Programming with Processing!

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A Warning about the Note Coverage

What Processing can do

What I know

What the notes cover

mjb – July 21, 2023
Why Do We Have These Notes?

Processing has thousands of "buttons" you can press. These notes are here to show you what certain combinations of buttons do in order to learn them the first time, and to remind you later when you’ve forgotten.

http://xkcd.com
A “program” is a set of instructions that you can store and playback later. This sounds like a computer-thing, but the idea of a “program” has been around for hundreds of years.

The earliest known "program" is (apparently) a mechanical music playback device developed in Baghdad in the 9th century. ([https://en.wikipedia.org/wiki/Music_box](https://en.wikipedia.org/wiki/Music_box)) You can find a similar device in Oregon today…
Music Box Programming

… at the Albany (Oregon) Carousel and Museum
Music Box Programming

Albany Carousel and Museum
Another Historic Example is Textile Programming

Jacquard Loom, circa 1804
Textile Programming

Jacquard Loom, circa 1804
And, of course, there is the Ever-fun Player Piano Piano

https://en.wikipedia.org/wiki/Piano_roll
Computers Eventually Imitated Historic Methods using Punch Cards

circa 1972
The *Processing* Programming Language

- Images of colorful shapes and patterns
- Oregon State University logo
- Oregon State University Computer Graphics
Where to Find *Processing*

In your favorite web browser, go to: [https://p5js.org/](https://p5js.org/)

Here’s what you will see:

Go here to start using *Processing*

These are good links to check out!

Processing includes a collection of *spectacular* example programs
Running *Processing*

Click on the **Editor** link, or navigate to: [https://editor.p5js.org/](https://editor.p5js.org/)

Either way, here’s what you will see:
Running *Processing*

**Menu headers**

**Run your program**

**Stop the program**

**Program-writing/editing area**

```
function setup() {
    createCanvas(400, 400);
}

function draw() {
    background(220);
}
```
Now, click this button!

Here’s what you will get

Don’t worry – it will get better 😊
Writing Processing Programs

(X=0, Y=0) → (X=width - 1, Y=0)

(X=0, Y=height - 1) → (X=width - 1, Y=height - 1)

(X=100, Y=200) → (X=100, Y=200)

ΔX=150, ΔY=50

(X=0, Y=0) → (X=100, Y=200)
With *Processing*, you get to do real-world programming that gives you visual output. You get to make cool pictures at the same time you are learning to program. This opens up a world of opportunities for you!
First, Remember How Graph Paper Works

The Greek letter delta, $\Delta$, is the mathematics symbol for “the change in”
This is the “Graph Paper” System for Processing Programs

(X=0, Y=0)  (X=width - 1, Y=0)

(X=100, Y=200)

ΔX=150  ΔY=50

(X=0, Y=height - 1)  (X=width - 1, Y=height - 1)
Colors are formed with combinations of **red**, **green**, and **blue**.

The smallest number you can use for each is **0**
The largest number you can use for each is **255**

<table>
<thead>
<tr>
<th>Color</th>
<th>Red</th>
<th>Green</th>
<th>Blue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>White</td>
<td>255</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>Red</td>
<td>255</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Orange</td>
<td>255</td>
<td>128</td>
<td>0</td>
</tr>
<tr>
<td>Yellow</td>
<td>255</td>
<td>255</td>
<td>0</td>
</tr>
<tr>
<td>Green</td>
<td>0</td>
<td>255</td>
<td>0</td>
</tr>
<tr>
<td>Cyan</td>
<td>0</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>Blue</td>
<td>0</td>
<td>0</td>
<td>255</td>
</tr>
<tr>
<td>Magenta</td>
<td>255</td>
<td>0</td>
<td>255</td>
</tr>
</tbody>
</table>
Colors for Computer Graphics Monitors: Additive Colors (RGB)

- Cyan = Green + Blue
- Magenta = Red + Blue
- Yellow = Red + Green
- Gray = Red + Green + Blue

Colors for Computer Graphics:

