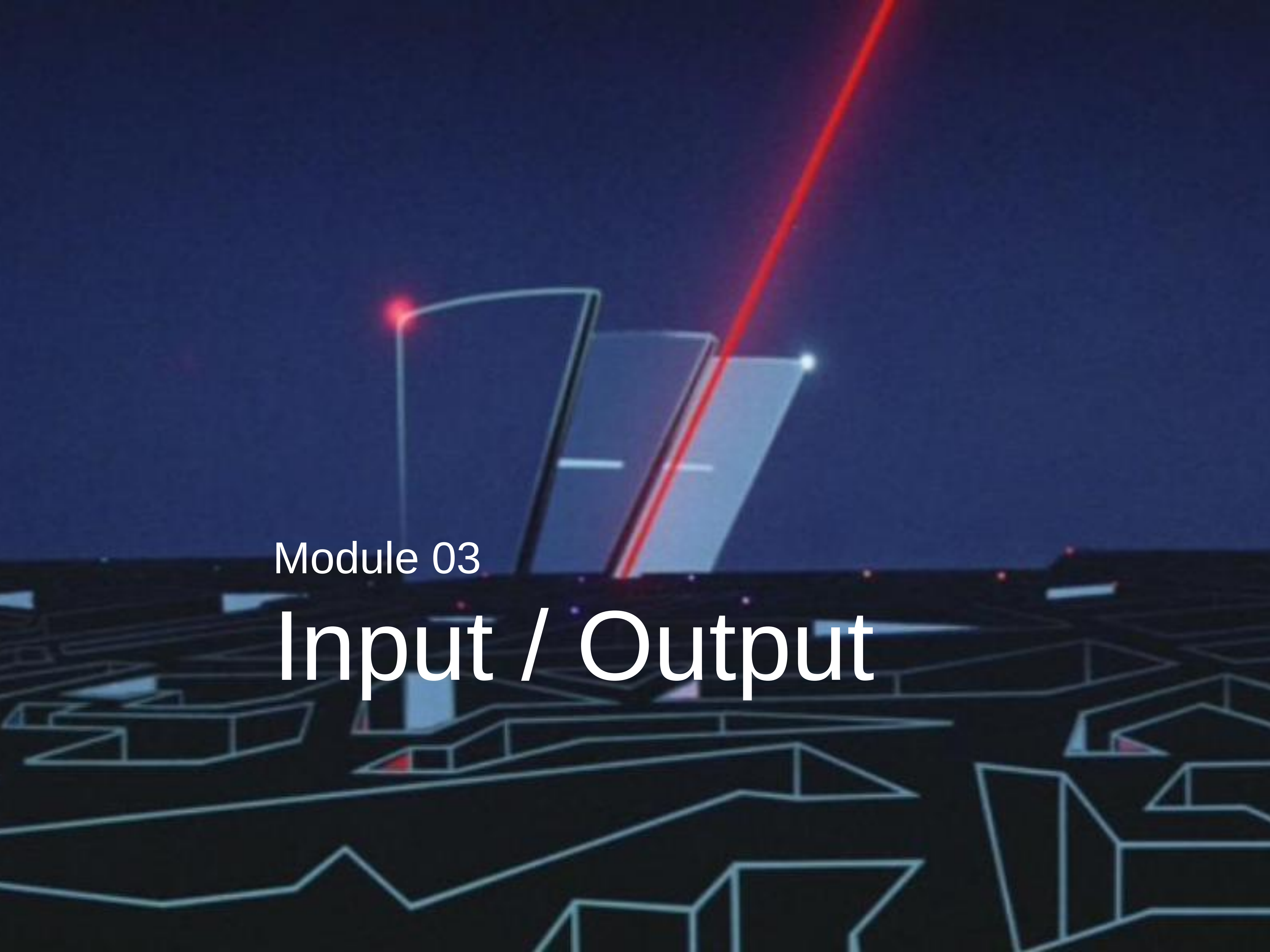
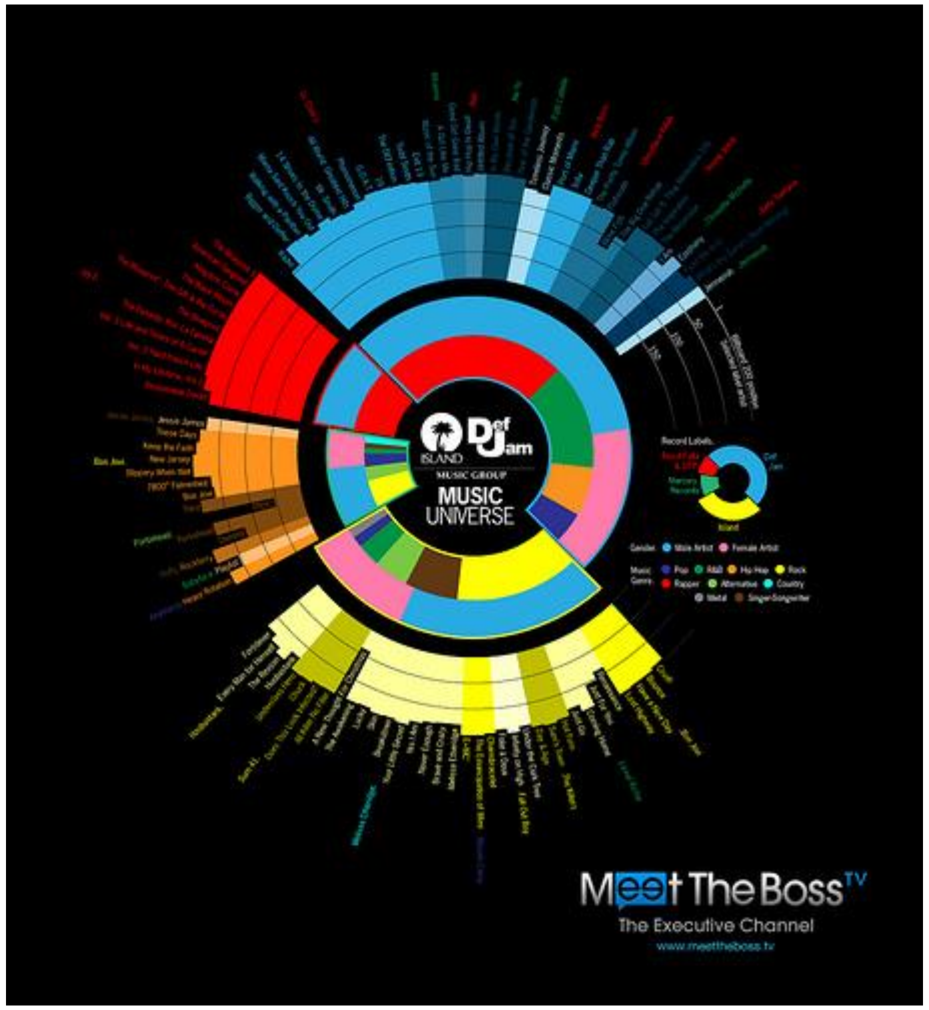


