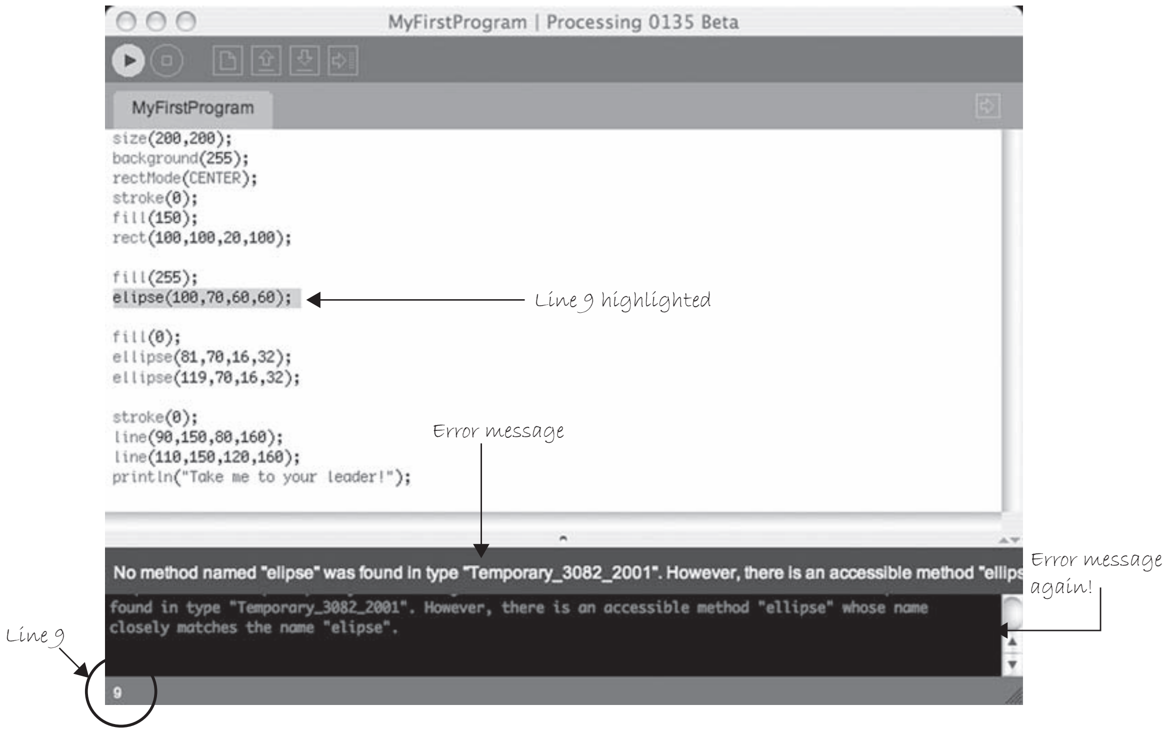
A hint about this code!

Exercise 2-4: Create a blank sketch. Take your code from the end of Chapter 1 and type it in the Processing *window. Add comments to describe what the code is doing. Add a* ***println()*** *statement to display text in the message window. Save the sketch. Press the "run" button. Does it work or do you get an error?*

2.6 Errors

The previous example only works because we did not make any errors or typos. Over the course of a programmer's life, this is quite a rare occurrence. Most of the time, our first push of the play button will not be met with success. Let's examine what happens when we make a mistake in our code in Figure 2.6.

Figure 2.6 shows what happens when you have a typo—"elipse" instead of "ellipse" on line 9. If there is an error in the code when the play button is pressed, *Processing* will not open the sketch window, and will instead display the error message. This particular message is fairly friendly, telling us that we probably meant to type "ellipse." Not all *Processing* error messages are so easy to understand, and we will continue to look at other errors throughout the course of this book. An Appendix on common errors in Processing is also included at the end of the book.



```
size(200,200);
background(255);
rectMode(CENTER);
stroke(0);
fill(150);
rect(100,100,20,100);

fill(255);
elipse(100,70,60,60);

fill(0);
ellipse(81,70,16,32);
ellipse(119,70,16,32);

stroke(0);
line(90,150,80,160);
line(110,150,120,160);
println("Take me to your leader!");
```

```
No method named "elipse" was found in type "Temporary_3082_2001". However, there is an accessible method "ellips
found in type "Temporary_3082_2001". However, there is an accessible method "ellipse" whose name
closely matches the name "elipse".
9
```

fig. 2.6

Processing ***is case sensitive!***

If you type *Ellipse* instead of *ellipse*, that will also be considered an error.

In this instance, there was only one error. If multiple errors occur, *Processing* will only alert you to the first one it finds (and presumably, once that error is corrected, the next error will be displayed at run time). This is somewhat of an unfortunate limitation, as it is often useful to have access to an entire list of errors when fixing a program. This is simply one of the trade-offs we get in a simplified environment such as *Processing*. Our life is made simpler by only having to look at one error at a time, nevertheless we do not have access to a complete list.

This fact only further emphasizes the importance of incremental development discussed in the book's introduction. If we only implement one feature at a time, we can only make one mistake at a time.

Exercise 2-5: Try to make some errors happen on purpose. Are the error messages what you expect?