<table>
<thead>
<tr>
<th></th>
<th>Red</th>
<th>Green</th>
<th>Blue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>White</td>
<td>255</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>Red</td>
<td>255</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Orange</td>
<td>255</td>
<td>128</td>
<td>0</td>
</tr>
<tr>
<td>Yellow</td>
<td>255</td>
<td>255</td>
<td>0</td>
</tr>
<tr>
<td>Green</td>
<td>0</td>
<td>255</td>
<td>0</td>
</tr>
<tr>
<td>Cyan</td>
<td>0</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>Blue</td>
<td>0</td>
<td>0</td>
<td>255</td>
</tr>
<tr>
<td>Magenta</td>
<td>255</td>
<td>0</td>
<td>255</td>
</tr>
</tbody>
</table>
Yes, Our Vision System Really Does Mush Red and Green Together to Make Yellow!
Colors for Paints, Toners, and Clear Plastic: Subtractive Colors (CMYK)

Yellow (=R+G)

Green = C + Y

Cyan (=B+G)

R = Red
G = Green
B = Blue
W = White
C = Cyan
M = Magenta
Y = Yellow
K = Black
Subtractive Colors (CMYK)

R = Red
G = Green
B = Blue
W = White
C = Cyan
M = Magenta
Y = Yellow
K = Black
Writing a **Processing** Program – Try This!

You must add code to the `setup( )` function. Processing calls this **once** when your program starts.

You must add code to the `draw( )` function. Processing calls this **every time** it wants to re-draw the scene.
Running Your Processing Programs

Click here to run your program

```javascript
1 function
2 setup(  )
3 {
4 createCanvas( 800, 600 );
5 background( 200, 200, 255 );
6 stroke( 0, 0, 0 );
7 fill( 255, 50, 50 );}

10 function
11 draw(  )
12 {
13 rect( 100, 200, 150, 50 );
14 }
```
Enjoying the Output of Your First Processing Program

Don’t worry – it will get better 😊
## Some Functions to use when Writing Processing Programs

<table>
<thead>
<tr>
<th>Category</th>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>color( r, g, b )</td>
<td>Set the current color to ( r, g, b )</td>
</tr>
<tr>
<td>Drawing</td>
<td>fill( c )</td>
<td>Fill using the color c</td>
</tr>
<tr>
<td>Drawing</td>
<td>noFill()</td>
<td>Don't do any filling</td>
</tr>
<tr>
<td>Drawing</td>
<td>noStroke()</td>
<td>Don't do any outlining</td>
</tr>
<tr>
<td>Drawing</td>
<td>stroke( c )</td>
<td>Outline using the color c</td>
</tr>
<tr>
<td>Drawing</td>
<td>strokeWeight( w )</td>
<td>Thickness of the outline</td>
</tr>
<tr>
<td>Math</td>
<td>abs( f )</td>
<td>Absolute value</td>
</tr>
<tr>
<td>Math</td>
<td>lerp( v1, v2, blend )</td>
<td>Linearly interpolate two values</td>
</tr>
<tr>
<td>Math</td>
<td>map( input, lowin, highin, lowout, highout )</td>
<td>Lineary map the input variable from the range [lowin,highin] to [lowout,highout]</td>
</tr>
<tr>
<td>Math</td>
<td>max( f1, f2 )</td>
<td>Maximum of the two numbers</td>
</tr>
<tr>
<td>Math</td>
<td>min( f1, f2 )</td>
<td>Minimum of the two numbers</td>
</tr>
<tr>
<td>Printing</td>
<td>print( s )</td>
<td>Print the string into the console</td>
</tr>
<tr>
<td>Randomness</td>
<td>random( low, high )</td>
<td>Return a random number between low and high</td>
</tr>
<tr>
<td>Setup</td>
<td>background( r, g, b )</td>
<td>Set the background to r, g, b</td>
</tr>
<tr>
<td>Setup</td>
<td>createCanvas( w, h )</td>
<td>Set the size of the graphics window to w x h pixels</td>
</tr>
<tr>
<td>Setup</td>
<td>draw()</td>
<td>The function that gets called over and over to draw your scene</td>
</tr>
<tr>
<td>Setup</td>
<td>setup()</td>
<td>The function that gets called when your program starts</td>
</tr>
<tr>
<td>Shapes</td>
<td>beginShape()</td>
<td>Start drawing to vertices</td>
</tr>
<tr>
<td>Shapes</td>
<td>ellipse( cx, cy, w, h )</td>
<td>Draw an ellipse</td>
</tr>
<tr>
<td>Shapes</td>
<td>endShape()</td>
<td>Finish drawing to vertices</td>
</tr>
<tr>
<td>Shapes</td>
<td>line( x0, y0, x1, y1 )</td>
<td>Draw a line</td>
</tr>
<tr>
<td>Shapes</td>
<td>point( x, y )</td>
<td>Put a dot at (x,y)</td>
</tr>
<tr>
<td>Shapes</td>
<td>quad( x0, y0, x1, y1, x2, y2, x3, y3 )</td>
<td>Draw a quadrilateral</td>
</tr>
<tr>
<td>Shapes</td>
<td>rect( ulx, uly, w, h )</td>
<td>Draw a rectangle</td>
</tr>
<tr>
<td>Shapes</td>
<td>triangle( x0, y0, x1, y1, x2, y2 )</td>
<td>Draw a triangle</td>
</tr>
<tr>
<td>Shapes</td>
<td>vertex( x, y )</td>
<td>(in between calls to beginShape and endShape)</td>
</tr>
<tr>
<td>Text</td>
<td>text( s, x, y )</td>
<td>Draw the text &quot;s&quot; on the screen at (x,y) with the current fill color</td>
</tr>
<tr>
<td>Variables</td>
<td>height</td>
<td>Screen height in pixels</td>
</tr>
<tr>
<td>Variables</td>
<td>PI</td>
<td>π</td>
</tr>
<tr>
<td>Variables</td>
<td>width</td>
<td>Screen width in pixels</td>
</tr>
</tbody>
</table>
function draw( )
{
    let x = 100;
    let y = 2*x;
    rect( x,  y,    150,  50 );
}