Module 03

Input / Output



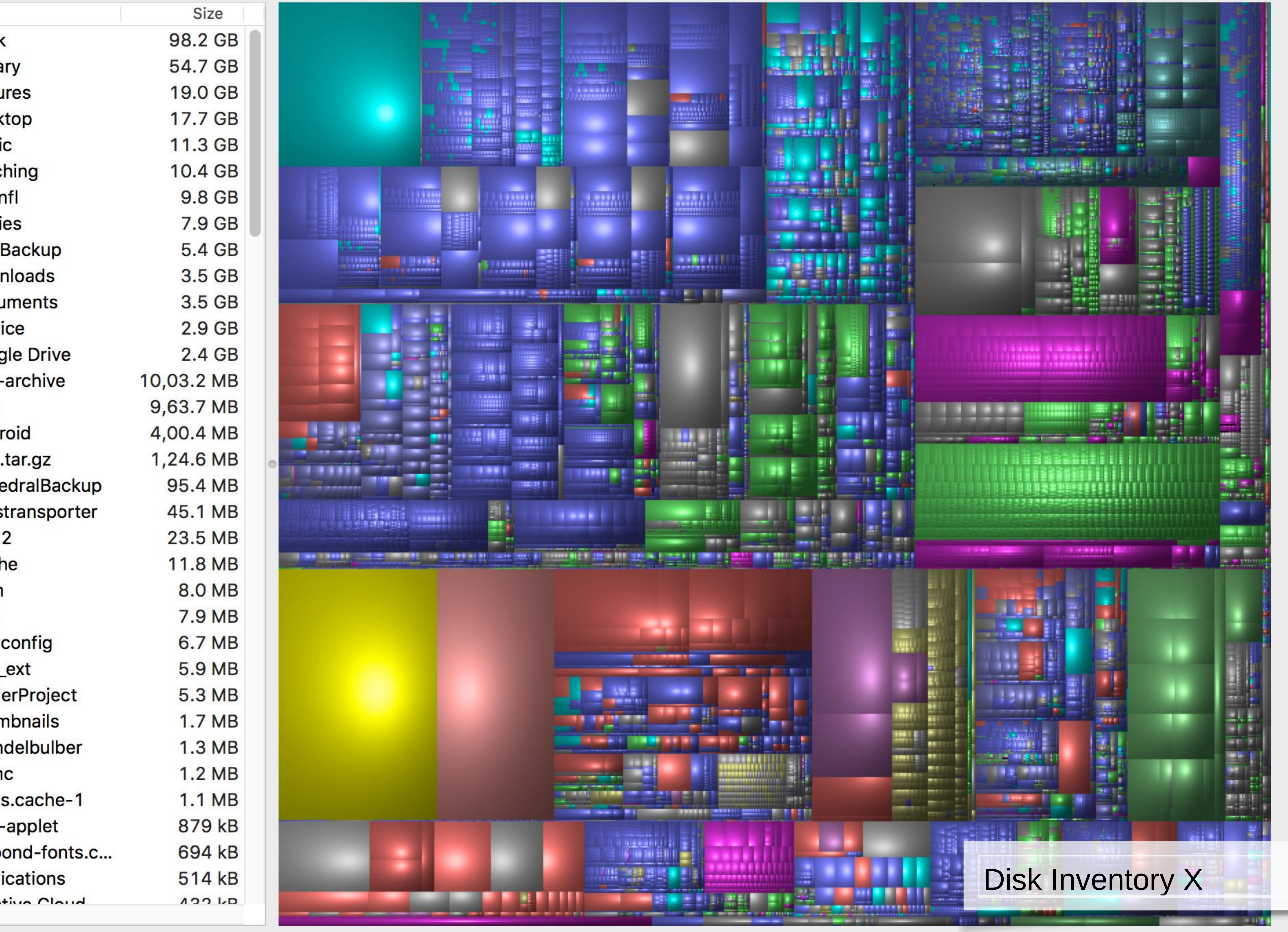
Data visualization

Procedural content

Workflow integration

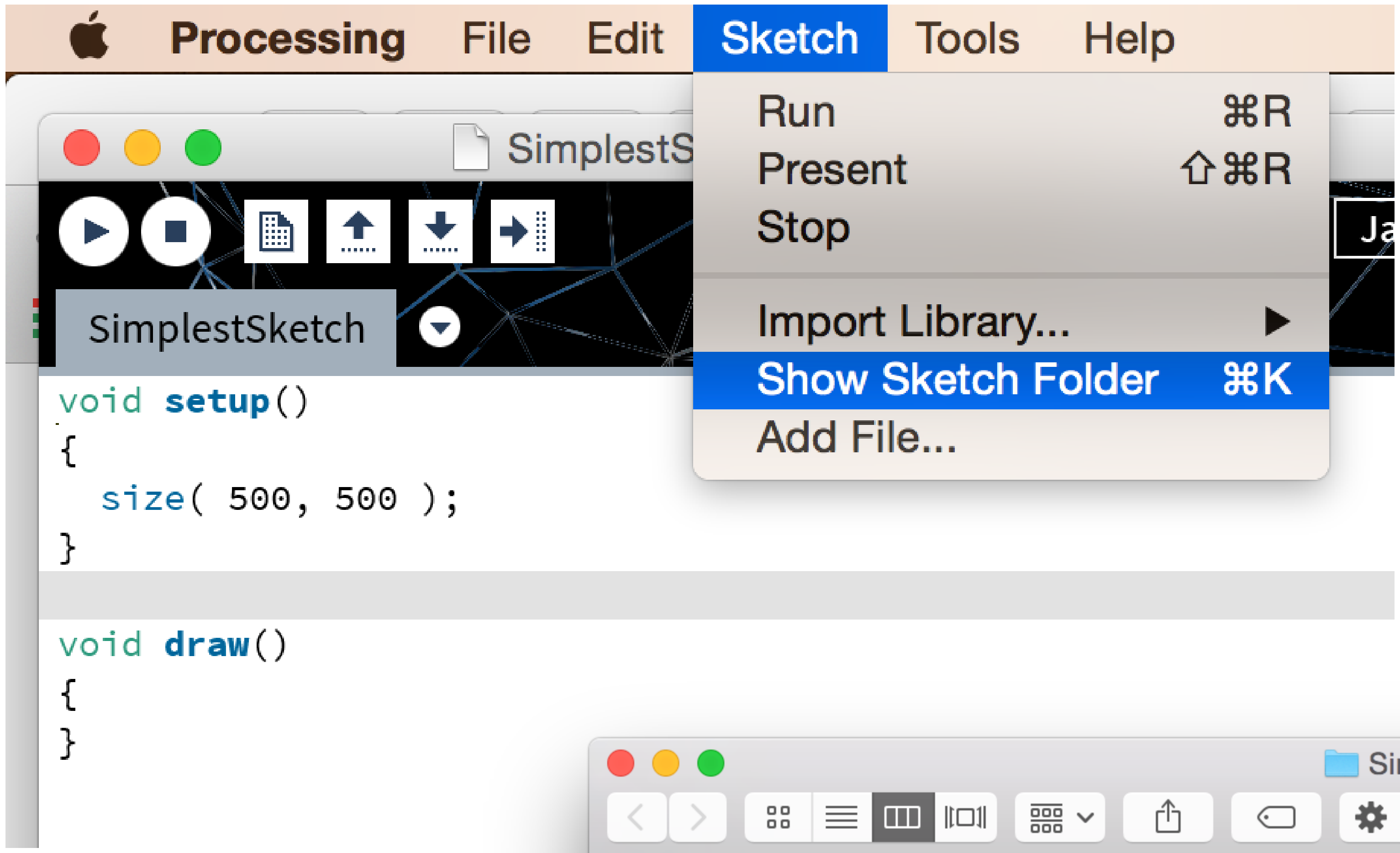
We can write more interesting programs when we can exchange information with the outside world.

Problem with the outside world: there’s a lot of it.