Exercise 2-6: Fix the errors in the following code.

```
size(200,200);       ______________________________

background();        ______________________________

stroke 255;          ______________________________

fill(150)            ______________________________

rectMode(center);    ______________________________

rect(100,100,50);    ______________________________
```

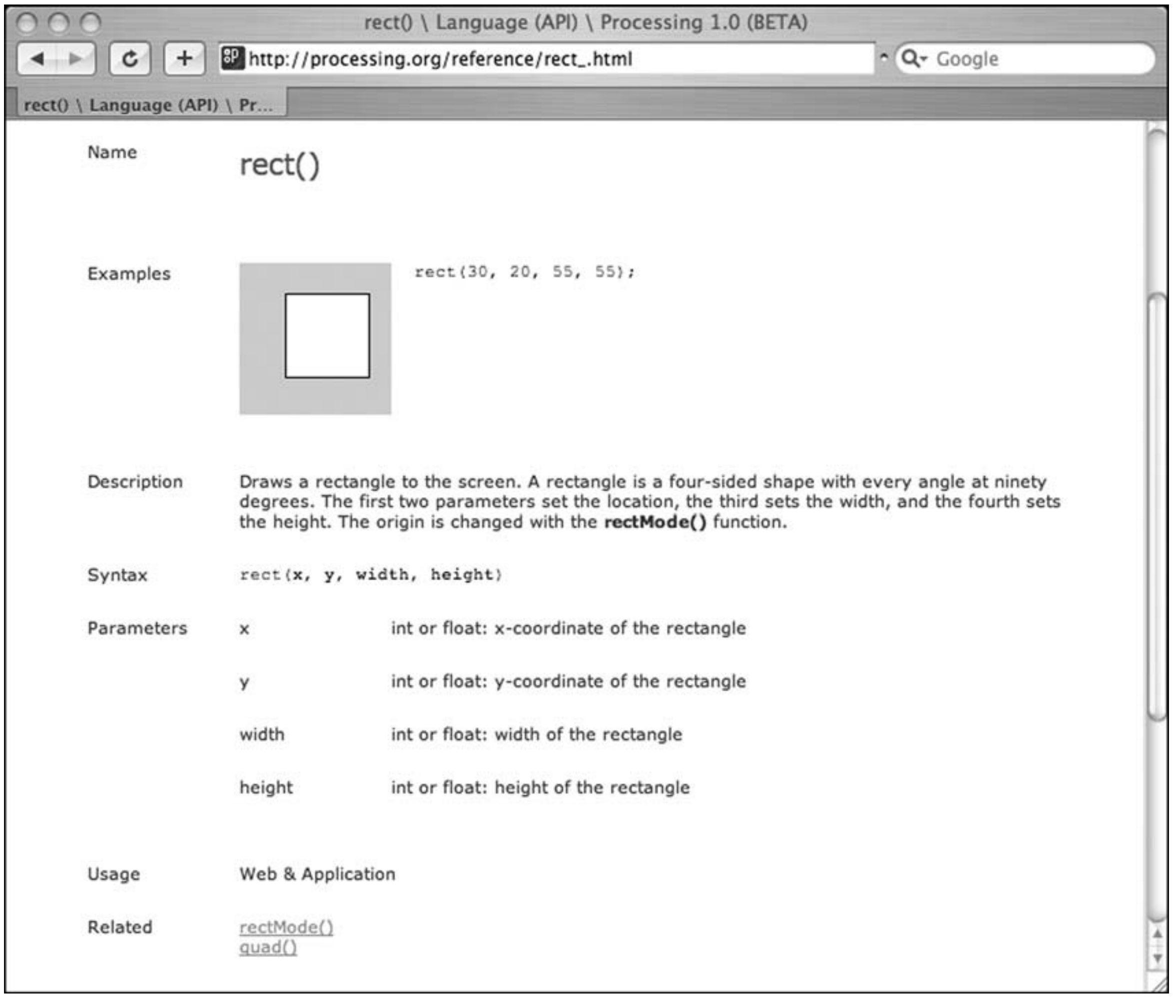
2.7 The *Processing* Reference

The functions we have demonstrated—***ellipse(), line(), stroke(),*** and so on—are all part of *Processing*'s library. How do we know that "ellipse" isn't spelled "elipse", or that ***rect()*** takes four arguments (an "*x* coordinate," a "*y* coordinate," a "width," and a "height")? A lot of these details are intuitive, and this speaks to the strength of *Processing* as a beginner's programming language. Nevertheless, the only way to know for sure is by reading the online reference. While we will cover many of the elements from the reference throughout this book, it is by no means a substitute for the reference and both will be required for you to learn *Processing*.

The reference for *Processing* can be found online at the official web site (*http://www.processing.org*) under the "reference" link. There, you can browse all of the available functions by category or alphabetically. If you were to visit the page for ***rect()***, for example, you would find the explanation shown in Figure 2.7.

As you can see, the reference page offers full documentation for the function ***rect()***, including:

- **Name**—The name of the function.
- **Examples**—Example code (and visual result, if applicable).
- **Description**—A friendly description of what the function does.
- **Syntax**—Exact syntax of how to write the function.
- **Parameters**—These are the elements that go inside the parentheses. It tells you what kind of data you put in (a number, character, etc.) and what that element stands for. (This will become clearer as we explore more in future chapters.) These are also sometimes referred to as "arguments."
- **Returns**—Sometimes a function sends something back to you when you call it (e.g., instead of asking a function to perform a task such as draw a circle, you could ask a function to add two numbers and *return* the answer to you). Again, this will become more clear later.
- **Usage**—Certain functions will be available for *Processing* applets that you publish online ("Web") and some will only be available as you run *Processing* locally on your machine ("Application").
- **Related Methods**—A list of functions often called in connection with the current function. Note that "functions" in Java are often referred to as "methods." More on this in Chapter 6.


rect() \ Language (API) \ Processing 1.0 (BETA)

http://processing.org/reference/rect_.html

Name rect()

Examples

```
rect(30, 20, 55, 55);
```

Description Draws a rectangle to the screen. A rectangle is a four-sided shape with every angle at ninety degrees. The first two parameters set the location, the third sets the width, and the fourth sets the height. The origin is changed with the **rectMode()** function.

