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COSC 123

Computer Creativity

Colours, Active Programs, and Coordinate Transforms

UBC Okanagan

Slides courtesy of Dr. Abdallah Mohamed.

Announcements

- Test 1 scores for multiple choice questions are now released
  - Manually graded questions have NOT yet been grade
  - Think of your score as out of 6 instead of 10
  - Do not count on the manually graded questions to be graded by Bonus Test 1
  - (Remember it cannot hurt you to take the bonus test)
- Bonus Test 1 will be available starting on Thursday at 6 PM!
- Update on procedure to request resubmission
  - If you submit another version of your assignment, the “Request Regrade” button on gradescope is not available ; that’s fine, still create the request on Ed Discussion
- Hopefully rest of the labs for the term will be released later this week

Key Points

1) Color background, shapes, text

2) Control transparency

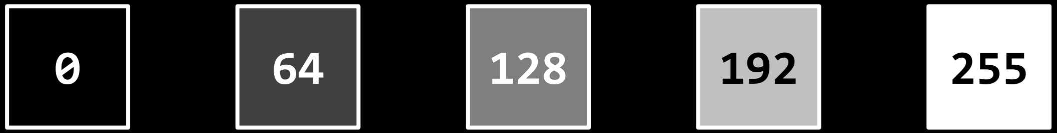
3) Understand two basic color modes: RGB vs HSB

4) Set color range

Color Representation

- You can use different colors for your drawings and the background.

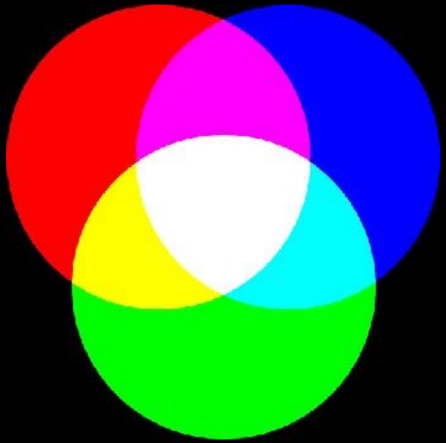
- You have two options:
  - ***Grayscale***: different shades of gray
    - A single digit (integer) ranging from 0 (black) to 255 (white)



  - ***Color*** : to represent a required color using a color model such as RGB or HSB (aka HSV).

RGB Color Model

- RGB is a color that is a result of mixing three primary colors, Red, Green, and Blue.
  - The amount of each color is represented by a value from 0 (none) to 255 (max).
- Examples:



	RED Component	GREEN Component	BLUE Component
Red	255	0	0
Green	0	255	0
Blue	0	0	255
White	255	255	255
Black	0	0	0
Yellow	255	255	0
Cyan	0	255	255
…	…	…	…

- Note: when you have same amounts, you get a shade of gray

Color Question

What is the best description of RGB color (210,0,190)?

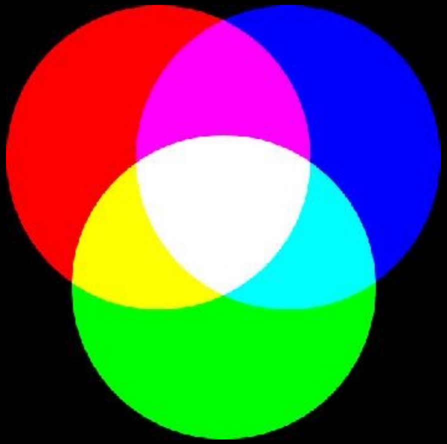
A. a shade of purple

B. a shade of yellow

C. a shade of blue

D. a shade of green

E. a shade of gray



Color Question

What is the best description of RGB color (120,120,120)?

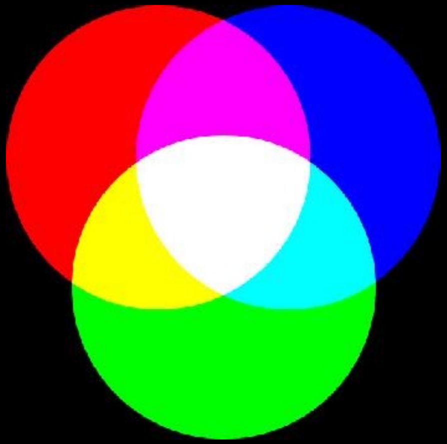
A. a shade of purple

B. a shade of yellow

C. a shade of blue

D. a shade of green

E. a shade of gray



How to Color?

- You can color the following items:
  - ***background*** using `background()` function.
  - ***outline*** and ***fill*** of a shape using `stroke()` and `fill()` before drawing the shape.

- Use either
  - one argument for gray shades. e.g. `fill(0)` is *black* fill.
  - three arguments for RGB color. e.g. `fill(255,0,0)` is *red* fill
    - Note that RGB mode is used by default.

- Once you set a color, it applies to *all shapes drawn afterwards*.

- ***Default values*** are used if no colors are chosen.
  - ***`background`***: 204 (light gray), ***`stroke`***: 0(black), **`fill`**: 255 (white).

- You can use **`noFill()`** or **`noStroke()`** functions to disable filling or outlining a shape.

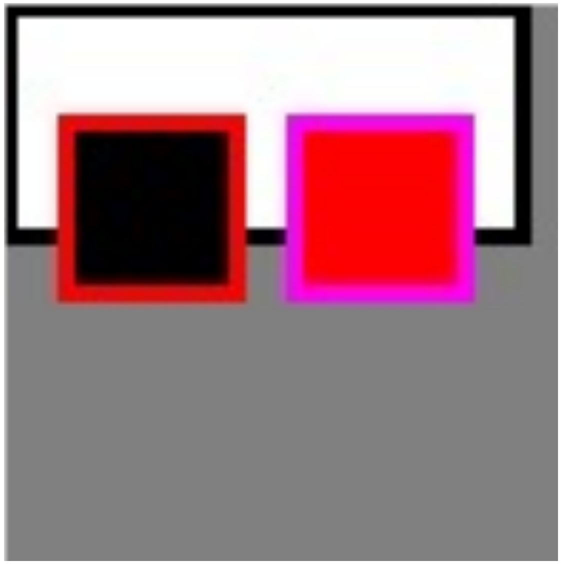
List of color functions so far…

- `background()`
  - Set background color
- `stroke(), noStroke()`
  - Set stroke (line) color
- `fill(), noFill()`
  - Set filling or text color

Example

Colourful Shapes

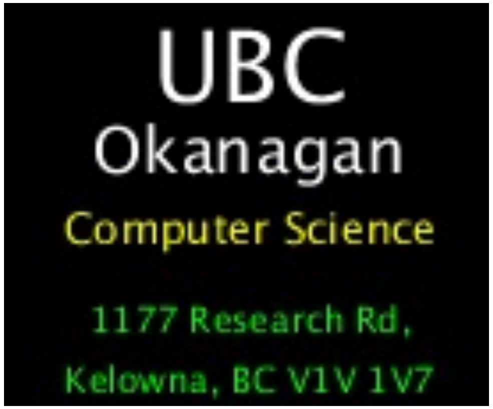
```
background(128);

strokeWeight(3);

fill(255);
rect(0,0,90,40);

stroke(255, 0, 0);
fill(0);
rect(10,20,30,30);

stroke(255, 0, 255);
fill(255, 0, 0);
rect(50,20,30,30);
```



Q: Can you link each statement to one of the output shapes?

Colourful Text

```
background(0);
size(140,120);

textAlign(CENTER);
textSize(28);
text("UBC", 70, 30);

textSize(18);
text("Okanagan", 70, 50);

fill(255,255,0);
textSize(12);
text("Computer Science", 70, 70);

fill(0,255,0);
textSize(10);
text("1177 Research Rd, Kelowna, BC V1V 1V7", 10,85,120,40);
```


UBC
Okanagan
Computer Science
1177 Research Rd,
Kelowna, BC V1V 1V7

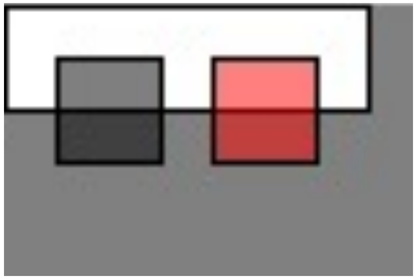
Colour Transparency

- An ***optional argument*** can be used for `fill()` and `stroke()` to ***control transparency***.

0	completely transparent	i.e. 0% opacity
255	completely opaque	i.e. 100% opacity

- Examples:
  - `fill(255)` is opaque white filling (default opacity is 100%)
  - `fill(0, 128)` is semi-transparent black filling
  - `fill(255, 0, 0, 128)` is semi-transparent red filling

```
background(128);
fill(255);
rect(0,0,70,20);
fill(0, 128);
rect(10,10,20,20);
fill(255, 0, 0, 128);
rect(40,10,20,20);
```



Question

Using Colours

What will be drawn on the screen?

A. A line, rectangle, and an ellipse

B. A rectangle and an ellipse

C. Only the ellipse

D. Nothing

E. This code has an error and won’t run.

```
noStroke();
line(30,30,50,30);
noFill();
rect(10,10,20,20);
stroke(255,0);
ellipse(50,50,20,20);
```

Using Colours

These two statements are exactly the same.

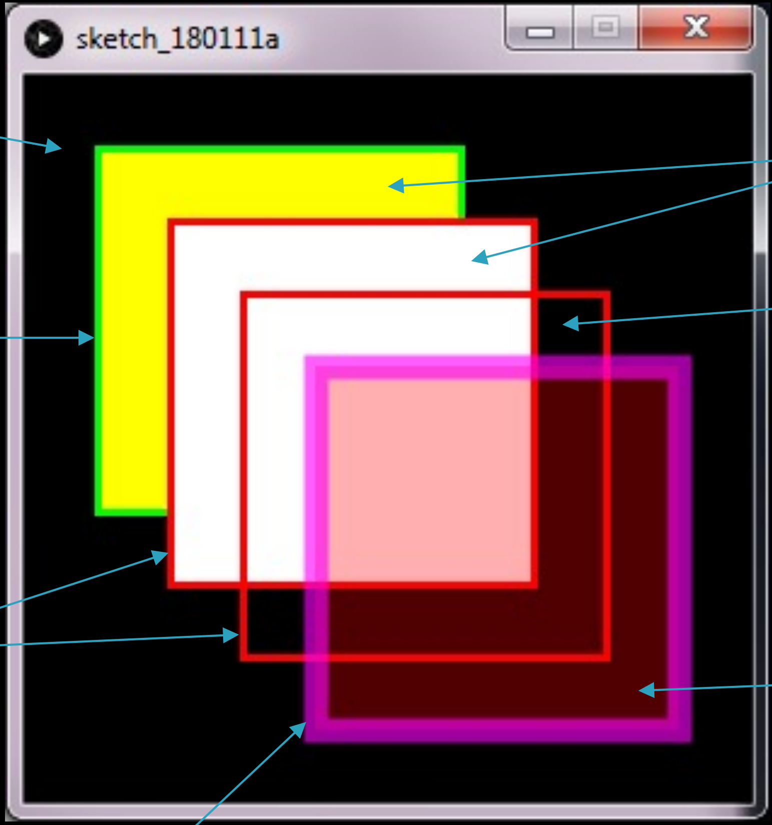
```
fill(255,255,255);
fill(255,255);
```

A. True

B. False

Use Colours!

- Write a code to create the following sketch



Black background

Green outline, thickness: 3

outline thickness: 3

Semi-transparent outline, thickness: 10

Opaque filling

No filling

Semi-transparent filling

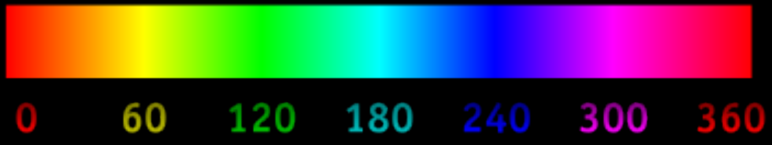
Aside: Hexadecimal Notation

- RGB colours can be represented using Hexadecimal notation.
  - Syntax: #RRGGBB
    - The # denotes the hex notation
    - RR is a two-digit hex number representing red value from 0 to 255
    - GG is a two-digit hex number representing green value from 0 to 255
    - BB is a two-digit hex number representing blue value from 0 to 255

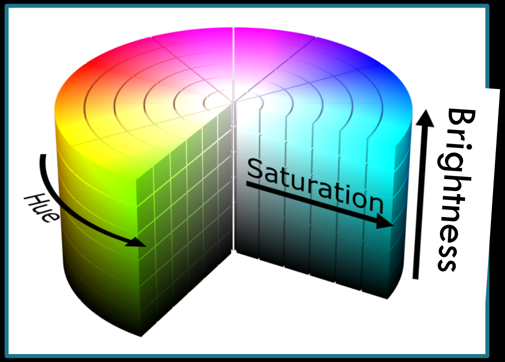
- Examples:
  - `fill(255,255,255)` equivalent to `fill(#FFFFFF)`
  - `fill(128,196,64)` equivalent to `fill(#80C440)`
  - `fill(0,0,255)` equivalent to `fill(#0000FF)`

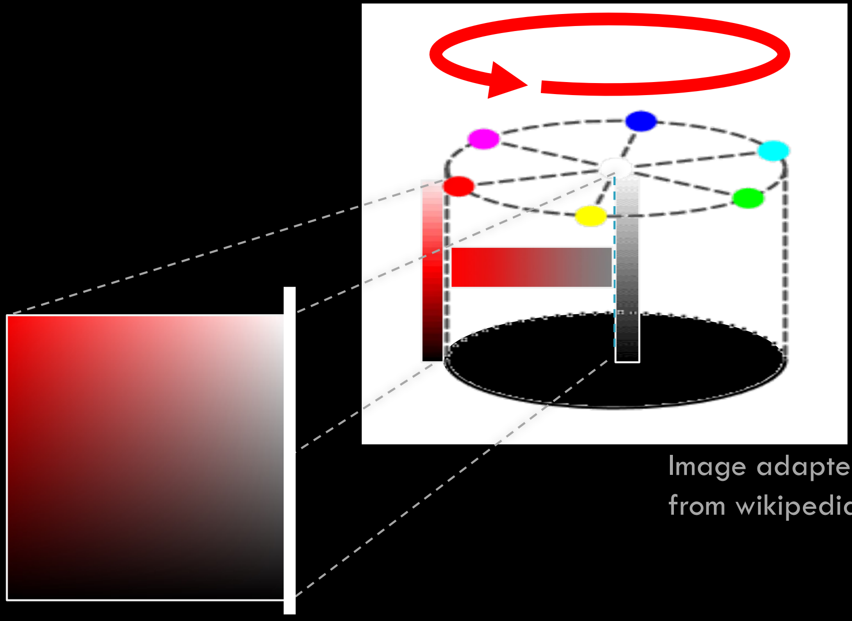
HSB Colour Model

- In this mode, a colour is represented by three components
  - *Hue*
    - Dominant pure color.