Arithmetic operations in programming are:
+   Addition
-   Subtraction
*   Multiplication
/   Division
( ) Grouping
**Variables** are the process of replacing numbers with symbols in order to generalize a computation to work in more than one situation.

```javascript
function draw() {
  let x = 100;
  let y = 200;
  rect(x, y, 150, 50);
}
```

"let" just says that you are defining a variable.
Variables – using symbols instead of just numbers

We can use variables to create *relationships*

```javascript
function draw( ) {
  let x = 100;
  let y = 2*x;
  rect( x, y, 150, 50 );
}
```

When you assign a number to `x`, then `y` will automatically be twice as big as whatever you set `x` to be.

Arithmetic operations in programming are:

- Addition (+)
- Subtraction (-)
- Multiplication (*)
- Division (/)
- Grouping ( )
Drawing Lines and Polygons

![Diagram showing a red polygon with vertices at (100, 100), (200, 400), (300, 300), and (400, 50).]
Rectangles are Fun, but Arbitrary Lines and Polygons are Funner

Easy – just list the coordinates:

beginShape( );

vertex( x0, y0 );
vertex( x1, y1 );
vertex( x2, y2 );

. . .

endShape( );
Rectangles are Fun, but Arbitrary Lines and Polygons are Funner

function draw() {
    beginShape();
    vertex(100, 100);
    vertex(100, 400);
    vertex(200, 400);
    vertex(300, 300);
    vertex(400, 50);
    endShape();
}
for-loops
Drawing One Rectangle is Pretty Straightforward

```c
rect( 100, 200, 150, 50 );
```
But, This Gets Awfully Boring if You Want to Draw 100 Rectangles!

```
rect( 100, 200, 150, 50 );
rect( 110, 210, 150, 50 );
rect( 120, 220, 150, 50 );
```
Repeating a code pattern is a common theme in programming.

This line is called a “for-loop”. It is very handy for repeating patterns of code.

The for-loop executes the commands **in the curly braces** a bunch of times. Using it looks like this:

1. Do this equation once at the start
2. Keep looping as long as this test is true
3. Do this at the end of one loop, but before the start of the next one

Yes, the semi-colons (;) are necessary!
for-loops to the Rescue!
Drawing Circles and Other Regular Polygons, I
First, We Need to Understand Something about Angles

If a circle has a radius of 1.0, then we can march around it by simply changing the angle that we call $\theta$. 
First, We Need to Understand Something about Angles

One of the things we notice is that each angle \( \theta \) has a unique \( X \) and \( Y \) that goes with it.

*The \( X \) and \( Y \) are different for each \( \theta \).*
First, We Need to Understand Something about Angles

Centuries ago, people developed tables of those X and Y values as functions of $\theta$.