Syntax `rect(x, y, width, height)`

Parameters	x	int or float: x-coordinate of the rectangle
	y	int or float: y-coordinate of the rectangle
	width	int or float: width of the rectangle
	height	int or float: height of the rectangle

Usage Web & Application

Related rectMode()
quad()

fig. 2.7

Processing also has a very handy "find in reference" option. Double-click on any keyword to select it and go to to HELP → FIND IN REFERENCE (or select the keyword and hit SHIFT+CNTRL+F).

Exercise 2-7: Using the Processing *reference, try implementing two functions that we have not yet covered in this book. Stay within the "Shape" and "Color (setting)" categories.*

Exercise 2-8: Using the reference, find a function that allows you to alter the thickness of a line. What arguments does the function take? Write example code that draws a line one pixel wide, then five pixels wide, then 10 pixels wide.

2.8 The "Play" Button

One of the nice qualities of *Processing* is that all one has to do to run a program is press the "play" button. It is a nice metaphor and the assumption is that we are comfortable with the idea of *playing* animations, movies, music, and other forms of media. *Processing* programs output media in the form of real-time computer graphics, so why not just *play* them too?

Nevertheless, it is important to take a moment and consider the fact that what we are doing here is not the same as what happens on an iPod or TiVo. *Processing* programs start out as text, they are translated into machine code, and then executed to run. All of these steps happen in sequence when the play button is pressed. Let's examine these steps one by one, relaxed in the knowledge that *Processing* handles the hard work for us.

Step 1. Translate to Java. *Processing* is really Java (this will become more evident in a detailed discussion in Chapter 23). In order for your code to run on your machine, it must first be translated to Java code.

Step 2. Compile into Java byte code. The Java code created in Step 1 is just another text file (with the .java extension instead of .pde). In order for the computer to understand it, it needs to be translated into machine language. This translation process is known as compilation. If you were programming in a different language, such as C, the code would compile directly into machine language specific to your operating system. In the case of Java, the code is compiled into a special machine language known as Java byte code. It can run on different platforms (Mac, Windows, cellphones, PDAs, etc.) as long as the machine is running a "Java Virtual Machine." Although this extra layer can sometimes cause programs to run a bit slower than they might otherwise, being cross-platform is a great feature of Java. For more on how this works, visit http://java.sun.com or consider picking up a book on Java programming (after you have finished with this one).

Step 3. Execution. The compiled program ends up in a JAR file. A JAR is a Java archive file that contains compiled Java programs ("classes"), images, fonts, and other data files. The JAR file is executed by the Java Virtual Machine and is what causes the display window to appear.

2.9 Your First Sketch

Now that we have downloaded and installed *Processing*, understand the basic menu and interface elements, and have gotten familiar with the online reference, we are ready to start coding. As I briefly mentioned in Chapter 1, the first half of this book will follow one example that illustrates the foundational elements of programming: *variables, arrays, conditionals, loops, functions,* and *objects*. Other examples will be included along the way, but following just one will reveal how the basic elements behind computer programming build on each other.

The example will follow the story of our new friend Zoog, beginning with a static rendering with simple shapes. Zoog's development will include mouse interaction, motion, and cloning into a population of many Zoogs. While you are by no means required to complete every exercise of this book with your own alien form, I do suggest that you start with a design and after each chapter, expand the functionality of that design with the programming concepts that are explored. If you are at a loss for an idea, then just draw your own little alien, name it Gooz, and get programming! See Figure 2.8.

Example 2-1: Zoog again

```
size(200,200); // Set the size of the window
background(255); // Draw a black background
smooth();

// Set ellipses and rects to CENTER mode
ellipseMode(CENTER);
rectMode(CENTER);

// Draw Zoog's body
stroke(0);
fill(150);
rect(100,100,20,100);

// Draw Zoog's head
fill(255);
ellipse(100,70,60,60);

// Draw Zoog's eyes
fill(0);
ellipse(81,70,16,32);
ellipse(119,70,16,32);

// Draw Zoog's legs
stroke(0);
line(90,150,80,160);
line(110,150,120,160);
```

The function ***smooth()*** enables "anti-aliasing" which smooths the edges of the shapes. ***no smooth()*** disables anti-aliasing.

Zoog's body.

Zoog's head.

Zoog's eyes.

Zoog's legs.

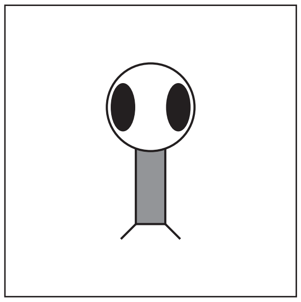


fig. 2.8

Let's pretend, just for a moment, that you find this Zoog design to be so astonishingly gorgeous that you just cannot wait to see it displayed on your computer screen. (Yes, I am aware this may require a fairly significant suspension of disbelief.) To run any and all code examples found in this book, you have two choices:

- Retype the code manually.
- Visit the book's web site (*http://www.learningprocessing.com*), find the example by its number, and copy/paste (or download) the code.

Certainly option #2 is the easier and less time-consuming one and I recommend you use the site as a resource for seeing sketches running in real-time and grabbing code examples. Nonetheless, as you start learning, there is real value in typing the code yourself. Your brain will sponge up the syntax and logic as you type and you will learn a great deal by making mistakes along the way. Not to mention simply running the sketch after entering each new line of code will eliminate any mystery as to how the sketch works.