	Size
k	98.2 GB
ary	54.7 GB
ures	19.0 GB
ktop	17.7 GB
ic	11.3 GB
ching	10.4 GB
nfl	9.8 GB
ies	7.9 GB
Backup	5.4 GB
nloads	3.5 GB
uments	3.5 GB
ice	2.9 GB
gle Drive	2.4 GB
-archive	10,03.2 MB
	9,63.7 MB
roid	4,00.4 MB
.tar.gz	1,24.6 MB
edralBackup	95.4 MB
stransporter	45.1 MB
2	23.5 MB
he	11.8 MB
n	8.0 MB
	7.9 MB
config	6.7 MB
_ext	5.9 MB
erProject	5.3 MB
mbnails	1.7 MB
ndelbulber	1.3 MB
nc	1.2 MB
s.cache-1	1.1 MB
-applet	879 kB
oond-fonts.c...	694 kB
ications	514 kB
tive Cloud	432 kB

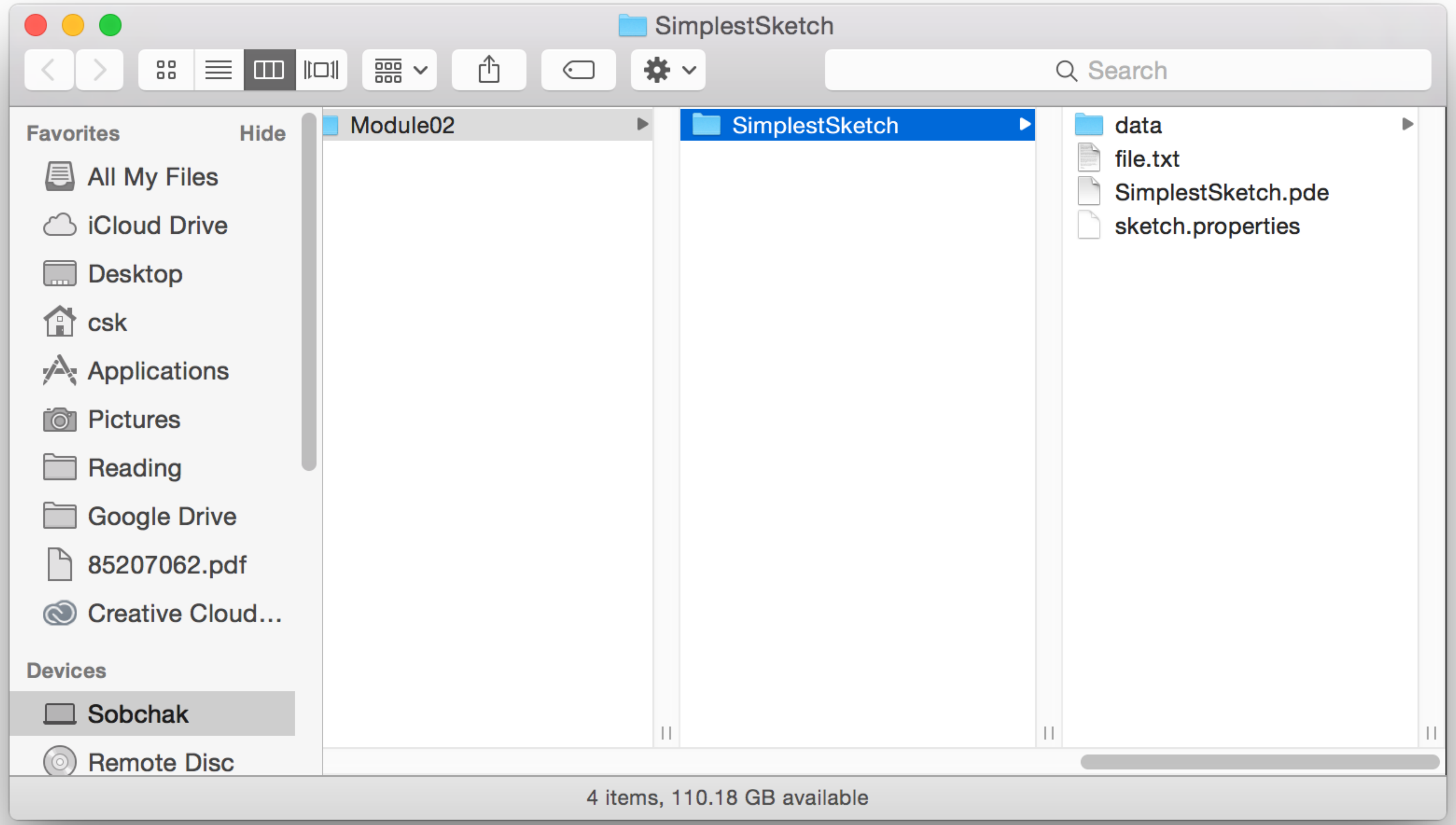
Disk Inventory X



```
void setup()
{
  size( 500, 500 );
}

void draw()
{
}
```

Use the **Sketch Folder** as a gateway to the outside world.



Use Sketch →Add File… to make a file available to your sketch, or drop the file into the sketch folder directly.

Any files created by the sketch will be left in the sketch folder.

1. Reading and writing images

```
PImage loadImage( String filename ) { ... }
```

A built-in function that takes the name of a file as a String parameter, finds that file in your sketch folder, and tries to import it as an image. Returns an object of type PImage.

High-level PImage operations

```
PImage img;

void setup() {
  size( 800, 800 );
  img = loadImage( “some_image.jpg" );
}

void draw() {
  background( 255 );
  imageMode( CORNER );
  noTint();
  image( img, 0, 0 );
  image( img, width - img.width, height - img.height );
  tint( 255, 120, 120 );
  imageMode( CENTER );
  image( img, width/2, height/2, 250, 250 );
}
```

High-level PImage operations

```
PImage img;

void setup()
{
  size( 800, 800 );
  img = loadImage( “some_image.jpg" );
}

void draw()
{
  background( 255 );

  imageMode( CORNER );
  noTint();
  image( img, 0, 0 );
  image( img, width - img.width, height - img.height );

  tint( 255, 120, 120 );
  imageMode( CENTER );
  image( img, width/2, height/2, 250, 250 );
}
```

Read the image into the running sketch.

High-level PImage operations

```
PImage img;

void setup(){
  size( 800, 800 );
  img = loadImage( “some_image.jpg" );
}

void draw(){
  background( 255 );

  imageMode( CORNER );
  noTint();
  image( img, 0, 0 );
  image( img, width - img.width, height - img.height );

  tint( 255, 120, 120 );
  imageMode( CENTER );
  image( img, width/2, height/2, 250, 250 );
}
```

Draw the image at the given coordinates, at its natural size.

High-level PImage operations

```
PImage img;

void setup() {
  size( 800, 800 );
  img = loadImage( “some_image.jpg" );
}

void draw() {
  background( 255 );

  imageMode( CORNER );
  noTint();
  image( img, 0, 0 );
  image( img, width - img.width, height - img.height );

  tint( 255, 120, 120 );
  imageMode( CENTER );
  image( img, width/2, height/2, 250, 250 );
}
```

Draw the image at the given coordinates, scaled.

High-level PImage operations

```
PImage img;

void setup() {
  size( 800, 800 );
  img = loadImage( “some_image.jpg" );
}

void draw() {
  background( 255 );

  imageMode( CORNER );
  noTint();
  image( img, 0, 0 );
  image( img, width - img.width, height - img.height );

  tint( 255, 120, 120 );
  imageMode( CENTER );
  image( img, width/2, height/2, 250, 250 );
}
```

Ask the image for its dimensions.