They called the X values **cosines** and the Y values **sines**. These are abbreviated cos and sin.

$\cos \theta = X$

$\sin \theta = Y$
In Earlier Times, People Looked up Sines and Cosines in Books and on Slide Rules – Fortunately We Now Have Calculators and Computers
Cosines and Sines are Really Ratios

If we were to double the radius of the circle, all of the X’s and Y’s would also double.

So, really the cos and sin are *ratios* of X and Y to the circle Radius

\[
\cos \theta = \frac{X}{R} \\
\sin \theta = \frac{Y}{R}
\]
So, if we know the circle Radius, and we march through a series of $\theta$ angles, we can determine all of the X’s and Y’s that we need to draw a circle.

\[
\cos \theta = \frac{X}{R} \quad X = R \times \cos \theta
\]
\[
\sin \theta = \frac{Y}{R} \quad Y = R \times \sin \theta
\]
Processing Doesn’t Include Regular Polygon-Drawing Functions, So We Add Our Own to the End of the Program

function Shape( xc, yc, r, numsegs )
{
    let dang = (2.*PI) / float( numsegs );
    let ang = 0.;
    beginShape( );
    for( let i = 0; i <= numsegs; i = i + 1 )
    {
        let x = xc + r * cos(ang);
        let y = yc + r * sin(ang);
        vertex( x, y );
        ang = ang + dang;
    }
    endShape( );
}

numsegs is the number of line segments making up the circumference of the circle.
numsegs=36 gives a nice circle.
5 gives a pentagon.
8 gives an octagon.
4 gives you a square. Etc.

Why 2.*PI (= 2π)?

dang = Δang = change in ang as we go around the circle
Why 2.*PI (= 2π)?

```plaintext
let dang = (2.*PI) / float( numsegs );
```

We commonly measure angles in **degrees**, but scientists, engineers, and computers like to measure angles in something else called **radians**.

There are 360° (degrees) in a complete circle.
There are 2π (~6.28) radians in a complete circle.

The built-in cos( ) and sin( ) functions expect angles to be given in radians.

Processing has built-in functions to convert between the two:

```plaintext
let rad = radians( deg );
let deg = degrees( rad );
```
function draw( )
{
    fill( 255, 50, 50 );
    Shape( 200, 200, 100, 36 );

    fill( 50, 255, 50 );
    Shape( 300, 300, 100, 5 );

    fill( 50, 50, 255 );
    Shape( 400, 400, 100, 8 );
}
function Shape2( xc, yc, rx, ry, numsegs )
{
    let dang = (2.*PI) / float( numsegs );
    let ang = 0.;
    beginShape( );

    for( let i = 0; i <= numsegs; i = i + 1 )
    {
        let x = xc + rx * cos(ang);
        let y = yc + ry * sin(ang);
        vertex( x, y );
        ang = ang + dang;
    }

    endShape( );
}
And, there is no reason the X and Y radii need to be the same…

```javascript
function draw( )
{
    fill( 255,  50,  50 );
    Shape2( 200, 200, 150, 75,  36 );

    fill(  50, 255,  50 );
    Shape2( 300, 300, 150, 75,    5 );

    fill(  50,   50, 255 );
    Shape2( 400, 400, 150, 75,    8 );
}
```
The Processing `map()` Function
More Sophisticated Relationships:

The `map()` function

This function takes an input value, the range of values it lives between, and the range of output values. It returns the output value that corresponds to the input value.

So, for example, if we wanted to turn an `x` value into a red color, we might say:

```javascript
let red = int(map(x, 0, 399, 0, 255));
```

0 ≤ x ≤ 399

0 ≤ red ≤ 255
function draw( )
{
  for( let x = 0 ; x < 400 ; x = x + 10 )
  {
    let y = x;
    let red = int( map( x, 0, 399, 0, 255 ) );
    let green = int( map( y, 0, 399, 0, 255 ) );
    fill( red, green, 0 );
    rect( x, y, 150, 50 );
  }
}
function draw( )
{
    for( let x = 0 ; x < 400 ; x = x + 10 )
    {
        let y = x;
        let red = int( map( x, 0, 399, 0, 255 ) );
        let green = int( map( y, 0, 399, 0, 255 ) );
        green = 3 * green / 4;
        fill( red, green, 0 );
        rect( x, y, 150, 50 );
    }
}
function draw() {
    for (let x = 0; x < 400; x = x + 10) {
        let y = x;
        let red = int(map(x, 0, 399, 0, 255));
        let green = int(map(y, 0, 399, 255, 0));
        fill(red, green, 0);
        rect(x, y, 150, 50);
    }
}

The `map()` function can also do blending. Interpolate one forward and the other one backwards.