  - ***Saturation***:
    - Vibrancy of the color
    - Range: 0 to 100
  - ***Brightness***
    - How bright the color is.
    - Range: 0 to 100





A plane with all S and B values for Hue=0 (red)

Image adapted from wikipedia

Colour Question

What is the best description of HSB colour (350,90,95)?

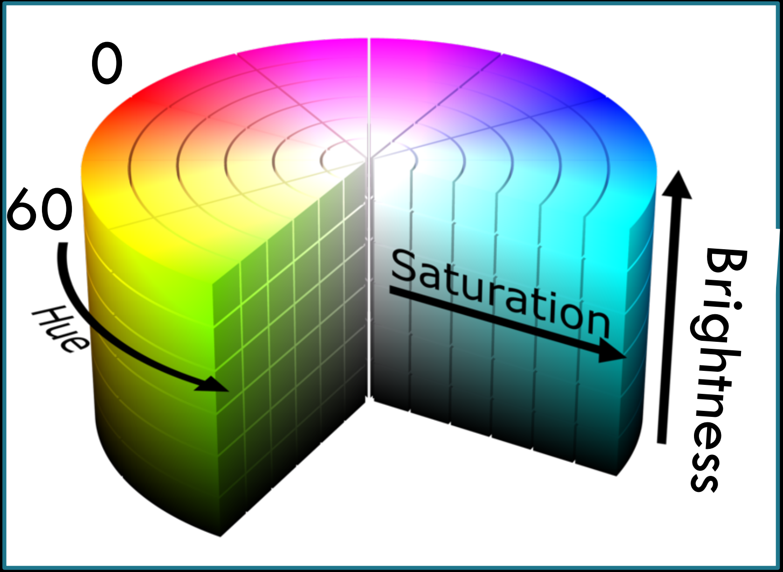
A. a shade of red

B. a shade of blue

C. Black

D. White

E. One of the ranges is invalid



Note: Assume the ranges (0-360,0-100,0-100)

Colour Question

What is the best description of ***HSB*** colour (300,0, 50)?

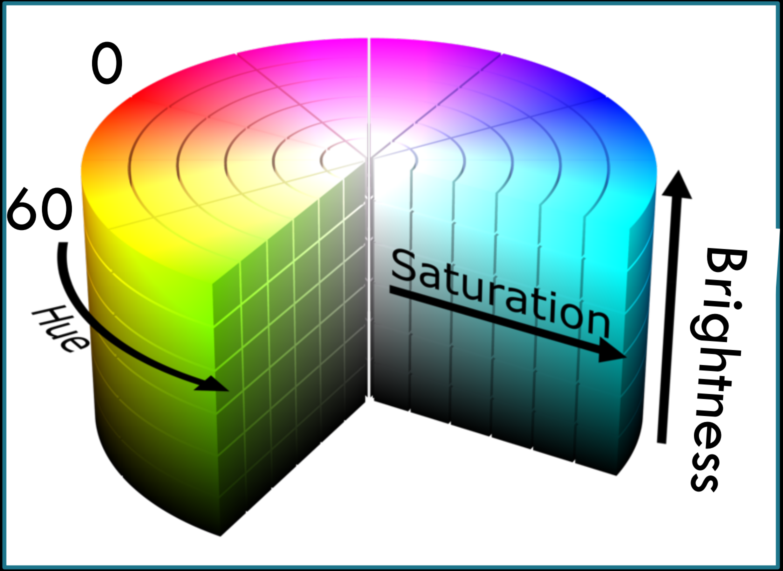
A. a shade of red

B. a shade of blue

C. a shade of gray

D. black

E. One of the ranges is invalid



Note: Assume the ranges (0-360,0-100,0-100)

Colour Question

What is the best description of HSB colour (300, 99, 0)?

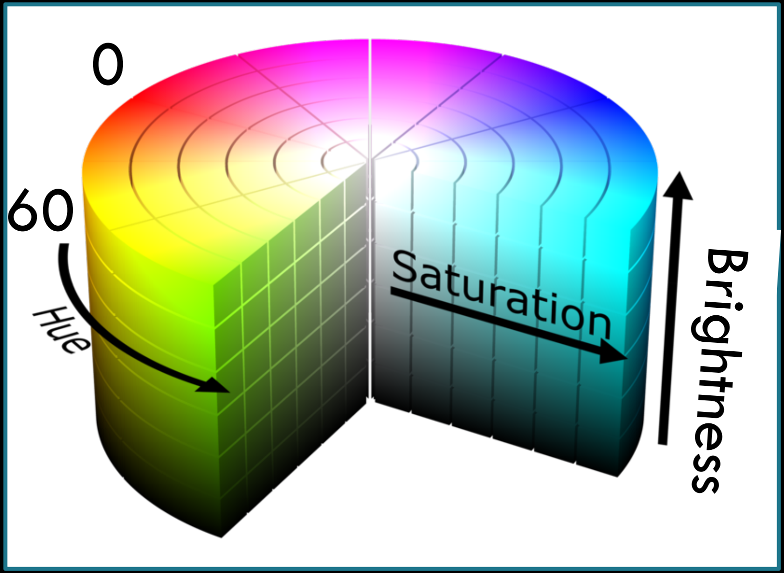
A. a shade of red

B. a shade of blue

C. a shade of gray

D. black

E. One of the ranges is invalid



Note: Assume the ranges (0-360,0-100,0-100)

Colour Question

What is the best description of HSB colour (200,0,150)?

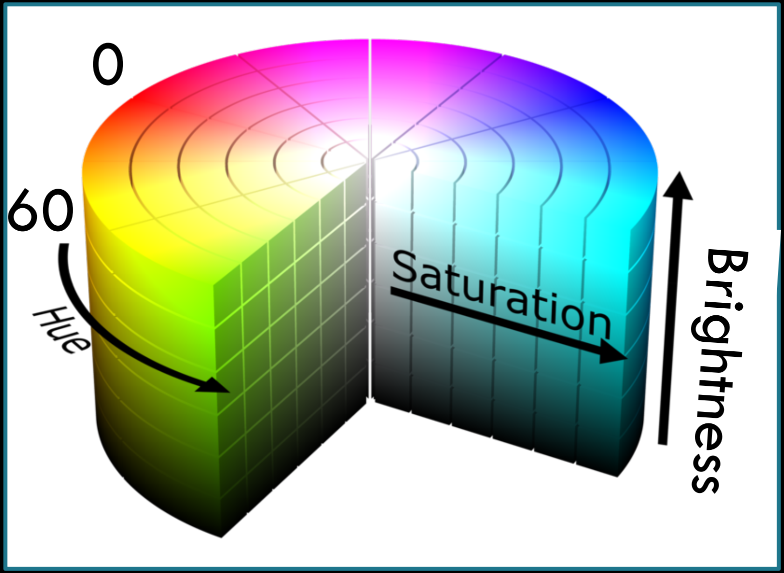
A. a shade of red

B. a shade of blue

C. Black

D. White

E. One of the ranges is invalid



Note: Assume the ranges (0-360,0-100,0-100)

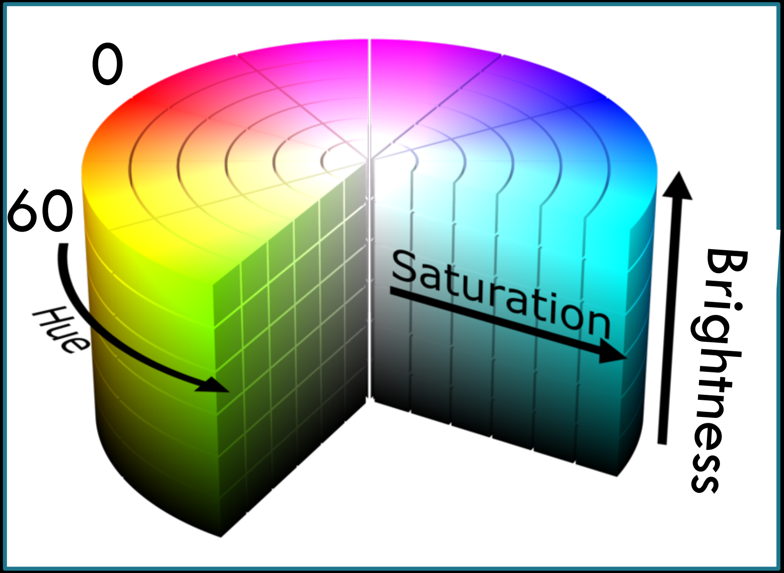
Colour Question

These two HSB colours look the same on the screen:

(200,0,50) and (50,0,50)

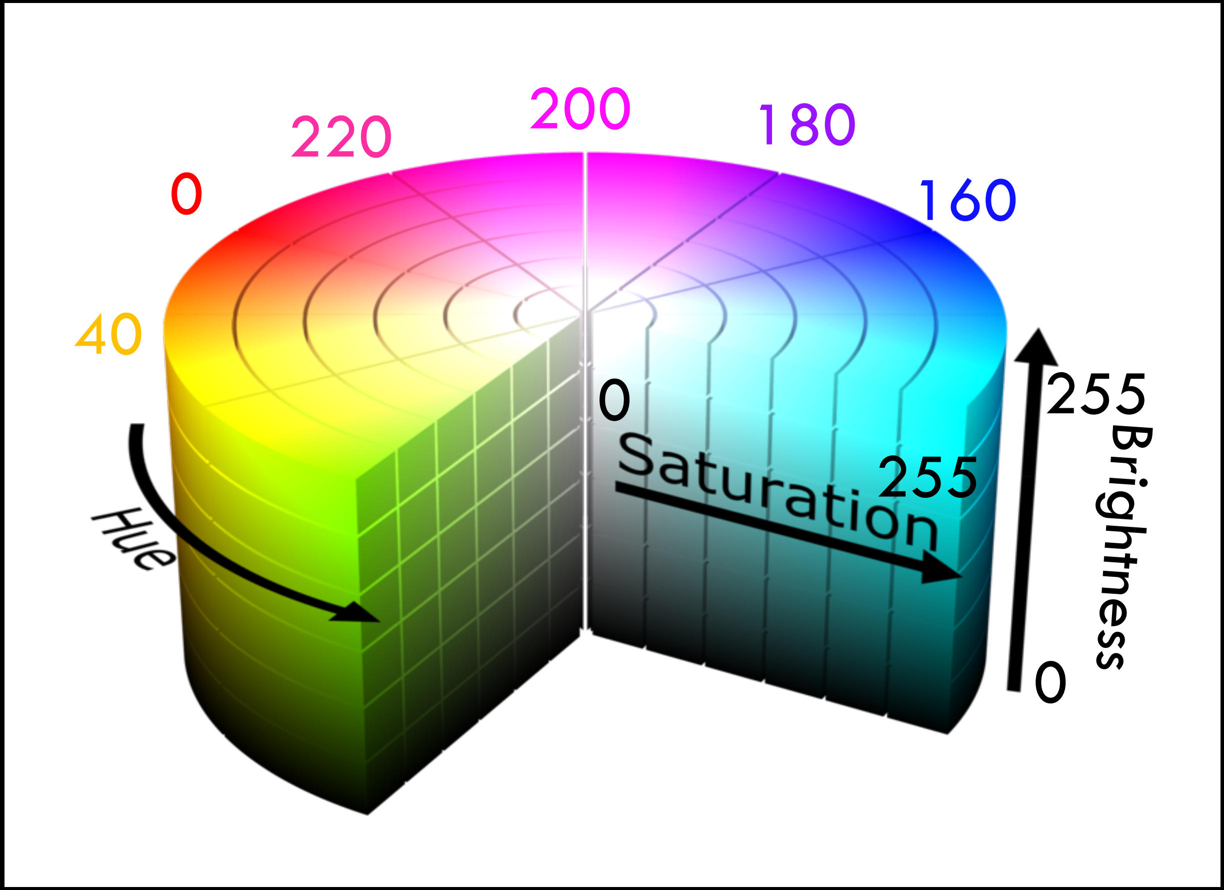
A. True

B. False



HSB Ranges in Processing

- While above ranges (i.e. 360,100,100) are standard in image processing, the ***Processing language*** uses **255,255,255** by default.



Changing the Color Mode

- By default, processing uses RGB mode with ranges from 0 to 255 for all color components R, G, and B.
- Defaults can be changed using `colorMode()` function.
- Syntax:

```
colorMode(mode)
colorMode(mode, max)
colorMode(mode, max1, max2, max3)
colorMode(mode, max1, max2, max3, maxA)
```

- Examples:
  - `colorMode(RGB)` RGB mode, use **default** ranges (0 to 255)
  - `colorMode(RGB,100)` RGB mode, ranges: 0 to 100 for all colors
  - `colorMode(HSB)` HSB mode, default ranges 0 to 255)
  - `colorMode(HSB,360,100,100)` change defaults to 360,100,100
  - `colorMode(HSB,1)` HSB, ranges 0 to 1.0 for all components
  - `colorMode(HSB,1,1,1,10)` same as above, opacity is 0 to 10.