High-level PImage operations

```
PImage img;

void setup() {
  size( 800, 800 );
  img = loadImage( “some_image.jpg" );
}

void draw() {
  background( 255 );

  imageMode( CORNER );
  noTint();
  image( img, 0, 0 );
  image( img, width - img.width, height - img.height );

  tint( 255, 120, 120 );
  imageMode( CENTER );
  image( img, width/2, height/2, 250, 250 );
}
```

Apply a colour wash to all images.

High-level PImage operations

```
PImage img;

void setup() {
  size( 800, 800 );
  img = loadImage( “some_image.jpg" );
}

void draw() {
  background( 255 );

  imageMode( CORNER );
  noTint();
  image( img, 0, 0 );
  image( img, width - img.width, height - img.height );

  tint( 255, 120, 120 );
  imageMode( CENTER );
  image( img, width/2, height/2, 250, 250 );
}
```

Change the anchor point of the image.

Image no-nos

```
PImage img = loadImage( "some_image.jpg" );


void setup()
{
  size( 800, 800 );
  ...
}
```

Don’t try to load the image in the global variable declaration. This will usually fail.

Image no-nos

```
void draw()
{
  PImage img = loadImage( "some_image.jpg" );
  image( img, 0, 0 );
}
```

Don’t load images in draw(). This won’t break the program, but it will work much harder than necessary. Load the image *once* in setup().

Standard image idiom

```
PImage img;

void setup()
{
  [redacted]
  img = loadImage( “some_image.jpg” );
}

void draw()
{
  [redacted]


  [redacted]

  image( img, 0, 0 );
  image( img, width - img.width, height - img.height );

  [redacted]

  image( img, width/2, height/2, 250, 250 );
}
```

Standard image idiom

```
PImage img;
```

Global variable to hold image.

```
void setup()
{
  [illegible]
  img = loadImage( “some_image.jpg” );
}

void draw()
{
  [illegible]

  [illegible]
  [illegible]

  image( img, 0, 0 );
  image( img, width - img.width, height - img.height );

  [illegible]
  [illegible]

  image( img, width/2, height/2, 250, 250 );
}
```

Standard image idiom

```
PImage img;
```

Global variable to hold image.

```
void setup()
{
  [illegible]
  img = loadImage( “some_image.jpg” )
}
```

Load image in setup().

```
void draw()
{
  [illegible]

  [illegible]
  [illegible]

  image( img, 0, 0 );
  image( img, width - img.width, height - img.height );

  [illegible]
  [illegible]

  image( img, width/2, height/2, 250, 250 );
}
```

Standard image idiom

```
PImage img;
```

Global variable to hold image.

```
void setup()
{
  [illegible]

  img = loadImage( “some_image.jpg” )
}
```

Load image in setup().

```
void draw()
{
  [illegible]

  [illegible]
  [illegible]

  image( img, 0, 0 );
  image( img, width - img.width, height - img.height );

  [illegible]
  [illegible]

  image( img, width/2, height/2, 250, 250 );
}
```

Use image in draw().

You can also copy a *region* out of a source image, and scale it to any rectangle in the sketch window.

```
copy( img, sx, sy, sw, sh, dx, dy, dw, dh );
```

You can also copy a *region* out of a source image, and scale it to any rectangle in the sketch window.

```
copy( img, sx, sy, sw, sh, dx, dy, dw, dh );
```

The source image to copy pixels from

You can also copy a *region* out of a source image, and scale it to any rectangle in the sketch window.

```
copy( img, sx, sy, sw, sh, dx, dy, dw, dh );
```

A rectangle of pixels in the source image. Just like the arguments in a call to rect()

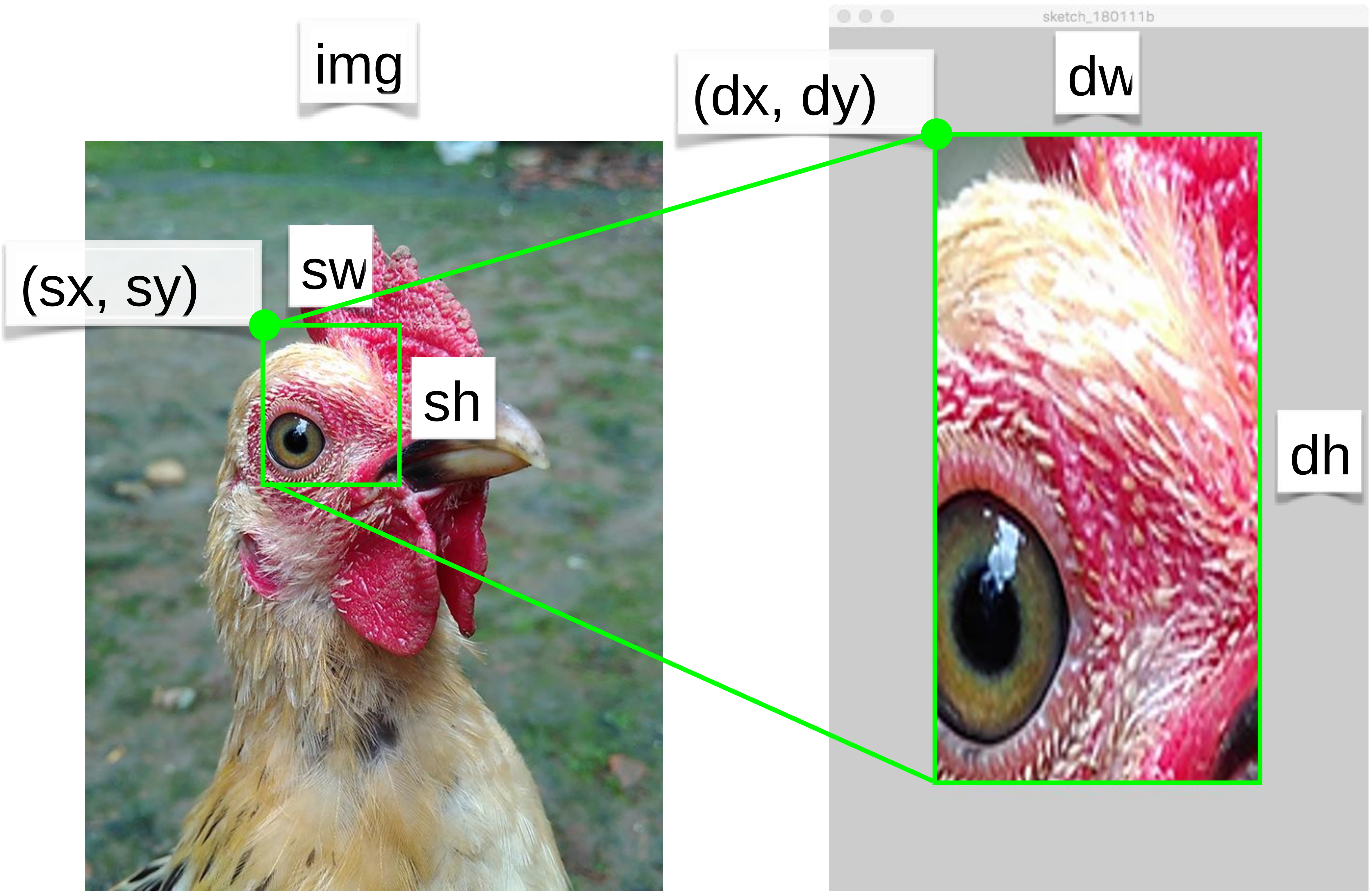
You can also copy a *region* out of a source image, and scale it to any rectangle in the sketch window.

```
copy( img, sx, sy, sw, sh, dx, dy, dw, dh );
```

A rectangle of pixels in the sketch window.