All-Green morphs into All-Red
Drawing Circles and Other Regular Polygons, II
There is also no reason we can’t gradually change the radius …

```javascript
function Spiral( xc, yc, r1, r2, numsegs, numturns ) {
    let dang = numturns * (2.*PI) / float( numsegs );
    let ang = 0.;
    beginShape( );

    for( let i = 0; i <= numsegs; i = i + 1 )
    {
        let newrad = map( i, 0, numsegs, r1, r2 );
        let x = xc + newrad * cos(ang);
        let y = yc + newrad * sin(ang);
        vertex( x, y );
        ang = ang + dang;
    }

    endShape( );
}
```
There is also no reason we can’t gradually change the radius …

```javascript
function draw() {
  strokeWeight( 5 );
  noFill( );
  Spiral( 300, 300, 20, 200, 1000, 10 );
}
```
function draw( ) {
    let numobjects = 10;
    let radius = 200.;
    let xc = 300;
    let yc = 300;
    let numsegs = 20;
    let r = 50;
    let dang = (2.*PI) / float( numobjects - 1 );
    let ang = 0.;
    for( let i = 0; i < numobjects; i = i + 1 )
    {
        let x = xc + radius * cos(ang);
        let y = yc + radius * sin(ang);
        let red   = int( map( i,   0, numobjects - 1,     0, 255 ) );
        let blue = int( map( i,   0, numobjects - 1, 255,     0 ) );
        fill( red, 0, blue );
        Shape( x, y, r, numsegs );
        ang = ang + dang;
    }
}
Polar Equations
function Polar(xc, yc, factor, numsegs, numturns )
{
  let dang = numturns * (2.*PI) / float( numsegs );
  let theta = 0.;
  beginShape( );

  for( let i = 0; i <= numsegs; i = i + 1 )
  {
    let r = 200. * sin(factor*theta);
    let x = xc + r * cos(theta);
    let y = yc + r * sin(theta);
    vertex( x, y );
    theta = theta + dang;
  }

  endShape( );
}

Setting the radius as a function of the angle

200 is the radius of the circle the shape fits in

sin(factor*theta) changes that radius by making it grow bigger and smaller
function draw() {
    stroke(50, 50, 255);
    strokeWeight(5);
    noFill();
    Polar(300, 300, 4, 1000, 8);
}

It’s a lot of fun to experiment with different values for the `factor` variable!
It’s a lot of fun to experiment with different values for the *factor* variable!

factor = 3

factor = 4

factor = 5

factor = 6

factor = 7

factor = 8
Randomness
Randomness

The Processing function `random()` takes in two numbers and returns a random number between them. Here it is being used to randomly position and size shapes:

```javascript
function setup( )
{
    createCanvas( 300, 300 );
    background( 200, 200, 255 );
    stroke( 0, 0, 0 );
    fill( 255, 50, 50 );
    noLoop( );
}

function draw( )
{
    for( let i = 0 ; i < 20 ; i = i + 1 )
    {
        let x = random( 0, 300 );
        let y = random( 0, 300 );
        let sizex = random( 10, 70 );
        let sizey = random( 10, 70 );
        rect( x, y, sizex, sizey );
    }
}
```
function draw() {
  for (let i = 0; i < 20; i = i + 1) {
    let x = random(0, 300);
    let y = random(0, 300);
    let sizex = random(10, 70);
    let sizey = random(10, 70);
    let r = random(50, 255);
    let g = random(50, 255);
    let b = random(50, 255);
    fill(r, g, b);
    rect(x, y, sizex, sizey);
  }
}
Setting the size and drawing the text

```javascript
function setup( )
{
    createCanvas( 400, 400 );
    background( 200, 200, 255 );
}

function draw( )
{
    fill( 0, 0, 0 );
    textSize( 20 );
    text( "ABC", 50, 50 );

    fill( 0, 0, 255 );
    textSize( 30 );
    text( "DEF", 50, 100 );
}
```

- **Use fill( ) to set the text color**
- **Text height in pixels**
- **Where (x,y) to draw the text**
- **Text to draw**
Saving Your Processing Program and Getting It Back Later
It saves to the cloud. But it only does it if you have an account.