You will know best when you are ready for copy/paste. Keep track of your progress and if you start running a lot of examples without feeling comfortable with how they work, try going back to manual typing.

*Exercise 2-9: Using what you designed in Chapter 1, implement your own screen drawing, using only 2D primitive shapes—**arc()**, **curve()**, **ellipse()**, **line()**, **point()**, **quad()**, **rect()**, **triangle()**—and basic color functions—**background()**, **colorMode()**, **fill()**, **noFill()**, **noStroke()**, and **stroke()**. Remember to use **size()** to specify the dimensions of your window. Suggestion: Play the sketch after typing each new line of code. Correct any errors or typos along the way.*

2.10 Publishing Your Program

After you have completed a *Processing* sketch, you can publish it to the web as a Java applet. This will become more exciting once we are making interactive, animated applets, but it is good to practice with a simple example. Once you have finished Exercise 2-9 and determined that your sketch works, select FILE → EXPORT.

Note that if you have errors in your program, it will not export properly, so always test by running first!

A new directory named "applet" will be created in the sketch folder and displayed, as shown in Figure 2.9.

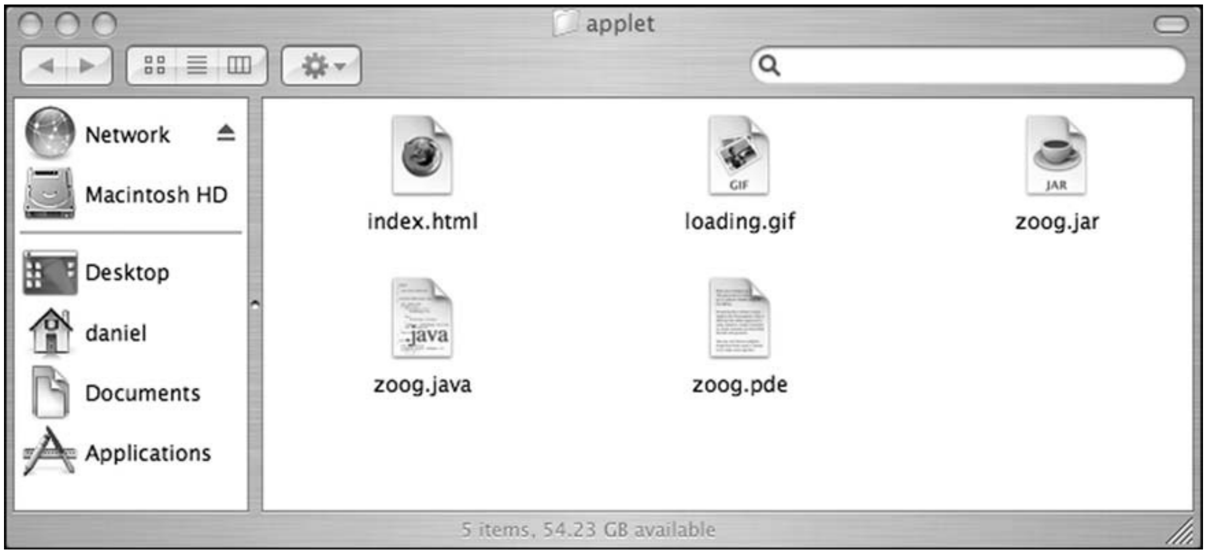
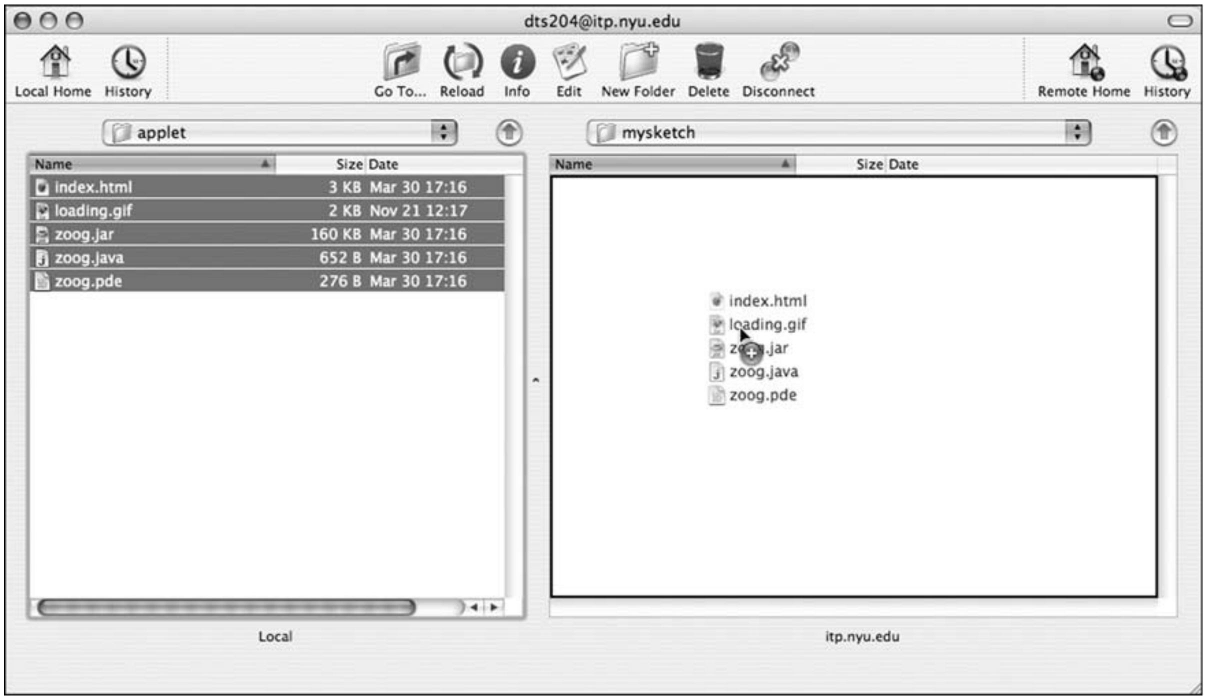


fig. 2.9

You now have the necessary files for publishing your applet to the web.