Changing the Colour Mode, cont'd

Be careful:

After changing the ranges with any of the statements above, those ranges will remain in use until they are explicitly changed again.

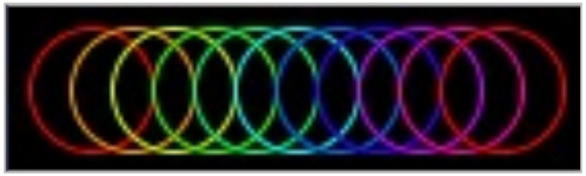
```
colorMode(RGB, 100, 100, 100);  //ranges are 100 for all R,G,B components
colorMode(HSB);                 //ranges are still 100 for all H,S,B components
```

List of colour functions we learned today

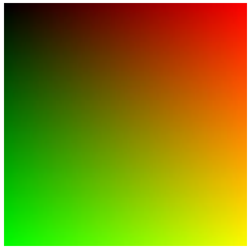
- `background()`
  - Set background colour
- `stroke(), noStroke()`
  - Set stroke (line) colour and transparency
- `fill(), noFill()`
  - Set filling or text color and transparency
- `colorMode()`
  - Choose between RGB and HSB, and optionally set the range

Examples

```
size(140, 40);
background(0);
noFill();
colourMode(HSB, 100);
for (int i = 0; i <= 100; i+=10) {
  stroke(i, 100, 100); //only change the hue in every iteration
  ellipse(i+20, 20, 30, 30);
}
```



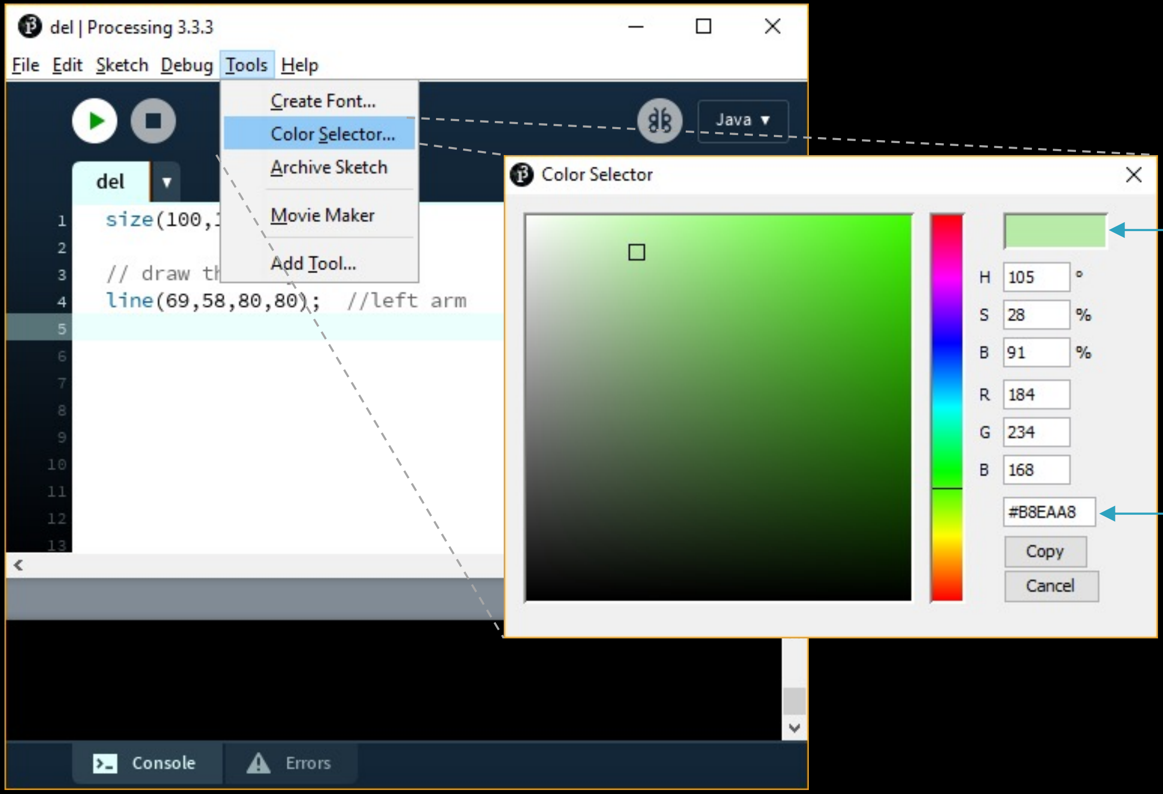
```
// this example is from Processing Documentation
colourMode(RGB, 100);
for (int i = 0; i < 100; i++)
  for (int j = 0; j < 100; j++) {
    stroke(i, j, 0);
    point(i, j);
  }
```



Note: don’t worry so much if you don’t remember for loops. We will go over it later.

PDE Colour Selector Tool

- You can use the PDE colour selector tool from the tools menu (`Tools->Color Selector…`) to get the values of your chosen color.



```
size(100,1

// draw th
line(69,58,80,80);  //left arm
```

H 105 °
S 28 %
B 91 %
R 184
G 234
B 168
#B8EAA8

Current color

HSB values of current color

RGB values of current color

Hex representation for the RGB values

Update Your Design

- Add code to your character that you designed previously so that it has colours now ☺… remember, be creative with your colors and shapes.
- Here is my design, but yours should be different

Active Programs

Slides courtesy of Dr. Abdallah Mohamed.

Objectives

- After finishing reading the materials, you should be able to:
  - Understand the difference between ***static*** and ***active*** modes.
  - Understand the order of execution of active sketches.
  - Create a simple animation using `setup()` and `draw()`.
  - Set the frame rate of an animation using `frameRate()`
  - Know where to place `size()` and `background()`
  - Use the system variables: `mouseX`, `mouseY`, `width`, `height`
  - Stop an animation using `noLoop()`

Static vs Active Modes

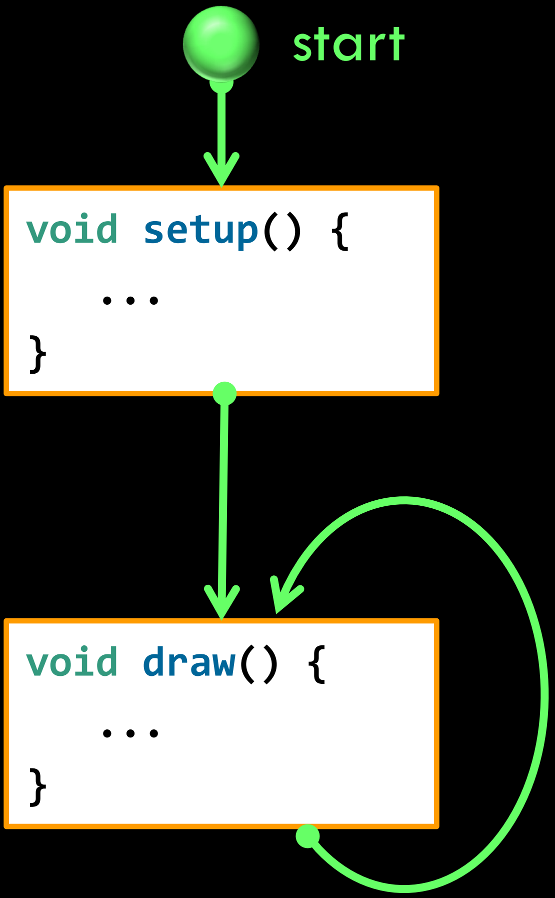
- All programs you have been writing so far are ***static*** sketches.
  - A ***static sketch*** is a series of statements that aim to draw a ***single image***; i.e.no animation or interaction.
- An ***active*** sketch on the other hand aims to draw a ***series of images*** (each called a ***frame***) that represent an ***animation***.
- Active sketches may be programmed to be ***interactive*** to user's actions.
  - Examples of actions: mouse movement, keyboard presses, etc.

How to Create Active Sketches

- Two ***built-in*** functions: `setup()` and `draw()` are always ***called automatically***.
  - `setup()` runs once **at the beginning**
  - Then `draw()` runs repeatedly.

- The rate of running the `draw` method is called the ***framerate***.
  - The default is **60 fps**, but it can be changed using the `frameRate()` function.

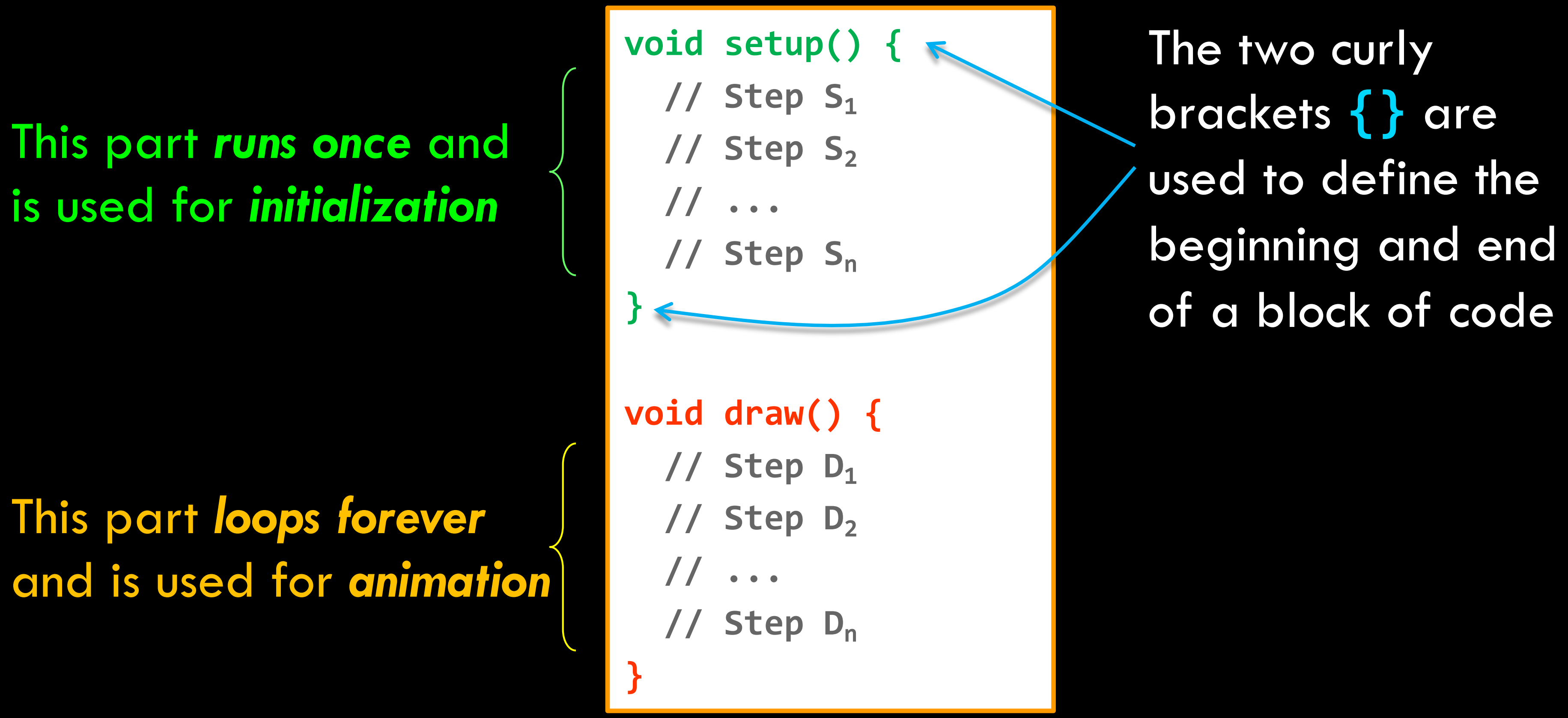
- You can ***stop*** repeating `draw()` using `noLoop()` function.



```
void setup() {
    ...
}
```

```
void draw() {
    ...
}
```

Active Program Structure



This part *runs once* and is used for *initialization*

This part *loops forever* and is used for *animation*

```
void setup() {
  // Step S_1
  // Step S_2
  // ...
  // Step S_n
}

void draw() {
  // Step D_1
  // Step D_2
  // ...
  // Step D_n
}
```

The two curly brackets { } are used to define the beginning and end of a block of code

Order of execution: S_1, S_2, .., S_n, **D_1**, D_2, .., D_n, **D_1**, D_2, .., D_n, **D_1**, …etc

Drawing a Static Sketch with setup/draw

- All these four programs produce the same output
  - *Justify?*

without setup/draw

```
size(200,200);
background(255);
rect(10,10,40,40);
```

three different ways with setup/draw

```
void setup(){
  size(200,200);
}
void draw(){
  background(255);
  rect(10,10,40,40);
}
```

```
void setup(){
  size(200,200);
  background(255);
}
void draw(){
  rect(10,10,40,40);
}
```

```
void setup(){
  size(200,200);
  background(255);
  rect(10,10,40,40);
}
```

Notes About Active Sketches

- You ***can't*** mix static and active modes!
  - Once you use active mode, you ***can't*** call any function, such as *`rect()`*, outside *`setup()`* and *`draw()`*.
- *`size()`* *can only be executed once*
  - *so it can't be part of draw()*

```
void setup(){
  size(200,200);
}
void draw(){
  background(255);
  rect(10,10,40,40);
}
```

✓

mix static & active

```
rect(10,10,40,40);
void setup(){
  size(200,200);
}
void draw(){
  background(255);
}
```

✗

wrong place for size()

```
void setup(){
}
void draw(){
  size(200,200);
  background(255);
  rect(10,10,40,40);
}
```

✗

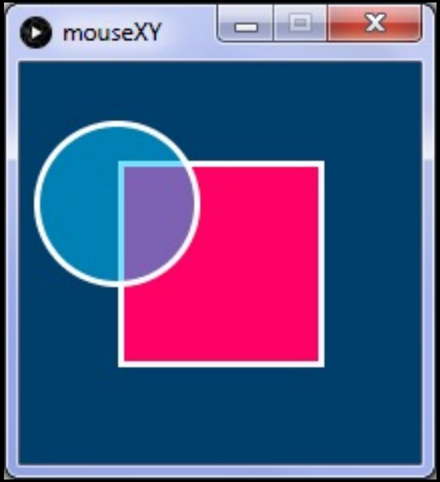
Mouse Location

- Processing has two keywords (*system variables*) that will always contain the current coordinates of the mouse cursor.
  - `mouseX` and `mouseY` contain mouse location (x,y) in current frame.
  - ***Default value*** is 0 for both variables.