Fortunately, AWSEM / STEM Academy already has one. So, go to the upper-right corner of your Processing window and click on **Log in**. Then enter:

Username: **awsem**  
Password: **corvallis72542**

You can create your own account if you want, *but only do it with your parents’ help.*
The next trick is to click here and change the goofy name it gave your program to something more sensible, preferably something with your name in it and maybe something about what you were working on.
Saving Your Processing Program and Getting It Back Later

Then click **File → Save**
Getting Your Processing Programs Back Later

To bring back programs, click **File → Open**, look at the list of program names there, then click on the one you want to bring back.

The two I put there are *FlowerGarden* and *PaintProgram*.
The Flower Garden
The Flower Garden

Be sure the call to `noLoop()` is included in `setup()`!

```javascript
function setup() {
  createCanvas(600, 600);
  background(200, 200, 255);
  stroke(0, 0, 0);
  noLoop();
}

function draw() {
  for (let i = 0; i < 200; i = i + 1) {
    let r = random(50, 255);
    let g = random(50, 255);
    let b = random(50, 255);
    let xc = random(0, width);
    let yc = random(0, height);
    let factor = random(3, 12);
    let size = random(5, 40);
    fill(r, g, b);
    Flower(xc, yc, factor, size, 150, 1);
  }
}

function Flower(xc, yc, factor, size, numsegs, numturns) {
  let dang = numturns * (2.*PI) / float(numsegs);
  let theta = 0.;
  beginShape();
  for (let i = 0; i <= numsegs; i = i + 1) {
    let r = size * sin(factor*theta);
    let x = xc + r * cos(theta);
    let y = yc + r * sin(theta);
    vertex(x, y);
    theta = theta + dang;
  }
  endShape();
}
```

Number of flowers to draw

Number of line segments to use
The Program Randomly Chooses the Flower’s Color, Position, Size, and Number of Petals
You Get a Different Garden Every Time You Run the Program!
if-statements
Your Code Often Wants to Test Something and Make a Decision Based On It

```c
if( condition )
{
    do this;
    do that;
}
```

These Operators Are the Possible Conditions to Test For:

- `<`  Is less than
- `<=` Is less than or equal to
- `>`  Is greater than
- `>=` Is greater than or equal to
- `==` Is equal to
- `!=` Is not equal to
- `&&` And
- `||` Or
Example

```javascript
function draw() {
    let x = 100;
    fill(0, 255, 0);
    for(let y = 0; y <= 500; y = y + 100) {
        if(y >= 200) {
            fill(255, 0, 0);
        }
        rect(x, y, 200, 50);
    }
}
```
Your Code Often Wants to Test Something and Make a Decision Based On It or the Opposite Condition

```c
if( condition )
{
    do this1;
    do this2;
}
else
{
    do that1;
    do that2;
}
```
Your Code Often Wants to Test Something and Make a Decision Based On It or on Other Conditions

```c
if( condition )
{
    do this;
}
else if( another_condition )
{
    do it;
}
else
{
    do that;
}
```
Your Code Often Wants to Test Something and Make a Decision Based On It or Lots of Alternatives

key is a Processing built-in variable that tells you what key has been hit on the keyboard

```java
if( key == 'r' )
{
    fill( 255, 50, 50 );
}
else if( key == 'g' )
{
    fill( 50, 255, 50 );
}
else if( key == 'b' )
{
    fill( 50, 50, 255 );
}
else
{
    fill( 100, 100, 100 );
}
```
Your Code Often Wants to Test Something and Make a Decision Based On It or Lots of Alternatives -- a Better Way

```c
switch( key )
{
    case 'r':
        fill( 255, 50, 50 );
        break;

    case 'g':
        fill( 50, 255, 50 );
        break;

    case 'b':
        fill( 50, 50, 255 );
        break;

    default:
        fill( 100, 100, 100 );
}
```
Some of Processing’s Variables Already Have the Condition Built-In

function setup( )
{
  createCanvas( 600, 600 );
  background( 200, 200, 255 );
  stroke( 0, 0, 0 );
  fill( 255, 255, 0 );
}