- **index.html**—The HTML source for a page that displays the applet.
- **loading.gif**—An image to be displayed while the user loads the applet (*Processing* will supply a default one, but you can create your own).
- **zoog.jar**—The compiled applet itself.
- **zoog.java**—The translated Java source code (looks like your *Processing* code, but has a few extra things that Java requires. See Chapter 20 for details.)
- **zoog.pde**—Your *Processing* source.

To see the applet working, double-click the "index.html" file which should launch a page in your default web browser. See Figure 2.10. To get the applet online, you will need web server space and FTP software (or you can also use a *Processing* sketch sharing site such as http://www.openprocessing.org). You can find some tips for getting started at this book's web site.



Name	Size	Date
index.html	3 KB	Mar 30 17:16
loading.gif	2 KB	Nov 21 12:17
zoog.jar	160 KB	Mar 30 17:16
zoog.java	652 B	Mar 30 17:16
zoog.pde	276 B	Mar 30 17:16

fig. 2.10

*Exercise 2-10: Export your sketch as an applet. View the sketch in the browser (either locally or by uploading).*0000200002

3 Interaction

"Always remember that this whole thing was started with a dream and a mouse."
—Walt Disney

"The quality of the imagination is to flow and not to freeze."
—Ralph Waldo Emerson

In this chapter:
– The "flow" of a program.
– The meaning behind ***setup()*** **and** ***draw()***.
– Mouse interaction.
– Your first "dynamic" *Processing* program.
– Handling events, such as mouse clicks and key presses.

3.1 Go with the flow.

If you have ever played a computer game, interacted with a digital art installation, or watched a screensaver at three in the morning, you have probably given very little thought to the fact that the software that runs these experiences happens over a *period of time*. The game starts, you save princess so-and-so from the evil lord who-zee-ma-whats-it, achieve a high score, and the game ends.

What I want to focus on in this chapter is that very "flow" over time. A game begins with a set of initial conditions: you name your character, you start with a score of zero, and you start on level one. Let's think of this part as the program's *SETUP*. After these conditions are initialized, you begin to play the game. At every instant, the computer checks what you are doing with the mouse, calculates all the appropriate behaviors for the game characters, and updates the screen to render all the game graphics. This cycle of calculating and drawing happens over and over again, ideally 30 or more times per second for a smooth animation. Let's think of this part as the program's *DRAW*.

This concept is crucial to our ability to move beyond static designs (as in Chapter 2) with *Processing*.

Step 1. Set starting conditions for the program one time.
Step 2. Do something over and over and over and over (and over …) again until the program quits.

Consider how you might go about running a race.

Step 1. Put on your sneakers and stretch. Just do this once, OK?
Step 2. Put your right foot forward, then your left foot. Repeat this over and over as fast as you can.
Step 3. After 26 miles, quit.

Exercise 3-1: In English, write out the "flow" for a simple computer game, such as Pong. If you are not familiar with Pong, visit: http://en.wikipedia.org/wiki/Pong.

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3.2 Our Good Friends, *setup()* and *draw()*

Now that we are good and exhausted from running marathons in order to better learn programming, we can take this newfound knowledge and apply it to our first "dynamic" *Processing* sketch. Unlike Chapter 2's static examples, this program will draw to the screen continuously (i.e., until the user quits). This is accomplished by writing two "blocks of code" ***setup()*** and ***draw()***. Technically speaking ***setup()*** and ***draw()*** are functions. We will get into a longer discussion of writing our own functions in a later chapter; for now, we understand them to be two sections where we write code.

What is a block of code?

A block of code is any code enclosed within curly brackets.

```
{
  A block of code
}
```

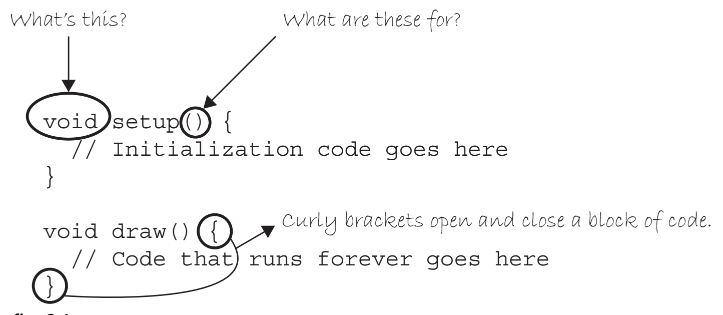
Blocks of code can be nested within each other, too.

```
{
  A block of code
  {
    A block inside a block of code
  }
}
```

This is an important construct as it allows us to separate and manage our code as individual pieces of a larger puzzle. A programming convention is to indent the lines of code within each block to make the code more readable. *Processing* will do this for you via the Auto-Format option (Tools → Auto-Format).

Blocks of code will reveal themselves to be crucial in developing more complex logic, in terms of *variables*, *conditionals*, *iteration*, *objects*, and *functions*, as discussed in future chapters. For now, we only need to look at two simple blocks: ***setup()*** and ***draw()***.