A Shape Following the Mouse

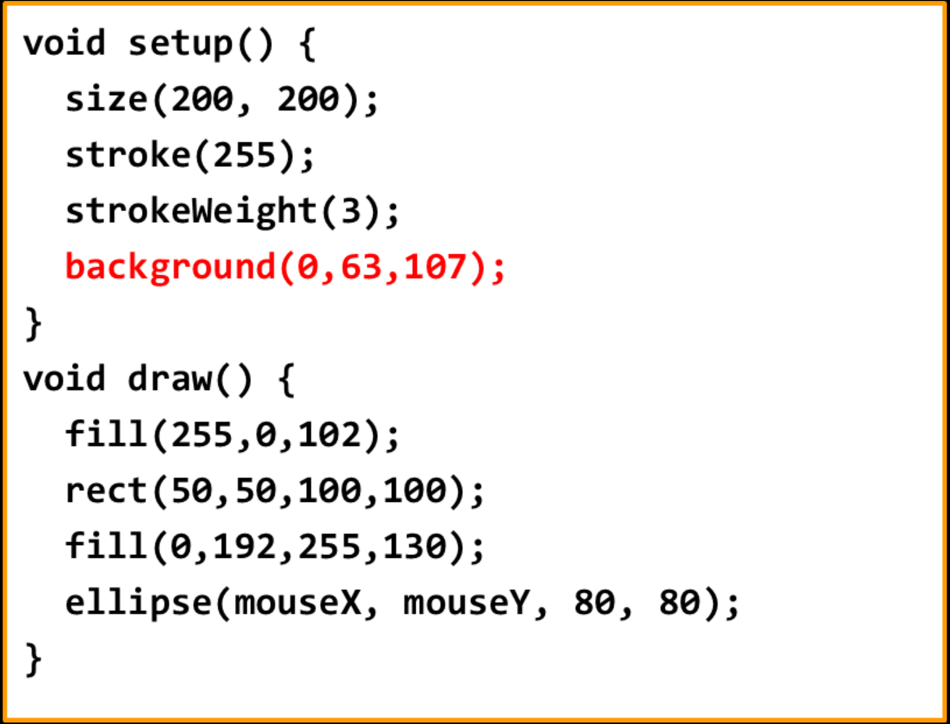
- In this example, the ball follows the mouse position.

```
void setup() {
  size(200, 200);
  stroke(255);
  strokeWeight(3);
}
void draw() {
  background(0,63,107);
  fill(255,0,102);
  rect(50,50,100,100);
  fill(0,192,255,130);
  ellipse(mouseX, mouseY, 80, 80);
}
```

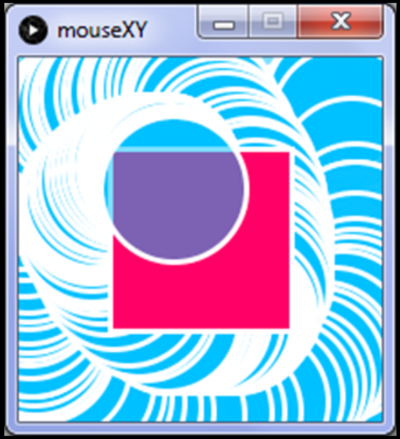


Where to put background()

- *If placed in draw()*, it clears the sketch at beginning of every frame
  - i.e. it flood the sketch with some color.
- *If placed in setup()*, it sets the background of first frame only and doesn't clear subsequent frames.
- If you move `background()` to `setup()`, this would be the output from the previous example.

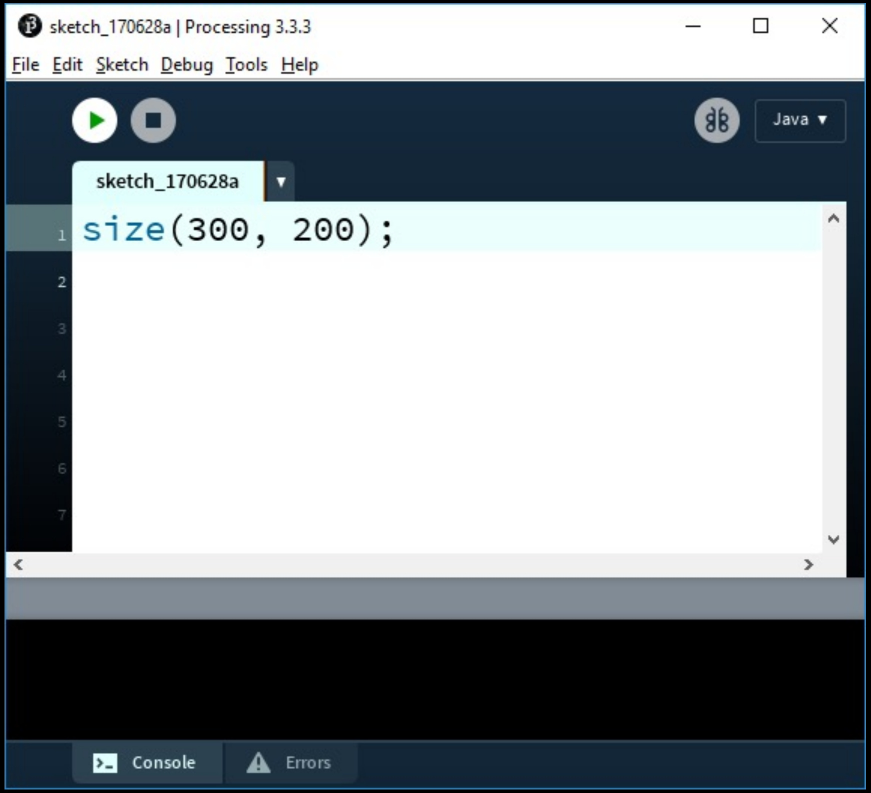


```
void setup() {
  size(200, 200);
  stroke(255);
  strokeWeight(3);
  background(0,63,107);
}
void draw() {
  fill(255,0,102);
  rect(50,50,100,100);
  fill(0,192,255,130);
  ellipse(mouseX, mouseY, 80, 80);
}
```

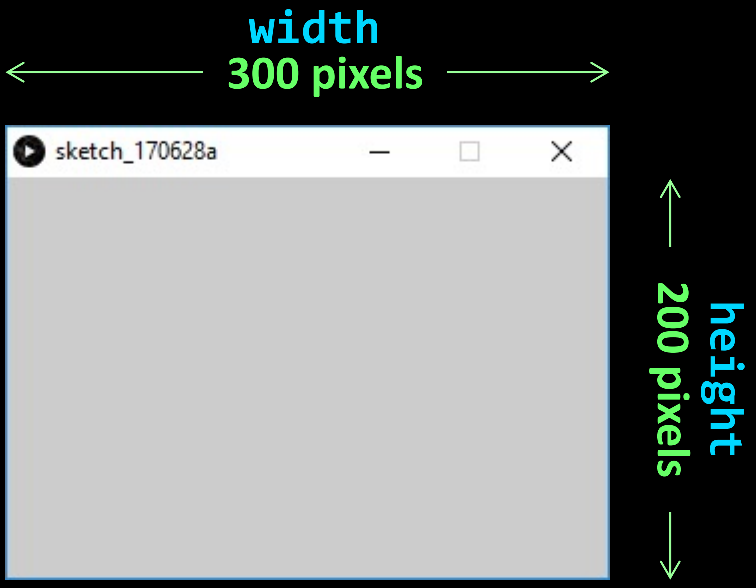


Window's width and height

- There are to more useful system variables: **`width`** and **`height`** that contain the size of the current display window.
  - We set these two values using the **`size()`** function.
  - Default value is 100 if **`size()`** is not used.


sketch_170628a | Processing 3.3.3
File Edit Sketch Debug Tools Help
Java ▾
sketch_170628a
Console
Errors

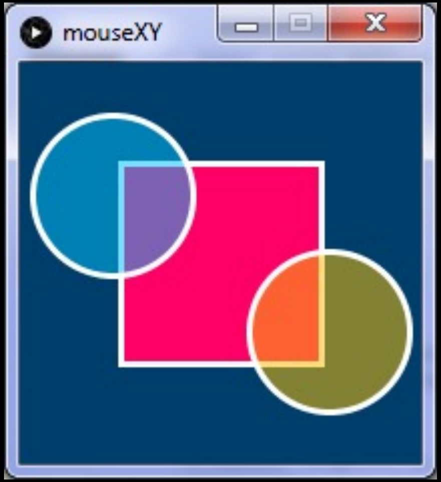
```
size(300, 200);
```



Two Shapes Controlled by the Mouse

In this example, we create a second ball positioned at the inverse of the cursor position.

```
void setup() {
  size(200, 200);
  stroke(255);
  strokeWeight(3);
}

void draw() {
  background(0,63,107);
  fill(255,0,102);
  rect(50,50,100,100);
  fill(0,192,255,130);
  ellipse(mouseX, mouseY, 80, 80);
  fill(255,192,0,130);
  ellipse(width-mouseX, height-mouseY,80,80);
}
```



Function Automatically Called

Which of these functions is *automatically called* by the system once we run the program?

A. size(200,200);

B. setup() and draw()

C. noLoop()

D. rect(0,0,width,height);

E. ellipse(0,0,width,height);

Question

Frame Rate

The default frame rate is _____ and it can be changed using the function _______

A. 15, frameRate()

B. 60, frameRate()

C. 15, setFrameRate()

D. 60, setFrameRate()

E. None of the above

Question

Where to write code?

Which code is valid?

A.

```
void setup(){
   ...
}
void draw(){
   size(100,100);
   ...
}
```

B.

```
void setup(){
   size(100,100);
   ...
}
void draw(){
   ...
}
```

C.

```
size(100,100);
void setup(){
   ...
}
void draw(){
...
}
```

D. None of the above.

Question

Where to write code?

Which code clears a the display window at the beginning of each frame?

A.

```
void setup(){
  size(200,200);
}
void draw(){
  background(255);
  rect(5,5,90,90);
}
```

B.

```
void setup(){
  size(200,200);
  background(255);
}
void draw(){
  rect(5,5,90,90);
}
```

C.

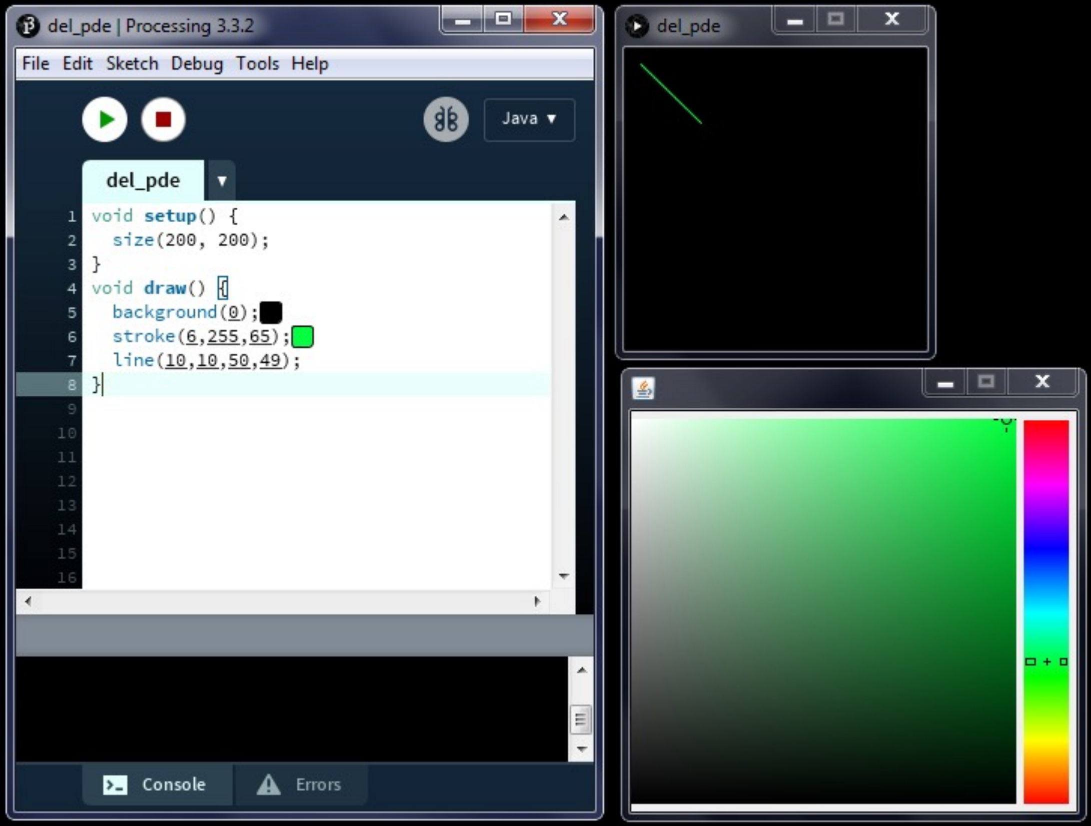
```
background(255);
void setup(){
  size(200,200);
}
void draw(){
  rect(5,5,90,90);
}
```