Again, just like a call to rect()

```
copy( img, sx, sy, sw, sh, dx, dy, dw, dh );
```



Writing images

Several ways to do this. Easiest is to take a screenshot.

```
void save( String filename ) { ... }
```

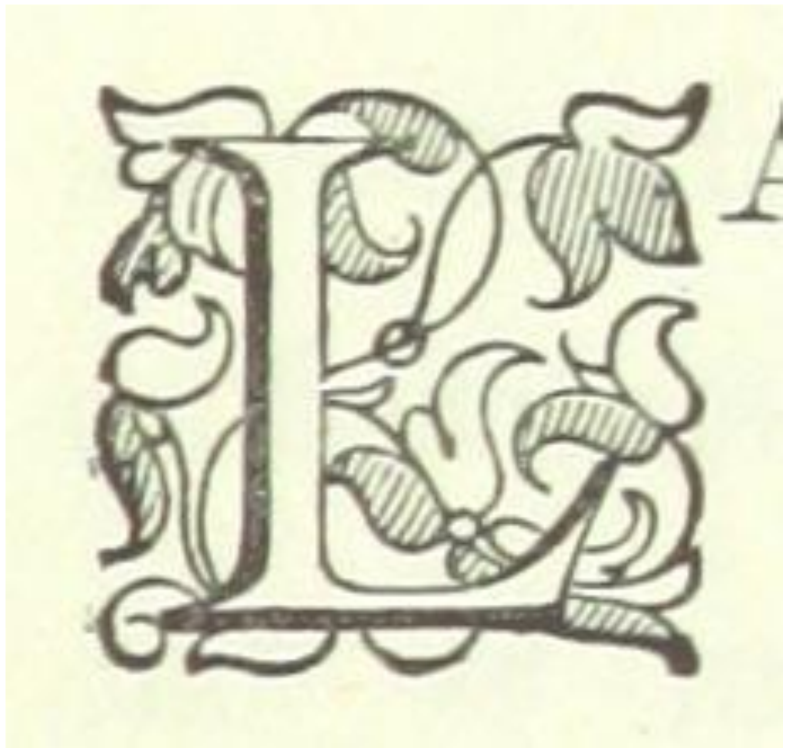
Save the contents of the sketch window to an image with the given file name.

```
void saveFrame() { ... }
void saveFrame( String name_template ) { ... }
```

Same as above, but include a counter in the saved file name. Useful for animations.

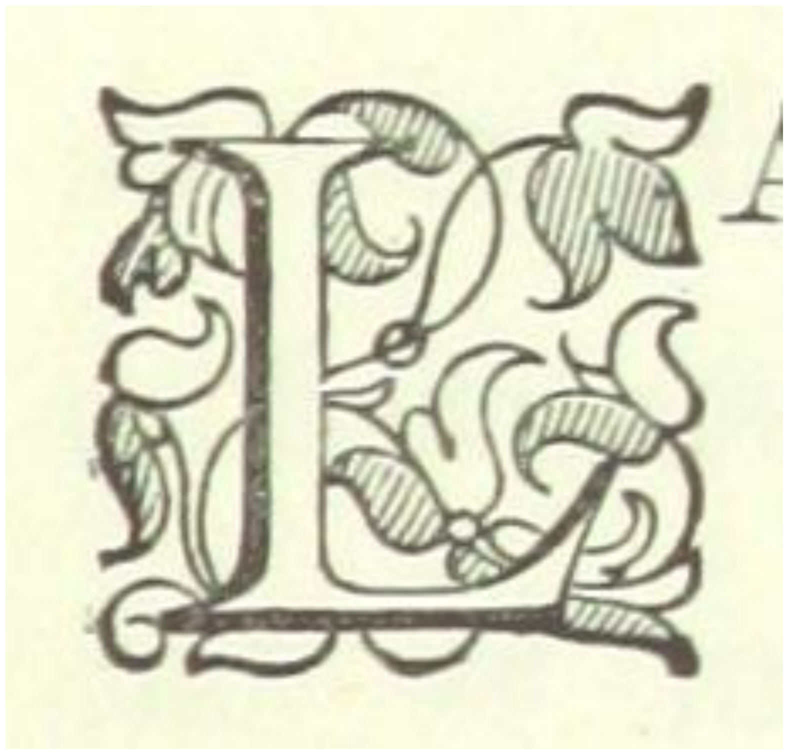
```
void keyPressed()
{
  if( key == 's' ) {
    save( "screen.png" );
  }
}
```

2. Reading and writing illustrations



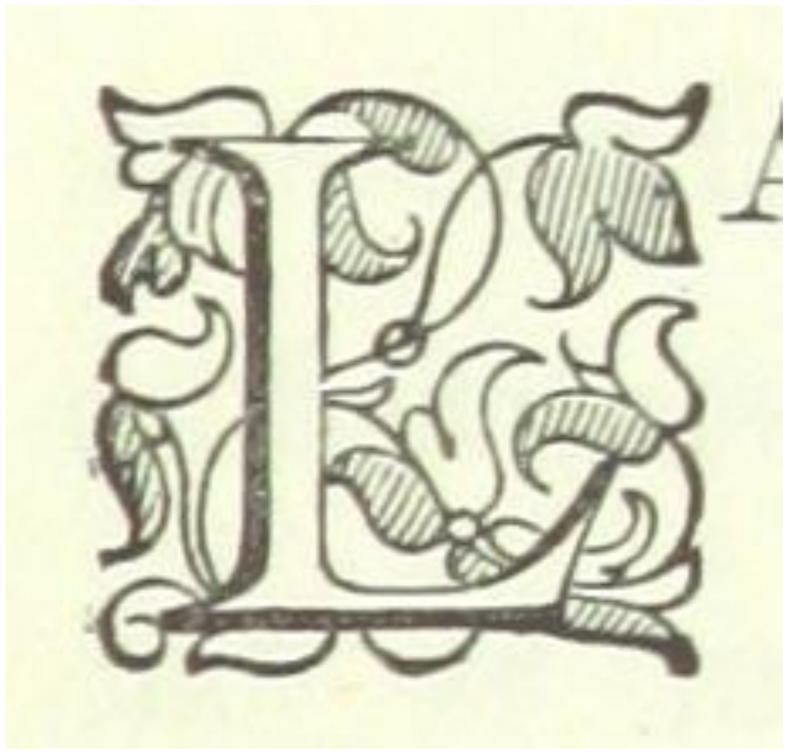
Raster image: represented using a grid of pixels.