Let's look at what will surely be strange-looking syntax for ***setup()*** and ***draw()***. See Figure 3.1.

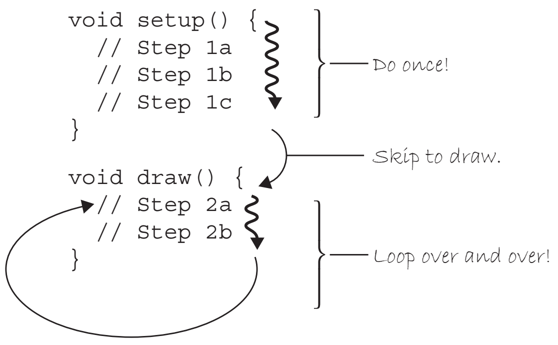

```
void setup() {
  // Initialization code goes here
}

void draw() {
  // Code that runs forever goes here
}
```

fig. 3.1

Admittedly, there is a lot of stuff in Figure 3.1 that we are not entirely ready to learn about. We have covered that the curly brackets indicate the beginning and end of a "block of code," but why are there parentheses after "setup" and "draw"? Oh, and, my goodness, what is this "void" all about? It makes me feel sad inside! For now, we have to decide to feel comfortable with not knowing everything all at once, and that these important pieces of syntax will start to make sense in future chapters as more concepts are revealed.

For now, the key is to focus on how Figure 3.1's structures control the flow of our program. This is shown in Figure 3.2.


```
void setup() {
  // Step 1a
  // Step 1b
  // Step 1c
}

void draw() {
  // Step 2a
  // Step 2b
}
```

fig. 3.2

How does it work? When we run the program, it will follow our instructions precisely, executing the steps in ***setup()*** first, and then move on to the steps in ***draw()***. The order ends up being something like:

1a, 1b, 1c, 2a, 2b, 2a, 2b, 2a, 2b, 2a, 2b, 2a, 2b, 2a, 2b …

Now, we can rewrite the Zoog example as a dynamic sketch. See Example 3–1.

Example 3-1: Zoog as dynamic sketch

```
void setup(){
  // Set the size of the window
  size(200,200);
}

void draw() {
  // Draw a white background
  background(255);

  // Set CENTER mode
  ellipseMode(CENTER);
  rectMode(CENTER);


  // Draw Zoog's body
  stroke(0);
  fill(150);
  rect(100,100,20,100);


  // Draw Zoog's head
  stroke(0);
  fill(255);
  ellipse(100,70,60,60);


  // Draw Zoog's eyes
  fill(0);
  ellipse(81,70,16,32);
  ellipse(119,70,16,32);


  // Draw Zoog's legs
  stroke(0);
  line(90,150,80,160);
  line(110,150,120,160);
}
```

setup() runs first one time. ***size()*** should always be first line of ***setup()*** since *Processing* will not be able to do anything before the window size if specified.

draw() loops continuously until you close the sketch window.

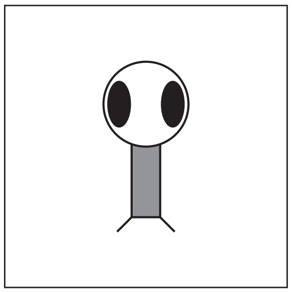


fig. 3.3

Take the code from Example 3-1 and run it in *Processing*. Strange, right? You will notice that nothing in the window changes. This looks identical to a *static* sketch! What is going on? All this discussion for nothing?

Well, if we examine the code, we will notice that nothing in the ***draw()*** function *varies*. Each time through the loop, the program cycles through the code and executes the identical instructions. So, yes, the program is running over time redrawing the window, but it looks static to us since it draws the same thing each time!

Exercise 3-2: Redo the drawing you created at the end of Chapter 2 as a dynamic program. Even though it will look the same, feel good about your accomplishment!

3.3 Variation with the Mouse

Consider this. What if, instead of typing a number into one of the drawing functions, you could type "the mouse's *X* location" or "the mouse's *Y* location."

```
line(the mouse's X location, the mouse's Y location, 100, 100);
```

In fact, you can, only instead of the more descriptive language, you must use the keywords ***mouseX*** and ***mouseY***, indicating the horizontal or vertical position of the mouse cursor.

Example 3-2: *mouseX* and *mouseY*

```
void setup() {
  size(200,200);
}

void draw() {
  background(255);

  // Body
  stroke(0);
  fill(175);
  rectMode(CENTER);
  rect(mouseX,mouseY,50,50);
}
```

Try moving ***background()*** to ***setup()*** and see the difference! (Exercise 3–3)

mouseX is a keyword that the sketch replaces with the horizontal position of the mouse.
mouseY is a keyword that the sketch replaces with the vertical position of the mouse.

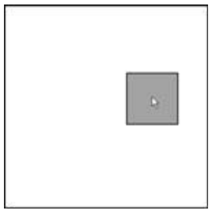
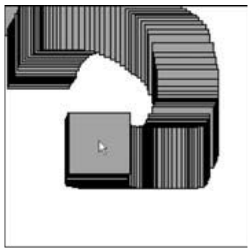


fig. 3.4

Exercise 3-3: Explain why we see a trail of rectangles if we move ***background()*** *to* ***setup()****, leaving it out of* ***draw()****.*



An Invisible Line of Code

If you are following the logic of ***setup()*** and ***draw()*** closely, you might arrive at an interesting question: *When does* Processing *actually display the shapes in the window? When do the new pixels appear?*

On first glance, one might assume the display is updated for every line of code that includes a drawing function. If this were the case, however, we would see the shapes appear onscreen one at a time. This would happen so fast that we would hardly notice each shape appearing individually. However, when the window is erased every time ***background()*** is called, a somewhat unfortunate and unpleasant result would occur: flicker.