D. None of the above; I have a better answer.

***Question:** what is the difference between A, B, and C?*

Tweaking Your Sketch At the Runtime

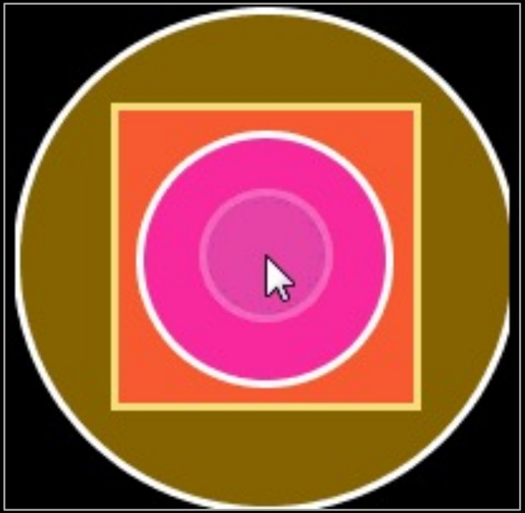
- Tweak Mode (**`Sketch->Tweak`**) runs the code so that you can change some color and variable values while the code is running and see instant feedback.
- Notes:
  - This only applies to ***active mode***.
  - You need to save your program before you can tweak it.



```
void setup() {
  size(200, 200);
}
void draw() {
  background(0);
  stroke(6,255,65);
  line(10,10,50,49);
}
```

Animation based on Mouse Location

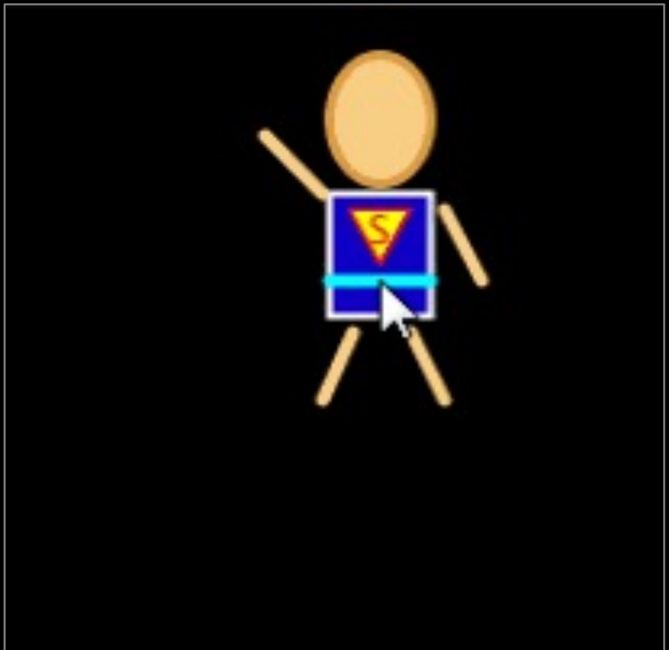
- Build on the code in the pre-class materials and use the mouse coordinates (`mouseX`, `mouseY`) to control other attributes in the animation, e.g. size, transparency, color, background, etc.
- Be creative! For example, in this animation →
  - I added a third circle, then had the size of each shape change differently:
    - Circle1: radius = `mouseX + mouseY`
    - Circle2: radius = `mouseX/2`
    - Circle3: radius = `mouseY*2`
    - `Box:` size depends on mouseX and mouseY
  - Controlled shapes' location with mouse location.
  - Changed the background color based on the combined size of all circle.



- Your interactive animation doesn't have to have any purpose for now, just try to make it look cool and have fun ☺

Moving YOUR Character

- Referring to the character you designed previously, add code to your program so that the character moves with your mouse cursor.
- Hint: the location of all shapes of your character should depend on mouseX and mouseY
- Here is the output (Your character could be different):



Notes

Active Programs (2)

Okanagan

Slides courtesy of Dr. Abdallah Mohamed.

Objectives

- After reading, you should be able to:
  - Use mouse location from previous frame (`pmouseX`, `pmouseY`)
  - Generate random numbers using `random()`
  - Write programs that are driven by mouse and key events
    - 1) Using mouse functions:

      `mousePressed()`, `mouseReleased()`, `mouseClicked()`, `mouseMoved()`, `mouseDragged()`
    - 2) Using key functions:

      `keyPressed()`, `keyReleased()`

Mouse Location… revisited!

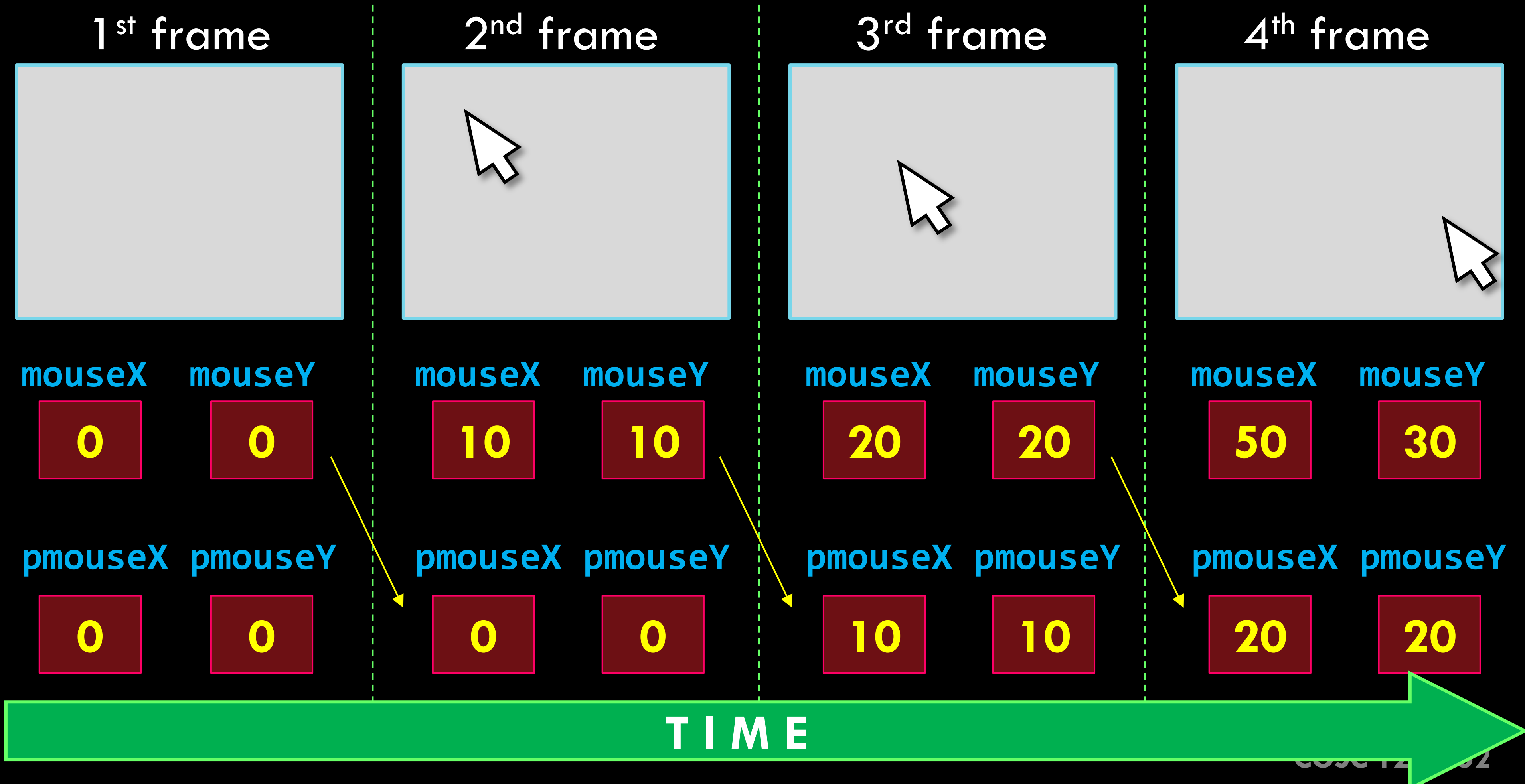
- You have seen before that Processing has two *system variables* that hold the current coordinates of the mouse cursor
  - `mouseX` and `mouseY` contain mouse location (x,y) in current frame.

- Furthermore, processing has two more system variables that will always hold the previous coordinates of the mouse cursor.
  - `pmouseX` and `pmouseY` contain (x,y) from the frame previous to the current frame (if used inside the **`draw()`** function).

- ***Default value*** is 0 for all four variables.

pmouseX **and** *pmouseY*

- You can use pmouseX and pmouseY whenever you want to use the mouse location in the previous frame.

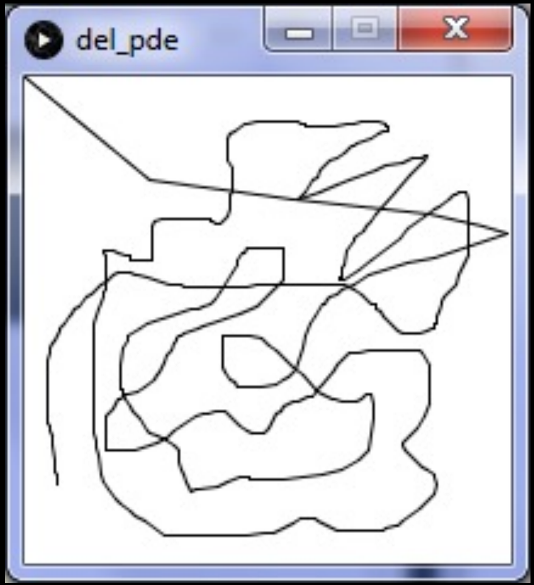


	1st frame	2nd frame	3rd frame	4th frame
mouseX	0	10	20	50
mouseY	0	10	20	30
pmouseX	0	0	10	20
pmouseY	0	0	10	20

pmouseX and pmouseY

- We can use previous mouse coordinates is to draw a ***continuous line***.
- Note where we placed background.

```
void setup() {
  size(200, 200);
  background(255);  // don’t clear previous frame
}
void draw() {
  line(pmouseX, pmouseY, mouseX, mouseY );
}
```



- Task: change the ***framerate*** to 4 fps and check the output

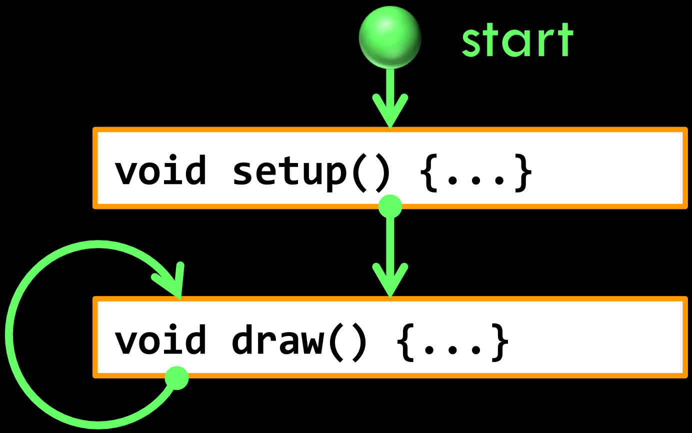
Mouse and Key Events

- While `setup()` & `draw()` are ***always*** invoked automatically, there are functions that are invoked ***based on users input.***

- Functions that are called based MOUSE events:
  - `mousePressed()`: called whenever a mouse button is clicked
  - `mouseReleased()`: called whenever a mouse button is released
  - `mouseClicked()`: called after a mouse button is pressed then released.
  - `mouseMoved()`: called whenever the mouse moves and the mouse button ***is not*** clicked
  - `mouseDragged()`: called whenever the mouse moves and the mouse button ***is*** clicked

- Functions that are called based KEY events:
  - `keyPressed()`: called whenever a key is pressed.
  - `keyReleased()`: called whenever a key is released.

Overall Structure of Active Programs



```
void setup() {...}
```

setup runs once

then

draw runs many times per second

```
void draw() {...}
```

```
void mouseClicked(){…}
void mousePressed() {…}
void mouseReleased(){…}
void mouseDragged() {…}
void mouseMoved(){…}
```

mouse functions are ***automatically*** called when a mouse event happens

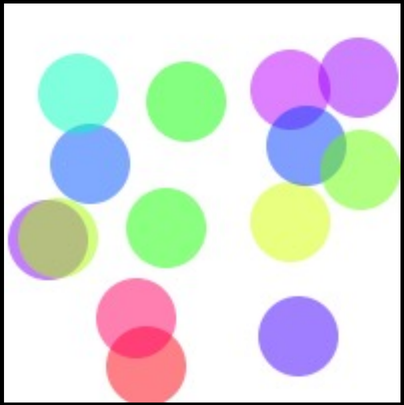
```
void keyPressed() {…}
void keyReleased() {…}
```

Key functions are ***automatically*** called only when a key event happens

Event Driven Program

- In this this example, a new circle is drawn ***wherever the mouse is clicked***. The color of the circle is random.
- Also, ***whenever a key is pressed***, the sketch is cleared!

```
void setup() {
  size(200, 200);
  colorMode(HSB,360,100,100);     //HSB mode is used
  background(360,0,100);          //white background
  noStroke();
}
void draw() {// nothing here}

void mousePressed() {
  fill(random(360),100,100,128); //random color
  ellipse(mouseX, mouseY, 40, 40);
}
void keyPressed() {
  background(360,0,100);         //clear sketch
}
```



Question: what happens if we add background() to draw()?

End of Tuesday’s Class

Active Programs (2)

Slides courtesy of Dr. Abdallah Mohamed.