function draw( )
{
  if( mouselsPressed )
  {
    rect( mouseX, mouseY, 50, 20 );
  }
}
Reacting to the Mouse and Keyboard: Creating Your Own Paint Program
function setup( )
{
  createCanvas( 600, 600 );
  background( 200, 200, 255 );
  stroke( 0, 0, 0 );
  fill( 255, 255, 0 );
}

function draw( )
{
  if( mouseIsPressed )
  {
    ellipse( mouseX, mouseY, 50, 50 );
  }
}
The `mouselPressed`, `mouseX`, and `mouseY` Variables
function draw() {
    if (keyIsPressed) {
        switch (key) {
            case 'r':
                fill(255, 50, 50);
                break;
            case 'g':
                fill(50, 255, 50);
                break;
            case 'b':
                fill(50, 50, 255);
                break;
        }
    }
    if (mouseIsPressed) {
        ellipse(mouseX, mouseY, 50, 50);
    }
}
What if you want to read the Special Keys?

```java
... if( keyPressed )
{
    if( key == CODED )
    {
        switch( keyCode )
        {
        case UP: // up-arrow
        ...
        break;
        }
    }
}
```

Values for `keyCode` can be:
- UP
- DOWN
- LEFT
- RIGHT
- ESC
- DELETE
- BACKSPACE
- TAB
- ENTER
- RETURN
Transformations
Let’s Use Our Rectangle Object as an Example of Transformations

```javascript
function setup( )
{
    createCanvas( 800, 800 );
    background( 200, 200, 200 );
    stroke( 0, 0, 0 );
    fill( 0, 255, 255 );
}

function draw( )
{
    rect( 0, 0, 100, 50 );
}
```
function setup( )
{
    createCanvas( 800, 800 );
    background( 200, 200, 200 );
    stroke( 0, 0, 0 );
    fill( 0, 255, 255 );
}

function draw( )
{
    translate( 100, 200 );
    rect( 0, 0, 100, 50 );
}

It is Often Nice to Transform Entire Objects at Once

The word “translate” means to “move around”
Rotations and Scaling Happen Around the Origin
Rotation

In math, science, and computer programming, angles are not given in degrees, they are given in radians.

1 radian = 0.01745 degrees  
1 radian = $\pi/180$. degrees

But, don’t worry about this.

Processing gives you a function, \texttt{radians( )}, to automatically convert degrees into radians, like this:

\[ \text{rad} = \text{radians( deg )}; \]

Use it!
function draw( )
{
    scale( 5., 1. );
    rect( 0, 0, 100, 50 );
}
function draw( )
{
  shearX( radians(45.) );
  rect( 0, 0, 100, 50 );
}

There is also a shearY transformation function.
Transformations Accumulate!

```plaintext
function draw( )
{
    rotate( radians( 10. ) );
    rotate( radians( 10. ) );
    ...
}
```

is the same as:

```plaintext
function draw( )
{
    rotate( radians( 20. ) );
    ...
}
```
Transformation Order Matters!

function draw( )
{
    1. rotate( radians(60.) );
    2. translate( 200, 300 );
    rect( 0, 0, 100, 50 );
}

function draw( )
{
    1. translate( 200, 300 );
    2. rotate( radians(60.) );
    rect( 0, 0, 100, 50 );
}
You Can Save and Restore Transformations

function draw( )
{
    translate( 200, 300 );

    push();  // "save"
    shearX( radians(45.) );
    rect( 0, 0, 200, 100 );
    pop();   // "restore"
    fill( 255, 0, 0 );

    rotate( radians(-45.) );
    rect( 0, 0, 200, 100 );
}
Transformations and for-loops

```javascript
function draw() {
    translate(200, 300);

    for(let degrees = 0; degrees <= 360; degrees = degrees + 36) {
        push();
        rotate(radians(degrees));
        rect(0, 0, 100, 30);
        pop();
    }
}
```
Transformations and for-loops

```javascript
function draw( )
{
    translate( 200, 300 );

    for( let degrees = 0 ; degrees <= 360 ; degrees = degrees + 36 )
    {
        push( );
        rotate( radians(degrees) );
        rect( 0, -15, 100, 30 );
        pop( );
    }
}
```
What’s the Difference?