Processing solves this problem by updating the window only at the end of every cycle through ***draw()***. It is as if there were an invisible line of code that renders the window at the end of the ***draw()*** function.

```
void draw() {
  // All of your code
  // Update Display Window -- invisible line of code we don't see
}
```

This process is known as *double-buffering* and, in a lower-level environment, you may find that you have to implement it yourself. Again, we take the time to thank *Processing* for making our introduction to programming friendlier and simpler by taking care of this for us.

We could push this idea a bit further and create an example where a more complex pattern (multiple shapes and colors) is controlled by ***mouseX*** and ***mouseY*** position. For example, we can rewrite Zoog to follow the mouse. Note that Zoog's body is located at the exact location of the mouse (***mouseX, mouseY***), however, other parts of Zoog's body are drawn relative to the mouse. Zoog's head, for example, is located at (***mouseX, mouseY-30***). The following example only moves Zoog's body and head, as shown in Figure 3.5.

Example 3-3: Zoog as dynamic sketch with variation

```
void setup() {
  size(200,200); // Set the size of the window
  smooth();
}

void draw() {
  background(255); // Draw a white background

  // Set ellipses and rects to CENTER mode
  ellipseMode(CENTER);
  rectMode(CENTER);

  // Draw Zoog's body
  stroke(0);
  fill(175);
  rect(mouseX,mouseY,20,100);

  // Draw Zoog's head
  stroke(0);
  fill(255);
  ellipse(mouseX,mouseY-30,60,60);
```

Zoog's body is drawn at the location ***(mouseX, mouseY)***.

Zoog's head is drawn above the body at the location ***(mouseX, mouseY-30)***.

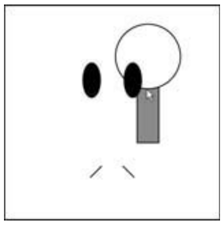


fig. 3.5

```
  // Draw Zoog's eyes
  fill(0);
  ellipse(81,70,16,32);
  ellipse(119,70,16,32);

  // Draw Zoog's legs
  stroke(0);
  line(90,150,80,160);
  line(110,150,120,160);
}
```

Exercise 3-4: Complete Zoog so that the rest of its body moves with the mouse.

```
// Draw Zoog's eyes
fill(0);
ellipse(_______,_______ ,16,32);
ellipse(_______,_______ ,16,32);

// Draw Zoog's legs
stroke(0);
line(_______,_______,_______,_______);
line(_______,_______,_______,_______);
```

Exercise 3-5: Recode your design so that shapes respond to the mouse (by varying color and location).

In addition to ***mouseX*** and ***mouseY***, you can also use ***pmouseX*** and ***pmouseY***. These two keywords stand for the "previous" mouse*X* and mouse*Y* locations, that is, where the mouse was the last time we cycled through ***draw()***. This allows for some interesting interaction possibilities. For example, let's consider what happens if we draw a line from the previous mouse location to the current mouse location, as illustrated in the diagram in Figure 3.6.

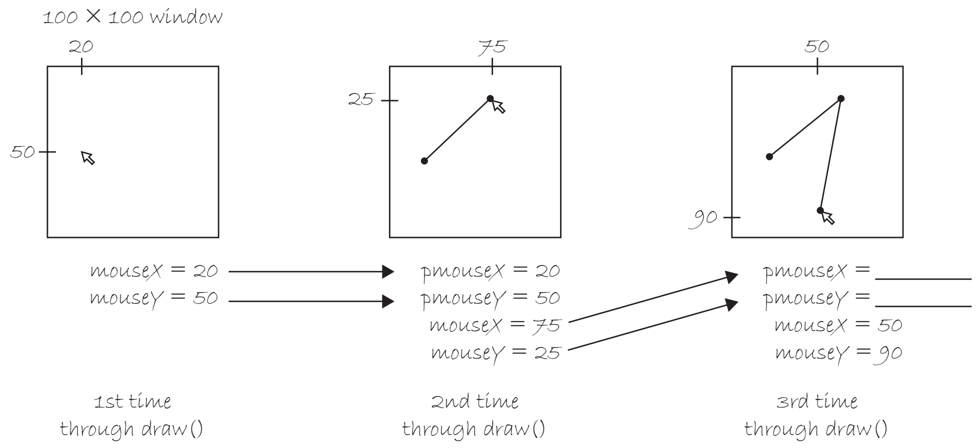


fig. 3.6

Exercise 3-6: Fill in the blank in Figure 3.6.

By connecting the previous mouse location to the current mouse location with a line each time through ***draw()***, we are able to render a continuous line that follows the mouse. See Figure 3.7.

Example 3-4: Drawing a continuous line

```
void setup() {
  size(200,200);
  background(255);
  smooth();
}

void draw() {
  stroke(0);
  line(pmouseX,pmouseY,mouseX,mouseY);
}
```

Draw a line from previous mouse location to current mouse location.