Summary of Notes

- The notes covered the following:
  - ***New*** keywords: `pmouseX`, `pmouseY`
  - ***New*** functions : `random()`
  - ***New*** event-driven functions
    - automatically invoked based on MOUSE events:

      `mousePressed()`, `mouseReleased()`, `mouseClicked()`,

      `mouseMoved()`, `mouseDragged()`
    - automatically invoked based on KEY events:

      `keyPressed()`, `keyReleased()`

Question

Mouse Location

Which of the following keeps track of mouse location from previous frame?

A. mouseX , mouseY

B. pmouseX , pmouseY

C. pFrame.x, pFrame.y

D. pFrame.mouseX, pFrame.mouseY

E. none of the above

Question

Drawing a continuous line

Which of the following can be used to draw a continuous line?

A.

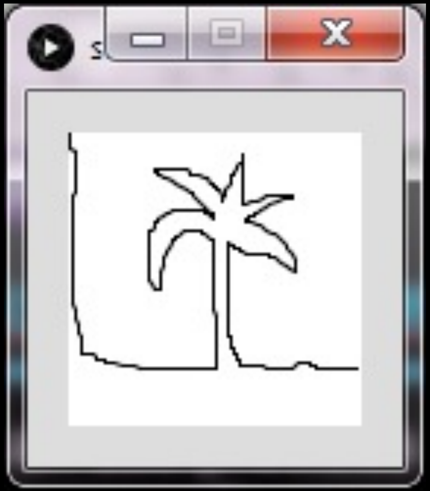
```
void setup(){  background(255); }
void draw() {
  line(pmouseX, pmouseY , mouseX, mouseY);
}
```

B.

```
void setup(){  background(255); }
void draw() {
  line(mouseX, mouseY, pmouseX, pmouseY );
}
```

C.

```
void setup(){ }
void draw() {
  background(255);
  line(mouseX, mouseY, pmouseX, pmouseY );
}
```



D. ***Either A or B***

E. ***All of them***

Question

Event Based Programming

Which of these functions is automatically called whenever the user presses the mouse button and moves the mouse at the same time.

A. mouseReleased

B. mousePressed

C. mouseDragged

D. mouseMoved

E. Both B and C

Question

Framerate

Which framerate has most probably produced this output?

A. 60

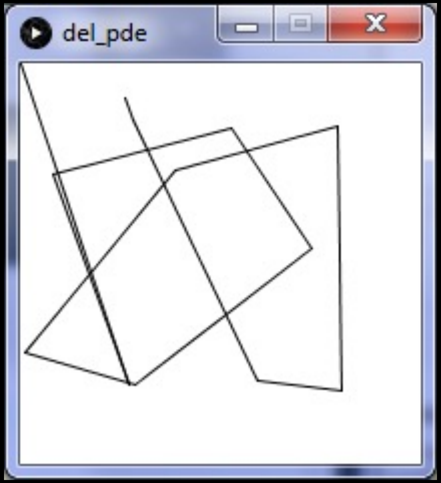
B. 45

C. 30

D. 25

E. 5

```
void setup() {
  size(200, 200);
  background(255);
  stroke(0);
  framerate(????);
}
void draw() {
  line(pmouseX, pmouseY, mouseX, mouseY);
}
```



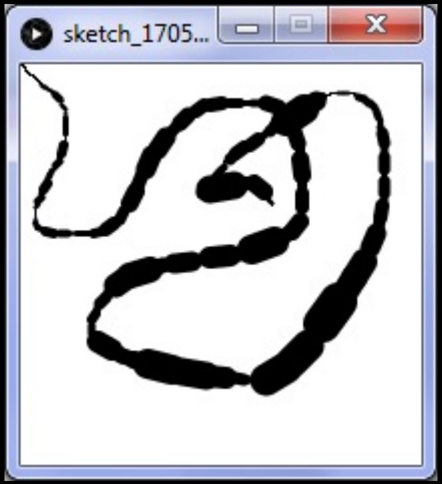
Lecture Activity Task

Mouse Speed

- this code is from the notes used to draw a continuous line.

```
void setup() {
  size(200, 200);
  background(255);
  stroke(0);}
void draw() {
  //... add code here ...
  line(pmouseX, pmouseY, mouseX, mouseY );
}
```

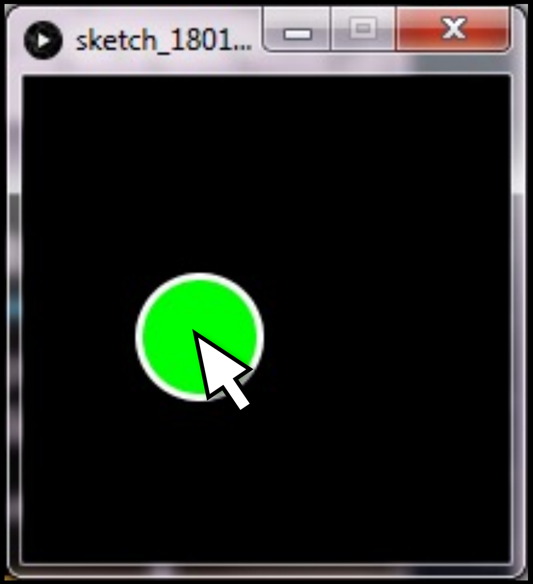
- Modify the code so that the thickness of the line is controlled by the ***mouse speed***. Here are some hints:
  - Mouse Speed is the distance the mouse travel per unit of time. Therefore, speed can be computed in terms of the distance the mouse travels in each new frame.
    - i.e. difference between current mouse position and previous one
  - Use `abs()` function to avoid negative values.
  - Don’t worry too much about having accurate calculations.



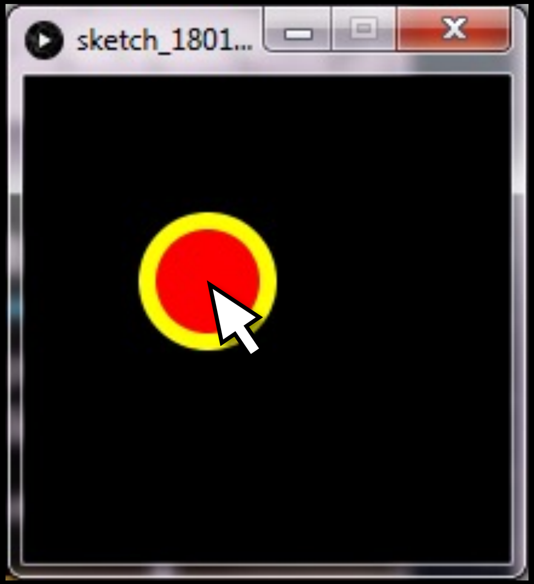
Exercise

Mouse Events

- Create a program that draws a circle which follows the mouse (same location as the mouse)
- The circle should be:
  - red with thick, yellow outline as long as the mouse is pressed.
  - green with thin, white outline as long as the mouse is not pressed.
- **Don't** use variables or **conditional** statements



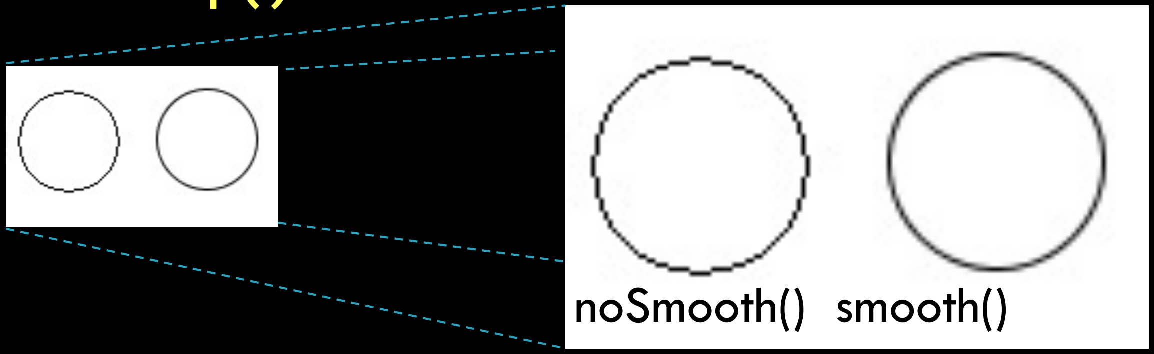
Mouse key is not pressed



Mouse key is pressed

Aside: `smooth()` and `noSmooth()`

- By default, all geometry is drawn with smooth (anti-aliased) edges. However, you can control this behaviour using `smooth()` function to enable this feature, and `noSmooth()` function to disable smoothing.
- Notes:
  - You don’t need to run **`smooth()`** as it is the default behaviour.
    - You may use it if you want to change the anti-aliasing level (1,2,4,8) – the default level 2; i.e. **`smooth(2)`**
  - The maximum anti-aliasing level is determined by the hardware of the machine running the software
    - i.e. no guarantee that **`smooth(4)`** and **`smooth(8)`** will work on your computer.
  - Use both functions inside the **`setup()`** function.



Coordinates Transformation

Slides courtesy of Dr. Abdallah Mohamed.

Key Points

1) How to translate, rotate, and scale the coordinates

2) Coordinates are reset before every new frame.

3) Transformation is cumulative ***within*** each frame.

4) Order is important when combining more than one transformation.

5) Storing and restoring coordinate systems.

6) How to use transformed coordinates in static and dynamic programs.

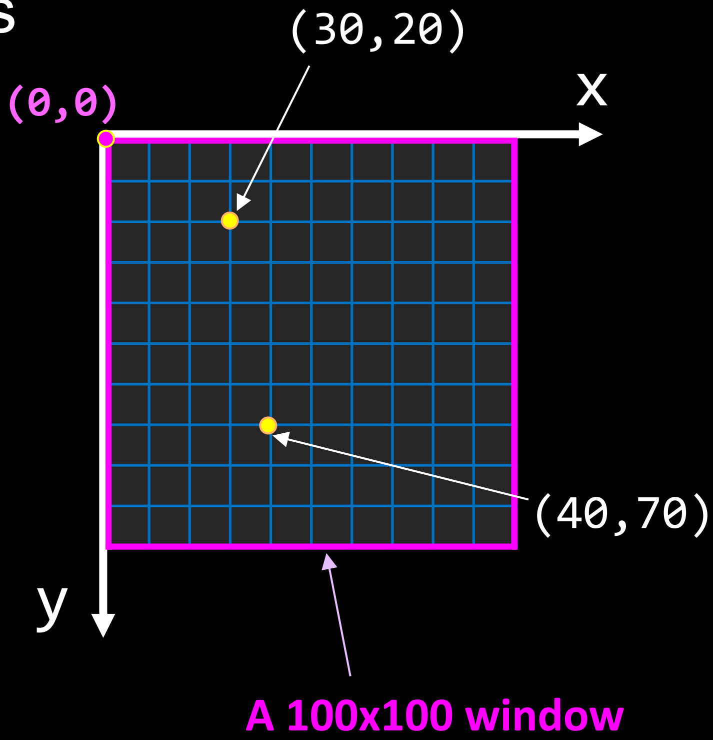
The *Default* Coordinate System

- By default, the coordinate system has its ***origin*** at the upper-left corner of the window, with x and y coordinates as shown in the figure.

- This default representation can be transformed, i.e. ***translated***, ***rotated***, and scaled using built-in functions:
  - `translate()`, `rotate()`, `scale()`

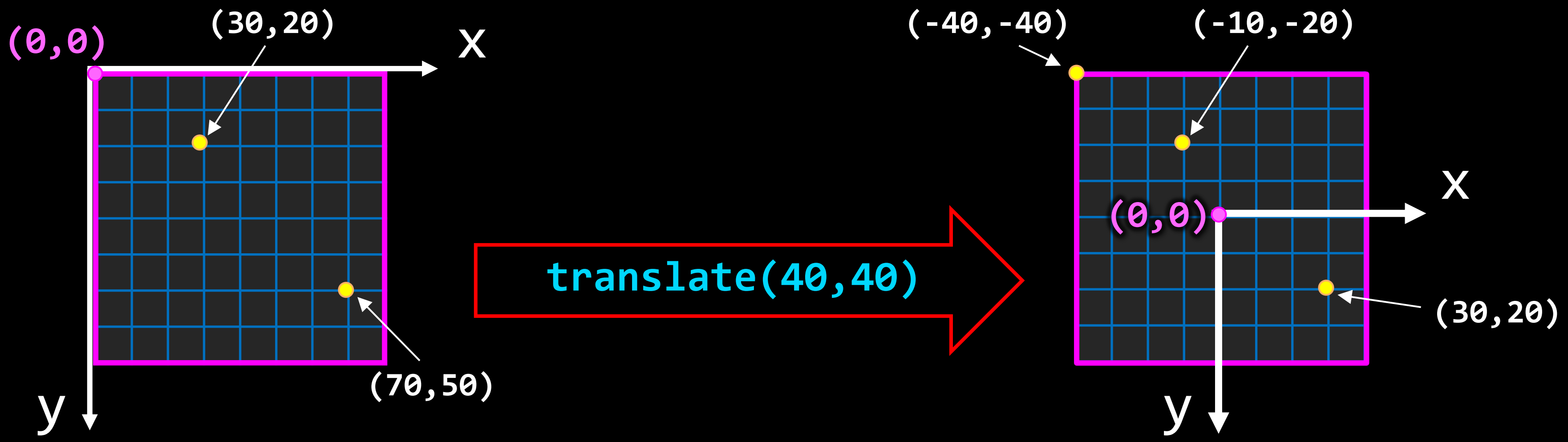
- Only shapes drawn ***after*** the transformation use the new coordinates.

- Coordinates are ***reset at the beginning*** of each new frame (inside `draw()`)



Coordinate Translation - *`translate()`*

- The `translate()` function moves the origin to a new location.