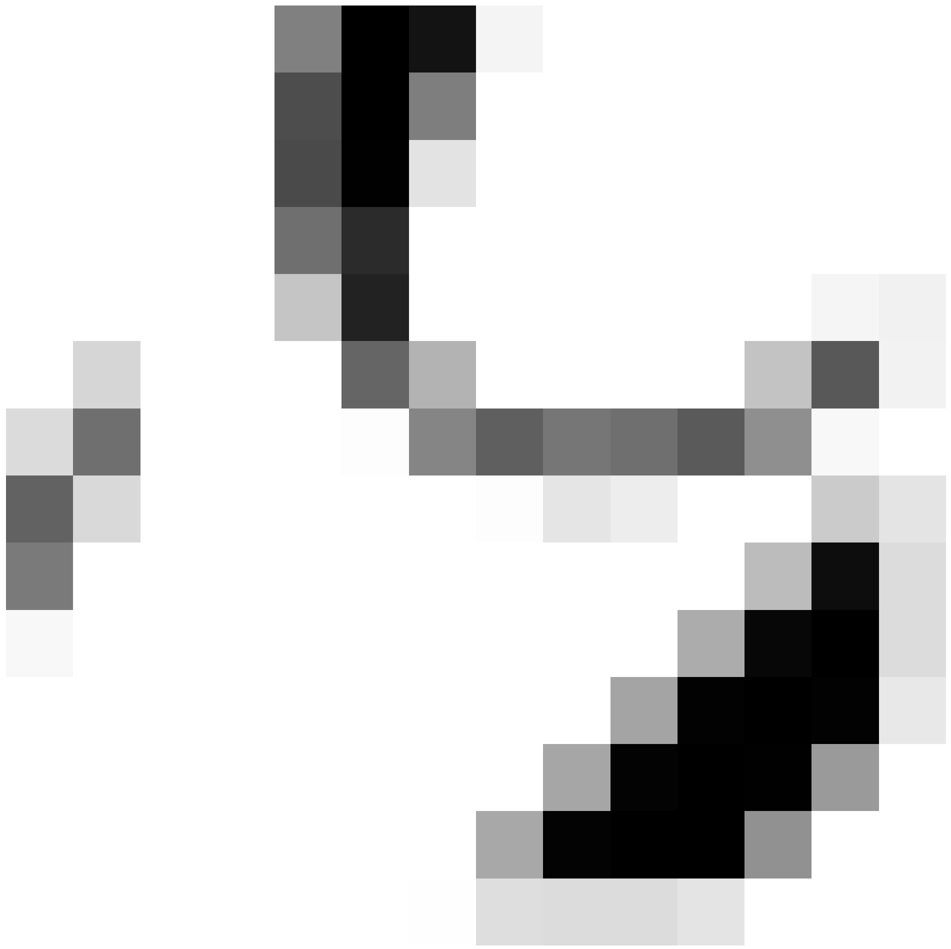
Vector illustration: represented using geometric paths.



Raster image: represented using a grid of pixels.
JPG, PNG, GIF, BMP, TIFF, …

Vector illustration: represented using geometric paths.
PDF, EPS, AI, SVG, …





Images	Illustrations
loadImage()	loadShape()
PImage	PShape
image()	shape()

```
PShape tiger;

void setup()
{
  size( 500, 500 );
  tiger = loadShape( "tiger.svg" );
}

void draw()
{
  shape( tiger, 0, 0 );
}
```

The PShape class has a disableStyle() method that forces the SVG to be drawn with the current fill and stroke settings.

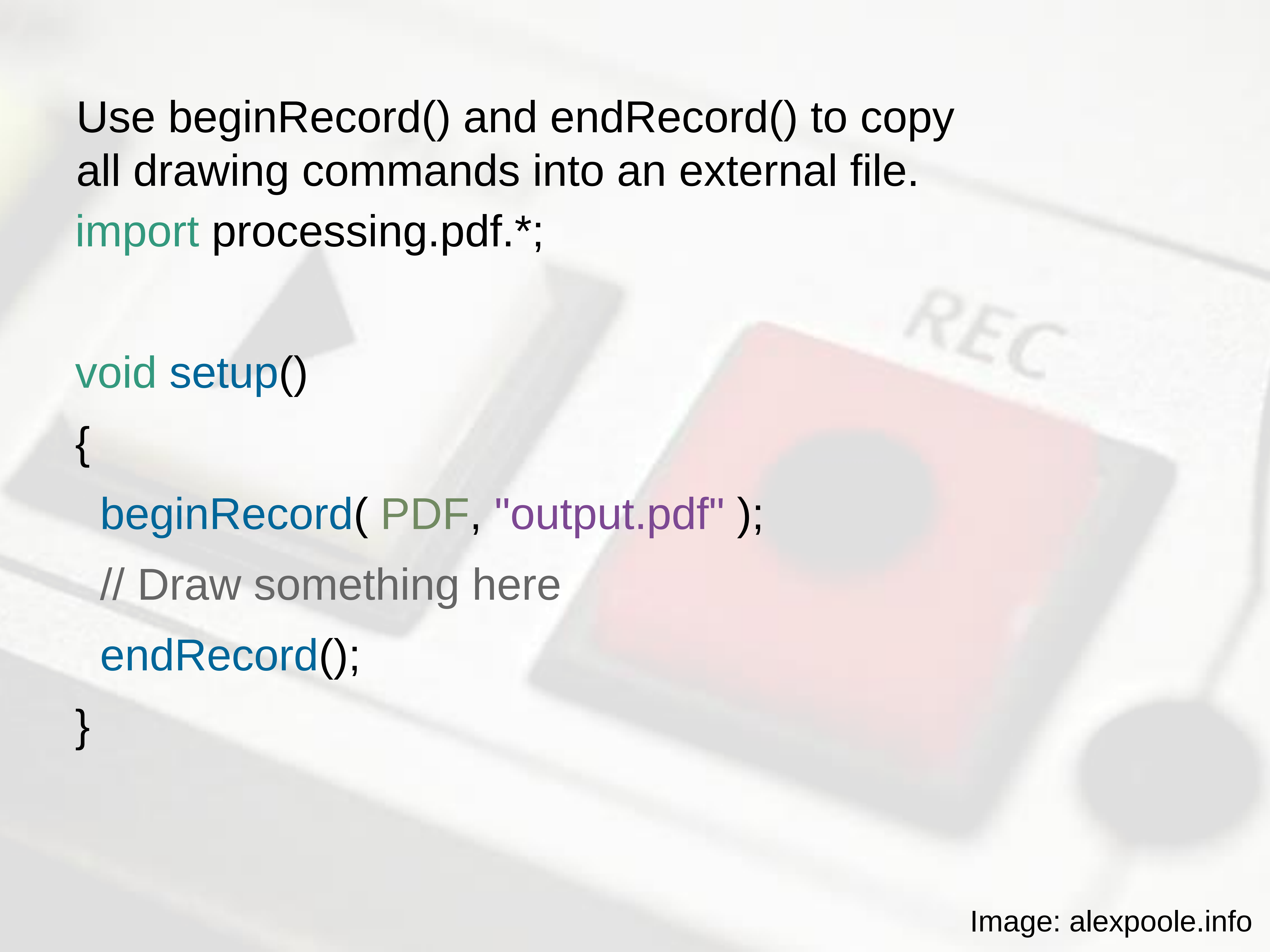
```
void draw() {
  background( 255 );
  if( keyPressed ) {
    tiger.disableStyle();
    fill( 255, 0, 0 );
    noStroke();
  } else {
    tiger.enableStyle();
  }
  shape( tiger, 0, 0 );
}
```

Writing illustrations

Processing can export any drawing to PDF or SVG (PDF is nicer). But the functionality isn’t built-in—you need to request it.

```
import processing.pdf.*;
```

“Import directive”: make all the functionality in the named library available in this sketch



Use beginRecord() and endRecord() to copy all drawing commands into an external file.

```
import processing.pdf.*;


void setup()
{
  beginRecord( PDF, "output.pdf" );
  // Draw something here
  endRecord();
}
```

Image: alexpoole.info

```
boolean recording = false;

void draw() {
  if( recording ) {
    beginRecord( PDF, "output.pdf" );
  }

  // Draw as usual

  if( recording ) {
    endRecord();
    recording = false;
  }
}

void keyPressed() {
  if( key == 's' ) {
    recording = true;
  }
}
```

Idiom for PDF recording

3. Reading and writing text

Plain text is the “default” mode of information storage and communication. Being able to work with text gives us access to large amounts of real-world data.