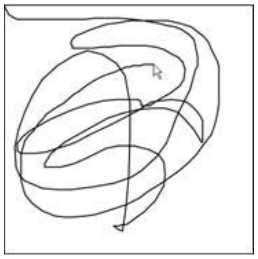


fig. 3.7

*Exercise 3-7: The formula for calculating the speed of the mouse's horizontal motion is the absolute value of the difference between **mouseX** and **pmouseX**. The absolute value of a number is defined as that number without its sign:*

- *The absolute value of –2 is 2.*
- *The absolute value of 2 is 2.*

In Processing, *we can get the absolute value of the number by placing it inside the **abs()** function, that is,*

- abs(−5) → 5

The speed at which the mouse is moving is therefore:

- abs(***mouseX-pmouseX***)

*Update Exercise 3-7 so that the faster the user moves the mouse, the wider the drawn line. Hint: look up s**trokeWeight()** in the* Processing *reference.*

```
stroke(255);
__________________________ (___________);
line(pmouseX,pmouseY,mouseX,mouseY);
```

3.4 Mouse Clicks and Key Presses

We are well on our way to creating dynamic, interactive *Processing* sketches through the use the ***setup()*** and ***draw()*** framework and the ***mouseX*** and ***mouseY*** keywords. A crucial form of interaction, however, is missing—clicking the mouse!

In order to learn how to have something happen when the mouse is clicked, we need to return to the flow of our program. We know ***setup()*** happens once and ***draw()*** loops forever. When does a mouse click occur? Mouse presses (and key presses) as considered *events* in *Processing*. If we want something to happen (such as "the background color changes to red") when the mouse is clicked, we need to add a third block of code to handle this event.

This event "function" will tell the program what code to execute when an event occurs. As with ***setup()***, the code will occur once and only once. That is, once and only once for each occurrence of the event. An event, such as a mouse click, can happen multiple times of course!

These are the two new functions we need:

- ***mousePressed()***—Handles mouse clicks.
- ***keyPressed()***—Handles key presses.

The following example uses both event functions, adding squares whenever the mouse is pressed and clearing the background whenever a key is pressed.

Example 3-5: *mousePressed()* and *keyPressed()*

```
void setup() {
  size(200,200);
  background(255);
}

void draw() {

}

void mousePressed() {
  stroke(0);
  fill(175);
  rectMode(CENTER);
  rect(mouseX,mouseY,16,16);
}

void keyPressed() {
  background(255);
}
```

Nothing happens in ***draw()*** in this example!

Whenever a user clicks the mouse the code written inside ***mousePressed()*** is executed.

Whenever a user presses a key the code written inside ***keyPressed()*** is executed.

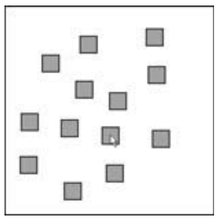


fig. 3.8

In Example 3-5, we have four functions that describe the program's flow. The program starts in ***setup()*** where the size and background are initialized. It continues into ***draw()***, looping endlessly. Since ***draw()*** contains no code, the window will remain blank. However, we have added two new functions: ***mousePressed()*** and

keyPressed(). The code inside these functions sits and waits. When the user clicks the mouse (or presses a key), it springs into action, executing the enclosed block of instructions once and only once.

*Exercise 3-8: Add "**background(255);**" to the **draw()** function. Why does the program stop working?*

We are now ready to bring all of these elements together for Zoog.

- Zoog's entire body will follow the mouse.
- Zoog's eye color will be determined by mouse location.
- Zoog's legs will be drawn from the previous mouse location to the current mouse location.
- When the mouse is clicked, a message will be displayed in the message window: "Take me to your leader!"

Note the addition in Example 3–6 of the function ***frameRate()***. ***frameRate()***, which requires an integer between 1 and 60, enforces the speed at which *Processing* will cycle through ***draw()***. ***frameRate (30)***, for example, means 30 frames per second, a traditional speed for computer animation. If you do not include ***frameRate()***, *Processing* will attempt to run the sketch at 60 frames per second. Since computers run at different speeds, ***frameRate()*** is used to make sure that your sketch is consistent across multiple computers.

This frame rate is just a maximum, however. If your sketch has to draw one million rectangles, it may take a long time to finish the draw cycle and run at a slower speed.

Example 3-6: Interactive Zoog

```
void setup() {
  // Set the size of the window

  size(200,200);
  smooth();
  frameRate(30);
}

void draw() {
  // Draw a black background
  background(255);

  // Set ellipses and rects to CENTER mode
  ellipseMode(CENTER);
  rectMode(CENTER);

  // Draw Zoog's body
  stroke(0);
  fill(175);
  rect(mouseX,mouseY,20,100);

  // Draw Zoog's head
  stroke(0);
  fill(255);
  ellipse(mouseX,mouseY-30,60,60);
```

The frame rate is set to 30 frames per second.

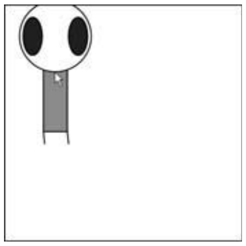


fig. 3.9

```
  // Draw Zoog's eyes
  fill(mouseX,0,mouseY);
  ellipse(mouseX-19,mouseY-30,16,32);
  ellipse(mouseX+19,mouseY-30,16,32);

  // Draw Zoog's legs
  stroke(0);
  line(mouseX-10,mouseY+50,pmouseX-10,pmouseY+60);
  line(mouseX+10,mouseY+50,pmouseX+10,pmouseY+60);
}

void mousePressed() {
  println("Take me to your leader!");
}
```

The eye color is determined by the mouse location.

The legs are drawn according to the mouse location *and the previous mouse location.*

Lesson One Project

(You may have completed much of this project already via the exercises in Chapters 1–3. This project brings all of the elements together. You could either start from scratch with a new design or use elements from the exercises.)

Step 1. Design a static screen drawing using RGB color and primitive shapes.

Step 2. Make the static screen drawing dynamic by having it interact with the mouse. This might include shapes following the mouse, changing their size according to the mouse, changing their color according to the mouse, and so on.

Use the space provided below to sketch designs, notes, and pseudocode for your project.

Lesson Two

Everything You Need to Know