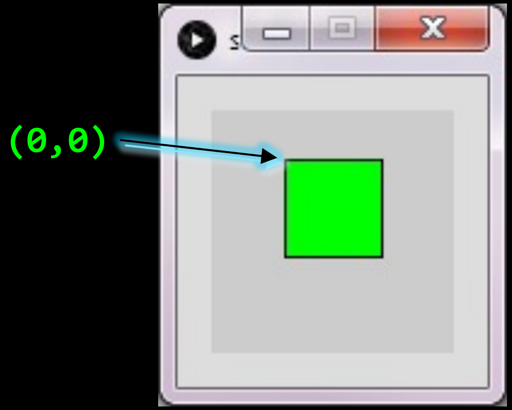


- `translate()` applies only to shapes drawn after the function call
- You can think of translate is if you are ***adding its arguments*** to all shapes that come after it. i.e. `(30,10) + (40,40) = (70,50)`

Example

translate() in static mode

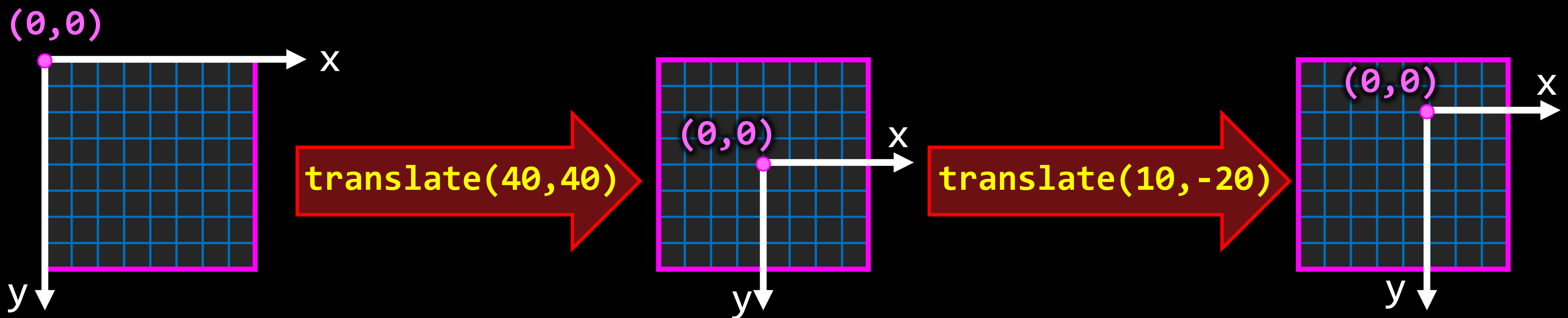
```
//  move origin 30 px right and 20 px down
translate(30, 20);
fill(0,255,0);
rect(0, 0, 40, 40);   // Draw at new origin
```



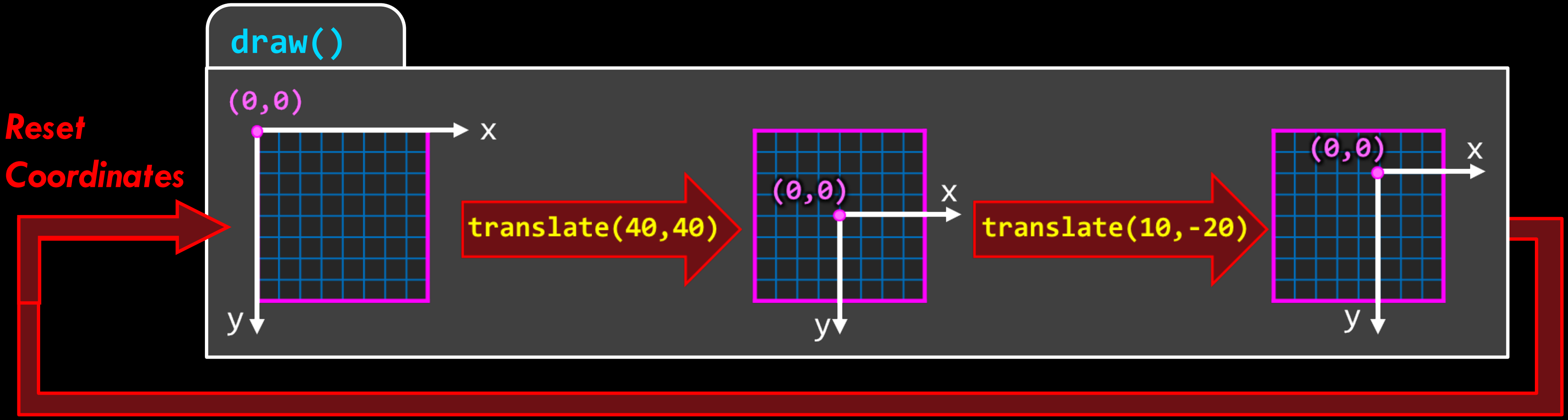
- ***Remember*** that we can think of the output as if we **add the translation** value to the **location of rectangle (assuming the original is still at top-left corner)**. That is,
  - The (x,y) of the green rectangle is (**0**+30,**0**+20) if the original is still at top-left corner.

Coordinate Translation - translate()

- translate() is **cumulative** **within each frame.**

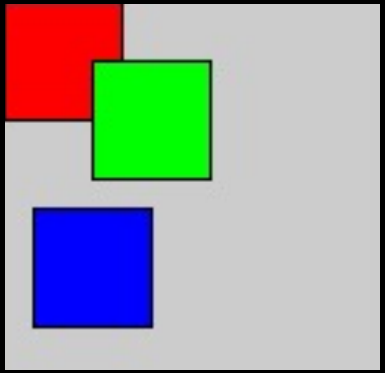


- However, the coordinates are **reset** for each new frame.
  - i.e. if you use transform the coordinates within draw() method, the next frame assumes default origins and then translate again.



translate() in static mode

```
//  Draw rect at default origin
fill(255,0,0);          // Red
rect(0, 0, 40, 40);

//  move origin 30 px right and 20 px down
translate(30, 20);
fill(0,255,0);          // Green
rect(0, 0, 40, 40);    // Draw at new origin

// move origin again 20 px left and 50 px down
translate(-20, 50);
fill(0,0,255);          // Blue
rect(0, 0, 40, 40);    // Draw rect at new
```

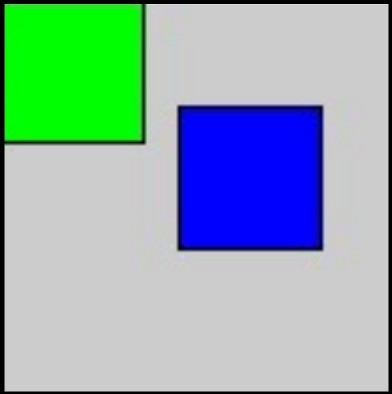


- ***Another way*** of thinking of the output is that we **add the translation** value to the location of shapes drawn after the function call. That is,
  - The (x,y) of the green rectangle is (**0**+30,**0**+20)
  - The (x,y) of the blue rectangle is (**0**+30-20,**0**+20+50)

Example

translate() in dynamic mode

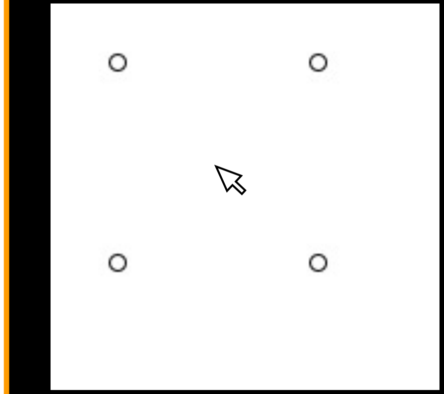
```
void draw() {
  // every beginning of new frame, default origin at (0,0) is used
  fill(0,255,0);          // Green
  rect(0, 0, 40, 40);  // Draw rect at new origin

  translate(50, 30);      // move origin to (50, 30)
  fill(0,0,255);          // Blue
  rect(0, 0, 40, 40);  // Draw rect at new origin
}
```

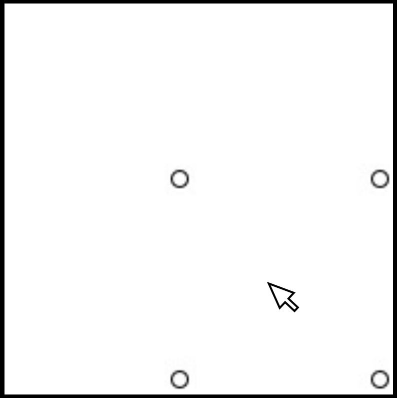


Example

Moving all items with the mouse

```
void draw() {
   background(255);
   // Translate to the mouse location
   translate(mouseX, mouseY);
   ellipse( 30,  30, 6, 6);
   ellipse(-30,  30, 6, 6);
   ellipse( 30, -30, 6, 6);
   ellipse(-30, -30, 6, 6);
 }
```





Q1: is there another way to write the code **without translate()?**

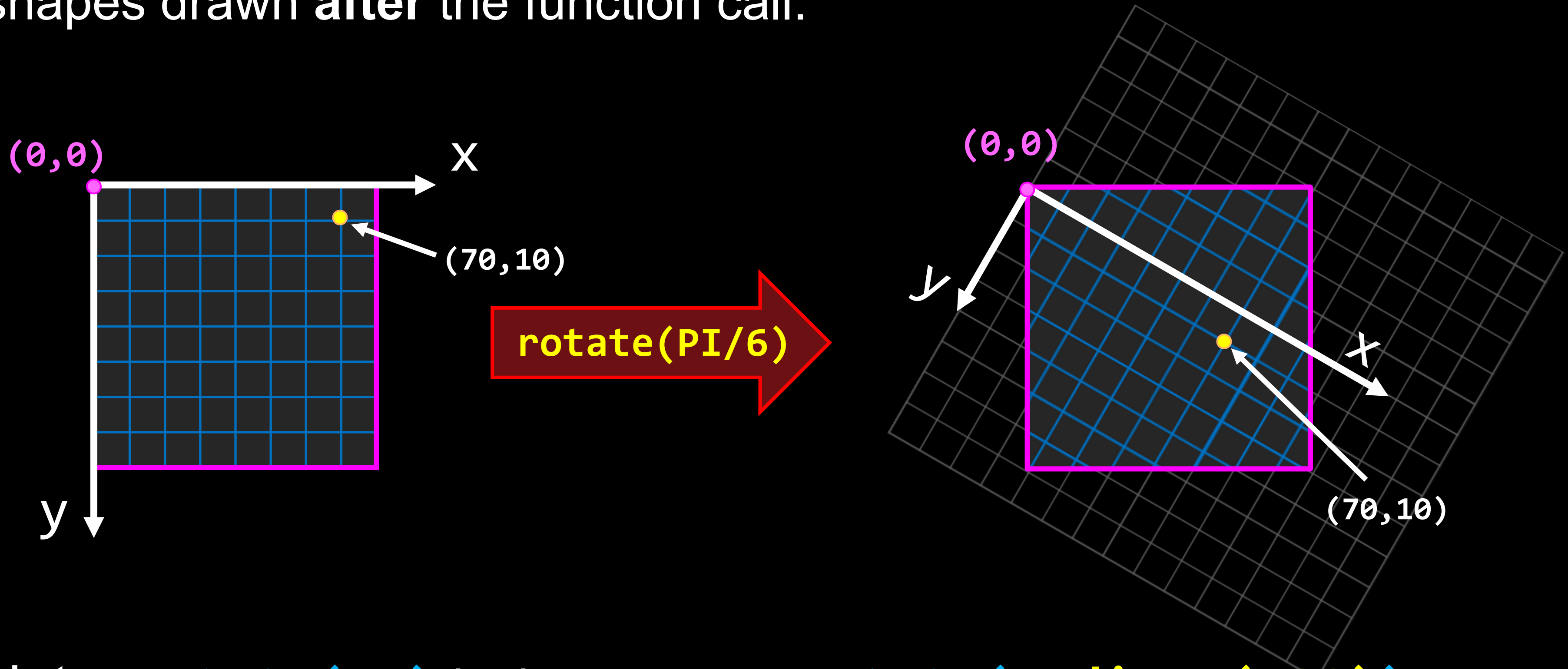
Q2: what is the ***benefit*** of using translate() over the other method?

(remember the exercise of moving your character with the mouse)

Example based on textbook

Coordinate Rotation - rotate()

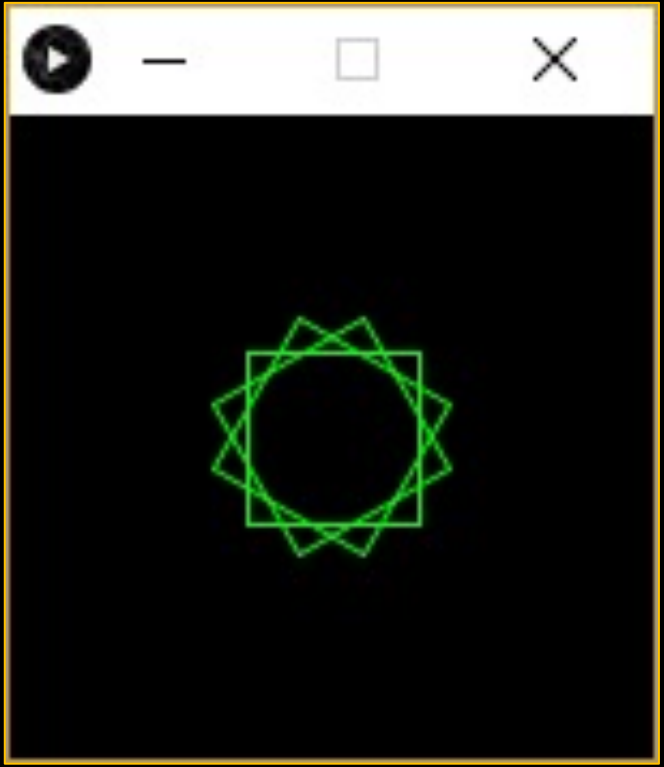
- The `rotate()` function rotates the axes to a new angle.
- It has one parameters, the angle specified in **radians**.
- Similar to `translate()`, rotate() is cumulative and applies only to shapes drawn **after** the function call.