Marley was dead: to begin with. There is no doubt whatever about that. The register of his burial was signed by the clergyman, the clerk, the undertaker, and the chief mourner. Scrooge signed
Mind! I don't mean to say that I know, of my own knowledge, what there is particularly dead about a door-nail. I might have been inclined, myself, to regard a coffin-nail as the deadest piece of i

Scrooge knew he was dead? Of course he did. How could it be otherwise? Scrooge and he were partners for I don't know how many years. Scrooge was his sole executor, his sole administrat

The mention of Marley's funeral brings me back to the point I started from. There is no doubt that Marley was dead. This must be distinctly understood, or nothing wonderful can come of the sto

Scrooge never painted out Old Marley's name. There it stood, years afterwards, above the warehouse door: Scrooge and Marley. The firm was known as Scrooge and Marley. Sometimes peop

Oh! But he was a tight-fisted hand at the grind-stone, Scrooge! a squeezing, wrenching, grasping, scraping, clutching, covetous, old sinner! Hard and sharp as flint, from which no steel had eve

External heat and cold had little influence on Scrooge. No warmth could warm, no wintry weather chill him. No wind that blew was bitterer than he, no falling snow was more intent upon its purp

Nobody ever stopped him in the street to say, with gladsome looks, "My dear Scrooge, how are you? When will you come to see me?" No beggars implored him to bestow a trifle, no children as

But what did Scrooge care? It was the very thing he liked. To edge his way along the crowded paths of life, warning all human sympathy to keep its distance, was what the knowing ones call "n

Once upon a time -- of all the good days in the year, on Christmas Eve -- old Scrooge sat busy in his counting-house. It was cold, bleak, biting weather: foggy withal: and he could hear the peop

The door of Scrooge's counting-house was open that he might keep his eye upon his clerk, who in a dismal little cell beyond, a sort of tank, was copying letters. Scrooge had a very small fire, bu

"A merry Christmas, uncle! God save you!" cried a cheerful voice. It was the voice of Scrooge's nephew, who came upon him so quickly that this was the first intimation he had of his approach.

```
Received: from CONNMBX02.connect.uwaterloo.ca ([129.97.149.109]) by
 connhub1.connect.uwaterloo.ca ([129.97.149.101]) with mapi id 14.03.0319.002;
 Tue, 17 Jan 2017 15:57:38 -0500
From: Rishabh Moudgil <rishabh.moudgil@uwaterloo.ca>
To: Craig Kaplan <csk@uwaterloo.ca>
CC: Kevin Harrigan <kevinh@uwaterloo.ca>, Kristina Bayda
    <kbayda@uwaterloo.ca>, Travis Bartlett <travis.bartlett@uwaterloo.ca>
Subject: A01 Marking Scheme
Thread-Topic: A01 Marking Scheme
Thread-Index: AdJw/+DUxNKRRlCRRKOZfc2CQLKSng==
Date: Tue, 17 Jan 2017 20:57:36 +0000
Message-ID: <748888CA42FDF349AF07A8978DDED060281C9EC0@connmbx02>
Accept-Language: en-CA, en-US
Content-Language: en-CA
X-MS-Exchange-Organization-AuthAs: Internal
X-MS-Exchange-Organization-AuthMechanism: 04
X-MS-Exchange-Organization-AuthSource: connhub1.connect.uwaterloo.ca
X-MS-Has-Attach:
X-MS-Exchange-Organization-SCL: -1
X-MS-TNEF-Correlator:
Content-Type: multipart/alternative;
    boundary="_000_748888CA42FDF349AF07A8978DDED060281C9EC0connmbx02_"
MIME-Version: 1.0

--_000_748888CA42FDF349AF07A8978DDED060281C9EC0connmbx02_
Content-Type: text/plain; charset="Windows-1252"
Content-Transfer-Encoding: quoted-printable
```

```
//gallery.bridgesmathart.org/exhibitions/2017-joint-mathematics-meetings" "Mozilla/5.0 (Windows NT 6.1; WOW64; r
v:50.0) Gecko/20100101 Firefox/50.0"
108.62.132.133 - - [17/Jan/2017:00:00:15 -0500] "GET /tmp/cache/images/cms/arrow-right.gif HTTP/1.1" 404 195 "ht
tp://bridgesmathart.org/tmp/cache/stylesheet_combined_6fa5fb1be8f2682b13e4cf7292f5937a.css" "Mozilla/5.0 (Window
s NT 6.1; WOW64; rv:50.0) Gecko/20100101 Firefox/50.0"
108.62.132.133 - - [17/Jan/2017:00:00:16 -0500] "GET /bridges-galleries/conference-photos/ HTTP/1.1" 200 14016 "
http://bridgesmathart.org/bridges-galleries/art-exhibits/" "Mozilla/5.0 (Windows NT 6.1; WOW64; rv:50.0) Gecko/2
0100101 Firefox/50.0"
73.64.123.57 - - [17/Jan/2017:00:01:24 -0500] "GET /2014/bridges2014-235.pdf HTTP/1.1" 200 948062 "-" "Mozilla/5
.0 (Macintosh; Intel Mac OS X 10_12_2) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/55.0.2883.95 Safari/537.36"
58.10.140.128 - - [17/Jan/2017:00:01:25 -0500] "GET /wp-login.php HTTP/1.1" 404 195 "-" "Mozilla/5.0 (Windows NT
 6.1; WOW64; rv:40.0) Gecko/20100101 Firefox/40.1"
58.10.140.128 - - [17/Jan/2017:00:01:26 -0500] "GET / HTTP/1.1" 200 12340 "-" "Mozilla/5.0 (Windows NT 6.1; WOW6
4; rv:40.0) Gecko/20100101 Firefox/40.1"
64.126.161.169 - - [17/Jan/2017:00:01:28 -0500] "GET /2012/cdrom/proceedings/92/paper_92.pdf HTTP/1.1" 200 21833
8 "-" "Mozilla/5.0 (Macintosh; Intel Mac OS X 10_10_5) AppleWebKit/602.3.12 (KHTML, like Gecko)"
64.126.161.169 - - [17/Jan/2017:00:01:29 -0500] "GET /apple-touch-icon-precomposed.png HTTP/1.1" 404 195 "-" "Sa
fari/10602.3.12.0.1 CFNetwork/720.5.7 Darwin/14.5.0 (x86_64)"
64.126.161.169 - - [17/Jan/2017:00:01:29 -0500] "GET /apple-touch-icon.png HTTP/1.1" 404 195 "-" "Safari/10602.3
.12.0.1 CFNetwork/720.5.7 Darwin/14.5.0 (x86_64)"
64.126.161.169 - - [17/Jan/2017:00:01:29 -0500] "GET /favicon.ico HTTP/1.1" 404 195 "-" "Safari/10602.3.12.0.1 C
FNetwork/720.5.7 Darwin/14.5.0 (x86_64)"
64.126.161.169 - - [17/Jan/2017:00:01:30 -0500] "GET /apple-touch-icon-precomposed.png HTTP/1.1" 404 195 "-" "Sa
fari/10602.3.12.0.1 CFNetwork/720.5.7 Darwin/14.5.0 (x86_64)"
64.126.161.169 - - [17/Jan/2017:00:01:30 -0500] "GET /apple-touch-icon.png HTTP/1.1" 404 195 "-" "Safari/10602.3
.12.0.1 CFNetwork/720.5.7 Darwin/14.5.0 (x86_64)"
64.126.161.169 - - [17/Jan/2017:00:01:30 -0500] "GET /favicon.ico HTTP/1.1" 404 195 "-" "Safari/10602.3.12.0.1 C
FNetwork/720.5.7 Darwin/14.5.0 (x86_64)"
64.126.161.169 - - [17/Jan/2017:00:01:31 -0500] "GET /apple-touch-icon-precomposed.png HTTP/1.1" 404 195 "-" "Sa
fari/10602.3.12.0.1 CFNetwork/720.5.7 Darwin/14.5.0 (x86_64)"
64.126.161.169 - - [17/Jan/2017:00:01:31 -0500] "GET /apple-touch-icon.png HTTP/1.1" 404 195 "-" "Safari/10602.3
.12.0.1 CFNetwork/720.5.7 Darwin/14.5.0 (x86_64)"
64.126.161.169 - - [17/Jan/2017:00:01:32 -0500] "GET /favicon.ico HTTP/1.1" 404 195 "-" "Safari/10602.3.12.0.1 C
FNetwork/720.5.7 Darwin/14.5.0 (x86_64)"
64.126.161.169 - - [17/Jan/2017:00:01:32 -0500] "GET /apple-touch-icon-precomposed.png HTTP/1.1" 404 195 "-" "Sa
fari/10602.3.12.0.1 CFNetwork/720.5.7 Darwin/14.5.0 (x86_64)"
```