push();
    rotate( radians(degrees) );
    rect( 0, 0, 100, 30 );
pop();
Transformations and for-loops

function draw( )
{
    translate( 200, 300 );

    for( let degrees = 0 ; degrees <= 360 ; degrees = degrees + 36 )
    {
        push( );
        rotate( radians(degrees) );
        rect( 100, -15, 100, 30 );
        pop( );
    }
}
function draw() {
    translate(200, 300);
    for (let degrees = 0; degrees <= 360; degrees = degrees + 10) {
        push();
        let blue = map(degrees, 0, 360, 255, 0);
        fill(0, 255, blue);
        rotate(radians(degrees));
        let xsize = map(degrees, 0, 360, 100, 10);
        let ysize = map(degrees, 0, 360, 30, 5);
        rect(100, -15, xsize, ysize);
        pop();
    }
}
Images in *Processing* Programming
Let’s Start with a Favorite Image

It can be in .jpg, .bmp, or .png format

Each pixel contains a red-green-blue, each in the range 0-255

The image has an **aspect ratio**, which is the ratio of the **number of Y pixels : the number of X pixels**

(this image’s aspect ratio is 1:1)
Loading Your Image into Your Program’s assets Area

Step #1: Click on this arrow

Step #2: Click on this arrow and select **Create folder**

If you already have an **assets** folder, then you can skip steps #2 and #3.

Step #3: Enter **assets** as the name of the folder and click on **Add Folder**
Loading Your Image into Your Program’s Assets Area

Step #4: Hover over the word `assets` and then click on this arrow.

Step #5: Click on `Upload file`.

Step #6: Drag your image file into this window or click on this window to browse to the image file.
let MyImage;

function setup( )
{
    createCanvas( 800, 800 );
    MyImage = loadImage("assets/zelda.jpg");
    background( 200, 200, 200 );
    stroke( 0, 0, 0 );
    fill( 255, 50, 50 );
}

function draw( )
{
    image( MyImage, 100, 100, 400, 400 );
}
let MyImage;

function setup( )
{
    createCanvas( 800, 800 );
    MyImage = loadImage( "assets/zelda.jpg" );
    background( 200, 200, 200 );
    stroke( 0, 0, 0 );
    fill( 255, 50, 50 );
}

function draw( )
{
    image( MyImage, 100, 100, 400, 400 );
}
What Happens if You Ask For a Different Aspect Ratio?

```javascript
function draw() {
    image(MyImage, 100, 100, 400, 200);
}
```
Translating an Image

```javascript
function draw( )
{
    for( let i = 0 ; i < 6 ; i = i + 1 )
    {
        push( );
        translate( i*100, i*100 );
        image( MyImage, 0, 0, 200, 200 );
        pop( );
    }
}
```

Notice how transforming images works just like transforming rectangles does!
function draw( )
{
    for( let i = 0 ; i < 6 ; i = i + 1 )
    {
        push( );
        translate( 300, 300 );
        rotate( radians(i*60) );
        image( MyImage, 0, 0, 200, 200 );
        pop( );
    }
}

Notice how transforming images works just like transforming rectangles does!
Advanced Polar Patterns
Some Other Polar Patterns

\[ r = \sin \theta + \sin^3 \left( \frac{5\theta}{2} \right) \]

Note: \( x^3 = x \times x \times x \)

\[ r = \sin \left( \frac{8\theta}{5} \right) \]

Imitating a Spirograph™

Looks like an Oreo, but it's not. 😊
Imitating a Spirograph™
let BigR = 200.;
let SmallR = 150.;
let D = 120.;

function setup() {
    createCanvas( 800, 800 );
    background( 200, 200, 255 );
    stroke( 0, 0, 0 );
    strokeWeight( 2 );
    noFill( );
}
function draw() {
  translate(400, 400);

  beginShape();

  for(let t = 0; t <= 10*360; t = t + 2) {
    let bigTheta = radians(t);
    let smallTheta = - (BigR / SmallR) * bigTheta;
    let x = (BigR - SmallR) * cos(bigTheta) + D * cos(smallTheta);
    let y = (BigR - SmallR) * sin(bigTheta) + D * sin(smallTheta);
    vertex(x, y);
  }

  endShape();
}
Imitating a Spirograph™
Programming with Processing!

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