- Note: `rotate(PI)` is the same as `rotate(radians(180))`

rotate() Example

```
size(150, 150);
background(0);
noFill();
stroke(0, 255, 0); // green outline
rectMode(CENTER);

translate(75, 75); // origin at sketch center

rotate(PI/6);      // rotate 30 degrees
rect(0, 0, 40, 40);

rotate(PI/6);      // rotate 30 degrees more
rect(0, 0, 40, 40);

rotate(PI/6);      // rotate 30 degrees more
rect(0, 0, 40, 40);
```

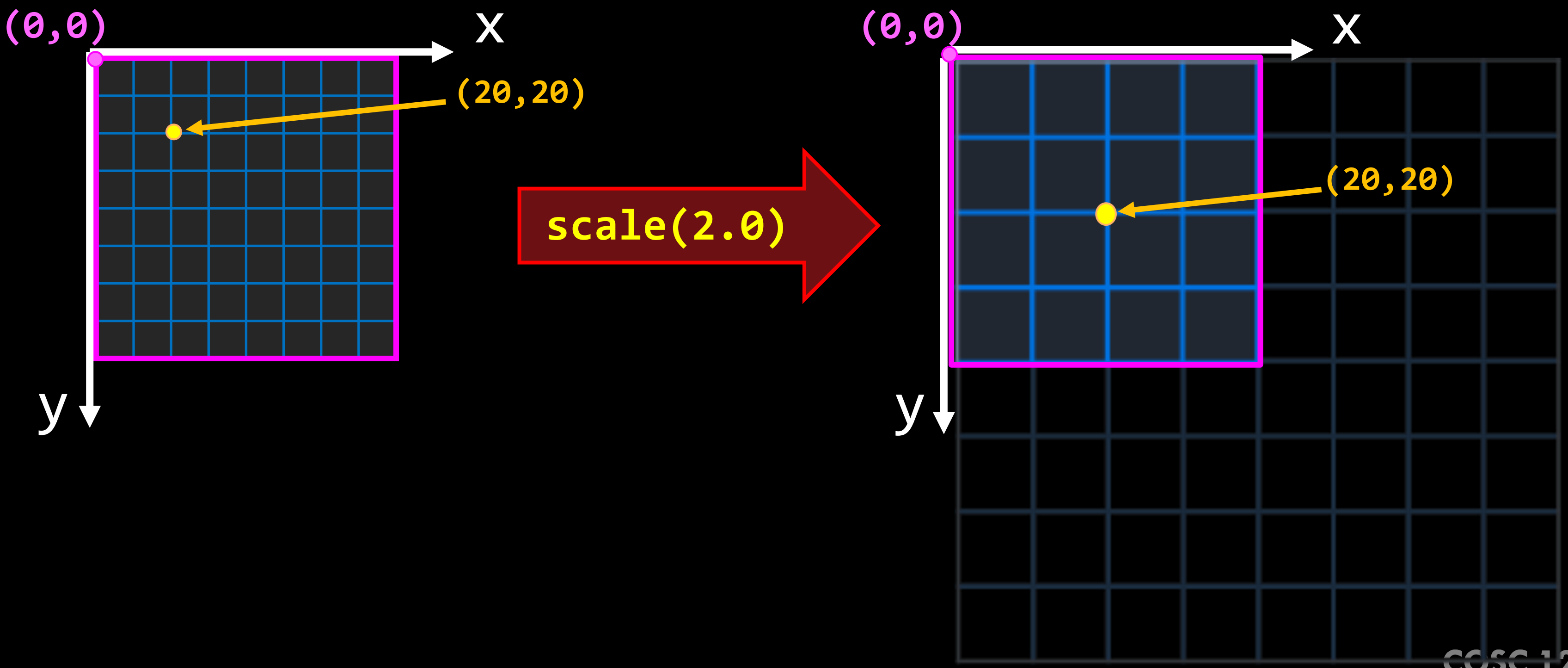


Q. Link statements to shapes in sketch.

Coordinate Scaling - `scale()`

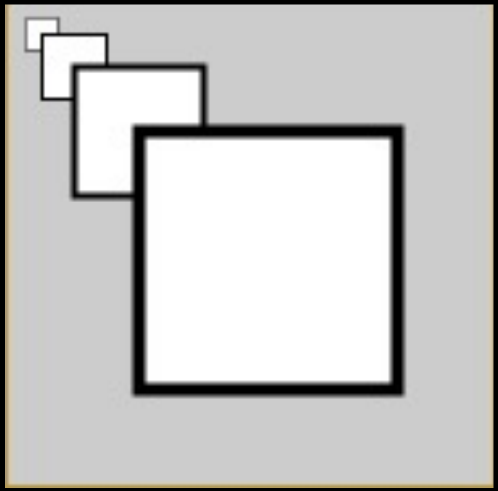
- The `scale()` function scales the coordinate system so that shapes are drawn in a different scale (this also affects pixel and border size).
  - Two functions: scale(size) and scale(xsize, ysize)

- Similar to other transforms, rotate() is cumulative and applies only to shapes drawn after the function call



scale() Example

```
size(150, 150);

scale(0.5);  // scale is 50%
rect(10, 10, 20, 20);

scale(2);    // now scale is back to 100%
rect(10, 10, 20, 20);

scale(2);    // scale is 200%
rect(10, 10, 20, 20);

scale(2);    // scale is 400%
rect(10, 10, 20, 20);
```



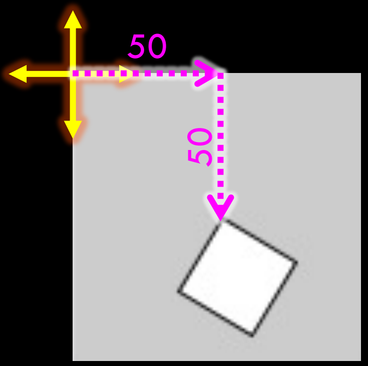
Q. Link statements to shapes in sketch.

Order Matters!

Order is important when combining more than one transformation.

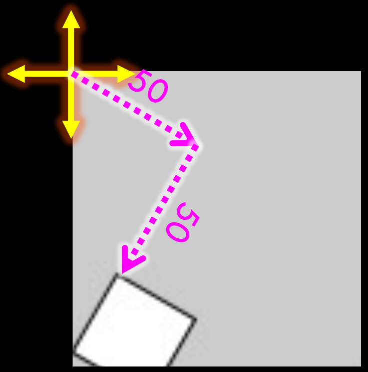
- In the first example, the coordinates are translated first then rotated

```
// translate then rotate
translate(50, 50);
rotate(PI/6);
rect(0, 0, 30, 30);
```



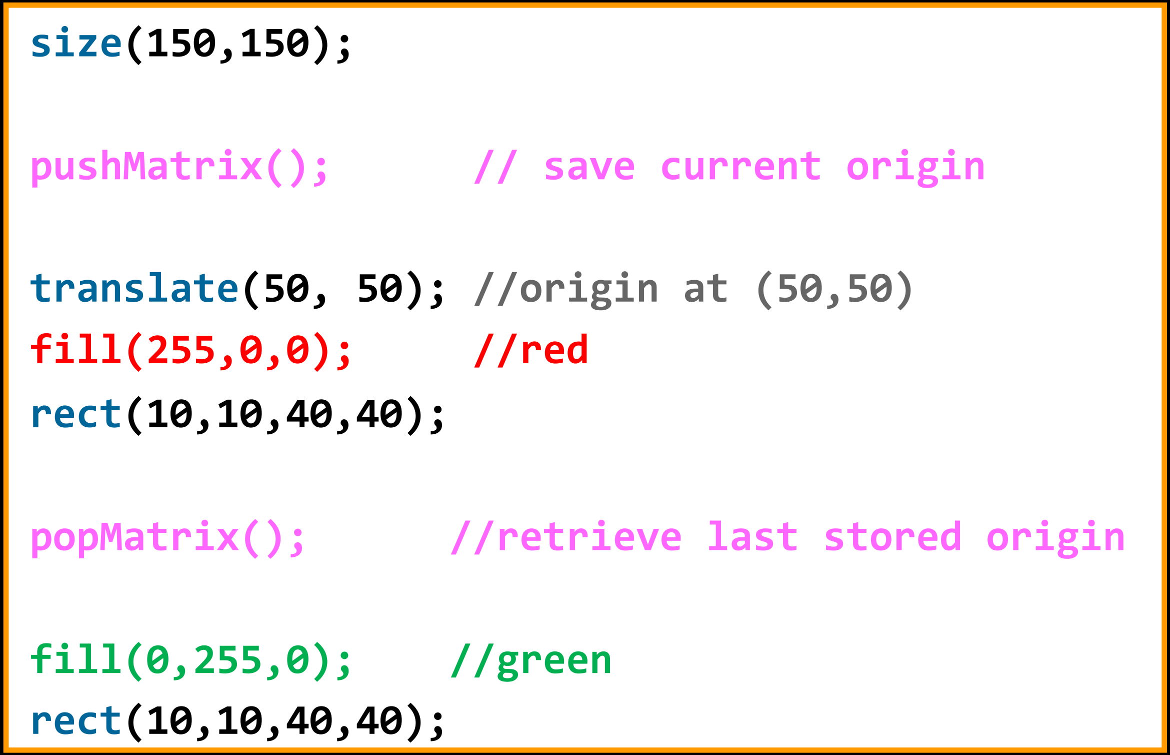
- In the second example, the coordinates are rotated first then translated.

```
// rotate and translate
rotate(PI/6);
translate(50, 50);
rect(0, 0, 30, 30);
```

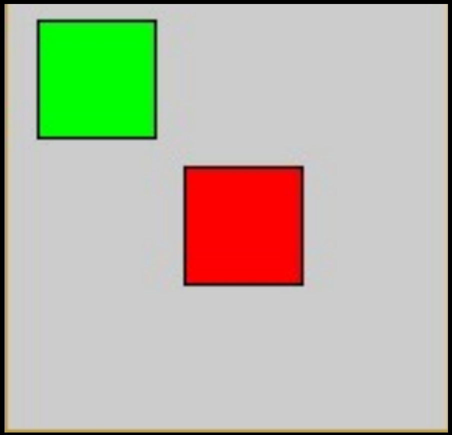


Storing and Restoring Coordinates

- The coordinate system is saved as a transformation matrix.
- You can use `pushMatrix()` and `popMatrix()` to store and restore the current coordinate system.
- Example:



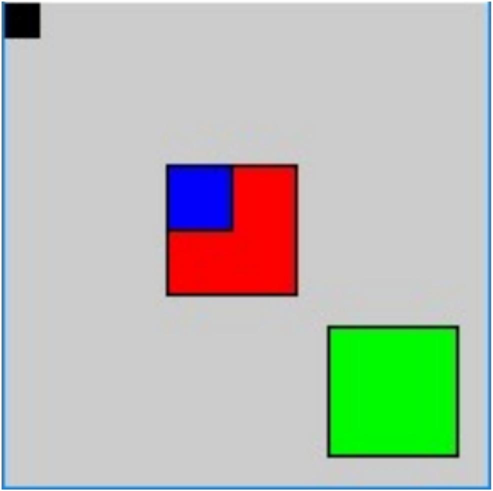
```
size(150,150);

pushMatrix();        // save current origin

translate(50, 50); //origin at (50,50)
fill(255,0,0);       //red
rect(10,10,40,40);

popMatrix();        //retrieve last stored origin

fill(0,255,0);      //green
rect(10,10,40,40);
```



Aside: stacking transformations

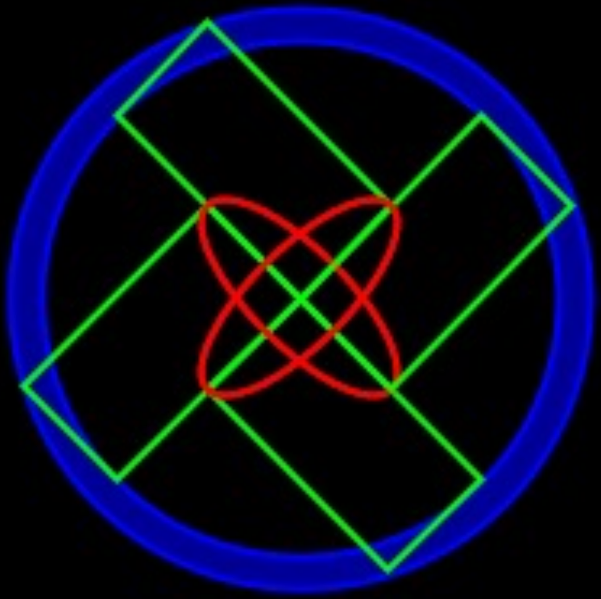
- You can use **pushMatrix()** and **pushMatrix()** multiple times
  - This case, the origin will be using the “matrix stack”.

```
size(150,150);

pushMatrix();      // save default origin
translate(50, 50); //origin at (50,50)
fill(255,0,0); rect(0,0,40,40); //red

pushMatrix();      // save current transformation
translate(50,50);  // origin at (100,100)
fill(0,250,0); rect(0,0,40,40); //green

popMatrix();      // restore prev origin - (50,50)
fill(0,0,250); rect(0,0,20,20);  //blue

popMatrix();      // restore original origin (0,0)
fill(0); rect(0,0,10,10);       //black
```



Coordinate Transformation

- Write code to produce the output below. You can only use `rect()` and `ellipse()` functions to draw the shapes. All shapes must be located at (x,y) = (0,0), i.e. the origin of the shape is (0,0) – use coordinate transformation to place the shapes.



Moving YOUR Character using transform()

Previously, you moved your character by adding mouseX and mouseY to every (x,y) of all shapes in your character.

Today, we will move the character using a simpler technique.

- 1) copy your character code from Exercise2 in the “Color” slides
- 2) add one statement at the beginning to move (translate) your character.

Demo of creating Animations