CMU Pronunciation Dictionary

PROCESSING	P R AA1 S EH0 S IH0 NG
PROCESSION	P R AH0 S EH1 SH AH0 N
PROCESSION(1)	P R OW0 S EH1 SH AH0 N
PROCESSIONAL	P R AH0 S EH1 SH AH0 N AH0 L
PROCESSIONAL(1)	P R OW0 S EH1 SH AH0 N AH0 L
PROCESSIONS	P R OW0 S EH1 SH AH0 N Z
PROCESSOR	P R AA1 S EH2 S ER0
PROCESSOR'S	P R AA1 S EH2 S ER0 Z
PROCESSORS	P R AA1 S EH2 S ER0 Z
PROCH	P R AA1 K
PROCHASKA	P R AH0 HH AA1 S K AH0
PROCHAZKA	P R AH0 HH AA1 Z K AH0
PROCHNOW	P R AA1 N AW0
PROCIDA	P R OW0 CH IY1 D AH0
PROCK	P R AA1 K
PROCKTER	P R AA1 K T ER0
PROCLAIM	P R OW0 K L EY1 M
PROCLAIMED	P R OW0 K L EY1 M D
PROCLAIMING	P R OW0 K L EY1 M IH0 NG
PROCLAIMS	P R OW0 K L EY1 M Z
PROCLAMATION	P R AA2 K L AH0 M EY1 SH AH0 N
PROCLAMATIONS	P R AA2 K L AH0 M EY1 SH AH0 N Z
PROCLIVITIES	P R OW0 K L IH1 V AH0 T IY0 Z
PROCLIVITY	P R OW0 K L IH1 V AH0 T IY0
PROCONSUL	P R OW0 K AA1 N S AH0 L

```
01-Jan-14,-15.6,-8.9,0.1
02-Jan-14,-17.7,-15.1,0.1
03-Jan-14,-23.4,-13.1,0
04-Jan-14,-12.7,-2.5,0
05-Jan-14,-3.7,-1.2,19.1
06-Jan-14,-19.6,-2.1,7.7
07-Jan-14,-26.1,-18.7,1.5
08-Jan-14,-19.1,-11.1,0
09-Jan-14,-22.2,-8.3,0
10-Jan-14,-8.3,2.4,0
11-Jan-14,0.3,5.4,26.4
12-Jan-14,-0.8,1.3,0
13-Jan-14,0.4,5.8,0.2
14-Jan-14,-2.5,3.3,0
15-Jan-14,-8.5,-0.4,1.4
16-Jan-14,-8.7,-4,2.7
17-Jan-14,-8,-0.3,3.9
18-Jan-14,-10.1,-4.6,1.7
```

Reading text

Reading text from a file can be quite painful in many programming languages. Processing keeps it simple:

```
String[] loadStrings( String filename ) { ... }
```

Load a text file from the sketch folder. Break it up into lines and return an array of Strings, one per line.

```
PROCESSING  P R AA1 S EH0 S IH0 NG
PROCESSION  P R AH0 S EH1 SH AH0 N
PROCESSION(1)  P R OW0 S EH1 SH AH0 N
PROCESSIONAL  P R AH0 S EH1 SH AH0 N AH0 L
PROCESSIONAL(1)  P R OW0 S EH1 SH AH0 N
AH0 L
PROCESSIONS  P R OW0 S EH1 SH AH0 N Z
```

dict.txt

```
void setup()
{
  String[] lines = loadStrings( "dict.txt" );
  printArray( lines );
}
```

```
[0] "PROCESSING  P R AA1 S EH0 S IH0 NG"
[1] "PROCESSION  P R AH0 S EH1 SH AH0 N"
[2] "PROCESSION(1)  P R OW0 S EH1 SH AH0 N"
[3] "PROCESSIONAL  P R AH0 S EH1 SH AH0 N AH0 L"
[4] "PROCESSIONAL(1)  P R OW0 S EH1 SH AH0 N AH0
[5] "PROCESSIONS  P R OW0 S EH1 SH AH0 N Z"
```

Breaking up long lines

A line in a file may contain lots of individual chunks of data separated by whitespace. We'd like to break lines into words, just as we broke files into lines.

```
String[] splitTokens( String line ) { ... }
```

Turn a line of text into an array of "words" (any non-whitespace characters separated by whitespace).

(Note that join() can reassemble individual strings into a single result.)

```
String s = "    Marley was       dead: to begin with. ";
String[] toks = splitTokens( s );
printArray( toks );
```

```
[0] "Marley"
[1] "was"
[2] "dead:"
[3] "to"
[4] "begin"
[5] "with."
```

Writing text

We know we can use println() to send any text to the console.

A similar mechanism allows us to create objects that stand in for text files. Sending those objects println() messages puts text into the file.

```
PrintWriter createWriter( String filename ) { ... }
```

Create an object that can output text to a file.

Idiom for writing text

```
PrintWriter pw = createWriter( "output.txt" );

pw.println( "Hello" );
pw.println( mouseX );
pw.println( PI );
pw.println( "THE END" );

pw.flush();
pw.close();
```

Idiom for writing text

```
PrintWriter pw = createWriter( "output.txt" );

pw.println( "Hello" );
pw.println( mouseX );
pw.println( PI );
pw.println( "THE END" );

pw.flush();
pw.close();
```

Create an object to write to.

Idiom for writing text

```
PrintWriter pw = createWriter( "output.txt" );

pw.println( "Hello" );
pw.println( mouseX );
pw.println( PI );
pw.println( "THE END" );

pw.flush();
pw.close();
```

Send some text to the writer object.

Idiom for writing text

```
PrintWriter pw = createWriter( "output.txt" );

pw.println( "Hello" );
pw.println( mouseX );
pw.println( PI );
pw.println( "THE END" );
```

```
pw.flush();
pw.close();
```

Send the data out to permanent storage and close the file.

Reasons to write text

Logging: Create a permanent record of the behaviour of the program to review later.

Persistence: Store information about the program's state in an external file so that the sketch can restart with that state later.

Workflow: create text output that can be read by another program for further processing.